Safety as Airline Business Aspect

From Data to Action by A Value Model for Big Data and Feedback Method for Small FlightStories

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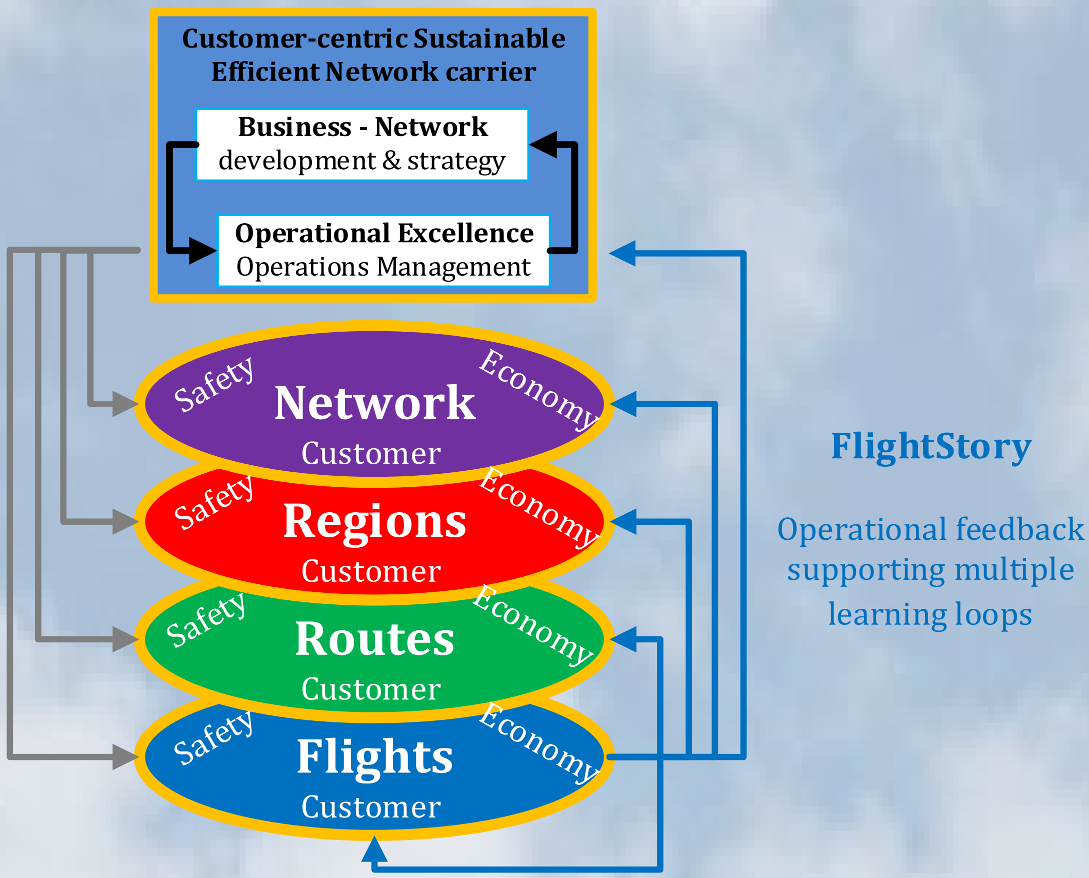
Airline Value Production Management Model



Arthur Dijkstra

In remembrance of my father, Johan Dijkstra, who motivated me to set ambitious goals.

Safety as Airline Business Aspect

From Data to Action by

A Value Model for Big Data and

Feedback Method for Small FlightStories.

Dissertation

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Reading guide

This is an extensive thesis that describes two interlacing and co-dependent research projects. Some chapters are obviously more relevant for both projects and some chapters are specific for one of the contributing projects.

For a quick assessment of the projects, I advise the reader the following sections: (blue titles are links to sections).

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Summary

This research was born out of a personal desire for increasing knowledge, improving existing systems and inventing new approaches for solving complex problems. My personal interests, development and career as a pilot, instructor, safety expert and researcher have provided the foundation for this research.

The organisational viability of a network airline depends on a sustainable exchange of value with its customers. Passengers receive value for their ticket purchase when their flight is actually executed, providing them with transportation, comfortable seats and in-flight services. Through interdependent and coordinated operations, many people in the airline organisation contribute to the delivery of value.

In this thesis, I argue that a more comprehensive management strategy is required to ensure organisational viability. Changes in economic markets, technology and society, in general, require advanced management systems to optimise the use of organisational resources for value creation. This requires integrated management of the essential variables or key performance aspects of safety, economics and passenger experience. Fragmented decision-making, which emerged as a strategy to deal with complexity, hinders holistic management and can lead to less-than-ideal outcomes, such as a potential misalignment between risk and commercial potential.

Both research initiatives fill gaps in the scientific literature. The assessment reveals a lack of studies that bridge the gap between safety and the business functions of an airline. Safety research focuses on safety with probably more references to the business side than vice versa, while business researchers remain in their field with sporadic references to safety. My two research initiatives focus on value production management and take an integrated approach to business and safety.

The research has produced two interrelated and interdependent concepts: an Airline Value Production Management Model (AVPMM) for an integrated approach to airline threats and opportunities, and FlightStory, a high-variety feedback method in which flight crews are intelligent feedback providers. They manage safety as an aspect of value production in their flight and can provide critical feedback to support the management of value delivery.

The **FlightStory** research topics are designed to investigate how and to what extent flight operational input from the flight crew can support many of the learning loops related to flight operations. Flight crew are the pilots of a flight. The execution of a flight is the most important component of delivering value to a customer and providing a memorable customer experience requires flexible and adequate flight operational support. The research questions focus on the various feedback loops that make up the learning loops of critical operational support systems. FlightStory is designed to provide critical data for these learning loops. Continuous updating is required to manage the impact of changes in the dynamics of the operational flight environment in which the organisation finds itself. FlightStory data includes a pilots' stories and the strategies they used to manage the disturbances in their flight. In addition, they evaluate the performance conditions and provide an assessment of their own and the organisation's safety performance capability. Based on the cybernetic logic of a variety amplifier, FlightStory provides data that can be used to support the following learning loops; pilots, to pilots, pilots to training, pilots to flight operations management and pilots to Safety Management.

The research questions address each of the learning loops outlined above and whether FlightStory provides insight into Safety-II and resilient performance. The survey responses from experts, managers and flight crews show a high level of agreement in most responses about an increase in learning performance in each learning loop compared to the current situation. The survey responses also show agreement that FlightStory data provides insights for a Safety-II and resilience perspective by providing lessons learned and operational strategies.

A second key research question relates to the contribution of FlightStory data to the AVPMM. The AVPMM experts broadly agreed that FlightStory data, which preserves the rich context of the often competing trade-offs between safety, cost and passengers, supports the AVPMM approach to integrated management.

All responses have at least descriptive, theoretical and indicative levels of evidence. Some causal levels of strength have been demonstrated, and for more specific issues where causal evidence is likely, further research on the application and further evaluation of FlightStory should be undertaken.

I conclude that this has been a very successful research project, as flight crews have provided data on five new topics that are not currently collected. The usability of the data is more extensive than current methods, without the need for additional resources in the offices for analysis. In principle, FlightStory data should be available to anyone who can learn from it and use that learning to improve the network, region, route or flight operation. The dissemination of FlightStory data will require governance decisions to change the data flow structures. The high level of agreement from respondents that the lessons from FlightStory should be used for improvement confirms my conclusion.

The **Airline Value Production Management Model** research project is developing and testing an integrated approach to value production. Value comprises the variables of safety, economics and customer satisfaction and provides a shared context and goal for organisational decision-making related to flight, route, region and network activities. The consequence of this logic of structuring and managing complexity is that no domain, safety, economy or customer satisfaction should be managed in a silo. Many issues and problems are interrelated and siloed decision-making would lead to sub-optimisation and sometimes risks in other domains. In the AVPMM evaluation, existing network and flight issues were discussed to see how the larger solution space involving the three variables could provide new risk mitigations that might not otherwise be so obvious and achievable.

Compared to the less specific and more general ICAO two-variable production versus protection model, the experts see advantages in the AVPMM for meaningful operationalisations.

Secondly, the experts agree that when safety is added as a network performance variable, new distinctions can be made and new decisions can be made. There is some agreement that the current safety assumption of either safe or unsafe is too simplistic, but caution is expressed that safety should not be traded for economy or customer satisfaction. For example, a new view of network performance allows the safety risk and performance of poor economic routes to be evaluated. This can lead to a route being discontinued and the resources of aircraft and people being reallocated to higher-value routes.

The values for the three key variables, particularly safety, are based on data-driven expert judgement. Reducing such a complex issue as safety to one or a few variables would be an oversimplification and would lead to a loss of the requisite variety. Flight operational risk is also very well managed by a competent flight crew, which illustrates that an issue does not need to be reduced to a few variables in order to be manageable by competent experts. Therefore, risk management as an aspect of the operational route, region and network decision-making can be carried out in a similar way. A prominent example is a network timetable change as a very effective mitigation measure to reduce safety risks. An integrated approach expands the range of possible solutions to problems compared to the current practices.

An extra kind of validation of its completeness and usability the AVPMM was used to derive a model of all the relevant issues for a business risk analysis of the impact of COVID.

While the two research projects may not be disruptive in the sense that they disrupt an economic market, they can be considered disruptive because they provide innovations that are not just improvements on existing methods. They show that compliance, which is considered sufficient, falls short of more effective methods, e.g. ASR versus FlightStory. Flight crews as active, intelligent feedback providers using a reporting system are a source of information that big data and artificial intelligence cannot provide. The AVPMM shows that a model-based, integrated approach provides a larger solution space for problems. The research projects also show the limitations of a single perspective. Outside the business context, a safety perspective is both limiting and insufficiently able to capture trade-offs and the consequences of resource constraints. Furthermore, a business perspective with security as a subsystem may not find the best value production solutions.

Both projects address gaps in the academic literature. The review shows a lack of research that bridges the gap between safety and the business activities of an airline. Business researchers stay in their domain with an occasional reference to safety, and safety research focuses on safety with probably more references to the business side than vice versa. My two research projects focus on value production management, which includes an integrated approach to both domains.

KLM's support for this research has been crucial and exemplifies the company's drive for an industry-leading approach to safety management.

Samenvatting

Dit onderzoek is geboren uit een persoonlijk verlangen naar het vergroten van kennis, het verbeteren van bestaande systemen en het bedenken van nieuwe benaderingen voor het oplossen van complexe problemen. Mijn persoonlijke interesses, ontwikkeling en carrière als piloot, instructeur, veiligheidsexpert en onderzoeker hebben de basis gelegd voor dit onderzoek.

De organisatorische levensvatbaarheid van een netwerkluchtvaartmaatschappij hangt af van een duurzame uitwisseling van waarde met haar klanten. Passagiers krijgen waarde voor hun ticketaankoop wanneer hun vlucht daadwerkelijk wordt uitgevoerd, met vervoer, comfortabele stoelen en diensten tijdens de vlucht. Door onderling afhankelijke en gecoördineerde operaties dragen veel mensen in de organisatie van de luchtvaartmaatschappij bij tot het leveren van waarde.

In dit proefschrift betoog ik dat een meer omvattende managementstrategie nodig is om de levensvatbaarheid van de organisatie te waarborgen. Veranderingen in economische markten, technologie en de maatschappij in het algemeen vereisen geavanceerde managementsystemen om het gebruik van organisatorische middelen voor waarde creatie te optimaliseren. Dit vereist een geïntegreerd beheer van de essentiële variabelen of essentiële prestatieaspecten van veiligheid, economie en passagierservaring. Gefragmenteerde besluitvorming, die is ontstaan als strategie om met de complexiteit om te gaan, belemmert een holistisch beheer en kan leiden tot minder dan ideale resultaten, zoals een mogelijk verkeerde afstemming tussen risico en commercieel potentieel.

Beide onderzoeksinitiatieven vullen hiaten in de wetenschappelijke literatuur. Uit de beoordeling blijkt een gebrek aan studies die een brug slaan tussen veiligheid en de bedrijfsfuncties van een luchtvaartmaatschappij. Veiligheidsonderzoek richt zich op veiligheid met waarschijnlijk meer verwijzingen naar de zakelijke kant dan omgekeerd, terwijl zakelijke onderzoekers op hun terrein blijven met sporadische verwijzingen naar veiligheid. Mijn twee onderzoeksinitiatieven richten zich op waarde productiebeheer en hanteren een geïntegreerde benadering van bedrijfsvoering en veiligheid.

Het onderzoek heeft twee onderling samenhangende en afhankelijke concepten opgeleverd: een Airline Value Production Management Model (AVPMM) voor een geïntegreerde benadering van bedreigingen en kansen voor luchtvaartmaatschappijen, en FlightStory, een feedbackmethode met een hoge variëteit waarbij de vliegtuigbemanningen intelligente feedbackgevers zijn. Zij beheren veiligheid als een aspect van waarde productie in hun vlucht en kunnen kritische feedback geven ter ondersteuning van het beheer van de waarde productie.

De **FlightStory** onderzoeksthema's zijn ontworpen om te onderzoeken hoe en in welke mate de operationele input van de bemanning veel van de leerprocessen in verband met vluchtoperaties kan ondersteunen. Het cockpitpersoneel is de piloot van een vlucht. De uitvoering van een vlucht is de belangrijkste component van het leveren van waarde aan een klant, en het bieden van een gedenkwaardige klantervaring vereist flexibele en adequate operationele ondersteuning van de vlucht. De onderzoeksvragen richten zich op de verschillende feedbacklussen die de leerlussen van kritische operationele ondersteuningssystemen vormen. FlightStory is ontworpen om kritische gegevens voor deze leerlussen te verstrekken. Voortdurende actualisering is nodig om de impact van veranderingen in de dynamiek van de operationele vliegomgeving waarin de organisatie zich bevindt te beheersen. FlightStory-gegevens omvatten de verhalen van de piloten en de strategieën die zij gebruikten om de verstoringen in hun vlucht te beheersen. Daarnaast evalueren zij de prestatieomstandigheden en geven zij een beoordeling van hun eigen prestatievermogen op het gebied van veiligheid en dat van de organisatie. Ontworpen op basis van cybernetische principes levert FlightStory gegevens die kunnen worden gebruikt om meerdere leerlussen te ondersteunen. Dit zijn vliegers naar vliegers, vliegers naar vlieger training, vliegers naar vliegdienst management, vliegers naar veiligheidsmanagement.

De onderzoeksvragen gaan over elk van de hierboven geschetste leerlussen en over de vraag of FlightStory inzicht geeft in Safety-II en veerkrachtige (resilience) prestaties. De antwoorden op de enquête van experts, managers en vliegtuigbemanningen laten in de meeste antwoorden een hoge mate van overeenstemming zien over een toename van de leerprestaties in elke leerlus ten opzichte van de huidige situatie. Uit de antwoorden op de enquête blijkt ook overeenstemming over het feit dat FlightStory-gegevens inzichten verschaffen voor een Safety-II- en veerkrachtperspectief door het leveren van lessen en operationele strategieën.

Een tweede belangrijke onderzoeksvraag betreft de bijdrage van FlightStory-gegevens aan de AVPMM. De AVPMM-deskundigen waren het er algemeen over eens dat FlightStory-gegevens, die de rijke context van de vaak concurrerende afwegingen tussen veiligheid, kosten en passagiers bewaren, de AVPMM-benadering van geïntegreerd beheer ondersteunen.

Alle antwoorden hebben ten minste beschrijvende, theoretische en indicatieve niveaus van bewijs. Er zijn enkele causale niveaus van sterkte aangetoond, en voor meer specifieke kwesties waar causaal bewijs waarschijnlijk is, moet verder onderzoek worden gedaan naar de toepassing en verdere evaluatie van FlightStory.

Ik concludeer dat dit een zeer succesvol onderzoeksproject is geweest, aangezien de vliegtuigbemanningen gegevens hebben verstrekt over vijf nieuwe onderwerpen die momenteel niet worden verzameld. De bruikbaarheid van de gegevens is uitgebreider dan de huidige methoden, zonder dat voor de analyse extra middelen in de kantoren nodig zijn. In principe moeten FlightStory-gegevens beschikbaar zijn voor iedereen die ervan kan leren en dat leren kan gebruiken om het netwerk, de regio, de route of de vluchtuitvoering te verbeteren. De verspreiding van FlightStory-gegevens zal bestuursbesluiten vereisen om de datastroomstructuren te wijzigen. De grote mate van overeenstemming onder de respondenten dat de lessen van FlightStory moeten worden gebruikt voor verbetering bevestigt mijn conclusie.

In het kader van het onderzoeksproject **Airline Value Production Management Model** heb ik een geïntegreerde benadering van waarde productie ontwikkeld en getest. Waarde omvat de variabelen veiligheid, economie en klanttevredenheid en biedt een context en doel voor organisatorische besluitvorming met betrekking tot vlucht-, route-, regio- en netwerkactiviteiten. Het gevolg van deze logica voor het structureren en beheren van complexiteit is dat geen enkel domein, veiligheid, economie of klanttevredenheid in een silo moet worden beheerd. Veel kwesties en problemen hangen met elkaar samen en besluitvorming in silo's zou leiden tot sub-optimalisatie en soms tot risico's op andere gebieden. In de AVPMM-evaluatie werden bestaande netwerk- en vluchtproblemen besproken om te zien hoe de grotere oplossingsruimte met de drie variabelen nieuwe risicobeperkingen zou kunnen opleveren die anders misschien niet zo voor de hand liggend en haalbaar zouden zijn.

In vergelijking met het minder specifieke en meer algemene twee-variabele productie- versus beschermingsmodel van de ICAO zien de deskundigen voordelen in de AVPMM voor zinvolle operationaliseringen. Ten tweede zijn de deskundigen het erover eens dat wanneer veiligheid wordt toegevoegd als een netwerkprestatievariabele, er nieuwe onderscheidingen kunnen worden gemaakt en nieuwe beslissingen kunnen worden genomen. Er is enige overeenstemming dat de huidige veiligheidsaanname van veilig of onveilig te simplistisch is, maar men waarschuwt dat veiligheid niet mag worden ingeruild voor zuinigheid of klanttevredenheid. Een nieuwe kijk op de netwerkprestaties maakt het bijvoorbeeld mogelijk het veiligheidsrisico en de prestaties van slechte economische routes te evalueren. Dit kan ertoe leiden dat een route wordt opgeheven en de middelen van vliegtuigen en mensen worden ingezet op routes met een hogere waarde.

De waarden voor de drie hoofdvariabelen, met name veiligheid, zijn gebaseerd op een op gegevens gebaseerd oordeel van deskundigen. Een zo complexe kwestie als veiligheid herleiden tot één of enkele variabelen zou een over-simplificatie zijn en zou leiden tot een verlies van de vereiste verscheidenheid. Het operationele risico van een vlucht wordt ook zeer goed beheerd door een competente bemanning, hetgeen aantoont dat een vraagstuk niet tot een paar variabelen hoeft te worden teruggebracht om door competente deskundigen te kunnen worden beheerd. Daarom kan risicobeheer als aspect van de operationele besluitvorming inzake routes, regio's en netwerken op soortgelijke wijze worden uitgevoerd. Een prominent voorbeeld is een wijziging van de netwerkdienstregeling als een zeer effectieve verzachtende maatregel om het veiligheidsrisico te verminderen. Een geïntegreerde aanpak breidt het scala van mogelijke oplossingen voor problemen uit vergeleken met de huidige manier van werken.

Als extra soort validatie van de volledigheid en bruikbaarheid ervan werd de AVPMM gebruikt om een model af te leiden van alle relevante kwesties voor een bedrijfsrisicoanalyse van de gevolgen van COVID.

Hoewel de twee onderzoeksprojecten misschien niet ontwrichtend zijn in de zin dat zij een economische markt ontwrichten, kunnen zij als ontwrichtend worden beschouwd omdat zij innovaties opleveren die niet slechts verbeteringen zijn van bestaande methoden. Zij tonen aan dat regel naleving, die vaak als voldoende wordt geacht, tekortschiet voor effectief veiligheid management, ten opzichte van effectievere methoden zoals bijvoorbeeld ASR versus FlightStory. Vliegend personeel als actieve, intelligente feedbackgevers die gebruik maken van een rapportagesysteem zijn een bron van informatie die big data en kunstmatige intelligentie niet kunnen bieden. De AVPMM laat zien dat een modelgebaseerde, geïntegreerde aanpak een grotere oplossingsruimte voor problemen biedt. De onderzoeksprojecten tonen ook de beperkingen van een enkel perspectief. Buiten de zakelijke context is een veiligheidsperspectief zowel beperkend als onvoldoende in staat om trade-offs en de gevolgen van resourcebeperkingen in beeld te brengen. Bovendien vindt een bedrijfsperspectief met veiligheid als subsysteem mogelijk niet de beste waarde productieoplossingen.

Beide projecten hebben betrekking op lacunes in de academische literatuur. Uit het onderzoek blijkt dat er een gebrek is aan onderzoek dat een brug slaat tussen veiligheid en de zakelijke activiteiten van een luchtvaartmaatschappij. Zakelijke onderzoekers blijven in hun domein met af en toe een verwijzing naar veiligheid, en veiligheidsonderzoek richt zich op veiligheid met waarschijnlijk meer verwijzingen naar de zakelijke kant dan omgekeerd. Mijn twee onderzoeksprojecten richten zich op waarde productiebeheer, dat een geïntegreerde benadering van beide domeinen omvat.

De steun van KLM voor dit onderzoek was cruciaal en illustreert het streven van het bedrijf naar een toonaangevende benadering van veiligheidsbeheer.

Thesis Chapter by Chapter

In **Chapter 1**, I introduce safety as an aspect of airline operations, illustrated by three personal stories from my time as a captain and safety investigator in the safety department. The stories from my experience as a captain will provide insight into the various factors that influence the delivery of safe flights; my story from my time as an investigator will provide an understanding of the inner workings of safety management and how novel methods can sometimes meet organisational resistance. Through these stories, I aim to demonstrate the context, importance and relevance of my research. I conclude the chapter by describing the scope and purpose of my research:

<u>The scope</u> of this Design Science Research (DSR) project is to develop a new solution for integrating safety and business management in international commercial aviation. The research is executed in an international airline with the support of several departments responsible for flight operations, network management, customer experience and safety management.

<u>Purpose statement</u>: The purpose of this research is to create new approaches and solutions that address the specific challenges of integrating safety and business management in the international commercial airline industry, in order to contribute to the existing literature and to provide valuable insights and recommendations for practitioners and managers in this field.

In **Chapter 2** I give a brief history of commercial aviation and the development of the regulatory system. I then provide an overview of safety management, including crew safety reporting and the challenge of integrating safety and business management. In this chapter, I describe the following problems and opportunities for improvement

<u>Problem statements:</u>

- There is a lack of integration between airline business management and safety management, resulting in the problem of a limited scope for solving safety issues. A risk reduction option by changing arrival times or aircraft type is not in scope from a safety silo perspective, whereas an integrated view makes this type of solution visible and part of the decision-making conversations.
- In addition, safety is not an aspect of the current network management system, which makes it difficult to achieve optimal allocation of company resources, e.g. redirecting resources from a risky route with an operational loss to new or better performing routes.
- The current compliance-driven safety reporting feedback to the other levels of the airline management system lacks the specificity required to improve the management of operational working conditions.
- In addition, the current feedback system only collects data when safety is lacking or at risk, and only collects factual data, which limits the usefulness of the

feedback data. The current system does not collect feedback on the full range of performance, from failures to successes, even though flight crews can provide this data. This data is critical to understanding how the system behaves when essential variables are affected by external or internal disturbances.

I conclude the chapter with the relevance of my research. Commercial aviation is a critical infrastructure in a rapidly changing world. Maintaining the current level of safety is already a challenge, but the projected growth of aviation demands even greater safety improvements, and this is where this research comes in. My research aims to provide answers to the problem of the lack of integration between airline business management and safety management by providing innovative solutions that can be used in practice. My research will provide a comprehensive and integrated approach to safety management that considers both safety and business objectives. The results of the research will enable the airline to improve its optimisation of resource allocation for maximum sustainable value production using a model-based approach. The research will also provide a method of utilising the expertise of flight crews to provide feedback on operational events that will benefit the SMS, but also all other stakeholders involved in flight operations.

In **Chapters 3 and 4** I present two systematic literature reviews. I start each review by describing field problems. For the FlightStory project, the problems to be addressed are:

1. a problem of the reductionist approach where safety is managed in a silo, disregarding other key performance indicators, by only collecting safety data.
2. a problem of the positivistic approach where (mainly) only facts are preferred and collected while data concerning contextual interpretations of these facts by the reporter is not explicitly collected. This can be expressed a problem of qualitative versus quantitative data, or structured versus unstructured data.
3. a problem of performance data bias where only Safety-I (near) incident data is collected and where no data about positive safety performance is systematically collected.

The problems the Value Production Model should address are:

1. The first problem is concerned with the lack of an explicit value production model which supports value production as the decision context for business decisions. Value production is a function of safety, economy and customer experience, these three variables, are integrally managed in each value production unit. Without a requisite model, a value production system lacks requisite variety and consequently will suffer sub-optimalisation.
2. A second problem is that safety is often managed in a silo, while it should be managed in the context of other business essential variables such as Economy and Customer experience. In the absence of other business values, safety in a silo

will cause sub-optimisation of the essential variables. In the AVPMM, safety is modelled as an aspect of the business, which is a step beyond safety as a sub-system. An aspect is an element of each sub-system, from top to bottom. Without safety as a business aspect, the organisation cannot ensure the optimal use of company resources for value production. The traditional two-variable approach of protection versus production lacks the requisite variety to manage complex ultra-safe flight operation systems, such as airlines effectively.

Both literature reviews reveal that very limited research has been published on both research topics.

In **Chapter 5** I present the research questions for both projects:

For FlightStory as a feedback system for the AVPMM and the SMS, the following sub-questions can be asked:

RQ1: How can pilots' flight operational experiences enhance Airline Value Production Management?

RQ 1.1 How can flight crew flight operational experiences feedback:

- Support flight crew performance self-reflection and learning?
- Support flight crew to flight crew learning?
- Support flight crew training?
- Support the management of flight operations?
- Support Safety Management?
- Provide insights for Safety-II and resilient performance?

RQ 1.2 How can flight crew flight operational experiences feedback:

- Support Airline Value Production management?

For the Value Production Model project, the following research questions have been compiled:

RQ2: How can we develop and use a Value Production Management model for the integrated management of Safety, Economy and Passenger experience for a Network Airline?

RQ 2.1 How can the AVPMM improve the management of production-protection?

RQ 2.2 How can the AVPMM improve Network Performance Management?

RQ 2.3 How can the AVPMM improve 'optimal resource allocation'?

In this chapter I argue that the purpose of this research fits with the DSR paradigm, which seeks to extend the boundaries of human and organizational capabilities by creating new and innovative models and methods. As stated by Hevner (Hevner, 2004), the design-science paradigm has its roots in engineering and the sciences of the artificial

(Simon, 1996). Furthermore, it is fundamentally a problem-solving paradigm. As conceptualised by Simon, DSR supports a pragmatic research paradigm that is proactive with respect to technology. I provide a mapping between the DSR steps as suggested in the literature and the structure of this thesis.

In this chapter I also explain my position as a constructivist and critical realist if the field of the philosophy of science.

In **Chapter 6** I follow all the required DSR steps. I describe a gap between desired and exposed knowledge. Several stakeholders involved in aviation safety lack knowledge of models and theory of safety performance, human factors and system safety. Current data collection methods do not exploit the potential of crew expertise to provide feedback on important issues such as how flight disturbances were handled and how well the Operational Performance Conditions, as managed by the organisation, supported conflict resolution.

My solution is to use cybernetic principles to improve the feedback system. Based on human factors and systems safety literature, I am creating questions for the flight crew to answer after an operational event during one of their flights where they had to actively manage some combination of safety, economics and customer experience challenges. I developed an app for the flight crew's iPad to enable them to complete a FlightStory at any time.

I designed 5 point scale evaluation questions for flight crew (159 participants), managers (7 participants) and experts (13 participants). Most experts responded from "agree" to "strongly agree" about the benefits of FlightStory. Managers were slightly less optimistic with an overall agree. Most flight crew respondents were positive about the concept, but the software solution for this test received some criticism.

I conclude that the lessons from FlightStory can be fully or partially implemented by the airline to improve the feedback loop from flight execution. The rigour of the DSR process allows other researchers to build on my findings to further enhance the expertise that flight crews can provide to inform different stakeholders in the organisation to improve safety, economy and customer experience.

In **Chapter 7**, I follow the steps required by the DSR to develop a model for the integrated management of safety and business, using the concepts of value exchange and value production. I address the lack of effective management of the balance between production and protection. This results in an inability to fully evaluate ongoing operations from an integrated perspective of safety, economy and customer satisfaction. This results in an inability to optimally allocate resources based on safety risk arguments. More generally, the inability to manage the balance between economy, safety and customer experience in the context of value production can be improved.

I am describing a gap between desired and exposed knowledge. Safety managers are experts in safety management processes and they train other airline managers in these processes. While safety managers have had introductory training in safety management content such as human factors and system safety, managers from departments related to flight operations have not had training in these topics. This knowledge gap hinders innovation, as managers first need to be convinced by experts and then make decisions about resources to develop and implement innovations. The gap between business and safety management is therefore very slowly closing without the help of scientific research.

I describe a generic solution based on cybernetic principles to develop a new decision structure in which safety and business decisions are integrated in a value production context. Based on an instantiation of the Viable System, Model I developed a specific solution in an operational software prototype with four nested recursions, namely Network, Regions, Route and Flight. At each recursion, the essential variables of safety, economy and customer experience have specific operationalisations which structure and reduce complexity.

I populated the model with test data to develop discussion scenarios to test and evaluate the concept. In a focus group meeting, 6 aspects of the AVPMM were discussed and then each expert independently answered questions in a survey. The evaluation analysis provides answers to the research question. The group results confirm that the ideas behind production and protection can be managed more effectively with the AVPMM. Furthermore, the group agrees that the AVPMM allows new types of network management decisions to be made, some of which are difficult to make today. The survey results support the assertion that the integrative approach increases the solution space for value production issues, thereby improving the company's resource allocation.

A lesson for practice was that real experts were able to apply the concepts to actual network planning issues and expressed that this way of working improved decision-making. They appreciated the way in which the effects of departmental silos were reduced.

This research provides a bridge for safety science and business management science to connect both fields. It contributes to the gap in the research literature on getting safety out of the silo. The AVPMM as an instantiation of the Viable System Model illustrates how complexity can be structured and made manageable.

In **Chapter 8** I provide an introduction to the theory I consider the reader to be familiar with to appreciate the extent of this research. The theory topics include:

- Human sense-making
- Different descriptions of the nature of the problem domain
- The Newtonian-Cartesian worldview
- A systems worldview

- Some concepts of system behaviour and complexity theory
- Cybernetics as the science of information and control
- Safety science theories concerning organisational accidents, human performance and safety as a control issue
- Scale resolution and scope

I conclude in **Chapter 9** that the results of both research projects fill gaps in the academic literature. This research did not enjoy the resources in terms of time and people that would be made available by the organisation if it were an innovation project fully supported by senior management. Nevertheless, I was able to carry out this research and identify improvements over current compliant practices. Engagement with the organisation increases the relevance of the research for the organisation.

Acceptance of the results in the organisation depends on many factors, including the perceived need and gap between current practices and innovation, and very importantly, support from senior management.

In **Chapter 10** I provide suggestions for further research related to FlightStory and the AVPMM such as:

- More DSR or action research. Involve safety managers and airline network managers.
- More multidisciplinary research:
    - Economics and safety scientists work together to bridge the gap between safety and the business.

I conclude with a vision of a future where a next version of the AVPMM and FlightStory will be implemented, where the organisation will be able to create memorable experiences for the customer and use available resources for optimal value production by monitoring opportunities and threats, being innovative in matching current conditions with future demands, coordinating activities, delegating and agreeing tasks and reviewing ongoing activities, and learning from operational experience at all iterations of the value production organisation in a way that minimises damage to the environment and supports people's wellbeing.

Chapter 1: Introduction

In this chapter, I introduce safety as an aspect of airline operations, illustrated by three personal stories from my time as a flight captain and safety investigator in the safety department. The tales from my experiences as a captain will offer insight into the various factors that influence the delivery of safe flights. My story from my time as an investigator will provide a glimpse into the inner workings of safety management and how novel methods can sometimes lead to conflicts. Through these stories, I aim to show the context, significance, and relevance of my research.

1.1 Safety in context

Even though aviation safety has reached a high level of safety, with accident probabilities at approximately 1 in every 100 million flights (IATA safety report 2015), there is still room for improvement. As the aviation industry continues to grow, it is essential to strive for even greater safety performance.

This research delves into the question of whether improvements in safety performance should be achieved by focusing solely on compliance, or by taking a more comprehensive approach to understanding and maintaining safety. The study argues that a holistic approach is necessary, as safety cannot be fully understood by solely relying on safety models. Safety is not a standalone concept but rather is created within the context of a commercial network airline whose ultimate goal is to provide passenger experiences at a minimal cost. This context, in turn, shapes the decision-making process of front-line operators, such as flight crew, who must consider safety, passenger needs, and economic factors. In a network airline, connections are essential to providing passengers and cargo shippers with a wide range of travel options. However, balancing resource allocation to maximize revenue with safety and risk considerations requires a broader perspective on airline performance. This research supports the claim that to truly understand safety, one must consider the dynamic context in which it is created.

In the following accounts, I aim to provide an in-depth look into the experiences of creating safety during two challenging flights. These "war stories" will offer a unique perspective on how safety is established and maintained in real-world settings.

1.2 Flight execution war story: Engine Oil Loss over Russia

This story was published in the company's safety magazine. This would have been one of FlightStories had they been available at the time.

An oil loss experience

After about 10 hours of flight from Manila to Amsterdam, between Moscow and St Petersburg, we noticed a secondary engine parameters page pop-up. The left engine oil indication was highlighted and showed 4 quarts, and the right-hand engine indication was the normal 15 quarts. I immediately noted the time so we could see how fast the indication was dropping. There is no Quick Reference Handbook (QRH), so we started to analyse the situation, possible consequences and our options. I anticipated that the developing non-normal situation could best be handled by the complete cockpit crew.

This was a flight with four flight crew. Two flight crew were sleeping, having their rest period. After the warning, I requested the purser to wake them up and request them to assist us in the cockpit. We cancelled the planned crew change, and we were now with four brains in the cockpit.

We checked the maintenance performance page to find other relevant indications to check whether the low oil indication was valid. We could not falsify the indication, so we were dealing with an actual oil loss. A complete loss of oil would result in an ENG OIL PRESS warning. The QRH procedure for this warning is to shut down the affected engine, which leads to an en-route diversion in an aircraft with two engines. Luckily, one of the FO's had already experienced an oil loss, and in that situation, the loss did not immediately result in an oil pressure warning. This information gave us some confidence that we had time to think.

Since no immediate action was required, we contacted dispatch. Our dispatcher was very helpful and immediately organised a conference call with the Flight Operations back-office and the flight technical pilot. I made it very clear that I wanted to land with two engines running and that a continuation of the flight was only possible as long as we were sufficiently confident that the ENG OIL PRESS warning was not imminent. In the conference call, we discussed how we could judge whether the ENG OIL PRESS warning was imminent or not. In the meantime, the quantity dropped from 4 to 3 quarts. As expected, Network Operations Control wanted us to continue towards Schiphol for as long as we could, and they had no specific preferences for a diversion airport. With dispatch, we discussed the en-route airports available for a possible diversion, and they sent us all required Notices To Airmen texts (NOTAMS).

We passed St. Petersburg and had Riga as our next diversion option.

From flight technical, we learned that an oil indication of 0 (zero) quarts does not immediately result in an ENG OIL PRESS warning. This is because the oil quantity is measured in the oil tank, and a considerable amount of oil remains in the engine itself during such a slow oil leak. This gave us some confidence. In the meantime, the oil quantity dropped from 3 to 2.

The drop from 3 to 2 quarts took longer than from 4 to 3. The rate of loss looked to be nonlinear, and that might give us more time. We also learned via dispatch that a cruise report with engine parameters is automatically sent by the airplane to the Maintenance Control Centre (MCC) approximately three hours after every take-off. Our flight had also sent this message. This report showed already an oil quantity indication of 10 quarts, and this is lower than normal. This confirmed a slow oil loss and increased our chances of making it to Schiphol.

My colleagues on the observer seats prepared possible diversions to the nearest suitable airports. A diversion to an en-route airport requires the checking of weather and operational conditions such as changes to Air Traffic and navigational procedures. We had to find this information in the several meters of NOTAMS for these airports creeping out of the printer. Since we had no iPad at the time, the alternate books were opened and closed for the airports we were passing, and it required quite some organisation to prevent the cockpit from looking like "a full paper" cockpit in contrast to the future "no paper cockpit".

We passed Riga and chose Stockholm as our next option, another step closer to home.

Still, the critical question was how confident we could be that the ENG OIL PRESS warning was not imminent. As soon as we lost confidence, we would decide to divert to Stockholm, Copenhagen, or finally Hamburg. So, we changed our course a bit to pass closer to these airports.

Since an en-route diversion was likely, I called the purser a few minutes after getting the pop-up. We discussed what the current situation could mean for the passengers and cabin crew. The plan was that the passengers would get the last service in about an hour. I wanted to reduce the possibility that we had to divert while the passengers were having their service and all galleys and cabin crew were in full swing. Such a situation could result in the need to stop the service and start cleaning up before all passengers had finished their meal. The purser suggested starting the service immediately with the argument of expected turbulence. That was an intelligent proposal, so the passengers were informed, and the service was started. All cabin crew was informed about the situation and acted very professionally.

We passed Stockholm, and Copenhagen was our next en-route diversion option.

We also discussed operating the engine with the oil loss at reduced thrust based on the assumption that lower thrust means lower pressure and a lower rate of leakage. However, reduced thrust would mean we could not stay at our present altitude, so we would have to descend. The descent could also be used to analyse engine response to check our confidence that the oil pressure warning was not imminent. During descent, we changed the thrust on the engines one by one and observed the difference in oil pressure change. The engine with a low oil quantity had only a slightly different oil pressure change than the other, and we judged that as acceptable. Therefore, we continued to operate the engine at a somewhat reduced thrust.

At one moment, I asked my colleagues to take a step back and evaluate whether we were executing groupthink or tunnel vision. We agreed this was not the case, but of course, you are never sure of that until after the event.

During one of our calls with MCC via dispatch, the topic of inflight shutdown and ETOPS status was mentioned. I short-circuited this discussion since my concern was the here and now, and involving more goals would make the situation more complex and outside my scope. Therefore, the ETOPS status was not further discussed.

In the meantime, we had passed Copenhagen, Hamburg, and the decision was made to continue to Schiphol with an oil quantity indication of 1 quart.

We could plan for a straight-in to runway 27, and during the approach, we operated the engine at normal thrust. As a precaution, we decided to make an auto-land because the autopilot is very good at handling an engine failure even after 13 hours of flight. An uneventful landing ensued.

After parking at the gate and passenger disembarkation, we went to the engine to have a look. Oil was spread throughout the whole engine casing, making this my first flight in 25 years to nearly shut down an engine. I had a great crew and a very interesting flight.

The following points are my lesson from this event.

- Since we do not normally check secondary engine indications, the oil loss went unnoticed for at least 5 hours. For this reason, I started on my subsequent flights to check secondary engine indications and the other synoptic display during crew changes. That means these indications are now checked about every 2 to 3 hours and the check is connected to a specific event, namely crew change.
- I think my statement about what was not acceptable to me gave a frame of reference for our decisions. I wanted to land with two engines running. We could have discussed this further in the bar after the flight, but that was my point of view at the time. Based on my background as flight crew instructor, human factor and safety expert and investigator, I tried to execute CRM practices by stating my limitations (landing with two engines) and ensuring coordination, delegation, verification, and anticipation. This seemed to work and was confirmed unsolicited.
- A non-QRH issue can be a lot of work. I was happy we had a four-person flight crew.
- An organisational learning point might be reviewing the data sent from each flight from an actual operational perspective and not only trending.
- An interesting topic for discussion could be an engine pop-up like we had during the ETOPS part of a flight over northern Siberia or the ocean.

This concludes my story of the only flight I had in 35 years that nearly ended in an engine failure. I will refer to this story in chapter 6 on FlightStory.

1.3 Flight execution war story: Flight departure in winter operations

I feel fortunate to have the opportunity to fulfil multiple roles as an airline captain, safety consultant, and researcher. In high-stress situations, my focus is primarily on the immediate operational situation, and I am not able to step back and consider different perspectives. However, during less hectic times, I can bring my different roles and perspectives together. I will be sharing an interesting flight departure I had in my 32 years of flying experience. I will provide an insight into my activities, as well as our crew's decisions and discussions, as we remembered them after the event. This is an attempt to give the reader an authentic glimpse of the day-to-day work of flight operations at the front line.

The story shows how different aspects and criteria are interdependent, how decisions are made and which arguments were used. Furthermore, it shows the need for communication outside of the cockpit to cabin crew, passengers, air traffic control, de-icing controller, and the Operations Control Centre. The departure took almost four hours and was intense and at some moments critical towards safety, economy and/or passengers. It is a story of how safety was created in an event where it was under pressure.

“The day before the flight, after the evening news, I checked the weather forecast for my flight. I could expect snow and wind for my early afternoon departure from Amsterdam to Dubai. So, I took my flight manual and browsed the procedures for icing conditions and airport procedures for de-icing. I told my wife that I had to leave for the airport earlier than normal to the next day because of the expected weather conditions. Preparation reduces the chance for surprise and under the expected weather conditions, I didn’t like surprises.

I left home early. About an hour before normal reporting time, I arrived at the airport. The sky had almost been clear until 11:00 local time. The expectation was that snowfall would start at 15:00, with initially some rain at 14:00. My departure to Dubai was scheduled at 14:30, so there could be a challenge ahead. At the crew centre, cockpit flight crews assigned to various flights discussed the upcoming weather conditions within and between them. Jokes were made about who would be lucky to sneak out before the weather and who would get the full pile of snow. At that moment, we seemed to be just ahead.

The Operations Control Centre (OCC) is the network manager. They strategically (about a day before actual operation) and operationally manage the flow of passengers and aircraft. Adverse weather reduces the number of aircraft Air Traffic Control (ATC) and the airport can handle. A reduction in capacity will lead to delays and passengers missing their connections. As a mitigating measure, the OCC will reduce the demand on ATC and the airport by cancelling some flights. These measures caused the outbound traffic peak to be a bit lower than normal at this time of the day.

We started our preparations in the crew briefing room 45 minutes before the official reporting time. A time buffer feels comfortable under these conditions. Flight dispatch had prepared a flight plan for us, which included fuel for de-icing because de-icing prolongs the taxi time. For some reason, call it expert judgement or trained hackles, I felt this proposed extra fuel was not sufficient for my comfort. I suggested my first officer take another 1500 kg extra. He fully agreed that (fuel) economy in this situation with high uncertainty about weather and subsequent delay has a very low priority. Our strategy is to simplify, to not worry about sufficient fuel by taking some extra. Normally I take 500 to 1000 kg extra, but this time I ordered a bit more. This bit appeared to be very important later.

I was lucky to have an experienced flight instructor as First Officer. We discussed the new procedures for determining 'hold-over times', the time a de-icing treatment delivers the required de-icing capabilities under the actual weather conditions. The week before, during my office week, I heard a discussion about the interpretation of hold-over-times in this new table. Some flight crew interpreted hold-over-times during specific low visibility conditions as undetermined and thus not guaranteed and thus take-off not allowed, while others regarded this specific visibility value as the minimum acceptable. My first-officer was aware of this issue and we agreed on our interpretation of the table. But who cared? The snow had even not yet started.

Well prepared, we went to our aircraft, also somewhat earlier than normal. A common phrase is that time and fuel are substitutes for brains, and so far, we have achieved having time and fuel. I explained to the cabin crew the expected weather deterioration and its consequences of longer taxi time and the need to do de-icing. A somewhat delayed arrival in Dubai was expected, but that was simply unavoidable, given the expected conditions. At the start of our cockpit preparation, the weather was such that no de-icing was required, so we kept our fingers crossed for an on-time departure just before the snow would hit the airport.

Just before our scheduled departure, it started snowing at the airport, and this had immediate consequences. Our ground handling process slowed down, and we incurred our first delay of half an hour. Other departing aircraft received ground handling before we got it. I explained and apologised for the delay to the passengers, but they did not seem to care so much since many were connecting from other flights and were happy to be seated for their flight to home, work, or their holiday destination.

My first officer had initially prepared a take-off performance calculation for runway 09 without contamination (snow, slush) at 14:17. Because of changes in the weather and runway conditions, we had to make a new performance calculation, which differed significantly from the first calculation. We ended up making a total of seven new take-off calculations. This was a record for me.

We were pushed back at 15:17, 45 minutes late, but we were on our way. Schedule times become less important under these conditions. We had to taxi to the de-icing platform for de-icing before we could taxi to our take-off runway. That is a special area at the airport, with special procedures, where all departing aircraft under snowy and icy conditions get sprayed with a de-icing and anti-icing fluid. This is necessary to have clean wings and a clean fuselage during take-off and initial climb. We started as number

4 in the de-icing queue. With the airport de-icing procedure and aircraft procedure pages open on our iPad, we were in no hurry and had time for a coffee.

After about half an hour of taxiing, it was our turn to park our aircraft at the de-icing spot. The weather had deteriorated to 2400 metres visibility, with a possible further deterioration to 600 metres and an increase in the snowfall intensity. We configured the aircraft according to the de-icing procedure, and I informed the passengers about the fact that they could see a cart on the outside spraying fluid on the wing and why that was needed. The de-icing process would take at least 15 minutes, so we could check the holdover time guidelines for the current situation in the meantime.

During the de-icing, the snowfall intensity increased, and the visibility reduced. We had a laugh because the visibility turned out to be into the bracket that we discussed in the crew centre, the bracket where some interpreted the holdover guidelines were not applicable and consequently, take-off was not allowed. And that was exactly what happened. One of our colleagues parked next to us on the de-icing ramp informed ATC that they could not depart under current weather conditions. So, they desired to return to their departing gate, creating more complexity to handle for ATC on the taxi tracks. My first officer and I confirmed our interpretation of the table and that take-off was permitted within a time window of 60 to 95 minutes after de-icing was started. For the third time, we updated our take-off calculation for the increased contamination on the runway.

Our interpretation that take-off was allowed under the given conditions could have been a serious event in an accident analysis if something went seriously wrong. Tunnel vision, confirmation bias, get-to-destination-itis and similar concepts would probably be used to describe our flight in an accident analysis. Sometimes I imagine what it would be like if I got involved in an incident and my safety investor colleagues had to interview me about the event. I was used to doing the interviews and sitting on the other side of the table.

Sometime after our flight, I discovered the explanation of the hold-over table was adapted and improved. This is a great example of an organisation that learns and the need for flight crew to give feedback to the people in charge of flight operations.

Although the engines were still running at idle, we held our fuel margins because we had planned for this. The visibility had become 600 metres and snowfall had increased to the extent that it exceeded the airport's snow clearing capacity. ATC decided to close the airport to all arriving and departing traffic so they could clear the runway and taxiways. Arriving aircraft had to enter a holding pattern if they had fuel to wait, or divert to their alternate airport. The delay for departing aircraft was indefinite, meaning ATC just didn’t know when departure was possible again. For this reason, our de-icing procedure was stopped. There we were, parked with two running engines, not completely de-iced, and the airport closed for departures and landings. Obviously, there is no procedure for this, so we discussed our options. Maintaining the current situation, with two engines running in this position and awaiting the airport to open, would surely reduce if not completely remove, our fuel margin to the extent that we had to refuel or even cancel our flight. That is obviously not desirable. So, we discussed whether we could shut down one engine. My first officer said that taxiing using a single engine during adverse weather is, according to procedures, not allowed. Well, I said, can be parked at a de-icing ramp be defined as taxiing? And if so, we would stand still, so the reason for the limitation to taxi on one engine would not apply to us, agree? But why not shut down two engines and save even more fuel? We are parked using the (APU) Auxiliary Power Unit, for electricity and air-conditioning. That would give us ample time to sit out this situation. He agreed, and we shut down the engines by using an adapted After Parking/Shut Down checklist. I informed first my cabin crew members and then the passengers about the indefinite delay and our strategy to increase our chances of getting them, be it late, to Dubai. In the meantime, another company flight, with the flight crew that we had spoken to in the crew centre, had to return to their departure gate because of lack of fuel to continue. We agreed that being number one at the de-icing spot, where we were parked, and the APU running would give us at least another hour to await improvement and a chance to depart from Schiphol as one of the first. We had used our extra fuel as planned by dispatch. Even now, we still had some margin because we added 1500 kg of extra fuel. We both felt we had made a good decision.

Adapting procedures to our situation could have been another issue in a safety investigation if our flight had incurred some incident. Making the case, in an incident analysis, that we should also return to the gate, would have been easy given the abnormal winter conditions we were experiencing, the minimum amount of experience with these winter conditions, the uncertainty of the hold-over times; and the fact that others were returning to their gates too. But we didn’t make that decision and followed our plan.

We had left our departure gate just over an hour ago, and after having completed our flight operational strategy, it was time to attend to the passengers. Their patience was being tested. I wanted to walk around the cabin and answer questions, but that would mean a split cockpit, which is undesirable when there could be a need to coordinate. We switched on our cell phones and exchanged our numbers so the First Officer could call me in case the airport opened before I returned to the cockpit. It is a custom to wear my jacket in the cabin, but it also helps very much for the passengers to see the captain is walking in the aisle. When passengers are seated and they look at their video screens, they can see my captain's stripes on my sleeve. Without my jacket, they have to look up to my shoulder to see if it is the captain walking by. I noticed that when passengers can easily see my stripes, I get more positive responses. I put on my captain's jacket and went into the cabin. After maybe 45 minutes, I arrived back in the cockpit, somewhat tired of all the interactions, but with professional pride since the senior purser gave me a compliment since she never saw a captain going through the economy class and answering all questions. I'm sure more colleagues would do this, but she had not met them yet.

Paying so much attention to the needs of my passengers could have been used against me in a safety investigation. I could have been blamed for wilfully losing situational awareness and creating a split cockpit situation. But given our company's mature safety culture, these kinds of arguments do not play into our operational decisions, but an investigation in some other country could run very differently.

About two hours after leaving our gate, my first officer gave me an update on the situation. He had called OCC in case we would not have sufficient fuel for our destination. He explained that they wanted us out, didn't care where we had to make a fuel and go stop as long as we got out of Schiphol. Landing traffic was allowed again, and the remaining aircraft in the holding stacks over the North Sea and Eastern Netherlands were allowed to land. We were informed that, in due time, ATC would allow departures. We contacted the de-icing crew to make sure that when departure was allowed, they would immediately start our second de-icing treatment. The first de-icing was invalidated since it had not been completely finished. I informed the passengers that in due time I could give them an estimate of the expected departure time.

Due to wind changes, ATC had changed the landing and take-off runways. We just made our 7th take-off calculation. This time we had more snow on the runway, and because of the reduced braking capacity, we also had to check the maximum allowable crosswind, which appeared to be just within limits. Flaps 20 and full thrust with anti-ice on. That was going to be the take-off configuration. Fuel economy is not a factor under these conditions. When ATC gave us an estimated time for departure, we informed our de-icing crew. After de-icing, we started our engines and requested taxi as the first departure after the closure. The taxiway ahead of us was covered with snow, and we triple checked our initial route towards the part that was cleaned. We didn't want to end up in the snow-covered grass. Slowly, we pulled out of the parking position and could make our way to the take-off runway. We completed the taxi-out procedure for contaminated taxiways and selected flaps 20 while approaching the runway. Indeed, we were the first of the pack to depart, nearly four hours behind our scheduled departure time.

This had been a special event, I had lost my sense of time and had been in a kind of flow. My first officer did a great job of supporting, challenging, and managing issues. The cabin staff went to great lengths to keep the passengers happy and comfortable. Everybody was happy and somewhat tired. During the flight, we had some dinner and had time to reflect on past events. Later, we found out that only five intercontinental flights had managed to depart.

After landing in Dubai, the passengers left the aeroplane just over three hours behind schedule. I was standing near the door, thanking them for their patience, flying on our airline, and wishing them well. I got no complaints, not even from the man who said it was unacceptable to wait as we did. Many gave us compliments, and this showed that a delayed flight can be a positive experience for crew and passengers."

We didn't have the impression that we had to fill out an Air Safety Report, but if we seriously reported every event that could have had an impact on safety, we would have to write at least ten reports. We submitted no ASR but my first officer wrote a FlightStory which was then still in testing mode.

Although these kinds of events are sometimes critical but not unique, they seldom result in Air Safety Reports because the outcome was as desired. Air Safety Reports are not designed for learning from success. Moreover, the safety science research literature review shows a very limited number of publications where these real-world insiders' accounts are part of the research.

1.4 Safety investigation war story

Another role I had in the safety organisation was that of an accident investigator. As I did with my FlightStories, I would like to share an investigator's story. The story is not intended to blame anyone. The account sheds light on the difficulties a learning organization may face when realizing the need for changes, specifically in the area of safety management operations. It offers insights on related problems. My intention with this story is to show safety managers' sensemaking and how they, with their best intentions, try to negotiate different forces at play when safety is considered outside of flight operations alone. It shows how safety management is developing from a subsystem of flight operations into an aspect system of the airline business.

In October 2010, an Airbus A330 experienced a bird hit during take-off from Entebbe airport. The crew handled the situation by using their expertise and by adapting procedures. Flight crew and safety officers were not surprised by this event because Entebbe's airport, situated in the middle of a bird sanctuary, had the highest rate of bird hits of any airport in the network.

The bird hit resulted in no injuries but it did result in severe aeroplane engine damage. The passengers were disembarked on the runway. The brakes were hot, but no tyre blowout occurred. The flight crew kept the plane on the runway by using differential braking and full reverse thrust on the live engine. Half an hour earlier, the right engine had suffered from a bird hit during the take-off roll. A Grey-crowned crane of about one metre in height and a weight of about 3.5 kilogrammes was close to his breeding grounds on the same runway and at the same time as the aircraft took off.

Figure 1-1 Grey Crowned Crane

Figure 1-2 Engine inlet with fan damage

The safety department started an investigation covering the operational and technical aspects of the flight regarding the circumstances of the incident and its causes and consequences following ICAO Annex 13 the international standard for accident investigations (ICAO, 2016). According to Annex 13, the sole purpose of an accident or incident investigation is to prevent accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The safety investigation followed two tracks. One is the flight operations part, which involves an interview with the flight crew. Technical experts from the technical department execute the other track by analysing the engine damage and technical effects on other systems, such as the hydraulic system. In the second stage of the investigation, the technical analysis informed the operational investigation to explain all the secondary effects of the bird hit damaging the engine. These secondary effects, beyond a loss of engine thrust control, included hydraulic problems affecting the flight controls. As a result, the flight crew had to deal with multiple failures.

Nevertheless, they did a great job of landing the aeroplane safely at Entebbe, from where it had departed 25 minutes earlier. The degraded aeroplane system configuration was so severe that a missed approach would have been challenging and risky. The Flight Operations department was offered four recommendations related to flight crew training and procedure handling; one recommendation was made to the technical department; and seven recommendations were made to Airbus. The investigation team met with Airbus experts to discuss the event; system behaviour; procedure design; and flight crew training. This was a serious event and was thought to be one of the most serious flight safety events in the last 15 years.

Beyond all the technical and flight operational issues, I was interested in the organisational decisions that had led to the situation where aircraft operate very close to a bird sanctuary. My suggestion for a recommendation about network development and evaluating network performance was seen as outside the scope of the investigation.

In 2009, I had a conversation with the network development manager, and we discussed network design and operation. He put me in contact with a manager on network schedule and capacity to further discuss network design. No safety investigator ever contacted managers in the corporate head office, and my meeting caused some managerial raised eyebrows. During this conversation, it became clear that a thorough safety analysis was not part of the selection criteria for new destinations in the initial network design. I viewed a network design process description in which safety was not explicitly mentioned. The manager explained that "to reduce the complexity of the network design decisions, we consult flight operations. We ask them if a specific operation is feasible. If they answer 'yes', we will include the airport in the new network design". An operational expert from Flight Operations conducted the operational review of potential new destinations. This expert collected information from the airport authorities. He visited the airport and requested operational information from other airlines. Following the review, network development had been informed that operations in Entebbe were feasible without restrictions. At the time, the safety assessment was binary: either safe or unsafe.

After I understood how the initial decision to start operations was made, I analysed how network performance management was executed. I compiled a safety data flow scheme covering all meetings and collected empty management dashboards to see how safety was addressed. Although safety was often the first topic in a meeting, it was not addressed in a way to make it sufficiently explicit and actionable. Someone from Flight Operations attempted to collect from different departments information regarding financial, customer, and network losses to understand the extent of the total damage caused by the bird hit. This attempt was unsuccessful, as experts could only give rough estimates.

In the month following the bird strike event, the network design was changed to schedule even more flights during the period during which bird strikes are likely. This shows that the network performance management system at the time could not handle a safety event. As expected, an increase in bird hits during take-offs and landings was reported and Flight Operations started a discussion with Marketing, Revenue Management, and Network Scheduling. Flight Operations offered a window for acceptable operations into Entebbe based on bird strike risks. Five months after the event, a very effective risk mitigation measure of changing arrival and departure times was introduced to comply with the proposed operating window. The alteration highlights the organization's approach to learning, but this alone is not enough. It must be coupled with an overhaul of the network development and performance management procedures to achieve real progress.

The investigation into organisational information collection and decision-making revealed a lack of requisite variety of safety feedback channels to inform network design and network operations. The development of the AVPMMM was inspired by this real-life safety investigator experience.

This first-hand account of a safety investigator highlights some of the challenges an organization may face when attempting to expand the scope of its safety management efforts. Currently, safety considerations are given more weight than before. However, they fall short of what is recommended by the AVPMM in this research.

1.5 Why are these war stories relevant?

As an active professional in the fields of flight operations, safety management, and safety science, I strive to utilize my unique perspective to transfer valuable knowledge from one domain to another with the goal of improving the overall airline management system and pushing the boundaries of safety science research. In these three narratives, I highlight common problems in the management of safety during flight operations and how it relates to network business decisions. These accounts demonstrate the potential of using learning opportunities to advance safety management and research.

1.5.1 Flight execution story: Engine Oil leakage over Western Russia

This FlightStory matters because:

- It shows how, from a captain's perspective how the flight crew managed a technical failure for which no procedure is available.
- We managed all three essential variables under my strictly defined condition that we should always land with two operating engines. I operationalised my theoretical knowledge of the Viable System Model and defined my minimal acceptable norms to create closure for our decision making.
- We used all available resources; from two flight crew, we scaled up to a four people flight deck crew, purser and home based ground experts.
- In our strategic decision taking, we included the purser to include the passenger service in our considerations.
- We simplified as much as possible by not considering the company's issue of inflight engine shutdown rate.
- The FlightStory shows the difference between an Air Safety Report and a story.

1.5.2 Flight execution story: Departure during extreme winter conditions

The Dubai FlightStory matters:

- To show actual flight operations is not concerned with only safety but with other goals as well. This means safety cannot be understood from a traditional safety perspective.

- To show that such a challenging flight does not trigger current safety management feedback systems Flight Data Monitoring and Air Safety Reporting (FDM, ASR).
    - FDM is insensitive to context. This means that events in high safety threat environments without actual parameter exceedance do not trigger the safety management system.
    - ASRs are written by flight crew when they have perceived actual threats to safety. Events without a perceived safety risk are not reported and the normalisation of risk perception will reduce the number of ASRs.
- To invite safety researchers to take a more holistic approach and support the development of new safety management practices (Oster et al., 2013) by not only researching on incident data but also on successful operations, as in my story.

1.5.3 Safety investigation story

The safety investigation story matters:

- To provide an insight into some growing pains of a developing safety management system. Conflicting issues are exposed when safety management exceeds its traditional organisational departments of concern, such as flight operations.
- Safety as an aspect system of all organisational activities is often accepted as a statement but the effective implementation remains a challenge as shown by this story. Safety is currently not an aspect of network performance since in the network development and network performance domains, safety is assumed to be take care of by the operational divisions.

1.6 About this research project

This research project has developed over 17 years in my capacity as a safety investigator, safety consultant and safety researcher. Circumstances allowed me to perform action research type of activities and access to relevant people and data. The projects I've executed have been discussed and adjusted to organisational needs to create a benefit for both the research and organisational learning.

1.6.1 Field problem in Airline Business and Safety Management

The scope of this Design Science Research (DSR) project is to develop a new solution for integrating safety and business management in international commercial aviation. The research aims to address the interdependency of safety and business management in the international aviation industry and to create a more effective approach to balancing these two important aspects.

In my capacity as Safety Consultant and Safety Investigator, I've not found a model for the integration of safety and airline business management. In several conversations with high-level managers, They explained that safety was left out of certain decisions to reduce complexity and that the flight operations department would take care of safety.

My claim is that simplification can lead to undesired suboptimal business decisions and undesired levels of risk.

In my experience as a Safety Investigator, Safety consultant, and flight crew, I've experienced the limitations of current operational feedback channels, such as Air Safety Reporting (ASR) and Flight Data Monitoring (FDM), Line Checks, and LOSA. One of the limitations of the current approach is the difficulty in obtaining accurate and useful information from the feedback about the quality of Operational Performance Conditions (OPC). Decisions of airline management, throughout the whole organisation, resulting in a flight configuration that should be able to deliver the desired customer surface under all conditions, such as adverse weather, technical failures, etc. Airline management should get feedback on the quality of the OPC to balance safety, production, and organisational resources. The current operational feedback channels lack the required variety to manage this critical balance.

1.6.2 Research purpose statement

The purpose of this research is to create a new approach or solution that addresses the specific challenges of integrating safety and business management in the international commercial aviation industry, in order to contribute to the existing literature and provide valuable insights and recommendations for practitioners and managers in this field.

The literature I used for my development as an expert in human factors and safety management appeared to have little research on the integration of safety and the airline business. My extensive experience of 12 years working in a flight safety department further confirms this gap also in practice. I have observed first-hand the desire for but lack of effective methods for balancing safety and production without compromising one over the other.

Considering this, my research project aims to make a valuable contribution to both safety science theory and airline safety management practices by investigating a holistic, top-down, and bottom-up model for integration. The goal is to provide insights, guidelines and practical tools to achieve this balance and make it manageable. Additionally, the research aims to bridge the gap between theoretical safety science and practical application in the aviation industry.

Chapter 2: Flight Operations and Safety Management

In this chapter, I will describe the research context and topics of flight operations and safety management. Based on the Design Research guidelines (van Aken & Andriessen, 2011) I will describe, evaluate and explain the current Safety Management practices. My research will address the problems as indicated at the end of the chapter.

2.1 Description of Flight Operations and Flight Safety current practices

Commercial aviation has been an integral part of our society for over a century. The industry has grown and developed, connecting people and businesses across the world. With the increasing importance of air travel, the regulatory framework for the industry has also evolved to ensure the safety and well-being of passengers and crew. In this chapter, we will look at the contextual factors that shape the airline industry and its flight operations, including regulations and safety management.

2.1.1 History

The Wright Brothers started heavier-than-air flight in December 1903. In 1908, T. Selfridge was the first passenger who died because of an aeroplane accident. He was the passenger of Orville Wright when the righthand propeller broke. The aeroplane became uncontrollable and Orville made a crash landing. Selfridge endured a severe skull injury and died three hours after the crash.

Commercial aviation started in 1909 with DELAG (Deutsche Luftschiffahrts-Aktiengesellschaft) operating Zeppelins. KLM Royal Dutch Airlines started in 1919 and is the oldest still operating airline. Throughout the 1920s and 1930s, commercial aviation continued to evolve and expand. Airlines formed alliances and routes expanded globally. With the outbreak of World War II, the industry was temporarily halted, but after the war; the industry began to recover and grow.

The industry continued to grow throughout the 20th century, with advancements in technology playing a major role. This includes the development of jet engines, which greatly increased the speed and efficiency of air travel. The first commercial jetliner, the de Havilland Comet, began operating in 1952.

The introduction of the Boeing 747 in 1970, commonly referred to as the "Jumbo Jet," revolutionized air travel by increasing the capacity of aircraft and making long-distance travel more affordable. Further technical developments, such as the use of composite materials and fly-by-wire systems, have led to the development of more advanced and fuel-efficient aircraft, such as the Airbus A380 and the Boeing 787 (Airbus, 2021; Boeing, 2021).

The International Air Transport Association (IATA) was founded in 1945, representing and promoting the interests of the global airline industry (IATA, 2021). As of 2021, according to IATA, the number of passengers carried by airlines reached 4.8 billion, and the cargo volume transported by airlines was 62.5 million tons. The aviation industry also continues to play a major role in the global economy, with the IATA estimating that the industry supports over 65 million jobs and generates $2.7 trillion in economic activity (IATA, 2021).

2.1.2 Context; Global Regulations

Aviation is a heavily regulated industry. In 1784, the first aerial regulation was promulgated in France concerning a special licence to fly a balloon. Government regulation was aimed at ensuring public safety. In 1910, the first international air law conference was organised aimed at creating a global regulatory system for civil aviation. Regulation proposals include safety-related topics such as registration of aircraft, airworthiness, and personnel licencing. These topics became part of the regulatory framework that was agreed upon in the Convention on the Regulation of Aerial Navigation in 1919 in Paris. The new addition to the rules was the international rules of the air, including rules for signals, lights, and the prevention of collisions. In 1944, the Chicago Conference adopted the Convention on International Civil Aviation. which resulted in the birth of the International Civil Aviation Organisation (ICAO) in 1947. Initial activities of the ICAO concerned regulations related to licensing, communication systems and procedures, rules for the air and air traffic control, airworthiness requirements, aeronautical meteorology and maps. In 2015, as an UN-specialised agency, ICAO worked with the Convention's 191 Member States and industry groups to reach a consensus on international civil aviation standards and recommended practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable, and environmentally responsible civil aviation sector. These SARPs and policies are used by the ICAO Member States to ensure that their local civil aviation operations and regulations conform to global norms, which in turn permits more than 100,000 daily flights in aviation's global network to operate safely and reliably in every region of the world.

ICAO has aviation safety as its top strategic objective. The organisation works in collaboration with the entire aviation community and strives "to further improve aviation's successful safety performance while maintaining a high level of capacity and efficiency". Here we can see an indication of competing objectives, which is typical for aviation and a main reason for governments to want to mandate a "bottom line" of safety, regardless of commercial incentives, as a level playing field for all commercial operators.

ICAO's 19 annexes cover the standards and recommended practices. Over the years, annexes are updated and changed by formal ICAO procedures. In 1951, Annex 13 was adopted, and it covers the Aircraft Accident and Incident Investigation. This annex is the basis for international accident investigations performed by organisations such as the National Transport Safety Board (NTSB) of the United States and the Dutch Onderzoeksraad Voor Veiligheid (OVV).

In 2013, the ICAO general assembly adopted Annex 19: Safety Management, which contained safety management provisions that were contained in six different annexes. The 3rd edition of the Safety Management Manual (SMM) supported the first edition of Annex 19. This SMM is fundamental to safety management regulations in nearly every country for all types of aviation service providers.

2.1.3 Context; Regulations: Continent.

In Europe, the Joint Aviation Authorities (JAA) was founded in 1970 as an associate body of regulatory authorities from several European countries. New regulations were then still established via the individual member states. In 2002, the European Parliament established the European Aviation Safety Agency (EASA). This is an agency of the European Union (EU), governed by European public law and having its own legal personality. It was given specific regulatory tasks in the fields of civil aviation safety and environmental protection.

EASA executes oversight of the member states' National Aviation Authorities (NAA), which implement EU legislation and perform oversight of national organisations, such as airlines, airports and air traffic control.

2.1.4 Context; Airline industry.

IATA was established in 1945 to promote inter-airline cooperation for safe, reliable, and economical air services. In 2014, IATA had about 260 airline members from 117 nations. Most Low-Cost Carriers (LCC), such as Ryanair, are not members of IATA. The IATA Operational Safety Audit (IOSA) programme is an internationally recognised and accepted evaluation system designed to assess the operational management and control systems of an airline. All IATA members are IOSA registered and must remain registered to maintain IATA membership. IOSA requirements include Safety Management System standards.

The airlines' economic battle is severe and is in constant flux. Until the 1980s, the ticket price was determined by the cost of the airline's execution of that particular flight. Since then, market influence has grown, and that means the market determines the price and the companies must follow. This led to developments such as a merger of legacy airlines to gain economy of scale, the introduction of LCC and market specialisation.

Passenger flight volume is expected to continue to grow. This by itself, leads to the desire to continue improving flight safety, as expressed by ICAO and IATA.

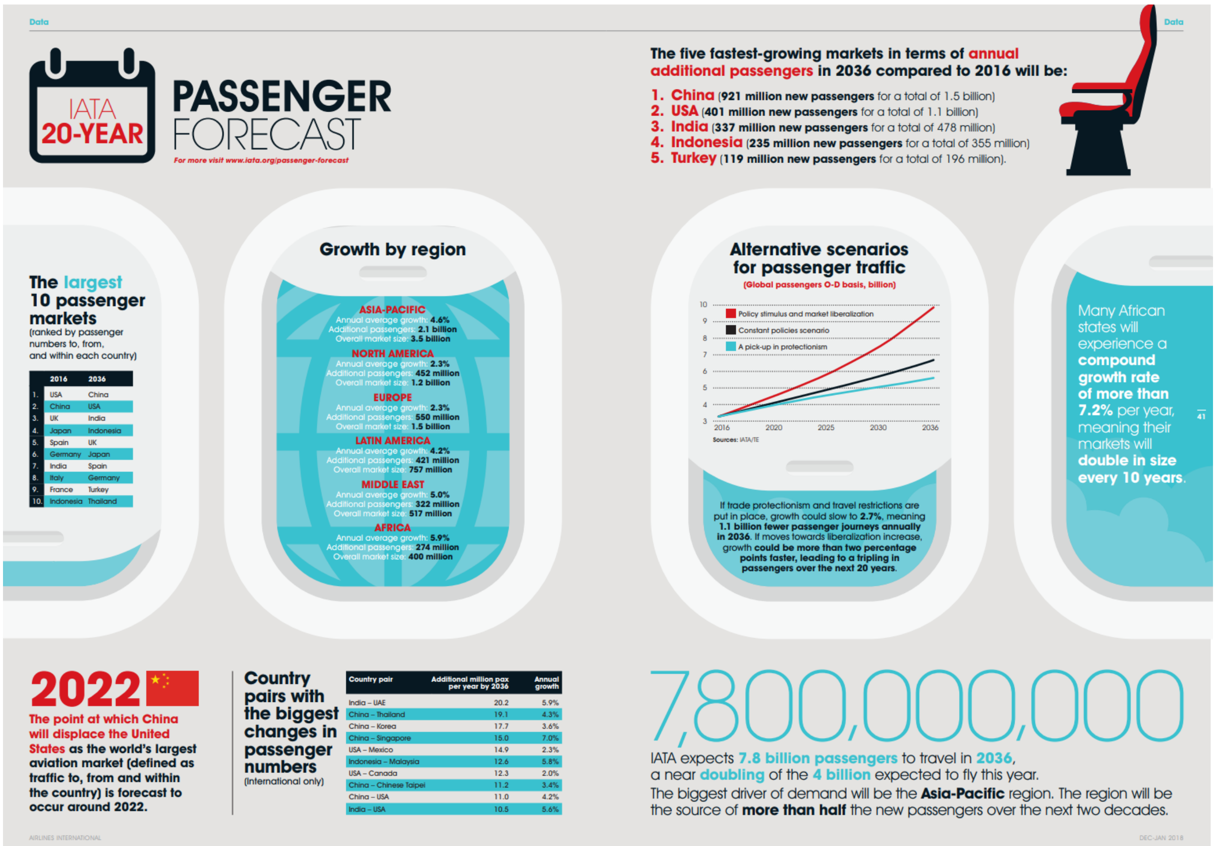


Figure 2-1 IATA forecast strategic guide - airlines. (2020)

2.1.5 Context; Company.

According to (Wiersema & Treacy, 1995), a company cannot simultaneously excel at delivering market-leading performance in the areas of Operational Excellence, Customer Intimacy, and Product Leadership. Each company should choose one of the three to excel in and be at least mediocre in the other two fields. The concept of value disciplines states that a company must make a strategic choice of which value discipline to pursue in order to achieve a competitive advantage.

Working in a company that chooses customer intimacy as a core value, the goal conflict space increases. This is because the company's focus on providing a personalized and unique experience for the customer may come into conflict with other goals, such as efficiency and cost-effectiveness, which are important for achieving operational excellence. Additionally, a focus on customer intimacy may also lead to trade-offs in product development and innovation, as the company may prioritize meeting current customer needs over investing in new and unique products.

On the other hand, in the other two value disciplines, the goal conflicts for the sharp end (such as flight execution) may be less since product leadership and operational excellence are more aligned with achieving safety. Companies that focus on product leadership may prioritize innovation and creating new products, which may not always align with achieving safety. Similarly, companies that focus on operational excellence may prioritize efficiency and cost-effectiveness, which may not always align with achieving safety.

The airline environment is highly regulated and economically very competitive. Hardware, software, and procedures for an airline are all set by the manufacturer and must follow strict rules. Flight crew training is highly regulated. There aren't many degrees of freedom for an airline, but there are enough for it to succeed or fail. Airline management has limited but crucial influence over the flight safety of their operations.

2.2 Aviation Safety: Balancing Business and Risk Management

Apart from ethical considerations, safety is important because unsafety can put an airline out of business, either by the regulator or by a lack of customers. Airline safety information is made accessible to the public through various websites, including skytraxratings.com and airlineratings.com, which offer comprehensive safety ratings for airlines. These ratings impact an airline's reputation, as a lower rating can harm its image and subsequently may lead to a decline in ticket sales (Wittmer, Bieger, & Müller, 2011).

Regulatory protection against unsafety is provided on several levels:

- Regulations protecting the individual in the aircraft and on the ground
- ICAO protecting the aviation system
- IATA protecting the industry

Accidents are very costly for an airline. (Čokorilo et al., 2010) estimate the minimum cost between 34-211 million euros (minimum severity accident) and maximum between 414-591 million euros, (catastrophic severity accident) of which not all is insured.

- Airline (nearly) bankrupt because of accidents:
- Pan Am 1988 bombing near Lockerby
- TWA flight 800 1996 over Long Island fuel tank explosion
- ValueJet's inability to recover following the crash of Flight 592 in 1992
- Swissair 111 crash near Halifax Canada 1998
- Malaysia Airlines MH 17 shoot-down and MH 370 disappearance.

Aviation safety performance has significantly improved over the past five decades. According to data from the National Transportation Safety Board (NTSB, 2020), the number of commercial aviation accidents in the United States has decreased from a high of 1,597 in 1970 to just 93 in 2020. This represents a 94% reduction in the number of accidents over the past 50 years. Additionally, the number of fatalities from commercial aviation accidents in the United States has also decreased, from a high of 1,597 in 1970 to just 93 in 2020, a 94% reduction in the number of fatalities.

Similarly, data from the International Air Transport Association (IATA, 2020) also shows a steady decline in the global commercial aviation accident rate over the past 50 years. The accident rate per million flights has decreased from 2.87 in 1970 to 0.02 in 2020, representing a 99% reduction in the accident rate. Similarly, the number of fatalities from commercial aviation accidents has also decreased from a high of 914 in 1970 to just 56 in 2020, a 94% reduction in the number of fatalities.

These improvements in aviation safety can be attributed to several factors, including advancements in technology, improved safety regulations, and increased training and education for flight crew and other aviation professionals. Additionally, organizations such as the International Civil Aviation Organization (ICAO) and the Federal Aviation Administration (FAA) have played a critical role in promoting and enforcing safety standards in the aviation industry.

According to the International Air Transport Association (IATA, 2020), commercial aviation is expected to experience significant growth in the coming years. The organization predicts that the number of passenger flights will more than double by 2037, reaching 7.8 billion annually. This represents an average annual growth rate of 3.7%.

Additionally, the International Civil Aviation Organization (ICAO, 2020) also predicts that the number of passengers travelling by air will continue to increase in the coming years. The organization estimates that the number of passengers will reach 7.2 billion by 2036, an increase of 4.1% per year on average.

As the number of passenger flights is projected to increase in the coming years ICAO, EASA and IATA are focused on continuously improving air travel to meet the expectations of the general public. This includes ongoing efforts to enhance the safety of aviation through regulations and the development of Safety Management Systems. The continuous improvement of aviation safety is crucial to ensure the safety and well-being of passengers and to maintain public trust in the aviation industry.

2.2.1 Safety Management Systems

Flight safety performance is a precondition for an airline to survive in the industry. Marketing research in the Swiss shows safety accounts between 2004 and 2009 for 14% to 22% of the choice passengers make when buying a ticket from a particular airline out of 9 variables including price, image, and schedule (Wittmer, Bieger, & Müller, 2011). Insufficient flight safety performance can lead to a plethora of problems for an airline, such as a bad reputation among customers, high-intensity audits by regulators, increasing insurance premiums, and unfavourable conditions for cooperation (code sharing) with other airlines.

The Safety Management requirements are described by the ICAO in Annex 19; Safety Management System. European, American, and other regulators adhere to the ICAO guidelines (ICAO, 2018a). The IATA, an organisation that sets guidelines for its members, follows the ICAO SMS principles. Airlines can achieve compliance in SMS practices by following all regulatory guidance, and current safety management practices in airlines are based on these regulations. Airlines have an SMS structure compliant with the ICAO SMS framework (ICAO, 2018a). It comprises four components, each with several elements:

SMS framework:

- SMS Component 1. Safety policy and objectives
    - SMS Element 1.1 State safety legislative framework
    - SMS Element 1.2 State safety responsibilities and accountabilities
    - SMS Element 1.3 Accident and incident investigation
    - SMS Element 1.4 Enforcement policy
- SMS Component 2. Safety risk management
    - SMS Element 2.1 Safety requirements for the service provider's SMS
    - SMS Element 2.2 Agreement on the service provider's safety performance
- SMS Component 3. Safety assurance
    - SMS Element 3.1 Safety oversight
    - SMS Element 3.2 Safety data collection, analysis and exchange
    - SMS Element 3.3 Safety-data-driven targeting of oversight of areas of greater concern or need
- SMS Component 4. Safety promotion
    - SMS Element 4.1 Internal training, communication, and dissemination of safety information
    - SMS Element 4.2 External training, communication and dissemination of safety information.

Airlines were given about four years to become compliant with SMS regulations. This might be illustrative of the realisation that it was not a simple task to become compliant. In 2014, Dekker warned (Dekker, 2014) of the extra complexity and work that would result from building and managing safety management systems. In 2015, other research by (Ulfvengren & Corrigan, 2015a) detailed the large number of organisational changes needed to build a compliant SMS.

2.2.2 Knowledge and skills

This section examines some discrepancies between existing knowledge and required knowledge in safety management and innovation, and some impact on current practices.

Knowledge levels cannot be defined in an easy objective way. Regulatory requirements for knowledge and skills are vaguely defined for those holding key positions in safety management. For example, in the United States, the Federal Aviation Administration (FAA) requires that safety managers in airlines have an "appropriate level of education, training, and experience" to effectively implement and maintain SMS. The FAA also recommends that safety managers have "specific safety management education and training" in order to understand the SMS requirements and principles. Obtaining a certification from the FAA or IATA through their SMS courses and assessments is a way to demonstrate that you have met these requirements. Even though passing a test or earning a certification may not be necessary for safety managers in airlines to work in safety management, more specific requirements are strongly advised as it shows that key managers have attained the minimal level of knowledge and understanding necessary to successfully implement and maintain safety management systems.

The system safety and human factors knowledge requirements for airline safety managers, airline SMS employees and civil aviation authority employees are very generic described. Initial safety training as described in the ICAO SMM (ICAO, 2018a) initial safety training should include, as a minimum;

- organisational safety policies and safety objectives;
- organisational roles and responsibilities related to safety;
- basic SRM principles;
- safety reporting systems;
- the organization's SMS processes and procedures; and
- human factors.

Work in aviation safety management in an airline requires a variety of skills. Some useful skills in this field include:

- Analytical and problem-solving skills: Safety professionals need to be able to analyse data, identify patterns, and identify potential risks. They also need to be able to develop and implement solutions to mitigate those risks.
- Technical knowledge: Safety professionals should have a good understanding of the technical aspects of aviation, including aircraft systems, flight operations, and regulations.
- Communication and interpersonal skills: Safety professionals need to be able to communicate effectively with a wide range of stakeholders, including management, flight crew, and regulators. They also need to be able to build and maintain relationships with these stakeholders.
- Project management skills: Safety professionals need to be able to plan, organize, and manage safety-related projects, such as the implementation of a new safety management system.
- Risk management skills: Safety professionals need to be able to identify and evaluate potential risks, and develop and implement strategies to minimize those risks.
- Leadership and decision-making skills: Safety professionals need to be able to lead and manage safety-related activities and make decisions based on safety data and information.

Safety in aviation is very high. An accident probability of 1 in every 10 million fights is very low, and therefore safety and safety management require in-depth knowledge of the domain. Safety is a multidisciplinary field including management science, systems science, complexity science, (cognitive) psychology, sociology, and aviation engineering.

In my view, the knowledge requirements as set by regulations are not up to par with the challenges of actual safety management.

An effective SMS requires knowledge of the processes but more importantly knowledge of system safety and human factors. Managers at the level of Vice Presidents, Executive Vice Presidents, and board level managers generally have followed short SMS process courses, but not system safety and human factor courses.

Scientific publications in journals, books by safety scientists, and articles in aviation magazines are potential sources to support knowledge increase in the field of safety management. However, accessibility to journal articles can be a challenge for safety practitioners, as they may require a subscription. The transfer of scientific knowledge to actual safety management practices requires educated readers and researchers who understand the needs of actual safety management practices. Additionally, books on safety and safety management may be readily available but can be time-consuming to read and may not always be relevant to airline SMS practices. Therefore, the knowledge gap between safety science publications and actual safety management practices can benefit from research like mine.

2.2.3 Models

Models are used in safety management because they provide a structured and systematic approach to identifying and evaluating hazards, and to developing strategies to prevent or mitigate those hazards. They help safety managers to understand the complex interactions between different components of a system and to identify potential weaknesses and vulnerabilities. Some different types of models we can find in airline safety management departments:

- Risk models: These models are used to identify potential hazards, to evaluate the likelihood and consequences of those hazards, and to determine the necessary controls to mitigate those hazards.
- Human factors models: These models are used to understand how human behaviour is affected.
- Decision models: These models are used to support decision-making in safety management by providing a structured approach to identify and evaluate alternative solutions to safety problems.
- Statistical models: These models are used to analyse data and identify patterns and relationships that can be used to improve the safety of a system.
- Process models: These models are used to understand how a process or system works and to identify potential hazards and their causes.

Models used in safety management are different from business models in that they focus on identifying and evaluating safety issues and developing strategies to prevent or mitigate those risks, while business models focus on identifying and evaluating opportunities and developing strategies to capitalize on those opportunities. Business models are concerned with maximizing profitability and efficiency, whereas safety management models focus on the safety aspects of the organization and how to optimize them for safety.

In (ICAO, 2018a) the management dilemma of balancing protection and production is introduced with reference to the work of Reason (Reason, 1997). The model that is used to visualise this concept separates financial management from safety management by a safety space. An important observation is that the interdependency between safety with other aspects of the business, such as cost and service, is further discussed in the safety manual but not further developed into methods or models.

The integration of safety and business management can only partly be achieved by using the simple protection-production trade-off model. Without a model that covers the relevant scale, scope and resolution of business topics and units, there is no coherence between all the local independent protection-production decisions. This can lead to local optimalisations and resource conflicts between departments negatively affecting the bottom-line airline performance.

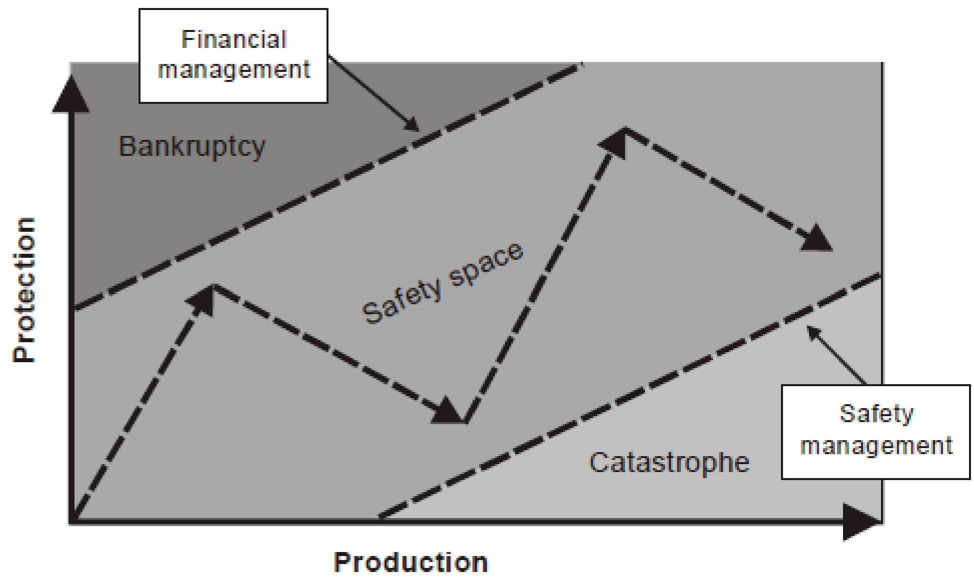


Figure 2-2 Reason's Production-Protection balance (Reason, 1997)

The use of explicit and agreed models compensates for individual buggy mental models. The management of the models, which includes changes and updates as learning progresses, can be used as an indicator for organisational learning.

2.2.4 Integration of safety and business management

In the introduction chapter of (ICAO, 2018a) many safety concepts for safety management are explained. There is a strong focus on safety and safety risk and related concepts, such as hazards and barriers. There is no elaboration of the interdependence between safety and other operational performance indicators, such as passenger service and costs. Although integrated management systems are mentioned in ICAO safety management Standards and Recommended Practices, they are judged to be out of scope. Consequently, the requirement to integrate different management systems is not part of the regulations.

Some of Dekker's (Dekker, 2014) concerns can be regarded as valid if we only look at the number of safety regulations, safety management procedures and processes (Amalberti, 2001). Additionally, a report by the International Transport Forum (ITF, 2018) found that compliance with safety regulations can be difficult for airlines due to the complex and ever-changing nature of the regulations. The report found that airlines may struggle to keep up with the rapidly changing regulatory environment, leading to challenges in achieving compliance.

Since achieving compliance in SMS is hard and full integration with other management systems is not a compliance requirement, we can understand why current safety management practices are mainly scooped at safety in isolation and not as an aspect of the business. This, somewhat reductionist, approach to safety makes it hard to understand how safety is achieved in actual flight operations, where all goals, trade-offs and possible conflicts need to be addressed by the flight crew and flight support (Cahill et al., 2007). In my literature review, I will discuss that much safety research is narrowly focused on safety in isolation, as a sub-system mainly in a silo, as opposed to safety as an aspect-system which makes it a topic of the total airline business.

2.3 Challenges for airline management

An airline must meet multiple requirements to be successful, including being profitable, ensuring safety, complying with regulations, being socially responsible, and providing a positive customer experience. However, these different requirements may lead to conflicts and trade-offs, as achieving one goal may come at the expense of another.

My research is conducted in a network airline, which is an airline that operates a network of routes connecting multiple destinations, often through a hub-and-spoke system. This means that the airline operates flights to multiple destinations, with a central hub or main airport where most flights originate or terminate, and from where the airline connects to other destinations.

The hub-and-spoke system allows the airline to maximize its operational efficiency by reducing the number of empty seats on flights, and by enabling passengers to connect to other destinations without having to change airlines. This system also allows the airline to offer a wider variety of destinations and to better serve the needs of customers travelling on multiple legs or to different destinations.

There are several factors that contribute to complexity in a network airline, including:

- Network size and complexity: A large and complex network of routes, destinations, and hubs can create complexity in terms of scheduling, routing, and fleet management.

- Fleet management: Operating a diverse fleet of aircraft with different capabilities, maintenance requirements, and operational costs can create complexity in terms of fleet management, maintenance scheduling, and training.
- Network operational management: The complexity of air traffic control systems and the impacts of weather on operations can create complexity in terms of routing and scheduling flights.
- Regulations and compliance: The complexity of regulatory requirements and compliance can create complexity in terms of training, maintenance, and operations.
- Maintenance and logistics: The complexity of maintenance, logistics and spare parts management can create complexity in terms of the supply chain, inventory management, and maintenance scheduling
- IT Systems: The complexity of IT systems used for flight planning, crew scheduling, revenue management, and other operational areas can create complexity in terms of data management, integration, and training.
- Competition: The complexity of competition in terms of pricing, route planning, and market positioning can create complexity in terms of revenue management and marketing strategies.

Flight operations is the core activity where airlines produce the value for customers. Flight safety is a critical constraint for airlines. The increase in safety performance is still demanded and requires more and more effort. The context in which flight safety must be produced has several interdependent constraints as described below.

Be profitable: The airline business requires high volumes of money. Interest on loans is dependent on the financial performance of the airline. The markets are very competitive and determine the ticket prices. Costs must be controlled to remain profitable. The relationship between safety and cost is complex and cascades down to flight operations.

Be compliant; an airline and its operations have many regulatory constraints. Many of these constraints are aimed at improving flight, occupational, and environmental safety, but not all regulations are made in joint agreement and coordination. An individual flight has to comply with regulations originating from International Civil Aviation Authorities (ICAO), European Aviation Safety Authorities (EASA), national law, the International Airline Transport Association (IATA), the aviation law of the overflying country, the regulations of the company, and finally the aircraft operating manual. The compliance requirement is the prime concern of safety management system developments, since non-compliance may lead to a shutdown of flight operations by the regulator.

Be Corporate Socially Responsible; (CSR) involves criteria such as being environmentally friendly, making a positive contribution to society, respecting human rights and labour agreements, and combating corruption, according to the KLM CSR website. Not all airlines strive for the best CSR, and as a result, the CSR aspects are part of the competition. For flight execution, this means using as little fuel as possible to reduce the CO2 footprint. But employees should also have a good place to work and good working conditions, such as time to work and time to rest. These topics can cause goal conflicts that can manifest themselves at unexpected moments.

Safety management activities should be capable of discovering these organisational tensions and goal conflicts to bring these discoveries to the attention of other business domains such as network management. This would support a multidisciplinary conversation and create a shared solution space where effective risk reduction measures can be found outside the safety domain, but in other domains such as network scheduling and reduce risk by e.g., a schedule change.

2.4 Drawing inspiration from Aristotle

In science and in the daily practice of airline management, the concepts of causation, influence, explanation, and prediction are critical. The simple reason is that we need to act in order to survive and accomplish our goals. Different theories provide different actor backgrounds, resulting in various interpretations of these concepts. Some knowledge strands are more appropriate than others, depending on the topic and issue at hand. Different explanations are frequently complementary, and in management situations, a consensus is reached because the view is that decisions and actions must be taken to resolve business issues, but in science, there is no need for joint action, and reaching consensus is not required.

Many different types of causal influences have been described in the different sciences. An early set of different types of causation were proposed by Aristotle (322-384 BC) that can be used to answer a why-question (Falcon, 2019):

- The material cause: “that out of which”, e.g., the bronze of a statue.
- The formal cause: “the form”, “the account of what-it-is-to-be”, e.g., the shape of a statue.
- The efficient cause: “the primary source of the change or rest”, e.g., the artisan, the art of bronze-casting the statue, the man who gives advice, the father of the child.
- The final cause: “the end, that for the sake of which a thing is done”, e.g., health is the end of walking, losing weight, purging, drugs, and surgical tools.

The final cause is a teleological explanation, which means it makes reference to an assumed purpose. (Ellis, 2016) suggests equating the levels of Aristotle with four types of causation:

	Aristotle	**Type**	**Causes**
Cause 1	Material	Lowest	Mechanical
Cause 2	Formal	Same level	Immediate
Cause 3	Efficient	Next higher	Contextual
Cause 4	Final	Topmost	Ultimate

Table 2-1 Levels of causation (Ellis, 2016).

Ellis (Ellis, 2016) provides an apt example of his for types of causation as an answer to the question: “Why does an aircraft fly?”

- In Bottom-Up Terms: It flies because air molecules impinge against the wing with slower moving molecules below creating a higher pressure as against that due to faster moving molecules above, leading to a pressure difference described by Bernoulli's law, which counteracts gravity, etc,
- In Terms of Same-Level Explanation: It flies because the pilot is flying it, because the airline's timetable dictates that there will be a flight today at 16h35 from London to Berlin, as determined by airline executives based on demand and carrying capacity at this time of year.
- In Top-Down Terms: It can fly because it was designed to. A team of engineers worked to achieve this within the historical framework of the advancement of metallurgy, combustion, lubrication, aeronautics, machine tools, computer-aided design, and other technologies, all of which were necessary to make this possible, as well as within the economic framework of a society with a need for transportation and complex industrial organisations capable of mobilising all the resources required for design and manufacture. Because it was not designed to fly, a brick cannot fly.
- Ultimate Explanation: And why was it designed to fly? To transport people and cargo in order to profit the manufacturers and the airline company. It would not exist if there was no prospect of profit.

He explains that these are all true non-trivial explanations at the same time because the plane would not be flying if they were not all true at the same time. The higher-level explanations, according to Ellis, involve goal choices and rely on the lower-level physics explanations to succeed. The higher levels have a different nature than the lower levels, and they cannot be reduced to the lower levels. Then he says that a bottom-up explanation would not be applicable to a specific context unless it was the result of human intentions to determine the ultimate cause's purpose.

It is my contention that airline business management is focused on the final cause and safety management focuses on the three lower material, formal and efficient causes. The reader should note that my investigator's war story was completely related to the ultimate cause. Considerations about the ultimate cause are often not included in the investigation report on the practice of flight safety investigations and investigations conducted in accordance with ICAO Annex 13 as exemplified in my investigations war story.

2.5 Mandatory and voluntary reporting systems in aviation

In Annex 19 (ICAO, 2016)], ICAO has stated the requirement for states to establish both mandatory and voluntary reporting systems. In the United States of America, the Federal Aviation Administration (FAA) and in Europe, the EASA, have established provisions for aviation workers to submit voluntary safety reports. The format of the regulation-based reporting form, the type of questions that are to be answered and thus the type of data that is collected is factual and aimed to support the regulatory bodies. The data is collected and analysed by the safety department of the reporter and regulatory bodies and other organizations responsible for aviation safety, such as the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB) in the US, and the European Aviation Safety Agency (EASA) in Europe.

The information collected through mandatory reporting systems is used to identify patterns and trends in safety incidents, to develop safety performance indicators and to prioritize safety actions. Additionally, the data is also used to help identify system-wide safety risks, to develop and implement regulations, standards, and guidance, and to support research and development of new technologies.

The regulatory-based reporting form is not optimised for the specific airline management in which the event occurred. The airline management is derived from available, but not collected warm data, generated by humans, which can be used to inform the different management systems in the airline. Such data can be about the quality of working conditions such as resources, training, support, tools etc in specific events for which the airline management bears large responsibility. To optimise the working conditions, airline management requires data about the way (safety) performance is achieved under conditions when the operation was affected by disturbances. This perspective generates a broader scope for reporting than just the events where safety was absent which requires a mandatory compliance-based report.

In (Beer, 1959) Beer explains we can learn from a system if it is perturbed by external or internal disturbances because disturbances cause the system to deviate from its normal state and behaviour. When a system is perturbed, it reacts and adapts to the change, and the way it reacts and adapts can provide valuable information about the system's behaviour, structure and underlying relationships. The trigger to submit a report should therefore be the effort of the crew to recover from threats and maintain control over the safety of the flight.

The safety department is responsible for receiving safety reports and determining which stakeholders, such as flight division managers, training staff, and flight crew, have access to the data. However, this decision is left up to the discretion of the safety experts, which can lead to limited dissemination of the reports to other stakeholders. As a result, important learning opportunities from the safety reports may not be fully utilized, as reports that could provide valuable insights for other stakeholders may not be shared. My research will address learning from operational experiences.

2.6 Problem statements

When we assume and airline company has the ambition for survival by sustaining a value exchange with its environment, we get a frame of reference. Optimal use of resources for maximum sustainable value production provides a decision criterion for decisions that affect safety and the decisions that protect safety.

There is a **lack of integration** between airline business management and safety management which results in the problem of having a limited solution scope for safety issues. A risk reduction option by e.g., changing arrival times or changing aircraft type is not in scope from a safety in a silo perspective while an integrated view would make this type of solution visible and part of the decision-making process. Integration requires suitable models that support integrated decision making preferably in the context of value production.

Additionally, **safety is not an aspect of the current network management** system which makes it hard to achieve an optimal allocation of company resources e.g., to redirect resources from a risky route with an operational loss towards new or better performing routes.

The above problems refer to issues related to the airline management model. The problems below are related to the feedback system that the management model requires for effective management of the airline resources for value production.

The current compliance-driven feedback system from flight execution to the other layers in the airline management system **lacks the required specificity** to improve the management of the operational working conditions.

The outcome of an event is often the trigger for submitting a required safety report. An outcome-based trigger **limits the number of learning opportunities** of an event. Events which the crew themselves experience as a learning opportunity should also be a trigger to submit a report.

Additionally, the current feedback system **only collects data in instances when safety is lacking or at risk**, **and it only captures factual data**, which limits the usefulness of the feedback data. The current system does not gather feedback on the full range of performance, from failures to successes, even though the flight crew can provide this data. This data is crucial for understanding how the system behaves when essential variables are impacted by external or internal disturbances.

Learning potential is not fully achieved because a limited set of stakeholders can read the reports. The report data can be beneficial for other stakeholders than the safety department such as training and other flight crew. Learning opportunities are increased when all stakeholders can have access to anonymised reports that suit their interests.

The standardised compliance-driven **ASR report is not fitted to specialised human factor and risk models** that may be employed by the safety department. Learning potential is increased when operational performance data is collected that fit the models that are in use.

The problems can be clustered in two groups, management model and feedback systems, which have been inspirational for this research project.

2.7 Why this research matters

This research matters because it delves into the complex and critical issue of integrating safety with business management in commercial aviation airline organizations.

My research aims to provide answers to solve the problem of the lack of integration between airline business management and safety management by providing innovative solutions that can be used in practice. My research will provide a comprehensive and integrated approach to safety management that considers both safety and business objectives. The research results will enable the airline to improve its resource allocation optimisation for maximum sustainable value production.

The research will deliver a method that uses the expertise of the flight crew to provide feedback on operational events that will serve the SMS but also all other stakeholders involved in flight operations.

As a Design Science Research (DSR) project, my research will not only focus on the development of new solutions to address the specific challenges of integrating safety and business management in the international commercial aviation industry but also on the practical application and testing of these solutions in a near real-world setting. The DSR approach emphasizes the creation of new knowledge that can be applied in practice, by testing the concepts in real-world cases. This makes the results of this research more valuable for practitioners and managers in the field. Additionally, by extending the scientific knowledge base, this research will contribute to the ongoing development of new methods and approaches for addressing the challenges of safety and business management in the aviation industry.

Chapter 3: Literature Review FlightStory

This chapter presents a systematic literature review to support the development and evaluation of FlightStory as a high-variety feedback signal. The purpose of this review is to find and evaluate existing knowledge in a way that is explicit and repeatable (Greenhalgh, 1997). Safety management field problems will be evaluated with relevant literature already available to show gaps between existing literature and the required knowledge for this research.

A systematic review was chosen because it has a structure that includes purpose, selection criteria, and critical review. The advantages of a systematic review (Greenhalgh, 1997) include explicit search criteria, allowing more reliable conclusions. The procedure for a systematic review for Design Science Research (DSR) by van Aken & Andriessen (2011) is followed. The steps in this literature review are problem definition, search strategy, evaluation, analysis, and synthesis. This section introduces the field problems which are further discussed in Chapter 6 about the FlightStory development. DSR field problem descriptions are based on an analysis by me as a researcher and safety expert and they are based on experiences and discussions in the field of safety management practices van Aken & Andriessen (2011).

3.1 Field problem description

Cybernetic requirements for the efficacy of a feedback channel are based on the concept of variety. Ross Ashby's concept of "variety" refers to the number of different states or conditions that a system can exist in. The greater the variety of a feedback channel, the more knowledge of the operation can be attained and the potential for managing operational performance conditions increases. Here, the Law of Requisite Variety provides a useful perspective(Ashby, 1956). When applied to an airline, the model of the operation as held by airline managers must be continuously updated to provide an accurate understanding of the gap between Work-As-Imagined (WAI) and Work-As-Done (WAD) (Hollnagel, 2014b). Three types of variety are essential for the efficacy of a feedback channel; change capacity, transduction capacity, and channel capacity (Beer, 1979)(Türke, 2008). Change capacity refers to the potential to recognise relevant states of the reported system for the reported issue at hand. Change capacity refers to the ability of a system to adapt and respond to different states or conditions within the system. This includes the ability to recognize and identify relevant states or variables that are related to a specific issue or problem that the system is facing. It is a requirement for the potential of the system to respond to different situations and adapt to changing circumstances. Transduction capacity refers to the ability to effectively communicate information across different departments or groups, such as from operations to airline management, in a way that is easily understood by the intended audience based on their knowledge and understanding of the subject matter. Channel capacity refers to the ability to transmit a certain amount of information, including its relevance and timeliness, through a communication channel. It is often referred to as the signal's bandwidth.

Actionable feedback from flight crew to both airline management and the SMS enables organisational learning. The variety of the feedback system, from flight execution to the airline organisation, should ideally provide the requisite variety to match the complexity of safe, economic, and customer-centric flight operations with the models through which the airline is managed (Conant & Ashby, 1970). This research addresses three problematic and related aspects of current feedback systems.

The application of the three cybernetics feedback concepts above has been used to define the specific research problem descriptions. After the literature review, I will then define specific research questions.

The first problem, is the separation between safety and all other aspects resulting in a safety in a silo approach. In this research, I mean the isolation of safety from airline system goal aspects such as network, the economy of flight and customer satisfaction. The combination of performance criteria used in flight operations results in goal conflicts and trade-offs. The operational strategies and decisions to manage these operational constraints cannot be understood from a safety perspective alone. Current compliance-driven Air Safety Report (ASR) formats do not explicitly collect contextual information related to the reported events. In the safety office, the event and risk analysts can only enrich the ASR with recorded data from Flight Data Monitoring (FDM) and other operational data systems but this data if used, can only help to partly reconstruct some contextual factors. Lacking collectable contextual data about events withholds airline management from possible lessons and thus in managing optimal operational safety performance conditions. This problem is mainly a problem of change capacity, but also a problem of the transduction capacity of the feedback channel.

The second problem is that of qualitative versus quantitative data, or structured versus unstructured data. The current safety reports contain mainly factual data including data such as time of day, flight phase, altitude and, in general, provide limited data related to how and why certain decisions were made. Furthermore, the ASR form does not request the flight crew to describe and *evaluate* the operational context. Therefore, the sense-making process and decision dilemmas the crew experienced are not available to airline and operations management as an additional means to direct their management activities. Data required to reconstruct and understand the pilots' local rationality and decision-making can hardly be extracted from a set of classifications from a pre-defined structured taxonomy. Only a personal account, in free format, can approach the requisite variety in explaining the pilot's perspective and sense-making (Dekker, 2011a). Moreover, the required format of safety reports contains data fields for a structured data approach (EASA, 2014). The qualitative data analysis from safety reports in the safety office often ends with only selecting classifications for the event to fill the safety report database. All data that is categorised using a pre-defined structure is assumed to be complete. However, the requisite variety for the data structure is never achieved since there is always the category of "other." Structured data supports easy quantitative analysis, and this has value for safety management, but the quantitative approach has its limits, especially in the ultra-safe domain of aviation (Amalberti, 2001). Counting classifications is simple and therefore attractive, but often reduces the actionability of the data. This second problem of lack of contextual and flight crew sensemaking data is also a problem of change and transduction capacity for the feedback channel.

The third problem is that ASR feedback is only provided about situations where safety was or could have been an issue. Regulatory compliant ASR's are typical Safety-I (Hollnagel, 2017) which means the reports are about *prescribed* situations related to safety underperformance or lack of safety. Regulatory requirements for ASR are very specific and not regarded as a minimum specification for reporting by airlines. Incident reports of near-miss reports are concerned with only part of the safety performance scope: mainly the lower band of safety performance. Although this has helped aviation to make safety progress, cybernetic theory suggests the feedback channel can be improved supporting even further improving safety performance. Partial and biased system performance data is insufficient for the requisite system understanding. The lack of understanding can be revealed when similar events occur and lessons have not been learned. There is always partial data due to the under-reporting of events (Johnson, 2003), and therefore the reporting that is received at the safety office should have a high information potential. An SMS initiative to increase the number of reports is striving for more of the same low informational data and this does not compensate for the lack of specific types of data. Safety-I events are a subset of the events where flight execution performance is challenged in terms of safety, economy, and customer experience. Less likely to be reported in an ASR are lessons that could be learned from how well operational disturbances were dealt with (Gilbey et al., 2016), i.e. the feedback channel lacks a “lessons learned from what went well” component. Consequently, airline management is deprived of data about successes in safety performance. Practising Safety-II and resilience concepts (Hollnagel, 2017) based on the current ASR format is labour-intensive and nearly impossible since a Safety-II and resilience analysis is not supported in the standard data classification taxonomies. This third problem is a problem of the change capacity of the feedback channel.

In other words, the feedback channel should have a high signal-to-noise ratio (Ashby, 1956). A high signal-to-noise ratio indicates that the desired signal is stronger than the background noise, making it easier for the system to distinguish and respond to the intended input. To adapt to its environment, a system must have a high signal-to-noise ratio so that it can effectively filter out unwanted or irrelevant inputs and respond to a wide range of inputs (Wiener, 1948). This is consistent with the law of requisite variety, as the more variety of responses a system has, the more adaptable it is.

In summary, the three identified problems are:

4. a problem of the reductionist approach where safety is managed in a silo, disregarding other key performance indicators, by only collecting safety data.
5. a problem of the positivistic approach where (mainly) only facts are preferred and collected while data concerning contextual interpretations of these facts by the reporter is not explicitly collected. This can be expressed a problem of qualitative versus quantitative data, or structured versus unstructured data.
6. a problem of performance data bias where only Safety-I (near) incident data is collected and where no data about positive safety performance is systematically collected.

This is a limited set of problems other problematic issues are beyond the scope of my research project. Further elaboration and explanation of these problems will be given in the FlightStory project chapter 6.

3.2 Search strategy

Literature research always requires publication databases and search engines. Based on (Martin-Martin et al., 2018) I've considered Google Scholar, Scopus and Web of Science. The advanced search possibilities for Scopus and Web of Science are higher than for Google Scholar. Especially the feature of searching in the abstract in Scopus and Web of Science was very useful to get more relevant search results. Both Scopus and Web of Science gave the same search results for search #1 below, while Google Scholar (GS) gave thousands of additional non-relevant results if the search is not limited to the publication title alone. For this systematic literature review, I chose Web of Science because I preferred the management of the search process. For completeness, I added Google Scholar search via title and keyword.

The search for literature was therefore conducted on the Web of Science (WoS) via the advanced search options. The search text is shown in the table below. The search was executed in the Web of Science Core Collection. The Web of Science Core Collection is described on its website as a curated collection of over 20,000 peer-reviewed, high-quality scholarly journals published worldwide in over 250 science, social sciences, and humanities disciplines. The search results showed that over 75,000,000 entries were queried.

An advanced search in the Web of Science Core Collection searches the following fields of each publication entry which is in the database: Title, Abstract, Author Keywords and KeyWords Plus®. KeyWords Plus terms are derived from the titles of articles cited by the author of the article being indexed, articles without references and articles whose references are not linked to source items will not have KeyWords Plus. All years of publication were included in the search criteria.

Although the Web of Science database is a widely used tool for searching scholarly articles in safety science, it did not include several influential books and journal publications in my search results. To overcome this, I included these books in my review, which were collected during my 15 years of experience as a safety expert and researcher.

Furthermore, I included a review of the ICAO safety management regulations. These regulations apply to all aviation service providers. Therefore, they shape to a great extent the formal safety management methods and practices in airline companies. Research about the regulated reporting systems is captured in the WoS searches.

3.2.1 Literature collection search process

The literature search was completed 1-sep-2020 using WoS (https://webofknowledge.com), and GS (https://scholar.google.nl).

The WoS search was executed using a Chrome browser with authentication via a VPN with TU Delft. The GS search was executed using the research tool Publish or Perish version 7.14.2619.7235 (Harzing, 2007).

All retrieved literature was stored in Qiqqa (www.qiqqa.com), which is a research assistant software application. This software allows tagging documents and parts of a text to support the review.

Due to the low number of search results using the strict systematic search strategy procedure, I continued to search using expert judgement which yielded another 37 relevant GS search results:

- GS to search in search results, this can be achieved by limiting a search only to the search in results of a previous search.
- Topics discussed in the shortlist of relevant safety science literature.
- Relevant references found during the literature review and relevant aviation regulations.
- Other work domains where relevant safety science research is conducted.

Review of literature collection The search result publications were reviewed regarding the three identified safety reporting problems. Most publications were relevant for one to two of the identified problems. Nearly none applied to each of the three issues.

The table in the appendix shows authors, types of publications and assigned review tags in the left column. The tags include relevant research domains and relevant safety research topics all of which will be explained in the specific review section. Mostly (peer) reviewed publications are shown while some non-peer-reviewed publications have been studied and referenced in the review. Some publications are relevant for more than one of the defined problem areas and are therefore referred to more than once.

3.3 Review of literature search results

The search result publications were reviewed regarding the three identified safety reporting problems. Most publications were relevant for one to two of the identified problems. Nearly none applied to each of the three issues.

That table with search results that were reviewed can be found in the appendix chapter 11.

3.3.1 Literature review related to the reductionist problem in event reporting.

The problematic issue, which I defined as the reductionist approach, is concerned with safety reporting that regards safety in isolation from other issues creating goal conflicts. Regulations require a safety report (ICAO, 2018a) when a flight crew, normally the captain, experienced an event where safety was compromised or where safety could have been affected. According to the regulations, a reporting system's purpose is to collect information to identify (new) safety hazards or risks (EASA, 2014). I refer to this approach as 'Safety in a Silo' and the two first rows in the table above show the related literature search results. It should be noted Safety-I and Safety-II can also be viewed as 'Safety in a Silo'. I tagged the search results publications as 'Safety in a Silo' when no explicit reference was made to the totality of operational performance. I also tagged 'Safety in a Silo' when the publication did not discuss data in safety reports related to trade-offs between safety and other critical key performance indicators.

The table below shows the tags and the reviewed publications.

Tag \ Type	Book	Journal	Thesis / Non peer-reviewed
"Silo No" Safety not in Silo	(Hollnagel, 2017) (Dekker, 2011a) (Rasmussen et al., 2000)	(Amalberti, 2001) (Sujan et al., 2017) (Rae et al., 2020) (Stone, 2006) (Wiegmann & von Thaden, 2003)	(Bramfitt-Reid et al., 2017) (Kingston-Howlett, 1996)
Safety in Silo	(Sánchez-Alarcos Ballesteros, 2007) (McKinnon, 2012) (Davies et al., 2003) (Van der Schaaf et al., 2013)	(Rae, 2016) (Madsen et al., 2016) (Roelen et al., 2011) (Stemn et al., 2018) (Lindberg et al., 2010)	

Table 3-1 'Safety-in-Silo' reviewed literature publications

Amalberti describes reporting as a simple principle of a general-purpose safety model (Amalberti, 2001). In the same publication, Amalberti addresses the reduced effectiveness of safety reporting in ultra-safe systems, systems where the accident rate is around 1 in a million, which is representative of the aviation system. He argues accidents are the result of a combination of factors, none of which alone would have led to an accident by itself. (Sánchez-Alarcos Ballesteros, 2007) adds that operators are not always capable of anticipating interdependencies before an accident occurs due to the complexity of flight operations. Safety reports are mainly concerned with single factors, and therefore, combinations of factors remain difficult to detect. Amalberti states ultra-safe systems seem to operate at the edge of the safety space defined by the pressures of individual concerns, technology and the commercial market. He refers to the risk model of (Rasmussen, 1997). System operation at the edge may lead to what Amalberti calls the trap of over-regulation, which may have the effect that while nothing actually changes in the operation but more violations are registered which might increase the reluctance and opacity in incident reporting. Although not explicitly stated by Amalberti, one can infer an argument for including in safety reports data about the pressures that influence the safety space. This would take safety out of the silo and consider other aspects as well, and this is in line with arguments found in (Hollnagel, 2017) (Sujan et al., 2017) (Dekker, 2011a).

Hollnagel in (Hollnagel, 2017) and (Sujan et al., 2017) discuss reporting as an essential factor to improve the potential to learn. Learning, as one cornerstone of the resilience potential (Hollnagel, 2013b) is supported by an effective reporting system that considers how reports are written and submitted and how information is processed and analysed in the safety department and how this information is stored and disseminated in the organisation. Furthermore, they suggest reporting should be about Work-as-Done, explaining how adjustments were necessary, going beyond the factual reporting of an event's safety aspect. (Dekker, 2011a) agrees to report a narrative of the event with a sufficient resolution that offers the organisation an understanding and finds opportunities for change. In other words, he addresses the specific need for change capacity in the safety report narrative. Similar conclusions were drawn in research related to accident storytelling (Rae, 2016). They showed safety learning was improved, but unfortunately, safety was accepted as the only performance perspective in the stories whereas (Stone, 2006) suggests every situation, and not only safety-critical events, are a learning opportunity.

Rasmussen and Svedung developed a systems approach to proactive risk management in a dynamic society (Rasmussen, 1997). In their model with nested levels of decision-making, from safety-sensitive work via several layers up to governmental law making the system is influenced by external factors. These factors include technological change, changing requirements for competence, changing market conditions and financial pressure, and political climate changes. They claim one of the requirements for proactive risk management is a closed-loop feedback control system and the recognition that humans are an important safety resource and not just an error source (Rasmussen et al., 2000). They provide general rules to identify the people and work situations related to the productive process that should provide feedback. The feedback should include factors related to the capability these workers should have to maintain control over the productive process.

They argue based on control theory that the success of a closed-loop feedback control strategy depends on accurate observation and measurement of the current state and response to control actions. The effectiveness of the control system is limited by the quality of the measuring channel (Rasmussen, 1997). It's crucial to have access to accurate information about the functions within the control domain and ensure compatibility with the objectives and constraints. Their suggestions and claims are in line with the argument I make for the need for FlightStory.

A non-peer-reviewed article discusses the question of whether an organisation can hear all the safety concerns their workforce has. (Bramfitt-Reid et al., 2017) of the UK-based Royal Aeronautical Society proposes a set of questions to diagnose the quality of listening an aviation organisation achieves. The effectiveness of the reporting system is specifically addressed. The questions that an organisation should ask itself about the effectiveness of its reporting systems, go beyond the aspects of a (EASA, 2014) compliant reporting system. They suggest exploiting and connecting data from other organisational departments to enrich the view on safety in an attempt to break down the silo walls. Their logic seems to make sense; however, no research has yet supported or falsified their claims. This lack of research was already noticed by (Lindberg et al., 2010). In their research, a model of all stages, from reporting to prevention, was built. These authors state that no research was found concerning the quality of the filed reports. They defined quality as the degree to which the report contained information that supported the selection of events to be investigated. In my research quality of reporting is related to the extent a report supports the learning in the management system.

Other research did not explicitly address the problems of the ‘Safety in a Silo’ perspective. (Roelen et al., 2011) argue for the need to link flight operational performance with the managerial system's quality. Such an approach provides, via the generic delivery systems resources and criteria for the flight operation, to operate safely inside the safe envelope (Hale et al., 2007). The delivery system includes a component of conflict resolution. When this is given the interpretation of supporting decision-making regarding trade-offs between other key performance indicators (e.g. cost and customer) safety can be taken out of the silo and be understood in a broader context, but this is not explicitly addressed in this research. It does not suggest asking the flight crew to submit the safety report to include data about the perceived quality of the delivery systems. Similarly, Reason in (Reason, 1997) addresses the need to consider what is manageable by the organisation. Those manageable organisational factors commonly known as Performance Shaping factors or Common Performance Conditions (Hollnagel, 1998) determine the organisation's 'safety health'. Good health is associated with a reduction in the probability of failures. However, Reason also does not consider including a flight crew assessment of these factors in the report format. A reporting system that does not collect organisational factors will be less effective in learning from incidents as concluded by (Drupsteen et al., 2013).

Wiegmann in (Wiegmann & von Thaden, 2003) developed and tested a method, incorporating Cognitive Task Analysis and Naturalistic Decision Making concepts, to support flight crew in giving a more structured and complete account of an event. The method appeared to have the potential in collecting richer real-world incident data. This method is like the Unique Report developed by (Leva et al., 2010). This reporting method provides a structure for the event description. (Wiegmann & von Thaden, 2003) also emphasised the importance of collecting operational performance conditions. The prototype reporting system was highly positively evaluated by relevant airline employees.

Some research books on safety management explicitly addressed safety reporting (Sánchez-Alarcos Ballesteros, 2007) (McKinnon, 2012)(Davies et al., 2003). They agreed on the importance of safety reporting by operators. Different aspects of reporting are discussed, such as compliance related to the reported event and the importance of reporters' confidentiality. However, none of the books argues for a broad operational perspective with the potential to increase the learning potential from safety reports.

In (Madsen et al., 2016), it was concluded that airlines do not learn from near-misses that had no obvious risk by using accident and incident data and statistical analysis. The researchers suggest that by broadening what is reported by the flight crew, airlines' learning could be improved beyond the current learning level. However, they are not specific on what type of "extra" data should be collected and how the data and analysis should be used to improve learning. Similarly, (Stemn et al., 2018) analysed literature about a failure to learn from safety incidents. They used a bowtie model to structure the reported themes related to threats, consequences and controls to prevent a failure to learn. Forty-five papers were identified, and the threat themes that emerged were learning input, learning process, learning agents, and learning context. The first three threats are like the topics for the literature review for the FlightStory project. They identified a specific threat of inadequate descriptions of reported incidents within the theme of the learning process. The single safety perspective was mentioned as problematic and limiting the learning potential. None of the papers in this specific research was related to aviation, but it can be argued that safety reporting has commonalities in different domains.

A cybernetic approach to Safety Management development (Kingston-Howlett, 1996) discusses cybernetic concepts, including the Viable System Model (Beer, 1972) concerning safety management systems. Based on the Law of Requisite Variety (Ashby, 1956) Beer has developed the notion of variety balancing. A broader treatment of this notion can be found in Chapter 8. Furthermore, Beer speaks specifically about reporting of operational units, (in this research a flight can be seen as an operational unit), to their management unit, (in my research Flight Operations Management can be seen as a management unit). Beer called this reporting the 'resource bargain' which is concerned with the execution of the operation and the resources provided by management. The resource bargain reporting should cover the management of all the essential variables such as in this research safety, economy and the customer. This kind of reporting takes safety out of its silo and into the context of the other key performance indicators. This argument is a logical consequence of the system-in-systems view, meaning that the SMS is embedded in the larger airline business management system, providing the embedded SMS context.

3.3.2 Literature review related to the problem of the positivistic approach to event reporting.

This section discusses the literature related to the positivistic and interpretative aspects of flight crew event reporting. I will address that epistemological and methodological preferences shape the preference for specific types of data for analysis.

The means by which a flight crew can report a safety event determines the extent to which the flight crew can provide a personal perspective on the event. In the problem statement, I argue that the pilots' safety reporting form must be designed to elicit the reporter's personal views and opinions. Without the insider story of local rationality, the analysts of the safety reports will lack data for a comprehensive analysis of the event. The lack of an insider's view data reduces the potential for lessons and makes analysis easier but comprehension harder. The analysis can is mostly limited to data statistics, reducing the specific learning potential of the reports (Stone, 2006) (Rae, 2016).

The table below shows the tags and the reviewed publications.

Tag \ Type	Book / Regulation	Peer reviewed	Thesis
Positivistic	(ICAO, 2018a) (EASA, 2014)	(Cabon et al., 2012) (Rae, 2016) (Cui & Liu, 2019)	
Interpretative	(Dekker, 2011a) (Hollnagel, 2017) (Davies et al., 2003)	(Fitts & Jones, 1947) (Sanne, 2008) (Gherardi & Nicolini, 2000) (Stone, 2006) (Stone, 2006)	(Kingston-Howlett, 1996)

Table 3-2 Reviewed literature labelled Positivistic or Interpretative

3.3.2.1 A quantitative approach to event reporting

Aviation regulations related to reporting show a preference for factual and structured, preformatted data supporting a quantitative analysis of trends and incident or accident probabilities (ICAO, 2018a)(EASA, 2014). The regulators desire to receive as many reports as possible and therefore prefer this type of reporting data. ICAO promotes a data-driven approach and has developed and supported the development of taxonomies and classification structures. ICAO (ICAO, 2018a) addresses the importance of safety data collection and processing systems in a dedicated chapter since effective safety management highly depends on them. They state reliable safety data and safety information is needed to identify trends and make data-driven decision-making possible. They recognise different levels, from global, regional, and national to organisational, of the aviation system to benefit from safety data. Mandatory and voluntary reporting systems are mentioned as a means for collecting safety data. Since mandatory reporting systems tend to collect more factual flight-related and technical data than human performance aspects, ICAO advises States to implement a voluntary safety reporting system. Voluntary safety reports should go beyond typical incident reporting and should include latent conditions, which they exemplify with, inappropriate safety procedures or regulations and human error.

Regulation (EASA, 2014) establishes a reporting system through which people working in the operational aviation domain can report safety-related occurrences to the aviation authorities. Compliance with this regulation is audited and thus seen as very important by the airline. Furthermore, software developers for airline safety management systems implement the regulation into their report and database structures. ICAO (ICAO, 2018a) recommends the use of taxonomies for data capture and storage. This kind of data classification is an attenuation of variety: differences that are not part of the taxonomy are lost. In the Commercial Air Safety Team (CAST) / ICAO Occurrence Categories taxonomy, a mix of intermediate and end states are listed. This list is not assumed to be complete since there is a category of 'Other'. Taxonomies are suitable for data classification and quantitative analysis but not for sharing stories with lessons between flight crew. Regulations about reporting should be seen as a minimum standard and suitable for every aircraft operator. Regulated reporting has been useful but has in the standard format probably reached its plateau (Amalberti, 2001).

In research to review human factor taxonomies, accident and incident reporting systems and data collection tools, (Beaubien & Baker, 2002) state that as a general rule, most human factor issues are described in the report narrative. The analysis of this content is costly and time-consuming. They want to address this problem by providing the industry with a generalised Human Factor taxonomy and electronic data reporting and analysis tool. Criteria for taxonomy development such as internal validity, which includes the reliability of using the correct descriptors for an event, and external validity which includes the notion that gaps in knowledge can be derived from the taxonomies, align with a positivistic worldview. (Tanguy et al., 2016) argue that software algorithms can map safety reports to a taxonomy but also to topics. Probabilistic topic modelling software processes the reports and builds a topic model. The reports then get assigned a list of relevant topics, of which the relevance is expressed in a percentage. A higher percentage indicates a better match. The safety data analyst can use the topics to find specific reports by filtering on the topic. This combination of software pre-processing and human analysis is tested in some airlines and regulatory organisations to handle the many incoming reports. The results are reported to be encouraging since they show how the expert's time can be better used, but no claims are made about the reports' effectiveness in terms of learning potential.

When event reports are seen as scientific samples and the number of reports as sample size, a difference in approach is seen in qualitative and quantitative research. In aviation, safety accidents are outliers and low in number. The accident sample size is too small to satisfy the generally accepted sample size needed to express the statistical properties of the sample with desired confidence. From a quantitative perspective, a story, an account of an event, might just be seen as N equals 1, while for a qualitative analysis, valuable data may be found. In a quantitative approach, the applied mathematical operations should comply with the problem space's nature under analysis. ICAO (ICAO, 2018a) suggests the use of descriptive statistics, such as mean and standard deviation, statistical hypothesis testing and other related concepts. The underlying positivistic assumption, which is not made explicit, is that safety data fulfils the requirements for these kinds of analysis. Given the ultra-safe characteristics as described by (Amalberti, 2001) where accident probability is around 1 in a million to 1 in ten million, the Gaussian probability distribution application is refuted by (Taleb, 2007)(Taleb et al., 2014). The point Taleb makes is that extreme events have a higher impact, which he called 'Black Swans' than expected from a Gaussian distribution. The point that Taleb makes in his concept of the "Black Swan" is that extreme events, or "tail events," have a much higher impact than what is predicted by traditional statistical models such as the Gaussian distribution. He argues (Taleb, 2009) that the Gaussian distribution, also known as the normal distribution or bell curve, is often used to model and predict the likelihood of various outcomes, but it fails to take into account the possibility of rare and extreme events that can have a significant impact on the system.

In 1945 a monumental human factors research was executed (Fitts & Jones, 1947) in an attempt to "eliminate a large proportion of so-called 'human-error' accidents by designing equipment in accordance with human requirements". Accounts of 460 errors made in operating controls in the cockpit were collected and analysed. The flight crew were asked to "describe in detail an error in the operation of a cockpit control …". Additional interviews were executed "to contribute an experience". This data collection method shows the appreciation of interpretive data, although there was a concern for the effect of personal opinion and preconceived ideas. This concern was handled by limiting the study to factual reports on actual flying experiences. Also, (Multer et al., 2013) address the need for a story of an event to get insights into the context for employees' decisions and actions to better understand why people did what they did.

In another research, the number of filed safety reports was evaluated as a quantitative indicator for possible reductions in safety during organisational changes (Herrera et al., 2009). The increase in reports was not regarded as a decrease in safety because, during the change, the importance of maintaining safety was emphasised, and this could also explain the increase in the number of reports. The number of reports was consequently not regarded as a useful safety indicator.

3.3.2.2 A qualitative approach to event reporting

The book (Davies et al., 2003) explicitly discusses the quantitative and qualitative approaches to safety management. They argue that quantitative and technical data downplay the role of human factors and 'subjectivity'. This book presents methodological 'tools' whose reliability and validity have been shown through extensive work in the rail and nuclear industries. They argue that a qualitative approach can be executed reliably. In their research, safety report analysis is discussed in which the analyst maps report details, on a human factor model taxonomy (Davies et al., 2003). They affirm the importance of qualitative data and human interpretation in contrast to (Cui & Liu, 2019) who researched a measurement of the amount of information in air safety reports. (Cui & Liu, 2019) proposes a measurement of the amount of information for the received reports to provide a reference for improving the quality of reporting information. The mathematical information quantity, based on grammatical information reflecting only a relative amount of information, did not yield any practical benefit. These methods will fall short, at least for the coming years, of the capability of human expert information extraction of air safety reports as shown by this reviewed research.

In a comprehensive book on reporting systems, which is often referred to by other publications, (Johnson, 2003) discusses the content of the safety report form. He states that the types of questions in the form and the guidance in the form for the reporter illustrate the report designers' assumptions about the reporter's knowledge, skills, and training. He addresses specific safety report questions that are non-factual but require some introspective ability to assess human performance-related factors. These considerations are essential when designing a reporting form to collect rich and reliable data. Reliable in this context means the reporter answers the questions based on a correct understanding of the question. Question format and supporting guidance information regarding a question should increase the accuracy of the answers to the questions. Johnson warns for a judgment by the report analyst on the accuracy of the reporters' perception of the event facts should not declare data unreliable. The report questions should give the analyst an understanding of the reporter's evolving worldview (Dekker, 2011a). These kinds of questions, related to the operating conditions and human performance conditions, are not part of the minimal question set as defined in (EASA, 2014; European Parliament, 2014) although such questions are suggested in the regulation guidance material accompanying the regulations (EASA, 2014).

Roelen in (Roelen et al., 2011) refers to the work of (Dekker, 2004) and (Leveson, 2004) to show safety science is progressing with advanced new accident models in which failures are not about broken components but about a web of relationships and transactions. (Dekker, 2004) describes the traditional understanding of accidents, based on the old models, in terms of a structuralist vocabulary with mechanistic metaphors. (Roelen et al., 2011) makes a significant observation that the new advanced models do not connect to the safety data collection practice. Roelen argues that making safety managers aware of the new models will not really change the practice in the safety departments in aviation, since regulatory changes are very slow and data storage and analysis methods have to be updated. Also at the time, the Swiss Cheese model of Reason was just being implemented in safety management departments. Therefore, they developed an event chain model that keeps compatibility with the safety departments' current practices. They notice a lack of data in airlines and regulators' data collection methods to populate the airline management's influences on flight operations.

Unfortunately, a regulatory minimal compliant event reporting system does not contain the desired questions to elicit the missing data. A reporting method that goes beyond compliance, such as FlightStory, is required to populate and fit the new accident models mentioned by Roelen, Dekker and Leveson.

Hollnagel in (Hollnagel, 2017) discusses in his book on Safety-II in practice his four cornerstones of resilience: to anticipate, to monitor, to respond and to learn. He expresses a concern related to the ability to learn. This is concerned with the amount of time and departments a report must travel through within an organisation, as this affects the distance between an event and the learning of that event. More processing of reports also often leads to a change from raw data to aggregated data, trends, and statistics, reducing the specificity of the event and thereby affecting the specificity of the possible lessons from that event. The raw data should include how people did their work, how they could cope with unexpected conditions and how they developed robust and effective methods to succeed rather than how they failed.

Chanen in (Chanen, 2016) argues that unstructured data in the form of narratives is indispensable for safety reporting. In general, the learning potential from safety reports which contain only structured data is limited since it does not fit the view a person has on their own work (Sanne, 2008) (Gherardi & Nicolini, 2000). Structured data alone does not have the variety to express important details and nuances. Human narrative analysis can be very labour-intensive and take time. To compensate for this problem, automated analysis methods are being researched. Natural Language Processing (NLP) and Deep Learning techniques are being developed to automate narrative processing to find word-level meaning. These techniques can maybe be used to assign structured data tags to a narrative, but conveying the message from a story is still best done by human experts (Chanen, 2016).

A generic complex systems approach to explore and assess complex systems behaviour by understanding and discovering interactions and dependencies (Madni et al., 2014) uses model-driven storytelling. Starting from human user-supplied initial conditions, stories or scenarios are generated and then evaluated on complex system behaviour. In flight operations, the stories are generated by the actual flight operation execution and not just by its model.

(Rae, 2016) researches the role of accident storytelling in safety teaching and concludes that it is an intrinsic part of safety education. This reviewed research explains that the realism of a well-told story, including the uncertainty and subjectivity of the interpretation, promotes transformative learning, which is agreed by (Gherardi & Nicolini, 2000). Transformative learning refers to a process of personal and social change and development that occurs when individuals engage in critical reflection on their experiences and perspectives. He also observes that safety literature uses an implicit positivist framework in which there is "abstract truth", which is somewhat clouded by investigator bias. (Dekker, 2011a) argues the importance of the narrative of the event description and the learning potential relative to the classification of events because classification disembodies and reduces the contextual description to such an extent that it the sense-making process of the actors in the reported event, is lost. Also, in rail safety, storytelling was evaluated as an effective method to increase comprehension of events (McHugh & Klockner, 2020). Similar to construction (Rajala & Väyrynen, 2010) researched core stories, including storytelling and narratives. This reviewed research suggests that this method may be useful and practical in other domains than in the construction industry alone.

Pasquini refers to the importance of the narrative of an event written by a flight crew or ATC controller (Pasquini et al., 2011). Their analysis of the Aviation Safety Reporting System's effectiveness in the USA addresses the standardisation of aviation operations, which reduces the need to describe the context of an event in every detail. They conclude that domain structural characteristics, such as standardisation, are a key dimension to consider when evaluating reporting systems. They argue that only the main events and actions are needed in aviation for a truthful reconstruction because the scene in which the event unfolded can be considered standard. While for some events, this may be a valid reasoning, in many cases the contextual data is needed to understand the pilots' sense-making. The operators, filing the narrative, are the ones that experienced the specifics of the context that often cannot be reconstructed by the analysts in the safety office. Furthermore, (Pasquini et al., 2011) address the concept of visibility; to which extent an operator is able to observe particular system behaviour. Visibility should be considered when deciding what to ask operators to report. Asking for invisible aspects may lead to the flight crew guessing, which leads to unreliable data. Visibility should be considered when a narrative is analysed. False assumptions on poorly visible aspects of the system, made by the operator and exposed via a safety report narrative, may show learning opportunities if, during the report analysis, the false assumptions are revealed.

Drupsteen concludes in a literature review on learning from incidents, accidents and disasters that research has shown limited attention to sharing and storing lessons learned (Drupsteen & Guldenmund, 2014). Furthermore, they conclude that double-loop learning opportunities are often missed because of the difficulties of identifying organisational factors that created the conditions for the incident to occur. Double-loop learning opportunities are opportunities for individuals and organizations to question and challenge their underlying assumptions and values, leading to a change in behaviour or decision-making processes.

In the cybernetic approach to Safety Management (Kingston-Howlett, 1996) addresses the problem of variety reduction in reporting. He explains how the variety of personal experiences is reduced via the reporting form's data options. The concern is that the variety reduction of the event, which occurs unavoidably, does not fall below the required variety for effective management. Qualitative reporting, e.g., storytelling about an operational event, provides a higher level of variety than a fixed taxonomy of factors and therefore supports the improvement of the SMS.

The literature search results show a preference for quantitative approach practices for safety data collection. These practices represent a positivistic epistemology that has been dominant in developing the aviation system and safety management systems. It is speculative to assume that technical engineering's influence explains the prevalence of positivism in the aviation system. Further research is needed to evaluate this suggestion. However, for safety management systems, the context of reporting systems, the influence of quality management is manifest in regulations and guidance material for regulations and practices (ICAO, 2018a) (Group, 2018)(Karanikas, 2014). An aspect of quality management that corresponds to the positivistic worldview is the use of statistical techniques such as statistical process control (SPC) and statistical quality control (SQC). These techniques are based on mathematical models that allow for objective data analysis, which aligns with the positivistic worldview's emphasis on the use of quantitative methods to gain knowledge (Guba & Lincoln, 1994). This might be a plausible explanation for the preference of the positivistic quantitative data-driven approach in safety reporting versus the qualitative interpretative approach in aviation safety reporting.

A final perspective on this part of the literature review will be given in the general literature review conclusion.

3.3.3 Literature review related to the problem of collecting only negative safety performance data in event reporting.

Partial and biased system performance data is insufficient for the level of understanding and knowledge required to effectively manage and control flight operations. Unfortunately, there is always partial data due to the under-reporting of events (Johnson, 2003). Incident reports of near-miss reports are concerned with the partial scope of safety performance where safety was absent. This is the Safety-I scope as defined by Hollnagel (Hollnagel, 2014b) where safety is achieved by ensuring things do not go wrong. The total safety performance scope covers the range from an absence of safety performance to maximum safety performance. Traditionally improved safety performance is assumed to have a high correlation with a reduction in the number of reportable safety events (Hollnagel, 2014b). The ASR (Air Safety Report) system logic, in compliance with the regulations (EASA, 2014) and (ICAO, 2018a), is focused on the Safety-I notion of eliminating hazards and causes of malfunctioning and does not accommodate the Safety-II notions of succeeding under varying conditions and ensuring success. The ASR report fields, to enter event data, are primed for Safety-I concepts and are not suitable for Safety-II concept data.

The concept of Safety-II is explicitly mentioned in the literature following the publication of (Hollnagel, 2014b). Publications found in the literature search and related to reporting that assume or take a Safety-I approach are shown in the table below.

Tag		Book / Regulation	Peer reviewed	Thesis
S1 **Safety-I**	[32]	(Sánchez-Alarcos Ballesteros, 2007) (Van der Schaaf et al., 2013) (Macrae, 2014) (Dekker, 2011a)	(Fitts & Jones, 1947) (Barach & Small, 2000) (Amalberti, 2001) (Wiegmann & von Thaden, 2003) (Davies et al., 2003) (Sanne, 2008) (Leva et al., 2010) (Roelen et al., 2011) (Hovden et al., 2011) (Valdés & Comendador, 2011) (Dekker, 2011a) (Pasquini et al., 2011) (McKinnon, 2012) (Cabon et al., 2012) (Drupsteen et al., 2013) (Drupsteen & Guldenmund, 2014) (Drupsteen & Hasle, 2014) (Rae, 2016) (Madsen et al., 2016)	
S1+S2 **Safety 1 and Safety 2**	[7]	(Hollnagel, 2014b) (Hollnagel, 2017)	(Stone, 2006) (Kelly et al., 2016) (Rollenhagen et al., 2017) (Sujan et al., 2017) (Thoroman et al., 2019) (Rae et al., 2020)	(Kingston-Howlett, 1996)

Table 3-3 Reviewed literature labelled Safety-I or Safety-II

The only relevant publication found related to reporting from before the publication of Hollnagel is (Stone, 2006). In this research, the author proposes that to be effective in any job, people should learn from mistakes but also from successes. This author suggests that every situation, thus not only a safety-critical event, is an opportunity for learning. He also stresses understanding the event from the reporter's or storyteller's perspective. This research was executed in the context of patient safety, and comparisons were made between healthcare and aviation event reporting.

Following the publication of (Hollnagel, 2014b), several researchers in the field of incident and event reporting incorporated the Safety-II concept into their studies. The publications found were related to health care (Kelly et al., 2016) (Sujan et al., 2017), aviation (Thoroman et al., 2019) and nuclear industry (Rollenhagen et al., 2017).

(Thoroman et al., 2019) provides limited guidance on how to accomplish learning from normal performance in near misses. This research shows that, based on the analysis of 16 serious incident reports using Rasmussen's risk framework, networks of protective factors can be identified. The factors were derived from Rasmussen's (Rasmussen, 1997) tenets of accident causation and rephrased into protective evaluation criteria. They suggest that standard reporting systems provide little information about the protective factors. Therefore, they advise more research into methods for the identification of protective 'human factors' as a starting point for a systemic analysis. This research goes beyond the airline company into the role of the regulator and the government. Furthermore, they used as data input serious incident reports compiled by the investigative body Bureau d'Equetes et d'Analyses (BEA) and not the company safety reports filed by the flight crew. Their findings are not very useful for airline managers since their findings are too general and lack specific actionability, and their data does not include flight crew reports.

In research into the development of safety management systems, using a cybernetic perspective (Kingston-Howlett, 1996) describes SMS performance in the context of a business system that contains the SMS. In other words, he describes how an SMS is contained in an airline business management system which provides the context and thus the criteria for SMS performance. He suggests that for safety management to cohere with business management, there is a need for a model of the organisation. This model should provide an organisational structure and the nature of regulation of general performance. A tight coupling between the safety and airline business management systems requires a coupling over the full operating range of these systems, which bears similarity to the Safety-II perspective. This logic also provides an explanation of why safety should not be managed in a silo.

A special publication in the Safety Science journal, an editorial, (Rae et al., 2020) is a proposal for framing empirical research for a better future of Safety Science. The authors suggest to research work and not just failures, referring to the analysis of (Hollnagel, 2014b), (Dekker, 2004) and (Amalberti, 2013) which argue that success and failure originate from similar sources.

3.4 FlightStory literature review conclusion

The FlightStory research project was developed to increase the effectiveness of flight crew reporting by increasing the organisational and individual learning potential of reports. Three problematic issues with current flight crew reporting practices were defined:

1. A problem of the reductionist approach where safety is managed in a silo, disregarding other key performance indicators, by only collecting safety data.
2. A problem of the positivistic approach where (mainly) only facts are collected and no contextual interpretation of these facts by the reporter.
3. a problem of performance data bias where only (near) incident data is collected, Safety-I and no data about the wider safety performance envelope, Safety-II.

Ref problem 1: The systematic literature search and the review show just two books, five journal articles, a magazine article and a theoretical safety management system review. To some extent, their authors advocate that safety should not be managed outside of the context of other business variables. In all the other reviewed publications, no indications were found that explicitly promote or argue for tearing down the walls of the safety silo. Many modern safety publications advocate a system safety approach. However, this asserted approach is then not fully expanded to a “system of systems” approach where safety is an aspect system of the business system.

Ref problem 2: The referenced research illustrates that aviation safety reporting, at least until 2011, has mainly been based on mechanistic and or deterministic models that employ a mainly positivistic worldview. Since quality management has served as an inspiration and example for safety management system developments, the positivistic epistemology underpinning quality management is visible in safety management. This aligns with the regulators' intention for a minimal system for every operator that can be audited. This background explains the format of safety report questions in which flight crew are asked about facts and not about their understanding and opinion on the safety event. Also, quantitative approaches are useful for airlines, but might be more suitable for regulators and IATA that collect aggregated data searching for high-level patterns matching their ways to influence the system. In contrast, qualitative data might be more useful for airline organisations, trying to understand how flight crew navigate the safety space and trade-off different performance aspects such as costs and customers.

Ref problem 3: Only nine publications were found that address the total scope of safety performance and thus employ a Safety-II perspective of which only one publication addresses aviation. This publication does not discuss flight crew safety reports, but formal, analysis of serious-incident reports. I would argue Safety-II and resilience in airline operations reporting systems need more research attention. Maybe reporting system experiments are conducted in an airline organisation and have not yet resulted in research publications. These experiments would then require airline safety professionals to close the gap of generic theory into practice. The FlightStory project can help these professionals.

The authors Hollnagel and Dekker, together with the PhD thesis (Kingston-Howlett, 1996) are the only three that address the three reporting system problems that I defined. While many authors recognise reporting systems to be essential for effective safety management, and since there is specific safety reporting regulation, research on effective reporting is still needed if further improvements of safety are desired.

Conclusion: No specific research, conducted in aviation, was found that addresses the need for a broad and rich description of an event and to go beyond the safety aspect of the reported event. In a manifesto for Reality-based Safety Science (Rae et al., 2020) arguments are given to investigate *work*, in a broad sense, and not just the safety aspect, in the Future of Safety Science. This suggestion aligns with (Margaryan et al., 2017) who propose a research and development agenda for learning from incidents. I support the manifesto's ambition because the literature review shows a lack of research on the crucial topic of safety reporting practices in aviation. I also support the latter ambition to treat practitioners' input with respect. Practitioners are safety experts working in safety departments in safety offices, but also the safety professionals doing the actual work of managing a safety-critical operation. These two groups of practitioners are fundamental to maintaining safe operations, and they can appreciate the research that fits their professionalism. This ambition, expressed in the manifesto, was published in the same year that during which my research was completed. It aligns very well with this literature review that quantitative Safety-I in a silo has reached its limits and that higher-resolution feedback loops and a broader perspective, as argued in my research, are needed.

As a researcher and a safety practitioner in a major airline with 15 years of experience, the literature review showed me a gap between the research topics and the desired and needed knowledge for airline safety innovation. Most of the research is from the outside-in without a sufficient appreciation of safety management complexities in a commercial company. Most research lacks specificity and access to airline data. From the 42 reviewed papers, only a few researchers worked for an airline or in a specific aviation research institute.

The systematic literature search and review reveals a research gap of research into flight crew providing operational feedback as a means to increase understanding of the safety capacity of flight operations. Therefore, my work is a beginning to fill that gap.

Chapter 4: Literature Review Airline Value Production Management Model

This chapter presents a systematic literature review related to an Airline Value Production Model development and evaluation. The review aims to find and evaluate existing knowledge in an explicit and repeatable (Greenhalgh, 1997). I will contrast the purpose of this research with available relevant literature to show gaps and overlaps between existing literature and this research.

Out of the different literature methods, the 'systematic review' is chosen because it has a structure that includes purpose, selection criteria, and critical review. The advantage of a systematic review (Greenhalgh, 1997) includes explicit search criteria allowing for more reliable conclusions. The procedure for a systematic review of DSR by van Aken & Andriessen (2011) is followed. These literature review steps are problem definition, search strategy, evaluation, and conclusion.

4.1 Introduction Airline Value Production Model

In this research, I develop a model for managing safety in the business's context of value production. The Airline Value Production Model (AVPMM) describes the airline business in four recursions of value production. Each recursion has one or more Value Production Units (VPU). Value is an aggregation of the essential variables of Safety, Economy and Customer Experience. In each VPU, these essential variables are integrally managed to maintain them within limits in a changing world. In the AVPMM, the essential variables are managed as aspect systems.

4.2 Problem definition

Based on the research questions, problematic topics can be defined. The main topics in the AVPMM research can be described as Value Production Modelling and safety and business integration. The existing research literature related to these topics might be informative for answering the research questions which are repeated below.

Two related problematic issues are identified. Each problem will be at the focus of a literature search.

The **first problem** is concerned with the lack of an explicit value production model. Any management system requires a management model according to the Conant-Ashby theorem (Conant & Ashby, 1970). The AVPMM should address two premises. First is a value production model for a network airline as the decision context for business decisions. Second, the notion of safety as one of the three core variables that jointly define value. The other two core values are Economy and Passenger experience. Value production is a function of these three variables, integrally managed in each value production unit. The value production system is a nested system of systems based on the logic of the Viable System Model (Beer, 1972). Without a requisite model, a value production system will lack requisite variety and consequently will suffer a lack of effectivity and inefficiency in value production.

A **second problem** is that safety is often managed in a silo, while it should be managed in the context of other business-essential variables such as Economy and Customer experience. In the absence of other business values, safety in a silo will cause sub-optimisation of the essential variables. In the AVPMM, safety is modelled as an aspect of the business, which is a step beyond safety as a sub-system. An aspect is an element of each sub-system, from top to bottom. Without safety as a business aspect, the organisation cannot ensure the optimal use of company resources for value production. The traditional two-variable approach of protection versus production (Reason, 1997) lacks the requisite variety to manage complex ultra-safe flight operation systems, such as airlines effectively.

Both problems combined make value production optimisation for the airline inadequate. A specific example would be whether the resources required for the value production on route operation to airport PQX can better be allocated to the route AWQ. This question can now be answered in terms of profit or loss or customer satisfaction level, but the current model does not include safety in the equation.

The answers to these two combined problems will be the AVPMM with the three essential variables of Safety, Economy and Customer Experience, to manage Safety as a business aspect.

4.3 Search strategy

Literature research always requires publication databases and search engines. Based on (Martin-Martin et al., 2018) I have considered Google Scholar (GS), Scopus and Web of Science (WoS). The advanced search possibilities for Scopus and WoS are higher than for GS. The feature of searching in the abstract in Scopus and WoS was useful to get more relevant search results. Both Scopus and WoS gave the same search results for search #1 below. GS gave thousands of additional results, of which most were non-relevant results when the search was only on the title of a publication. For this systematic literature review, I choose WoS because of the search process options. For completeness, I added a GS search via title and keywords.

The literature search was conducted on the WoS via the advanced search options. The search text is shown in the table in the appendix. The search was executed in the WoS core collection. The WoS Core Collection is a curated collection of over 20,000 peer-reviewed, high-quality scholarly journals published worldwide in over 250 science, social sciences, and humanities disciplines. The search results showed that over 75,000,000 entries were queried.

An advanced search in the Web of Science Core Collection searches the following fields of each publication entry which is in the database: Title, Abstract, Author Keywords and KeyWords Plus®. KeyWords Plus terms are derived from the titles or articles cited by the article's author being indexed. Articles without references and articles whose references are not linked to source items will not have KeyWords Plus. No year of publication was excluded.

The formal searches in WoS and GS resulted in a limited set of hits. Several journal publications and books that were inspirational during my safety science development were not in the search results. Most of the authors of this shortlist of publications are the most referenced and influential writers in safety science. The formal systematic literature search process yielded a limited set of results. Although the Web of Science database is a widely used tool for searching scholarly articles in safety science, it did not include several influential books and journal publications in my search results. To overcome this, I included these books in my review, which were collected during my 15 years of experience as a safety expert and researcher.

Furthermore, I included a review of ICAO safety management regulations. These regulations apply to all aviation service providers. They, therefore, shape to a great extent the formal safety management model in airline companies.

4.3.1 Airline Value Production Management Model search terms

Search terms will determine the search results. The goal was to find value related literature, applied in aviation or in an airline that included a discussion around a model. I applied the following search terms:

Search term	Argument
Value production Value exchange Value chain Value formation Creating value Creation of value Value based Value-based Value proposition	Value is the fundamental characteristic of the AVPMM. Each of the value related activities such as production etc., is a possible description that might be used in the relevant literature.
Airline Aviation	The two search terms will exclude domains that differ from the research domain.
Model	Since the AVPMM is a conceptual model, the search results should also discuss this topic at this abstraction level.

Table 4-1 Literature related to Value Production search terms

4.3.2 Safety as a business aspect (SABA)

Search terms will determine the search results. I defined five topics for search terms. The goal was to find literature the included safety management that was integrated, as an aspect, with a business model in aviation or an airline.

Search term	Argument
Safety Management	It is not just safety but the management of safety that is the central aspect.

Integrated	This term often references to combining activities
Aspect	Aspect is a specific concept that describes the critical difference between other ways of integrating safety into a business.
Business model Business structure Organisational structure Organisational model	This is the central theme of the AVPMM. The goal is to find discussions that discuss organisational models for business purposes.
Aviation Airline	The two search terms will exclude domains that differ from the research domain.

Table 4-2 Literature related to Safety As Business Aspect search terms

Apart from the database and GS search, I reviewed the AVPMM and SABA in my shortlist of about 40 relevant publications that shaped my thinking around this thesis. Only a selection of this shortlist of mainly books is relevant for the AVPMM and SABA, which may explain they did not show up in the literature search.

4.4 Review of literature collection

The relevance of the publications that have been found for this research is much determined by its research topic and research questions. The degree of relevance of a publication is based on the provided evidence and support for the claims being made by, e.g. other publications. Publications in journals with high impact factors generally provide claims that are well supported while claims made in publications such as professional- or business magazines generally provide less verifiable support(van Aken & Andriessen, 2011).

4.4.1 Review of Airline Value Production related literature

The 4 WoS search results (WoS AVPMM) contained: 1 book and 3 journal articles that were in total 254 times cited.

The 6 Google Scholar search results (GS AVPMM) contained: 2 journal articles, 3 Master theses and 1 PhD thesis that were in total 38 times cited.

Publications	**Type of value creation**	**Unit of analysis**	**Type of publication**	**01-01-2021 Cited by (GS)**
(Xu & Sun, 2009) (Wassmer, 2007)	Mergers and acquisitions Alliances	Airline industry	MSc Thesis MSc Thesis	1 9
(Novani et al., 2012) (Nikita & others, 2016) (Spoelstra & Verspuij, 2011)	Customer interaction	Person	Journal MSc Thesis MSc Thesis	32
(Della Corte & Del Gaudio, 2014)	Employee added value	Person	Journal	79
(Bieger & Wittmer, 2011) (Franke, 2007)	Aviation value chain	Airline industry	Book Journal	58 99

(Wittmer, Bieger, & Müller, 2011)			Book	58
(Gillen & Morrison, 2005) (Bieger & Wittmer, 2011)	Business models	Airline industry Airline	Journal Book	120 58
(Phillips et al., 2019)	Corporate Social Responsibility	Airline	Journal	15
Brewis et al. (2011)	Business Value	Product	Journal	3

Table 4-3 Literature related to Airline Value Production

The AVPMM principles of value production led to specific literature search keywords. The results were all reviewed for relevance to my research premises. Only 12 publications met the criteria of sufficient relevance to creating value in the airline or aviation context. Given the limited number of relevant search results and the diversity in which value is discussed, a pattern cannot be found.

In several publications of the search results (Wittmer, Bieger, & Müller, 2011) (Wassmer, 2007)(Nikita & others, 2016) (Della Corte & Del Gaudio, 2014) value creation is discussed. For the notion of value, these publications refer to (Porter, 1979). These authors use value in different contexts and in different units of analysis, such as the aviation system, the airline industry, or the relationship between the airline and its customers.

WoS AVPMM search results

(Franke, 2007) argues in his 2007 paper that innovations such as new business models, advanced customer segmentation and new technologies are needed to create a competitive advantage and possible sustainable profits. Although he addresses how customer satisfaction could improve as a result of these innovations, he does not provide guidance on including customer satisfaction or safety as a decision criterium in a business model or value creation model. This journal article has only one reference.

The journal paper (Gillen & Morrison, 2005) focuses on business strategies and network structure decisions in the commercial aviation industry in an environment of regulatory changes. They suggest the hub-and-spoke network structure to add value to the passenger offering because of the high number of possible connections. Mainly traditional legacy carriers are using this network model and offer full service favoured by high-yield passengers. This business strategy shows relatedness to the logic of making network structure decisions to increase value production. They continue to contrast hub-and-spoke network full-service airlines with point-to-point networks with a low-cost strategy. They explain how the network model creates challenges for revenue management to achieve sufficient yield for the full service and the importance of flight schedules. They explain how point-to-point network low-cost airlines maintain a low cost by keeping processes and products simple. The ticket cost difference may defect business travellers from full-service to low-cost airlines, but loyalty programs helped to maintain this segment of the demand. Here the emphasises is on the importance of passenger service as value production aspect in a network airline. In their model of the rise of the hub-and-spoke system (which I call network airline), they show how passenger service aspects (e.g. loyalty programs, increase service bundle and connectivity) and economic aspects (e.g. decrease fares, increase pax volume, balance and maintain load factors and economies of density) created market growth. The (Gillen & Morrison, 2005) model supports my selection of economy and passenger experience as two essential variables for value creation and decision context. They recognise the complexity of a network full-service airline, but they do not address the reduction of complexity by unfolding the network model as I did in the AVPMM. This journal paper has 7 references.

In (Phillips et al., 2019) safety is mentioned in relation to customer satisfaction. They make some general safety remarks on the importance of safety but do not go into safety management specifics. In their model, safety contributes to customer satisfaction, which is a parameter for sustainable performance. At a high level, this aligns with my approach to include safety in the value production equation.

The book (Wittmer, Bieger, & Müller, 2011) addresses the aviation system value chain from a system's perspective. They recognise several levels in the aviation value chain. At the highest level, there is a supply system and a demand system connected by a market and situated in an environment with social, economic, political, regulatory, technological and ecological aspects. Within the supply system, they describe the sub-systems of aircraft manufacturers, airlines, airports, ground services, industry associations and regulators. The aviation industry value chain is modelled as General Service Providers, split up into Manufacturing Industry and Suppliers, Airline Industry and Airports.
My research area of interest, the airline, can be found in The Airline Industry part of the value chain. They do not define value production units inside the airlines. The market forces (Porter, 1979)of new competitors, manufacturing, suppliers, and customers are discussed at the network and region levels. The unfolding or the Airline industry as a system is done into:

1. International full-service network carriers based upon the operation of a hub-and-spoke network focusing strongly on transfer traffic, such as Lufthansa, British Airways and AirFrance/KLM.
2. Network niche carriers such as SAS and SWISS.
3. Regional carriers which link remote areas to a network, such as BA City Flyer and Air Dolomiti.
4. Low-cost carriers (LCC) concentrated on high volume, short to medium-haul point-to-point traffic with a minimum service approach and lean operations such as EasyJet and RyanAir.
5. Charter airlines services for tourist markets.
6. Air cargo carriers.

Along a similar structure (Nikita & others, 2016) discusses a value proposition of several Russian airlines. He differentiates between long, medium and short-haul and business and leisure travel.

Although not identical but similar, (Wittmer, Bieger, & Müller, 2011) shows a multi-level systems approach is useful in reducing complexity for the management of important topics. For the airlines, as a system in focus, they describe fields of strategic forces. The three fields are Market (Pricing and distribution channels, Resources (customer loyalty, brand image, hub dominance and service level) and Networks (network structure, partners and alliances). They declare two main variables of Airline Network design, and these are the location of a hub and connectivity (i.e. the number of connections per inbound flight). The network management processes are said to be aimed at achieving the highest possible profitability. They mention each step of network changes. The change process ranges from 2 to 3 years before a new flight until the day of flight execution. The network configuration capability is emphasised as fundamental for the overall success of an airline. This statement aligns well with the AVPMM approach to model the network as the highest recursion level, encapsulating the whole airline.

(Wittmer, Bieger, & Müller, 2011) recognise the relevance of using value modelling at different levels of the system. However, they do not model the airline itself into multiple levels of value production. The four-level AVPMM can be seen as a model with higher resolution and can be seen as a possible and compatible extension of their model.

Also, the concept of the fields of strategic advantages by (Wittmer, Bieger, & Müller, 2011) seems compatible with the AVPMM. The fields represent network, resources and the market. The network field is composed of network structure and alliances. The resources are related to achieving the customer's preference by, e.g. service level and customer loyalty, and the market field makes up pricing and ticket distribution channels. These forces have similarities to the AVPMM focus on network management while maintaining safety, economy and customer experience in balance. The AVPMM adds recursion levels to distribute the complexity of the management of value production over the recursions. (Wittmer, Bieger, & Müller, 2011) mentions topics relevant to specific recursions and VPUs in the AVPMM, but they are not explicit in how to manage this complexity.

(Phillips et al., 2019) researched the relationship between Corporate Social Responsibility (CSR) culture and leadership and the airline's value chain capabilities. Their value chain model is related to the Porter (1979) model. They discuss value creation in relation to effective management and leadership style, but otherwise, value creation or production is not discussed.

The following publications refer to value creation in relation to an airline, but less to value creation as a business concept. In (Wassmer, 2007), value creation is analysed through alliances between airlines at the unit of analysis of an airline company. The research focuses on the synergy of resources in relation to value creation and value appropriation to the different partners in an alliance. Likewise, using the airline company at the unit of analysis (Xu & Sun, 2009) investigates the impact of mergers and acquisitions on value creation for the bidding firms, focusing on stock prices.

The following three publications use the customer and the employee as units of analysis. (Novani et al., 2012) investigates the co-creation of value for customers by mutual interaction between customers. Airline service selection is used as a typical case to clarify influences on the value co-creation process produced by different types of customer-to-customer communication, such as social media and face-to-face. An agent-based simulation was used to compare the communication styles of customers. In research related to employees' value, creation and appropriation (Della Corte & Del Gaudio, 2014) empirically verified personnel's productivity value creation in some U.S. airlines. Employee groups were compared using no model of value creation. In a structural equation model, the employees' productivity and an airline's performance were related. The employees were divided into groups of flight attendants, handling, maintenance, and flight crew. No classification into full-service airlines or low-cost carriers was made. The study showed no statistically significant links between employees' productivity and value creation. The lack of differentiation between long-haul and short-haul and between full-service and low-cost airlines might contribute to this finding. These under-specifications make this research not informative for the AVPMM proposal.

Service-Dominant-Logic (SDL) (Spoelstra & Verspuij, 2011) recognises that services differ from products. He states services are co-created with the customer because production and consumption happen simultaneously. In this co-creation, value can be created. This is a relevant notion for full-service airlines, such as in which the AVPMM was developed. The research showed that airline front-line employees, employees in contact with the customer, can enhance value creation when enabled by the organisation. (Spoelstra & Verspuij, 2011) researched how front-line airline employees can make differences in the creation or destruction of value by their effect on the customer's travel experience. These findings are relevant for the AVPMM since customer experience is considered an essential variable and can be taken into focus at the four different levels of the AVPMM. These four levels add essential aspects to the service delivery, and thus to value co-creation. E.g. on the lowest AVPMM level of flight on-time departure and arrival are vital in contact with passengers, especially during delays. At the Network level, the highest level of the AVPMM, connection information is essential for passengers, especially during delays.

The paper by Brewis et al. (2011) and with whom I have had personal conversations was the inspiration for the AVPMM. His Cybernetic Business Model publication has only been referenced three times, only one other than the authors themselves. In the referencing publication, only the fact that the Cybernetic Business Model is based in cybernetics was mentioned and nothing about the value structure. In Brewis et al. (2011) a decision-making framework for senior managers is presented that can be used to 'navigate the value space'. The article introduces a value vector that ensures the requisite unfolding by management through objectives. The objectives are maintained congruent by the value vector concept. This research was applied to the business processes in a large telecommunications company. The model helps build the business's operational context in terms of value transactions with the commercial environment. The components used to catalyse these value exchanges need to be continuously benchmarked to ensure they remain survival worthy.

Airline Value Production literature review conclusion: It can be concluded that none of the literature search results is explicit about an airline value production structure. (Wittmer, Bieger, & Müller, 2011) comes close by referring to levels (global, national and local). The AVPMM can be seen in this light as a logical extension of the increase of lower specific levels into network, region, route and flight. The Cybernetic Business Model by Brewis et al. (2011) was very inspirational for the AVPMM as shown by the required ability by the AVPMM to support answering questions of flight or route viability in terms of Value Production as the aggregation of Safety, Economy or Customer Experience.

4.4.2 Review of Safety as Business Aspect related literature

The WoS search results (WoS SABA) was just one result; a journal article cited 3 times.

The GS search results contained 4 journal articles, 1 Master thesis, 1 book which were in total 43 times cited.

The review is executed against relevance to the discussion of integrating safety as a business aspect in any way.

Publications	**Search**	**Main Unit of analysis**	**Type of publication**	**01-01-2021 Cited by**
(Ulfvengren & Corrigan, 2015b)	WoS	Airline company	Journal	14
(ICAO, 2013b)	WoS	Company	Regulation	
(Wittmer, Bieger, & Müller, 2011)	GS	Company	Book	58
(Turek & Bajdor, 2019)	GS	Process	Journal	0
(Behm et al., 2008)	GS	Person	Journal	8
(Vogt et al., 2010)	GS	Person / Process	Journal	31
(Okema-Opira, 2012)	GS	Process	MSc thesis	1
(Barbosa et al., 2018)	GS	Process	Journal	27

Table 4-4 Reviewed Safety-As-Business-Aspect literature

WoS SABA search results

In (Ulfvengren & Corrigan, 2015b) EU funded case study research is presented about the challenge for an organisation to manage system changes and maintain safety performance in a Lean Airline. The lean aspect is important in this research in this company's processes and SMS development. The researchers discuss the Integrated Management of dominant management structures and processes. No specific management systems for integration are mentioned. However, the advantages as published in the ICAO Safety Management Manual (ICAO, 2013b) are listed as: reduction of duplication and therefore of costs, reduction of overall organisational risks and an increase of profitability, the balance of potentially conflicting objectives and elimination of potentially conflicting responsibilities and relationships. No references are given to support the beneficial claims. Details, specifications or requirements for the integration are under-specified. The reference to Rasmussen (Rasmussen, 1994) shows the researchers recognise the importance of integrated management since Rasmussen's model shows how human activities under pressure might lead to loss of control and "an unacceptable state of affairs". The research explains that Lean is not sufficiently comprehensive for SMS and system safety. They argue for integrating Lean process-oriented approach with a Human Factor human-oriented approach to balance production and protection. In the discussion section, they describe how a joined-up organisation is not easy to develop. Departmental interests may lead to priorities that are not always shared. There appears to be often competition for power or influence, which tempers collaboration, which is a significant barrier to creating an integrated management system. With an integrated approach, a common operational picture could be developed. Furthermore, they state that for a particular context, a context that is relevant for the members of the integrated systems, there is a positive influence of people's motivation to share data in the name of safety. The AVPMM intervention might support their claim. In the case study, a software tool was developed that was able to render a common picture for managers of different departments in an attempt to create a more holistic picture of risk. The application was developed to support both the safety department but also the operations departments; Flight Operations, Technical Operations, Ground Operations and Security.
In the discussion section, the researchers state that Safety Science struggles with developing new safety management approaches that include organisational change. Even they do not suggest nominating safety as an airline business aspect. The lack of scientific literature concerning the integration of safety and the business, as shown in this review, might be considered support for their claim.

GS SABA search results

The marketing chapter of their Aviation Value Chain book (Wittmer, 2011) shows that safety is an attribute for customer choice. In the years 2002–2008, the weight of safety in customer preference was between 14% and 22%. They advise a more holistic approach to risk management and integrate Enterprise Risk management, Environmental Safety Management, Quality Management, Safety Management, Security Management and Supplier Management Systems. Safety, risk and business management are not discussed as integral business systems.

Turek in (Turek & Bajdor, 2019) shows the opportunity to integrate enterprise processes with Occupational Health and Safety (OHS) processes when using Enterprise Resource Planning (ERP) software. ERP finds its origin in Business Process Re-engineering (BPR). The process approach binds together information, knowledge, and quality management. They suggest that the processes of OHS management are like the enterprise process approach. The OHS processes follow the Plan Do Check Act (PDCA) of Deming and affect other areas of the enterprise activity, which brings about the consideration of integration. Then they show an example of integration in ERP software but do not discuss the actual activities that bring the integration alive.

The research (Behm et al., 2008) is about providing Environmental Safety and Health (ESH) education in business schools. They argue business managers view the ESH function as compliance-oriented and as a cost burden. Therefore, they contend that the ESH professional should speak more business language, but the business manager should also be educated about the strategic value of ESH. A survey of American Business schools showed an agreement about the importance of a company's management having knowledge of occupational and environmental safety.

Vogt in (Vogt et al., 2010) suggests integrating human factors in the safety management of aviation businesses and managing it with professional tools such as Balanced Score Card (BSC). They present a Human Resource Performance Model (HPM) that facilitates the integrative assessment of human factors programmes based on a systematic performance analysis of the whole system. A BSC is a management tool for implementing corporate strategies. In the BSC, they deduced the organisation's strategic goals, a sub-BSC for health and human factors, to map the relationship between health and human factors and organisational performance. The authors reviewed the development of a strategy map from the BSC showing the relationships between health or human factors in safety management in an automobile production setting. They concluded that the automobile industry study was reliable and valid, and then they reflect on what this could mean for aviation safety management. They argue a human factors oriented BSC/HPM might improve the safety culture. They announced a plan for the development of a BSC approach for human factors in an aviation organisation. However, five years after the announcement of this plan, no publication was found describing the plan's execution and findings.

Okema in (Okema-Opira, 2012) researched what inhibits and promotes SMS implementation in aviation using a questionnaire with questions based on a theoretical framework. Business objectives were defined as an enabler for SMS implementation. The business objectives were defined as "positioning and actions taken by an enterprise, in response to or anticipation of changes in the external environment, intended to achieve competitive advantage". 71% of the respondents regarded this variable as important or very important. 26% were uncertain out of 31 respondents. Nearly the same figures apply to "Organisational structure" as a factor in promoting SMS. No further discussion on any organisational structure design was made in this research.

(Barbosa et al., 2018) publication aims to formulate propositions that help align of certifiable Quality, Environmental and Occupational Health and Safety management systems (all integrated into an Integrated Management System (IMS)) with the business strategy. They claim that among the benefits that the IMS can offer are cost and tasks reduction, a decrease in bureaucracy and conflicts among the systems, simplification of the documentation, manuals, procedures and registrations. The alignment is understood as the interface relation of the business strategy with the IMS and vice versa. They state that the IMS and business strategy influence each other. The AVPMM shows an operationalisation of this interdependence.

4.4.3 AVPMM and SABA by safety science most referenced writers

During my research, I have invested much time in reading safety science publications and books that did not appear in the specific AVPMM literature search results. Still, it is needed to review my shortlist of inspirational literature in the context of this research project.

The shortlist contains the following authors: **Reason, Rasmussen, Leveson, Hollnagel, Woods, Amalberti, Dekker.** The authors are ordered on the date of first publication.

Reason wrote the most referenced book (over 7000 times on 01-01-2019) in this review (Reason, 1997). In his book, he labels safety as an organisational topic. Reason describes what he calls the right level of explanation. When being zoomed in on the details, all accidents are different and zoomed out all are nearly the same. The appropriate level of understanding lies between these two extremes. Using a barrier-based safety model, he recognises three factors involved in breached barriers. These are human, technical and organisational, and all three will be governed by two processes common to all technological organisations: production and protection. Reason nominates production and protection as two universals since all technological organisations produce something and productive operations expose people to danger and thus require various forms of protection. The type of hazards is related to the type of production. He argues protection always consumes productive resources such as people, money and material. The right picture is from the ICAO Safety Management Manual (ICAO, 2018a) conveying a similar message. It is described as a metaphor to illustrate a safety space, the zone where an organisation balances desired production with profitability while maintaining required safety protection through safety risk controls. In this research, I argue this metaphor lacks variety as for actual protection and production management.

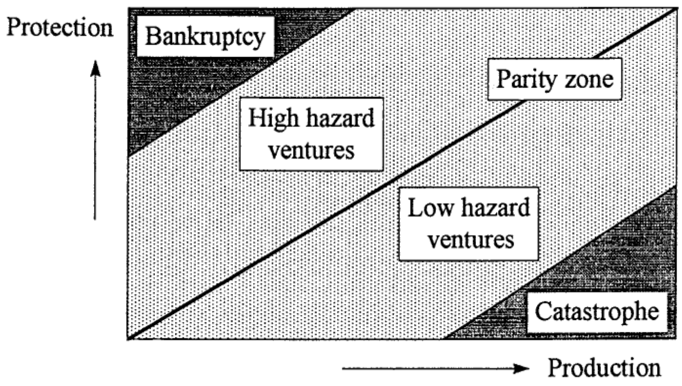


Figure 4-1 Outline of the relationship between production and protection. (Reason, 1997)

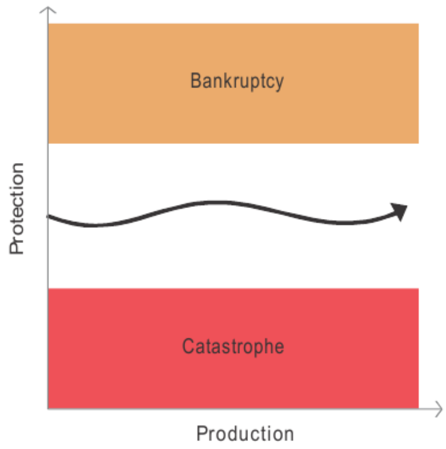


Figure 4-2 Concept of a Safety Space (ICAO SMM, 2018)

Rasmussen (Rasmussen, 1997) as a control and systems engineer, has written about proactive risk management. His work is much referred to. He argues after several decades of modelling, it has become evident that models created through interdisciplinary efforts are valuable for the design of work support systems for individuals and decision-makers. However, these models are not as effective when analysing the performance of the entire risk management system. To address this issue, a top-down, system-oriented approach is necessary, utilizing control theoretic concepts. The reason for this approach is that a system is more than just the sum of its components and often, attempts to improve the safety of a system through models of individual features can result in unintended consequences from people adapting to the change in unexpected ways. Thus, it is important to consider the initial conceptual control framework in a complex, adaptive socio-technical system context (Rasmussen et al., 2000). His suggested approach should not focus on human error and violations but on the mechanisms generating behaviour in the actual dynamic work context.

Market conditions and financial pressures are mentioned explicitly and show in the model. This type of model specifies interrelations between systems and is compatible with the AVPMM approach. Both approaches originate from cybernetics and control theory. Rasmussen states that objectives and constraints shape human behaviour in any work-system(Rasmussen, 1997). These constraints can explain the degree and nature of the success of the work. Rasmussen shows how economic and workload pressure push work towards a boundary of acceptable performance in the much-referenced figure below.

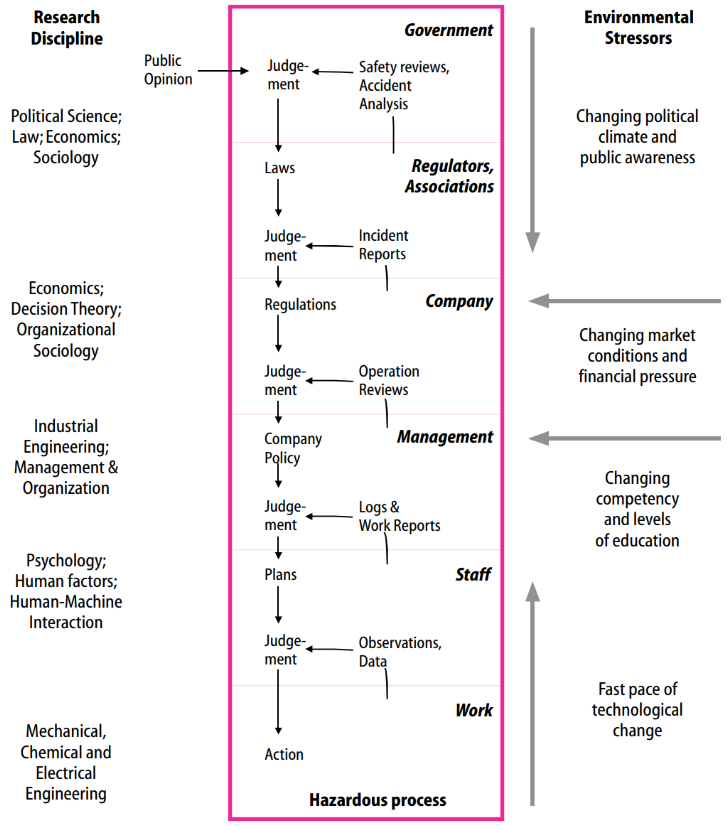


Figure 4-3 Socio-technical system involved in risk management (Rasmussen, 1997) (Rasmussen et al., 2000)

The model illustrates that Rasmussen takes an integrated (normal work aspects and safety work aspects) view on work performance. This systemic view is required to understand workers' behaviour to a sufficient degree to influence the work and the constraints effectively(Rasmussen et al., 2000). It follows that safety and business integration must be understood to understand how work can migrate towards boundaries of performance.

The AVPMM model, with safety as a business aspect, is compatible with the work of Rasmussen. The AVPMM may be seen as an extension because the AVPMM will introduce a hierarchy within an airline company where at each level the dynamic safety model can be operationalised for that specific level.

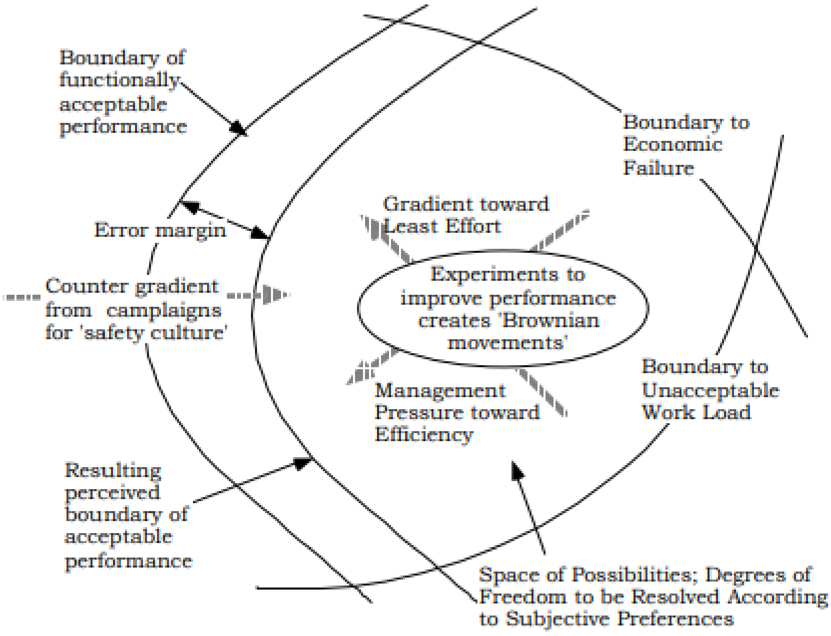


Figure 4-4: Dynamic safety model (Rasmussen, 1997)

Leveson (Leveson, 2011) agrees with Woods and Rasmussen that people adapt to their environment to suit their purposes. Consequently, safety defences are likely to degenerate systematically through time, especially when pressure towards cost efficiency and increased productivity. Leveson argues that accident causation must be viewed as a complex process involving the entire socio-technical system, including legislators, government agencies, industry associations, insurance companies, and company internal departments and functions. The AVPMM model, with safety as a business aspect, covers the scope of influences that Leveson should be included. The relevant environment of the organisation is just meant for these outside forces, which shape organisational activities. The relevant organisational functions for value production are also included in the AVPMM. Systems and control theory are both the basis for the work of Leveson and the AVPMM. The AVPMM is designed as a management model and not just a description, and it builds on the notion of Requisite Variety (Ashby, 1956) which is much less visible in the work of Leveson.

Hollnagel has introduced two safety approaches called protective safety as Safety-I and productive safety as Safety-II (Hollnagel, 2017). Since protective safety focuses on preventing adverse outcomes, safety competes with productivity (Hollnagel, 2014b). Safety-II changes safety management from focusing on how things can go wrong to productive safety and a focus on how things can go well (Hollnagel, 2017). Hollnagel states that typical performance is continuous rather than discrete, so proposals for improvements refer to a broad spectrum of performance rather than single instances. The broad view on performance and Safety-II seems to align with the view that safety and business management must be integrated, and congruent with the AVPMM and the notion of SABA.

Aviation is the most referenced domain in Resilience Engineering (RE) literature (Righi et al., 2015). Although definitions of RE have changed, they remain compatible with safety as a business aspect view. Hollnagel in his chapter (Hollnagel et al., 2007) states: "The essence of resilience is, therefore, the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap in the presence of a continuous stress". Based on this resilience description, safety as a business aspect seems remarkably compatible with the resilience concept.

Woods and Hollnagel in (Woods & Hollnagel, 2006) explain that their set of laws that govern Joint Cognitive Systems (JCS) at work builds on a foundation of mutual adaption. "Agents' activities are understandable only in relation to the properties of the environment within which they function; an environment is understood in terms of what it demands and affords to actors in that world. Each is only understandable in relation to the other so that one is a necessary background or frame to help bring the other target into focus as foreground." Thus, JCS performance is an integrated view without taking apart production activities and safety activities, which agrees with the AVPMM and SABA approach.

Amalberti (Amalberti, 2013) describes with the title of his book Navigating Safety the metaphor of making trade-offs and compromise decisions between safety and other variables. The book offers keys for these decisions.

Amalberti generalises risk to all risks that can "kill" the enterprise, whether social, technical or financial. This resembles the concept of essential variables which are specific variables that should be managed to stay within limits, or the organisation will lose its viability. He argues that the reduction of risks concerning these variables is, therefore, a complex challenge. His book is structured around keys to the success of a systemic approach: (1) controlling the four stages of the trade-offs which are always present in building the safety structure of a complex system, (2) doing well what one has decided to do, and knowing and controlling what one has decided not to do, (3) future thinking rather than past thinking.

In the discussion on his step 1, he introduces the importance of cost-benefit analysis in relation to risk analysis. A negative balance of cost-benefit while being exposed to risk differs from being exposed to risk with a positive cost-benefit and will probably lead to different decisions. Amalberti poses the enterprise as a system, incorporating contradictory tensions and requiring trade-off in the area of safety. Risk affecting one part of the organisation will affect other risks and often increase them. Economic risk can affect resource risk, which can affect compliance risk. Moreover, the ongoing tensions must be managed in order to survive on each dimension.

His view of the enterprise as a system incorporating contradictory tensions and requiring trade-offs in safety requires a systemic view in risk management. He then recognises four critical areas of risk:

- "not winning the contract" which means not having a sellable product, not executing the value exchange,
- "inability to produce in time, to the expected quality and the expected cost",
- "failure to control the financial support for innovation, production and sales",
- "inability to control the safety of production or the product being sold".

The management of these risks is distributed between different organisational divisions, which try to optimise its own activities, often to the detriment of other divisions. He recognises three levels of organisational risk management, the macro (the aviation system in this research), the meso (the airline) and the micro (the workplace, i.e. the flight).

Here, we can find parallels between Amalberti and the AVPMM and SABA approach. The four risks mentioned above seem similar to the three AVPMM essential variables. Risk 1 is related to the need for a value exchange and passenger satisfaction. Risk 3 is related to the essential variable of finance, and risk 4 is similar to the safety essential variable. Furthermore, the challenge of managing these risks in different parts of the organisation can be facilitated by creating a value production decision context. Local sub-optimal decisions can be made visible and discussed if the overall value production is optimised, relieving local managers from the adverse effects of local underperformance. The three levels, as mentioned above, are also addressed in the AVPMM value production system unfolding. At each level of the value unfolding, a specific function is concerned with the level properties as mentioned by Amalberti.

Dekker, an author in the school of Rasmussen, Hollnagel and Woods, supports the view that safety should be understood from a perspective of complex adaptive socio-technical systems (Dekker, 2004) (Dekker, 2012) (Dekker, 2014b). He discusses, in several chapters and publications, (Dekker, 2014a) the challenge of successful strategies to balance resource scarcity, competition and safety (Dekker, 2012). This shows an integrated view of safety well aligned with the safety as a business aspect view.

4.4.4 ICAO regulations

In (ICAO, 2013b) the 3rd edition of the SMM a list of typical management systems for what is called holistic management is given: quality (QMS), safety (SMS), security (SeMS), environmental (EMS), occupational health and safety (OHSMS), financial (FMS), documentation (DMS). Larger and more complex service providers may also have management systems for suppliers, marketing, personnel, facilities, ground equipment, production, training, flight operations, cargo operations, aircraft maintenance, dispatch and fatigue risk (FRMS). Depending on the type of organisation and business model, a unique integration will be made.

In the (ICAO, 2018a) 4th edition, an important criterion for integration is added. The integration should be completed to the satisfaction of the Civil Aviation Authority (CAA), and in a way that the CAA can effectively "see" and monitor SMS. Furthermore, ICAO explicitly states that "Safety management should be considered part of a management system (and not in isolation)."

The safety accountabilities, responsibilities, and authorities desired by the ICAO SMM (ICAO, 2016) should align with business accountabilities, responsibilities and authorities to support SMS implementation effectiveness since a mismatch between business and safety accountabilities will create power discussions and distractions.

4.5 AVPMM literature review conclusion:

This systematic literature review complemented by a review of the most influential authors shows that concerning the Airline Value Production:

- A Value concept has been used in aviation research.
- The concept of value has many literature references. However, the concept of a value production model for a network airline is new. This means that value production as VSM is new in aviation and the concept of layer unfolding.
- Some research shows that customer satisfaction is also critical for sustained performance.
- The influential authors discuss value creation very minimally.
- The influential authors use systems and control theory, which is the same foundation as used for the AVPMM and SABA approach.
- Thinking in organisational layers is not new, but none of the authors has gone beyond the sharp and blunt end metaphors to make the layers explicitly like the AVPMM.

It also shows:

- A value production model for a network is new.
- An unfolding of the value production management system is new.
- The combination of safety, economy and customer satisfaction as elements of the value production equation is to some extent researched only once.

This SABA systematic review shows:

- SABA is compatible with the systems approach and fulfils the requirement for addressing safety in the context of normal work.
- SABA is compatible with Resilience Engineering and Safety-II.
- The influential authors stress the need for an integrated approach to production and protection management.
- ICAO SMS regulations urge for the integration of management systems but safety science and management science have not provided useful operationalisations for airline companies.

It also shows:

- The SABA approach is one step beyond the classic and often-used metaphor of production versus protection.
- No literature has been found that describes an operationalisation of a safety and business-integrated management model. The AVPMM with SABA is probably the one of the first attempts that includes both business and safety management in an integrated model and is reviewed by actual safety and business managers.

Based on this review, I conclude the AVPMM and SABA research will contribute to the knowledge base of modern integrated safety and business management..

Chapter 5: Research Questions and Methods to Answer them

This chapter describes how the aim of this research leads to the research questions. This research will develop decision-making tools that help the organisation to integrate safety and business management. From the available and accepted research methods, a suitable method must be chosen.

Several descriptions of scientific research will be addressed before arriving at the choices that I made to conduct my thesis research.

5.1 Introduction

Research differs from practice because the rules of application of knowledge and action comply with scientific standards. The traditional scientific method, as applied in physics, is by some taken as the gold standard. In the social sciences, this 'physics envy' is often debated. (Clear, 2001). Some think the mission of science is to offer explanations of the existing world, while others argue a science can be applied to design a better world (Simon, 1996). My research falls into the latter category, and to do so, a suitable research method and research design will be chosen, taking into account the context of my study—within an actual, operational network airline—as well as the potential utility of the research findings.

5.2 Aim of research

By offering a tool for managing safety as a business aspect within the context of value creation, this research aims to assist the viability of a network airline. Effective safety and business management are two criteria for survival for an airline organisation. The narrow economic margins for airlines require effective and efficient management practices and allocation of resources. A lack of integration between safety and business may reduce the airline's performance and, ultimately, its viability. The results of this research and the engagement of the organisation with this research during the intervention and the evaluation will lead to learning opportunities.

5.3 The objective of this research

The scope of this research is commercial aviation in network airline companies. This research can be described as a problem-solving activity in actual airline management practices. The objective is twofold. One is to deliver a decision support system and the other is to contribute to the knowledge base of science. The enhancement of the management system is a normal business activity, illustrated by the nearly continuous organisational changes in the management system and the related processes. The management system enhancements can also be driven by scientific projects. The additional requirements required for change activities to qualify as scientific do not directly improve the bottom line of the business, but they do make the changes more visible. This research will also seek to bridge the gap between practitioners and the wider body of knowledge in the field, by making the results of this study widely accessible and easily understandable.

Two topics will be the objects of this research. A method and model will be designed, tested, and evaluated.

Lack of rich operational feedback; this first topic that will be researched is the feedback that flight crew provide of their operational experiences. The feedback loop, by collecting and sharing of data, is a required element of a management and learning system. The problem of feedback with low informational content is that it does not prompt stakeholders to action. Current Air Safety Reports do not deliver the requisite feedback. They lack data, such as a contextual description of the event, an evaluation by the flight crew of the working conditions, a description of the strategy applied to handle the event, and no lessons learned by or advice from the crew. Furthermore, operational feedback should include all key performance variables, such as safety, economy, and passenger experience. The integrated management of these variables can lead to goal conflicts for the flight crew. The airline organization should be made aware of these conflicts and provide support for conflict resolution. The usage of the data should be maximised by sharing with stakeholders. All this data should help support as many stakeholders as possible to learn their lesson from operational safety-related events. I propose a reporting method for reporting by flight crew and an analysis model and method by safety analysts and airline managers to improve and use operational feedback and ultimately the value production of the airline.

Integration of safety as an aspect of airline management; this second related topic considers safety as an essential aspect of airline business and network decisions. Flight safety is an essential variable in providing a transport service by operating aircraft worldwide at large and small national and international airports. Efficient use of all company resources to achieve this operation at minimal cost and the highest customer appreciation is complex. The drive to reduce complexity by delegating an essential variable, in this case, safety, to another department, introduces a sub-optimisation problem. The report on the Entebbe in Chapter 1 bird hit illustrates this finding. From a network management perspective, a particular flight or route operation (as was initially the case for Entebbe) is safe or unsafe. They work with a binary view of safety. Network management expects the operation to be suspended when flight operations declare the operation unsafe. This approach to safety might explain why safety is not an aspect of network performance management, and this approach does not meet the required variety for the management of safety as an aspect of business decisions. This demonstrates that a network change, a different arrival and departure time at Entebbe, a very effective safety risk mitigation. I propose an operational prototype model with concepts and processes for handling much of the inherent complexity of the network airline business.

When the research topics would have been researched in isolation, any possible synergy would be lost. The network management model represents the controller, and the operational feedback system provides essential feedback. The controller and feedback system should be considered as an inseparable whole.

Another objective of this research is to contribute to science itself by providing different kinds of knowledge. The fields of safety and management science have not provided the solutions to the described problems. The gap in knowledge will be discussed in the literature review.

The choice for this kind of research objective, where relevance and utility are important, can be described as a pragmatist approach.(Goldkuhl, 2011). Pragmatists and the managers of the organisations care more about how the intervention helps the business and how many problems it solves than about finding the truth. Support for organisational development is therefore a criterium for the success of this research.

The objective of this research produces requirements for research design and methods. The research questions and the research design will provide the means to deliver the objective of this research.

5.4 Research questions

To achieve its purpose and to deliver its objectives research must be structured around the problematic topics (Thuan et al., 2019). The research questions to be answered by this research will improve the problematic situations and generate the purpose for new knowledge development (van Aken et al., 2016).

This first question will address the topic of rich operational feedback by flight crew and the second question will address the topic of safety as an aspect of business management.

5.4.1 RQ1: Can flight crew flight operational experiences enhance Airline Value Production Management?

The first part of this research question addresses the capture of the operational experiences of flight crew. The second part connects these experiences to the enhancement of the management of value production management which includes all aspects of network management and flight operations.

This question will be answered while considering flight crew operational experiences as a contribution to the AVPMM and to the SMS.

Without considering the specifics of the AVPMM the following sub-questions can be asked:

RQ 1.1 How can flight crew flight operational experiences feedback:

- Support flight crew performance self-reflection and learning?
- Support flight crew to flight crew learning?

- Support flight crew training?
- Support the management of flight operations?
- Support Safety Management?
- Provide insights for Safety-II and resilient performance?

When the context of the AVPMM is considered, we can ask:

RQ 1.2 How can flight crew flight operational experiences feedback:

- Support Airline Value Production management?

The first set of sub-questions can be answered independently of the AVPMM while the second sub-question can only be answered after the next research questions are answered.

5.4.2 RQ2: How can we develop and use a Value Production Management model for the integrated management of Safety, Economy and Passenger experience for a Network Airline?

Starting from safety management and making contact with other aspect systems of the organisation we encounter what the ICAO Safety Management Manual calls 'the management dilemma' (ICAO, 2018a). This dilemma is modelled by describing a "safe space" as an area of acceptable balance between production and protection (profitability and safety). This model is used in conversations between the safety department and other operational departments when, e.g., operational pressure as a safety threat is discussed. From a management science perspective, we can research the effectiveness of the production-protection model and compare it to an alternative model that should subsume the ICAO model and offer more features.

The first AVPMM research question addresses to what extent the ICAO model supports "the management dilemma" as defined by ICAO in comparison to the model that will be developed in this research. The following questions will require a review of the actionability of the ICAO model in comparison with the AVPMM as an alternative and new approach to business-integrated safety management.

RQ 2.1 How can the AVPMM improve the management of production-protection?

Value can be viewed as a function of Safety, Economy and Customer experience. Current network performance management does not include safety as a performance variable. This question will evaluate the potential benefits of including safety as a network performance indicator.

The second AVPMM research question addresses the development of the concept of value production as a function of Safety, Economy and Passenger experience in airline network management for which a model of value production is developed. The potential benefits of this model for integrated network management of safety, economy, and passenger experience will be assessed using the following question:

RQ 2.2 How can the AVPMM improve Network Performance Management?

The third AVPMM research question is related to resource allocation in the context of value production. The challenge for the airline is to sustain a value exchange with customers. A traditional, more siloed approach to resource optimisation might be improved by an approach that uses a wider solution space for topics that have interdependencies which should not be disregarded for optimal solutions. The possible benefits of an integrated approach to the three essential variables will be evaluated by answering the following research question:

RQ 2.3 How can the AVPMM improve 'optimal resource allocation'?

The answers to the sub-questions can be combined to provide an answer to the main research question regarding the Value Production Management Model approach to integrated airline network management.

5.5 Research designs

Having established research objectives and research questions, a suitable research design must be defined. Since this is a scientific endeavour, the domain of scientific research must be evaluated for a suitable design.

Science, as a domain of systematic methods to gain and apply knowledge, has many schools of thought. Many distinctions can be used to characterise science(Pruzan, 2016). There is the stated distinction of gaining versus applying knowledge. The first is related to the field of basic science, while the second is related to applied science. Other distinctions allow us to define natural-, life-, behavioural-, and social sciences. (van Aken, 2004) draws distinctions between:

- the formal sciences e.g. philosophy and mathematics
- focused on internal logical consistency and no experimentation
- the explanatory sciences e.g. natural sciences and a large section of the social sciences
- focused on describing, explaining and when possible predicting observable phenomena. This often involves causal models and quantifications.
- the design sciences e.g. engineering sciences and medical sciences
- focused at solving field problems such as construction, medical- and health problems.

Van Aken in (van Aken, 2004) avoids describing design science only as an applied science because design science also develops knowledge as opposed to only applying existing knowledge. Both (Hevner & Chatterjee, 2010) and (van Aken & Andriessen, 2011) refer to the Stokes diagram mapping research types (Stokes, 1997).

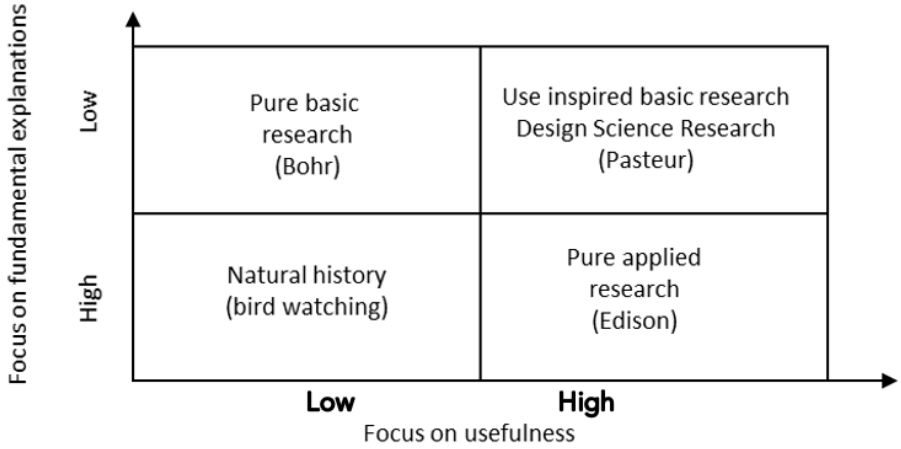


Figure 5-1 Stokes diagram (Stokes, 1997)

Descriptive and explanatory research methods are not so much focussed on problem-solving in contrast with Design Science Research (DSR) (van Aken & Andriessen, 2011). DSR combines both descriptive- and explanatory research in field problem analysis and attempts to find science-based solutions. DSR requires both research in practice and research, in theory, to get a fundamental understanding of the problem and use this as an input for a new design and the evaluation of the new design in practice.

Based on this classification of the sciences, the design sciences seem a useful science to achieve the desired research objective.

5.5.1 Design Science Research

The present research aligns with the Design Science Research (DSR) paradigm, which aims to expand human and organizational capacities by producing novel and innovative artefacts. According to Hevner (2004), the design-science paradigm originates from engineering and the sciences of the artificial (Simon, 1996) and is primarily focused on problem-solving. As conceptualised by Simon, DSR supports a pragmatic research paradigm that is proactive with respect to technology. It is aimed at the creation of innovative artefacts to solve real-world problems (Hevner et al. 2004).

Van Aken (van Aken, 2007) describes DSR as having a holistic orientation because of its interest in wholes and coherence. He argues a design has to be a whole and not partial and the testing of the design should be holistic and not just on certain aspects. Therefore, design thinking and systems thinking are closely related since systems thinking provides the concepts for understanding the problematic situations and the relevant relations between the elements of the problem as input for the design requirements.

Van Aken (van Aken et al., 2016) argue DSR can be regarded as an engineering approach to Operations Management in social technical systems. Action Research (AR) is another research approach that is deployed in socio-technical systems. The authors note as an important difference between AR and DSR is the more case-specific improvements in AR and the more generic knowledge development in DSR.

DSR is viewed by (Hevner, 2007) as three closely related cycles of activity. The relevance cycle connects the 'real world' context of the topic of application with the activities of design research. The requirements for the research containing the problematic issues and criteria for design evaluation are the input for the design cycle. The output from research to the environment of the application will be tested in a relevant context. The test results can be the input for another relevance and design cycle.

The rigor cycle draws from the domain of scientific theories and methods for a thorough design science research project execution. In this cycle, the researcher also selects and applies appropriate theories and models for an adequate design. Often through a process of abduction, the researcher relates design requirements to existing theories to inform the design cycle. Newly generated knowledge and additions or further specifications to existing knowledge will become available as a result of the design evaluation and field testing.

In the design cycle, design proposals, alternatives, and prototypes are evaluated against the required criteria. The activities for building and evaluating the evolving design artefact must be closely linked to the relevant business needs and requirements and also to the selected applicable theories and models.

From a cybernetic perspective, an organisation is a system of communication and regulation. Safety and business management sensemaking strongly depend on information technology. Therefore, an Information System (IS) compatible research method approach to develop practical artefacts was chosen.

according to Hevner and Chatterjee (2010), research can be defined as a systematic process that aims to obtain answers to questions, resolve problems, or enhance understanding of a particular phenomenon through the use of data. This process is commonly referred to as research methodology and consists of eight distinct characteristics.

- Research originates with a question or problem
- Research requires a clear articulation of a goal
- Research follows a specific plan of procedure
- Research usually divides the principal problem into more manageable subproblems
- Research is guided by the specific research problem, question, or hypothesis
- Research accepts certain critical assumptions
- Research requires the collection and interpretation of data or the creation of artefacts

Research is by its nature cyclical, iterative, or more exactly helical

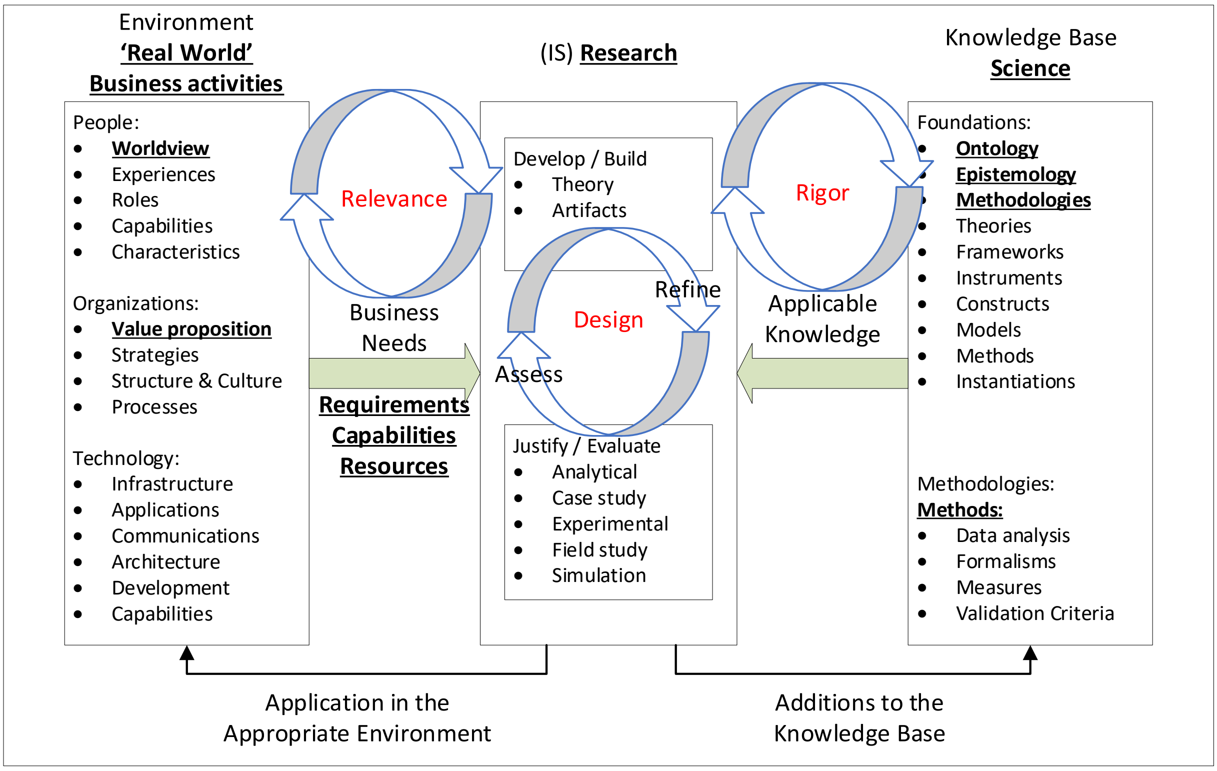


Figure 5-2 Design Science Research cycles based on (Hevner & Chatterjee, 2010)

The DSR principles need to be executed in a logical order to achieve a systematic and repeatable research process.

5.5.1.1 Survey analysis

When sufficient text is used in the qualitative responses to the intervention surveys, they will be analysed using a thematic analysis. This type of analysis describes what topics or issues are addressed by the participants. The essential purpose of this approach is to search for themes, or patterns, that occur across a data set (such as a series of interviews, observations, documents, diaries or websites being analysed). Thematic Analysis involves a researcher coding her or his qualitative data to identify themes or patterns for further analysis, related to his or her research question (Saunders et al., 2019).

Thematic Analysis may be used irrespective of whether you adopt a deductive, inductive, or abductive approach. In a deductive approach, the themes the researcher wishes to examine would be linked to existing theory. Here, the research question is also more likely to be firmly established and this and the research objectives may be used to derive themes to examine in the data. This may lead the researcher to focus on parts of the data set rather than seek to analyse it all undiscriminatingly. In an inductive approach, themes will be derived from the data. The researcher will search for themes to explore related to the research interest but will not impose a framework of themes to examine the data set based on existing theory (Saunders et al., 2019).

Where a researcher uses an inductive approach and has defined a research question, the researcher should be able to use this question to help select which data to code. Here, while all the data may be potentially interesting, the research questions will help you focus on which data to code (Saunders et al., 2019).

Following these suggestions, I take an inductive approach and make a thematic analysis of the experts' answers. Each answer or part thereof will be coded with emerging themes, besides the degree of agreement with the specific question. Based on the coding result, I will provide an aggregated answer summary for each survey question.

Some of the answers were over 300 words and a few were just one single sentence. On average, the explanation for each answer was about 150 words.

5.5.1.2 Epistemological Analysis Framework

The DSR principles are compatible with the framework for epistemological analysis (Xiao & Vicente, 2000), which provides support for Human Factors cognitive field researchers who are in search of behavioural patterns and design principles. The framework supports two processes, similar to the relevance and rigour cycle in DSR. First a process for moving from general context-independent theory towards increased specificity and context dependency and second, a reverse process for moving from data from a specific context to context-independent generalisable theory. These processes are concerned with the limits and validity of knowledge, hence the name epistemological analysis. Research findings generated through these processes are expected to show external validity, a critical quality of research findings. The figure below is adapted from their work and shows both research projects, the AVPMM and FlightStory, can follow similar research processes which are compatible with DSR.

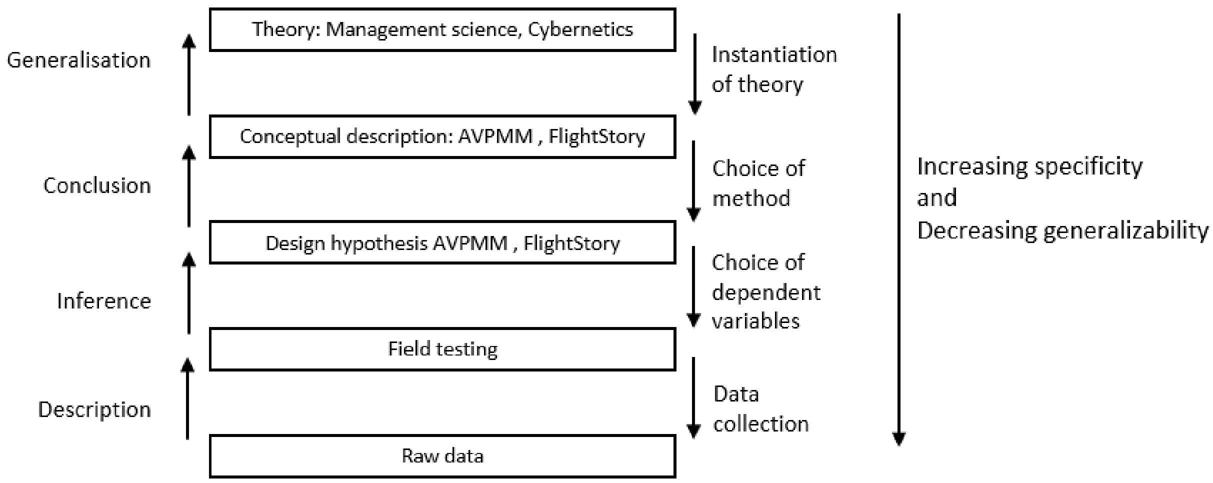


Figure 5-3 Linking theory to data. Adapted for AVPMM and FlightStory (Xiao & Vicente, 2000)

5.5.1.3 Strength of evidence

In DSR, depending on the rigour of the testing of a new design, evidence-based claims can be made. Strong evidence for a design is to test a design artefact in actual operations.

The table below shows incremental steps of increase of the strength of evidence relative to research methods in DSR (van Aken & Andriessen, 2011). From bottom to top stronger evidence is claimed. Each higher step includes the levels below.

Level	Strength of evidence	Description	Type of Research	Qualification of efficacy of intervention
4	Causal	All below and there is evidence that positive outcomes result from the intervention.	Empirical research Repeated case research (N=1) Quasi-experimental research.	Operational
3	Indicative	All below and it can be claimed, based on empirical data that problems are reduced and the situation is improved.	Quasi-experimental research. Theoretical change research Change research Customer satisfaction research Norm related research	Effective
2	Theoretical	All below and there is an adequate intervention theory about which conditions are related to the problems and why the intervention will bring an improvement.	Meta analysis Literature study Expert elicitation	Theoretical supported and promising
1	Descriptive	There is a clear description of the elements of an intervention and the conditions and requirements for the intervention.	Descriptive research Observation research Document analysis Interviews	Potential

Table 5-1 Levels of the strength of evidence

(van Aken & Andriessen, 2011) argue that testing a new design by experts and potential future users of the design the strength of evidence that can be collected is maximum level 3; indicative. In my view, a full level four claim can only be made when a new design is implemented and the design is also confronted with the sociological aspects of the work environment such as culture

5.5.2 Design Science Research process

The generic Design Research Structure as described by (van Aken & Andriessen, 2011) is meant to result in solutions or improvements for practical problems in business activities and on the other hand contribute to the scientific knowledge base via a scientifically suitable method. The research process proposed by (Andriessen, 2008) and repeated in (van Aken & Andriessen, 2011) is shown in the figure below.

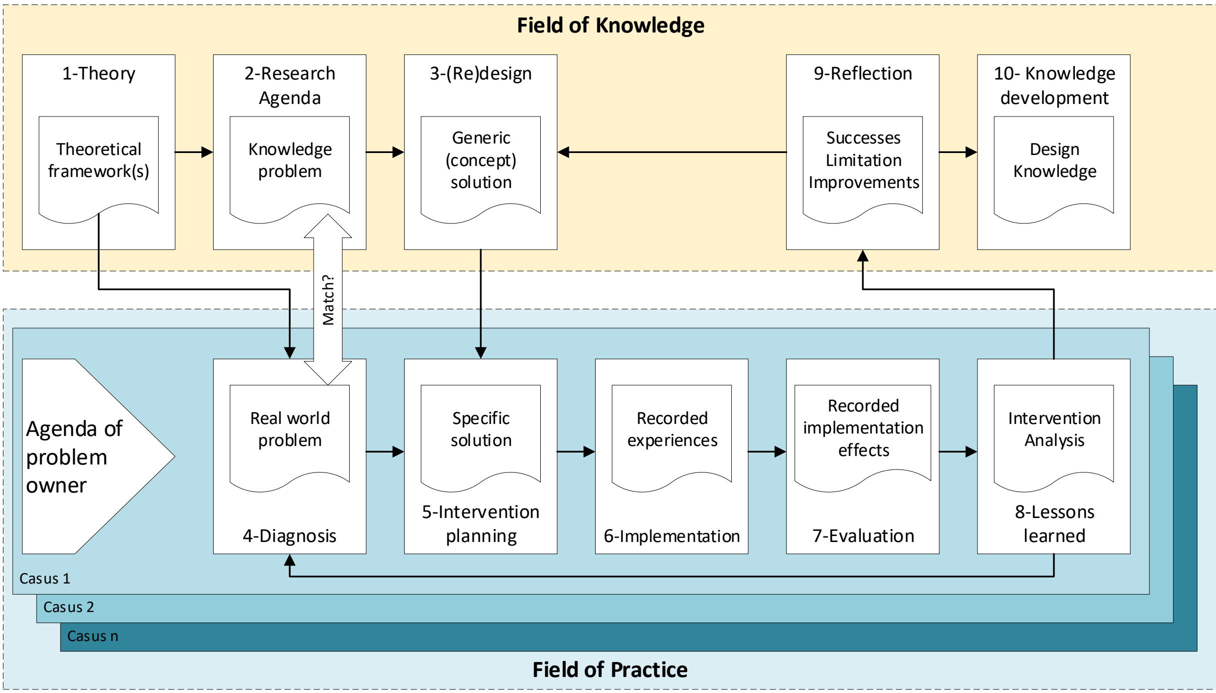


Figure 5-4 Steps and products in knowledge- and practice fields (van Aken & Andriessen, 2011)

Both the field of practice and the field of knowledge are important for DSR and used interdependently by the researcher. This research process is suitable for my research. In the table I describe the research process steps and indicate in which chapter of this thesis they are executed.

Design Science Research process steps	Thesis chapter
Agenda of problem owner: Description of challenges in integration of Business and Safety management and insufficient learning from operational experiences.	1 2
Theory: Selection of ontological, epistemological and methodological perspectives providing concepts, models and methods.	5 Research questions and methods to answer them 8 Relevant theories in Field of Knowledge.
Research Agenda: Safety science and safety management literature review to formulate the two thesis research topics knowledge gaps.	4 Literature review AVPMM 3 Literature review FlightStory
Design of solution: Generic theory based model that should be operationalised for the specific 'real world' problem situation.	For each research project: 6. FlightStory 7. AVPMM
Diagnosis: Description of current problem of improvement opportunity with involvement of business topic owner. The problem description depends on the theory in use by the researcher.	For each research project: 6. FlightStory 7. AVPMM
Intervention planning:	For each research project: 6. FlightStory

Describe specific project setup and objectives with business stakeholders.	7. AVPMM
Implementation: Execution of project interventions.	For each research project: 6. FlightStory 7. AVPMM
Evaluation: Evaluation of project interventions.	For each research project: 6. FlightStory 7. AVPMM
Lessons learned: Description of lessons learned. After the intervention execute focus group interviews.	For each research project chapter paragraph 11
Reflection: Analysis of intervention project effects on the business and possible lessons for practice and for the science knowledge base.	For each research project chapter paragraph 11 and chapter 9
Knowledge development: Research report, this thesis, and possible proposals for further research.	For each research project chapter paragraph 11 and chapter 9

Table 5-2 Mapping between DSR steps and thesis chapters

5.6 Ontology, epistemology and methodology

It is considered good practice for a researcher to articulate the basis for claiming to know what we know. My philosophy of science background can help the reader fill in the gaps I left and position the claims I make.

The scientific method, especially in the multifaceted social domain, while offering a rigorous framework for obtaining and validating knowledge, is not a neutral or unbiased process. This is particularly true for research in the social domain, such as this research, and the applied DSR method should clarify how claims are being substantiated and identify potential weaknesses in the type of evidence used to support these claims.

In this section, I like to begin at a very fundamental level and build towards an argument of the applied methods in this research. The steps I make in this argument should be of sufficient detail for the reader to understand my argument. A more complete description is beyond this research project and has been a realm of research itself since the Enlightenment.

This research is a human endeavour and thus the human nature of understanding the world and ourselves should be included. “Everything said is said by an observer.” This statement, made by biologist Maturana in Biology of Cognition (Maturana, 1970) urges us to realise our epistemological position when we observe, write a thesis or read a thesis. Maturana (Maturana, 1978) and von Foerster (von Foerster, 1988) defend their constructivist position by emphasizing the active role of the observer in shaping their understanding of the world. They argue that knowledge is not a passive representation of an objective reality, but is actively constructed by the observer through their interactions with the environment. My research has been an interaction with my professional activities as captain, safety expert and researcher and the constructivist position makes a lot of sense to me.

Spencer Brown, in his fundamental treatment of logic and mathematics (Brown, 1969), begins with the statement that 'a universe comes into being when a space is severed or taken apart'. Every statement is based on the distinctions made by the statement maker. The autopoietic process of making distinctions is a continuous process in humans. Making distinctions is a fundamental cognitive operation (Maturana & Varela, 1980). Based on (Bateson, 1972) who coins the notion of a difference, which makes a difference, we can note that all distinctions are not similar. This research should be explicit about which differences make a difference.

At the initiation of this research project, I arrived at the stage with a certain worldview which developed as a consequence of my interests and activities during my life. The distinctions I make for this research are based on a pragmatic approach to making improvements in human activities. These activities are executed by actors based on the images (mental models) they have of the situation, their intentions, and their perceived context. In the context of working for an airline, I assume teleological, goal-directed behaviour, while realizing that each actor has his own goal image. The differences that make a difference are those differences that are perceived to be relevant in relation to steering towards a goal. The goal here is not an ideal end-state, but a desired path in the evolving situation. The ideal endpoint cannot be defined because of the complexity of the activities.

A relevant distinction can be drawn between us, humans, and the world that surrounds us. Distinct does not mean independent. My ontological stance is a critical realist (Bhaskar, 2013) in that I believe there is a real world that exists independently of us and of which any human can only have imperfect and incomplete knowledge. Humans interpret the world through a subjective process of sensemaking (Weick et al., 2005). Noë argues that in embodied realism perception is not a passive process of receiving information from the world, but is an active process of constructing meaning through our bodily interactions with the world (Noë, 2004). The way the world, or a reality, appears to us is not independent of us. Consequently, the notion of 'is-ness' as properties of objects as independent of the observer becomes problematic. As an example, the claim that the colour of the flower is red as an independent property of the flower is contested without the use of an instrument. The colour of things arises in the interaction between the observer and the object (Varela & Thompson, 1990). Accounting for the is-ness issue in every sentence in this thesis makes it incomprehensible therefore the reader is informed about my basic view on this topic.

As noted by (Maturana & Varela, 1987) and (von Foerster, 2003) and explained in (Heylighen & Joslyn, 2001) humans cannot have direct access to how the world "really" is. According to their claim, the nervous system cannot differentiate between a perception and a hallucination, as both are patterns of neural activity. This view can lead to extreme ideas like solipsism, which suggests that only one's own mind is certain to exist, or relativism, which implies that any model is as valid as any other. To avoid such dangers, it is necessary to adhere to the requirements of coherence and invariance as supporting evidence for claims. More coherence between knowledge and information makes it more reliable. Furthermore, except from the scientific method and technology, the biological sensing system similarities between people reduce the variances in perceptions and agreements on the perceptions will lead to a consensus about what is "real" (Heylighen & Joslyn, 2001). Heylighen describes these ideas as an aspect of constructivism: the philosophy that models are not passive reflections of reality, but active constructions by the subject.

Human sensemaking, the building and updating of mental models, is often based on data, especially in business management. Checkland describes data as a mass of facts, which are statements about the world that are in principle checkable (Checkland & Holwell, 1998). Capta is defined a subset of the data that we select for our purposes. The information is not out there in the world but is generated by the observer who takes in the data and, based on personal characteristics information is internally generated.

The above is part of a cyclical process. The data doesn't simply exist out there in the world. It is selected by someone from many possibilities. The choice depends on agreements between sense-makers who each have their own background and context. Based on the understanding, new data sources can be selected to generate new information in each of the participants as a basis for a continuous conversation as we see in the practices of safety and business management.

A pragmatist approach is to describe an Airline Company as a social-technical system where people in different groups collaborate and share information to conduct experiments (Achterbergh & Vriens, 2010) and use high-tech technology in a safety-critical environment to fulfil their aspired purpose. This description of an organisation shapes the characterisation of the research topics in terms of challenges in regulation and information. A kind of cybernetic characterisation since cybernetics was coined as the 'science of information and control in the machine and the animal' (Wiener, 1948).

The purpose of this research requires the design and evaluation of models and methods. The choice of DSR results in a methodology that fits the requirements of analysis of the problematic situation, the design, implementation, and evaluation of a solution in a coherent research project and report. DSR research can employ a variety of research designs, including qualitative, quantitative, and mixed methods(Creswell & Creswell, 2017). Specific research methods are selected based on the purpose of this research, the epistemological stance, a pragmatist approach and the constraints imposed by work in an organisation such as access to data and people. A characteristic of DSR is a kind of nesting of research methods. The choice for DSR is most influential in the orchestration of the research methods.

In summary, I think it suffices to indicate that my epistemological stance is compatible with constructivism and embodied realism (Maturana & Varela, 1980) (Lakoff & Johnson, 1980). I take a critical realist ontological position and apply a pragmatist approach to research methodology.

5.7 How the research objective will be achieved

The topics of operational feedback and safety management were viewed from a perspective which includes cybernetics, systems, control and complexity theory. Using this perspective, I was able to present solutions to the problems. These solutions pushed the safety management developments, and the managers perceived the benefit of contributing to the projects. Given the workload in the safety department, I had to do all the work myself. The benefit was that I was very much in control of the projects. The synergy between my work as an incident investigator and safety consultant and researcher allowed me to execute the research projects next to regular safety consultant work.

The principles of DSR provide guidance for the two research designs and project planning. The combination of these two research topics provides the required principles for a systemic management approach to flight safety as an aspect of airline business management.

Since the projects represent a cycle involving operations as feedback providers and management as feedback users and decision-makers the sequence of the projects become a choice. The practical constraints for the research in the organisation led to the order presented in this thesis. A logic for another sequence could be that after the design of a decision-making top-down model, feedback from flight operations was missing, which led to the development of FlightStory.

5.7.1 FlightStory as bottom up data provider

DSR as a research approach requires several steps. First, there must be an agreement on the problem of lack of data in the Air Safety Reports (ASR). Then a solution should be proposed that fits the needs and the possibilities in terms of resources capabilities and regulations. When all stakeholders agree a test of the new reporting tool, FlightStory, should be executed. Then a review of the usage of the tool by the flight crews and the information the tool provides to stakeholders should be evaluated.

5.7.2 Integrative top-down Model: Manage safety as an aspect of the value production of a network airline.

The following DSR steps for the AVPMM are required. It is necessary to first agree on some of the problematic properties and limitations of safety management as a subsystem. Then a proposal that addresses these issues and could potentially improve the safety management system should be developed. This proposal should be tested by actual airline managers from different relevant departments dealing with different aspects of the organisation. The evaluation of the test is planned as focus group interviews with at least two groups of relevant managers.

5.8 Drawing conclusions from research results

In the social domain, research primarily focuses on the study of human behaviour, social interactions, and the functioning of societies and organisations. This domain encompasses a wide array of disciplines, such as sociology, psychology, anthropology, and political science, among others. The complexity of human behaviour and social phenomena often leads to a higher degree of uncertainty in research findings within the social domain as compared to those in the physics domain. The following points elucidate the reasons behind the caveats in research result claims in the social domain based on (Creswell & Creswell, 2017) :

- Complexity and dynamism: Human behaviour and social systems are incredibly complex, often influenced by a multitude of factors that can be challenging to isolate and measure. These factors are also subject to change over time, further complicating the research process.
- Subjectivity: Social research often deals with subjective experiences and perceptions, which can vary significantly among individuals. This subjectivity can lead to challenges in ensuring the reliability and validity of research findings.
- Difficulty in establishing causality: Due to the complex nature of social phenomena, it can be challenging to establish clear causal relationships between variables. Researchers may be able to identify correlations, but determining causation can be more difficult.
- Variability in research methods: Social research often employs a range of methodologies, including quantitative and qualitative approaches, each with its strengths and limitations. The choice of method can impact the generalizability and applicability of research findings.
- Researcher bias: Social researchers may be influenced by their personal beliefs, values, and experiences, which can inadvertently introduce bias into the research process. This can lead to skewed results and limit the objectivity of research findings.

In contrast, the physics domain involves the study of natural phenomena and the fundamental laws governing the physical universe. Research in physics typically follows the scientific method, with a strong emphasis on empirical observation, experimentation, and mathematical modelling. Consequently, claims made in the physics domain tend to be more precise, objective, and universally applicable than those in the social domain. However, it is important to note that research in both domains has its unique challenges and limitations.

5.9 Research projects relationship

Each research project can be executed independently of the other. The generic concepts on which the solutions are built are similar. Both projects have their basis in cybernetics and complexity theory.

The end results of the projects can be used independently in an airline company. The AVPMM is a more intrusive innovation and requires more different data sources. The integration of these data sources is new and therefore new collaborations between departments and goal alignments have to be established. Conversations concerning the new data integration should bring about new insights. These conversations are expected to be more insightful when FlightStory data is added to the business data, which becomes possible when the project results are combined.

The AVPMM proposal will be evaluated with some simulated FlightStory data. This data is mainly added to demonstrate the integration of the AVPMM and FlightStory. This demonstration should show the new kind of discussions and discussion topics that could develop but which are not held in the current Safety Management System and Network performance activities.

The FlightStory proposal is less intrusive than the AVPMM. FlightStory can be seen as an extension of the already existing Air Safety Reporting system. FlightStory will provide more learning opportunities when the anonymised stories, flight crews' perspectives, and opinions are shared with the other flight crews and flight operations managers and back offices. The new aspect of collaboration between the safety department and the flight operations department does not require the AVPMM. The evaluation of FlightStory will not include the complete AVPMM concept.

In short, both projects are interconnected and have synergy which should be discussed during the evaluation phase.

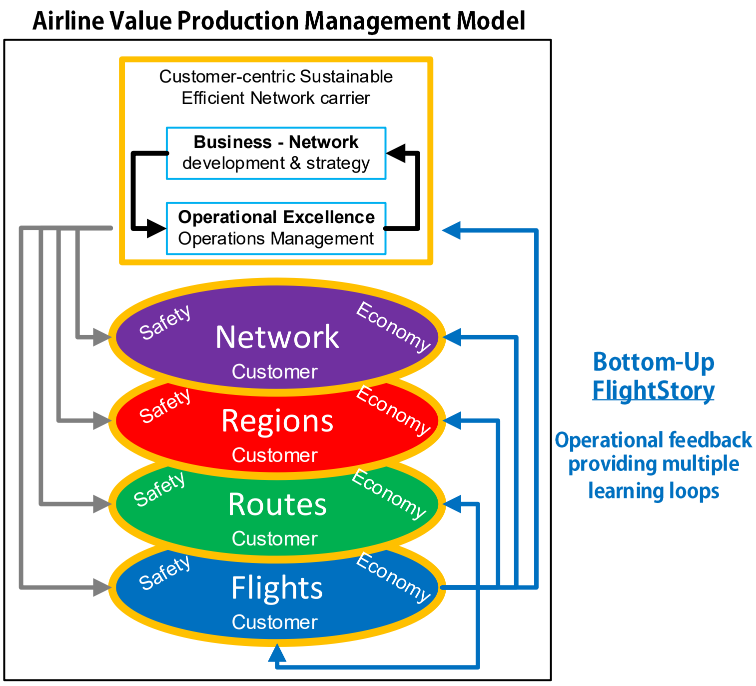


Figure 5-5 Model of two interconnected research projects

Chapter 6: FlightStory a Project to Empower Flight Crew as Intelligent Feedback Providers

As the manager of a flight, the flight crew can provide the organisation with unique feedback from operational experiences. FlightStory is a project to use the pilots' expertise to enhance organisational learning.

This project uses the logic of the Design Research Science as described in chapter 3. This chapter starts with a description of a problematic area of flight operations management. This description is then followed by a diagnosis of the current problematic situation. I will then compare the current situation with the desired situation. This comparison will be the basis for describing knowledge gaps in the design and operation of a flight operations feedback system. Then the relevance of this research topic will be explained.

I will then develop a generic solution for the problematic topic and subsequently, a specific solution for the airline will be developed, which will be tested by the flight crew in a natural setting. Experts and managers will complete a survey about the solution, which will provide the data for answering the research questions. Finally, lessons for practice, design and science will be offered.

6.1 Introduction

Safety is a critical variable for the survival of an airline. Airline organisational management and safety management are demanding when the competition is fierce, the impact of regulations is strong, traffic is increasing, and technology is getting more connected. Safety in aviation is already at a high level and requires new methods for further improvements.

The scope of this project is flight crew reporting of operational flight experiences inside the airline organisation. Out of scope is the state reporting system, such as regulated by EASA and ICAO. I will consider the requirements of EASA EU376/2014 regulations affecting the airlines' minimal reporting requirements. In the aviation system, the learning loop via the regulatory system is partly based on the state reporting system. This loop is slow and non-specific for airline companies. The focus of this project is organisational learning, specific to the organisation, based on its own specific operational experiences.

An effective Safety Management System requires high variety feedback from flight operations (ICAO, 2018b) (Sánchez-Alarcos Ballesteros, 2007). Current methods for gathering operational data are not suitable for the pilots' personal, contextual opinions and views at the 'sharp end' of flight operations (Hollnagel, 2017) . This feedback from operations to the supporting management system must inform the organisation about the strengths and weaknesses in flight operations. Operational risk mitigation and the handling of disturbances are an essential quality of the flight crew. The organisation must optimally support this quality, which requires the organisation to understand how safety is achieved during disturbances in flight.

The description and analysis of the current problematic situation will show the need to improve feedback from operational flights. I developed FlightStory as a specific solution for improving the effectiveness of reporting. The method builds on generic feedback and management concepts. FlightStory, supporting operational feedback, makes the flight crew more part of a human sensor system to improve a safe, economical and customer-centric service. The management involved in flight operations can learn from FlightStory reports how actual practices created safe performance under goal conflicts and resource limitations. FlightStory provides a high variety feedback system. The flight crew have access to an app on their iPad to submit their stories. Relevant aspects of Resilience Engineering and the Viable System Model, as cybernetic management model (see Chapter 8) are used to find patterns in the effective handling of all types of events and not just safety incidents.

Reporting is effective when the supporting organisation can act on the operational feedback to improve operational resilience. The organisation should constantly update their understanding of how different operational performance requirements, such as safety economy and passenger satisfaction, create operational complexity. A safety-in-a-silo approach to reporting and organisational management lacks the variety to manage effectively the airline's operational complexity.

6.2 Problem description and diagnosis

The focus of the problematic situation will be on the organisational management system that should support and enable the resilient performance capability of the flight crew.

An effective management system requires an effective linkage between regulatory management activities and operational activities. Each linkage component affects the variety of the total regulatory system (Hoverstadt, 2011). For example, report classification methods and management dashboards reduce variety. Variety should be reduced to prevent that operational details will swamp organisational managers. However, this reduction should not fall below the requisite variety for effective management of conditions for resilient operational performance (Hollnagel, 2008b).

The gap between the adequacy of the currently employed methods in the airline company and the requirements for a requisite management system is indicative of the current problematic situation this research attempts to resolve. The specific solution developed in this research should reduce this gap.

6.2.1 Description of the current problematic situation

The problem this research is addressing is an under-utilisation of learning opportunities from operational flight events. Flight crew who experienced operational disturbances and were challenged to execute a safe, economical and passenger-centric flight can provide very informative data. The systematic collection, analysis and sharing of operational pilots' experiences for organisational learning should support an organisation in becoming more adaptive.

This research considers the current lack of actionable data available for organisational employees and managers to support operational resilience. Decisions aimed at any of the essential variables of safety, economy and passenger service should consider the interdependencies between these variables and how they independently or in interaction can challenge the flight crews' capability for resilient performance.

The operational experiences of the flight crew are much richer than the current Air Safety Reporting (ASR) form can handle. An ASR form format requires an objective, neutral description of the event with facts about the flight. Current ASR reporting form focuses on what has happened. The form requests a factual answer to the 'what' question. The answer to this question does not provide much insight on how the crew handled the situation. Event and risk analysts in the safety department carry out the analysis and interpretation of the ASR. Current ASR does not collect the richness of the flight crew experience combined with the pilots' judgement on performance conditions, the strategy used to handle the operational disturbance, and the lessons learned. Therefore, this data is not available for organisational learning, and no other source can provide this unique data. The flight crew uses their own experiences as part of crew resource management practices to only debrief themselves, and the rest of the organisation cannot benefit from the crew's experiences and expertise.

There are many steps in between the ASR writeup and management actions to improve the operational conditions. Each step reduces variety. From the flight crew to event analyst, to risk analyst, to safety action group, to operational managers' decisions, many transductions are made, and requisite variety can easily be lost.

The pilot's feedback to the manager's action linkage is very much dependent on the personal characteristics of the persons involved. There is no usage of an agreed model of safety management and human performance. The lack of a model reduces the effectiveness of the feedback system, and this is undesired in an ultra-safe system (Amalberti, 2001).

The current under-utilisation of learning opportunities that flight crew can provide to organisational learning includes the following stakeholders:

- **Flight crew.** Pilots like to share stories of challenging operational events. As professionals, they are interested in the experiences of others and the lessons they can extract from these stories.
- **Operations support employees and managers:** Every flight receives operational support from, e.g., flight dispatchers. However, flight crew and the support organisation do not systematically share the contribution of operational support to handling an event, both negative or positive.

- **Flight Operations employees and managers:** The risk analysts of the safety department share the relevant ASRs with the business pilots safety who are part of the Flight Operations department. These business pilots discuss issues with Flight Operations managers. The quality of the Operational Performance Conditions (OPC) results primarily from Flight Operations department managers' decisions. They shape the pilot's performance (Reason, 1997)(Hollnagel, 1998). The safety department and the Flight Operations department do not collect direct feedback from the flight crew about the quality of these OPC's and therefore learning opportunities are missed.
- **Other departments that influence flight execution:** Currently, the safety department does not systematically share ASRs with these other departments. The safety department shares an ASR after de-identification with a department that is explicitly addressed in the ASR. Pilots' stories of operational events could increase the organisational learning for ground services, maintenance, cargo, network planning and passenger service. Pilots' stories can help understand the dependencies between the decisions made in these departments and the execution of the flight. In addition, these stories can help to discover undesired side effects. E.g., the concept of operational pressure addresses these conflicts between departments. While one department maximises production, people in other departments, such as operations, are missing the buffers for handling operational variability and they might be tempted to take shortcuts.
- **Flight crew training.** Especially the Alternative Training and Qualification Program (ATQP) can benefit from direct flight crew experience feedback. This flight crew training programme requires the airline to collect and analyse data to match training and operational requirements. Currently, the training department uses ASRs as a data source, but they desire more useful data. Pilots' stories and their judgment of training and experience adequacy provide valuable data for flight crew training.

Safety education of people who influence flight execution and create preconditions for a safe flight execution is minimal. Compliance-driven training is more focused on safety management processes than on safety theory. Consequently, managers lack knowledge of safety management and human performance models. Therefore, they do not use these models; the models are mostly unknown and not regarded as essential for effective safety management.

The overall consequence is that organisational management has a buggy and an incomplete mental model of how the flight crew manages operational disturbances. An incomplete model and incomplete data mean organisational managers will struggle to fully understand the gap between Work-As-Done and Work-As-Imagined. A difference of understanding between the assumed situation and the actual situation reduces the effectiveness of management interventions and may even make them counterproductive. A discussion in the organisation about adherence to procedures might serve as an illustration. The flight crew did not recognise the procedure deviance while managers, based on the data they had from e.g., ASR, judged the pilots deviated from the procedure. This problem involves a gap of understanding of the trade-offs being made by the flight crew. The crew makes these decisions based on their knowledge, resources, goal conflicts and situational understanding. Current data collection methods do not capture the data to make a rich reconstruction of the operational event and the pilot's perspective. As a result, the pilots' sensemaking process cannot be reconstructed, and therefore, organisational managers and flight crew training cannot support it.

Currently, the ASR system regards safety in isolation, also known as safety in a silo. We cannot understand safety in isolation as one aspect of operational performance. The current ASR form does not cover the other aspects of economy and passenger service that also drive flight crew decision-making and are interdependent with safety. When the flight crew do not report on interdependencies, these interdependencies remain hidden for the safety management system. The ASR analysts in the safety department receive no data on these interdependencies. Even when they enrich ASRs and FDM data with other flight-related data in a data warehouse, models and experts' knowledge is required to find possible indicators for undesired interdependencies. E.g., the department that attempts to reduce operating costs on a specific route by reducing the published flight schedule times does not analyse possible undesired effects on operational pressure, as can be experienced by flight crew. Flight crew always aim to fly according to schedule to deliver the passengers the service they expect. Reduced scheduled flight times make it harder for them to arrive on time and thus they might feel the temptation to hurry-up, which can be undesirable in certain conditions. My suggestion to analyse this supposed interdependency as a part of this thesis was welcomed, but I did not have sufficient time to execute this analysis.

Some of the described problems related to organisational learning are also applied to accident and incident investigations. The thoroughness of such investigations reveal often reveals interdependencies and gaps between Work-As-Done (WAD) and Work-As-Imagined (WAI). The trigger to start such an investigation is a Safety-I perspective on an event with the purpose of learning from the event to prevent a reoccurrence of a similar event. Such an investigation requires considerable resources in terms of people and time. The investigation report produces an analysed risk which should be mitigated. Currently, a resilience and Safety-II approach is not yet common in safety investigations. Employing such an approach would open-up new learning opportunities. Although the safety investigation report can provide many organisational learning opportunities, only a few people read the report, which limits the exposure of the lessons learned. Publishing a summary of the report in the safety section of the digital in-house news magazine regains some of the learning potential.

The research questions for this research project aim to solve the described ASR problems and include the feedback loop from data collection of operational events to organisational management decisions affecting resilient operational performance.

6.2.2 Explanation of the current situation

A commercial airline flight is a value exchange with a customer, which makes up a safe, economical and customer-centric service. Different data sources are used to extract data from flight operations to manage the value exchange with the customer. I describe these value aspects as essential variables in Chapters 7 and 8. The organisational management system also uses these variables as key performance indicators but not in the integrated manner proposed in the AVPMM model. The management of these variables requires data, analysis, and effective management actions. Organisational learning can be described as the improvement of the management of these variables. Learning leads to increased knowledge and updated procedures, processes, skills and training.

6.2.2.1 Data collection

Many departments in the airline organisation collect data generated by commercial flights. Commercial and inflight service departments collect passenger-related data, while the commercial and network departments collect revenue data. Network and operations management collects operational flight performance data such as departure and arrival punctuality, fuel usage statistics and many more. The maintenance department collects technical aircraft system performance data from onboard aircraft computers. The safety department collects safety data, comprising safety reports filed by the flight crew and Flight Data Monitoring (FDM) data. The different departments analyse the data in their management systems. As a result, processes, procedures and resources are updated for a continuous improvement of the airline's service delivery.

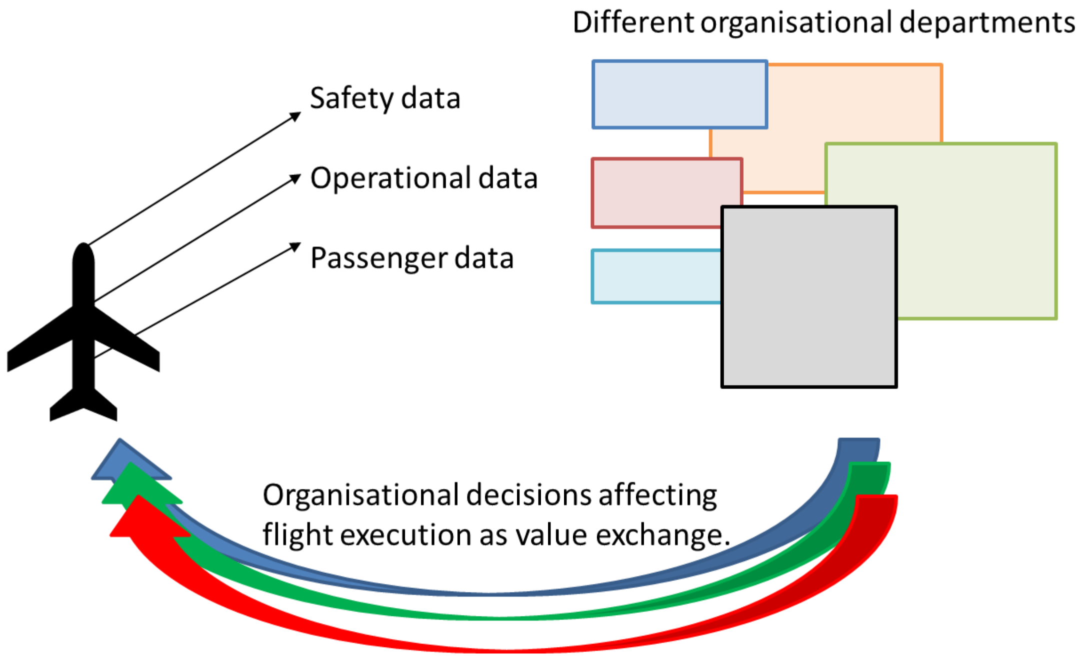


Figure 6-1 Data, departments and decisions

A more detailed description of the collection of safety-related data shows three types of data sources.

Technology generated data

Current practices for collecting safety-related data from flight operations comprise systematic data collection from onboard computer systems and recorders, such as the black box. The onboard recorders store from each flight many operational flight variables and technical system parameters. The FDM section of the safety department processes this data, comprising about 160 parameters. Flight parameters are, e.g., indicated airspeed, altitude and course. System parameters are, e.g., flap setting, thrust setting, autopilot mode and many more. After each flight, computer software scans the flight parameters for value exceedance. The value thresholds for an exceedance can be conditional on the flight phase or other conditions. The degree and time of a value exceedance determine a class 1, class 2 or class 3 event categorisation. FDM analysts verify each Class 3 exceedance for its validity. Flight Data specialists verify data accuracy, integrity and completeness. They compile statistics of a subset of the parameters as desired by the flight operations department and as deemed informative as judged by the risk analysts.

Making sense of flight data can be difficult because the parameters show only a partially factual perspective of the flight execution. Although computer systems record essential parameters, the parameters by themselves or in combination cannot tell the story of the recorded event. FDM is not contextual, and it does not include weather information, the air traffic control situation, and other conditions that might explain a flight parameter value exceedance. The data analyst might guess the pilot's intention by combining data, but analysts can only understand the data in combination with the pilot's description of their perception, sensemaking, and intentions. FDM specialists, in consultation with the risk analysts, have established limits for each parameter exceedance. The safety department might invite the flight crew for a flight replay when such a limit has been exceeded. The airline company has established a process for the flight replay in agreement with the pilot union. The purpose of a flight replay is to create a potential learning opportunity. The flight crew who had a flight-replay might volunteer to write a 'share your experience' narrative to inform other flight crew of their experience and lessons learned.

FDM trend reports can be an important first step for further analysis. FDM data is also essential for incident and accident investigation but is almost never sufficient for an effective, actionable management intervention.

Human observer generated data

Airline flight inspectors execute flight inspections as required by regulations. The flight inspector compiles a report about the general performance of the inspected flight crew member. These reports are confidential and rarely contain more than formally checked boxes and short narratives, making it hard to extract lessons from these reports.

Some airlines use the Line Oriented Safety Audit (LOSA) (Klinect et al., 2003) for flight inspection. During LOSA, a trained observer fills out a LOSA form listing his observed threats, how the flight crew managed these threats and what type of errors or violations the crew made. Klinect in (Klinect et al., 2003) developed LOSA based on the Threat and Error Management (TEM) model. We can classify this model as a Safety-I model since it assumes 'error' as a useful concept. TEM predates the notions of resilience and Safety-II, and the observer forms do not contain specific Safety-II or resilience entry fields in 2017. The LOSA procedures do not allow the observer to ask a question to the crew. This procedure aims to make the observer 'like a fly on the wall' to make the crew behave as if they were not observed. Consequently, the observer must infer the Intentions, local rationality and sensemaking processes employed by the flight crew. However, the narrative, written by the observer, might include resilience and Safety-II remarks.

Human observers can generate data that technology cannot capture. This data allows the reconstruction of a richer picture of the flight execution. However, human observer-generated data adds an interpretative layer between the flight events and the flight report. Observers, without the possibility of asking questions, can only infer the sensemaking process of the flight crew. This inference can be problematic since interpretations may be different depending on observer backgrounds. E.g., an Airbus pilot as an observer in a Boeing aeroplane might be surprised about particular crew behaviour and vice versa. Observation booklets and note-taking guidelines improve inter-observer consistency. While the observer is only concerned with observation and note-taking, the flight crew are operating the aircraft. The difference in workload and attention may lead to differences in sensemaking. The observed flight crew cannot verify the observer's interpretation since the observation notes remain hidden from the flight crew. Also, the observer might fall into the trap of hindsight. After some less favourable situation occurred, the observer might infer an action execution or an omission to execute an action as an error, while at that moment in time, the consequences were not likely. Thus, the human error concept as used in LOSA is problematic (Hollnagel, 1983). Safety scientists debate the usefulness of error counting and the execution of statistics on the count numbers (Dekker, 2004).

The form used by the observer to record the observation reduces variety and affects the analysis. In addition, the categorisations used in the LOSA report may not fit the airline's language. This mismatch can reduce the set of interventions by organisational managers to improve flight operations. As a safety consultant, I was part of a team that converted a standard LOSA report into a report that allowed actionable actions by flight operations management.

Flight crew generated data

Company procedures require flight crew to file a standardised feedback report on any incorrect or missing operational data item, such as a wrong or missing procedure description for a particular airport. The flight crew sent these reports to the department responsible for the completeness and accuracy of the operations documentation. These reports are not part of the safety feedback channel. However, when the flight crew relate the specific topic to a safety event, they submit an ASR.

The main channel for operational feedback is safety reporting. The ASR is subjected to regulations (European Parliament, 2014) that require specific data items in the reporting form. These required items are a subset of the fields of the current company-defined ASR form. A reporting procedure describes situations and conditions under which the flight crew have to use an ASR form to report the safety aspects of their flight. The operating procedure requires flight crew to file an ASR when “Any event, circumstance or difficulty encountered, related to the safety of the operation, not defined as ’incident’ but possibly important as judged by the crew for the continuous assessment of existing threats and risks within the Safety Management System (pro-active safety management).” The format of the ASR form offers the reporter the following free text entry fields: “Subject”, “Description”, “Do you have a suggestion to address a safety issue?”. A form gives no guidance about the desired contents of these data entry fields. It is assumed that the form is self-explanatory, and the result is a wide variety of descriptions ranging from a few words too long and emotion loaded stories. A great variety of answer styles of these essential data fields makes the usability of the data problematic and inefficient. The next part of the form gives the reporter the option to choose the type(s) of events. These include types such as “Airport/ATC”, “Wake turbulence”, “Pax behaviour”, “Injury or unsafe situation”, “Fatigue”, “Other incident”. A selection of an event type is followed by specific topic-related, mainly closed questions.

We can describe the free text type of questions as ‘What’ questions. These questions are designed to get a factual topic description instead of getting an opinion or judgement. The ASR form does not include ‘How’ questions. This type of question would explicitly elicit process narratives of how the flight crew handled the safety threats. Such reports would deliver essential data about who, when, conditions and decisions, enabling an understanding of the sensemaking process of the flight crew. Unfortunately, the current analysis methods and database registration are not designed for this kind of qualitative data.

The current ASR form format has a history of over 20 years. The form has not had significant updates. This type of feedback form, requiring factual answers, shows a preference for an etic perspective, where the safety analyst will interpret the meaning of all the facts. The current form does not request for the reporter’s interpretation or judgment, the pilot him/herself. The current form complies with relevant regulations. ICAO SMS regulations (ICAO, 2018a) focus on reporting for identifying hazards and not collecting the pilots' perspectives and opinions. Regulatory bodies use taxonomies for the classification of the reported events, such as a Human Error taxonomy. The taxonomies are Safety-I oriented and used for learning at the state level. Based on lessons learned from the submitted reports, the regulator may develop new guidelines or regulations. These regulations are not airline-specific and often become applicable on top of other regulations. This learning loop is slow and not company operations-specific.

ICAO SMS regulations (ICAO, 2018a) advise several safety data collection methods, such as voluntary reporting, self-disclosure reporting, audits and inspections, and safety data collection. The voluntary safety reporting system aims to collect data not captured by mandatory safety reporting. E.g., latent conditions, inappropriate safety procedures and human error. This type of reporting can be effective when the airline uses it in combination with safety management and human performance models. Unfortunately, the airlines seem to focus on the mandatory compliance-based reporting system. The literature review revealed little research that could help airlines to install a voluntary reporting system, as suggested by the ICAO.

6.2.2.2 From data to information to action

This research focuses on flight crew-generated data. The ASR is a digital form filled out on the digital tablet of the flight crew. The safety department receives and processes the digital form. An event analyst reviews the form and redirects the report to the applicable department. The analyst distinguishes whether the report is safety-related, lacking specific guidance, model or criteria. The analyst's internal model of safety determines the decision to accept or reject the form. The safety management managers do not see this reliance on individual expertise as problematic while event analyst training and expertise is less than a risk analyst. The high number of reports that have to be processed leads to a focus on the efficiency of the ASR processing process. Hollnagel would caution for organisational Efficiency Thoroughness Trade-Off (ETTO) (Hollnagel, 2012b).

The event analyst will then check the ASR form for administrative correctness, such as the event date and aircraft registration. Next, the event analyst will assign the ASR to the most relevant department for the event. This process assures the ASR will become a topic to discuss in that department's Safety Action Group Meeting. Finally, the analyst applies the Event Risk Classification (ERC) method (ARMS, 2010). A single analyst analyses an event with an ERC rating of Low, and this analysis is not verified by another analyst. When the analyst doubts the correct ERC risk level, the analyst will put the reports on the agenda for an ERC meeting in which a team of analysts will assign an ERC risk level. When the analyst does not assign a Low ERC risk level, the analyst must fill out a concise description field. This requirement means the analyst reduces the variety of the report by using an incomplete mental model to compile a low variety "short description". These "short descriptions" are used for labels in management dashboards. If this is the only usage, then there is no problem, and the variety reduction is acceptable. However, requisite variety may be lost when the short description is used for any other analysis.

When an analyst notices a high rate of occurrence of some event type, he might inform other risk analysts about the interpretation. The analyst's judgement is subjective and will differ between analysts. These notification actions are not part of the standard event registration process.

The next step is to assign classifications to the event registration. The purpose of the classification tags is to allow the registration to be found via database searches. The classification categories contain descriptors, such as 'bank angle' and explanatory categories for the event occurrence. The category assignment depends on the analyst's understanding of the operational conditions and his knowledge of available categories. Another analyst will verify the event classifications when an event's assigned ERC risk level is Medium or High. The analysts realise they can improve the inter-analyst consistency for category classification. Machine learning experiments are being executed to improve this process of category assignment. These kinds of automation solutions have their own problems which are beyond the current scope of this research.

In the ERC meeting, a minimum of two risk analysts will assign an ERC risk level. They use a combination of expertise and a limited bowtie model to evaluate the remaining barriers as required by the ARMS method. Currently, no complete risk model describing flight safety is available, and consequently, the risk evaluation depends on the analysts' available expertise. For events rated as Medium, the risk analysts will consider compiling an Event Assessment Form. For events rated as High, an Event Assessment Form will always have to be compiled. This form explains the assigned risk classification, announces specific actions taken by the safety department, and informs the business partners. The analysts can also propose to the safety managers for a full reactive Safety Issue Risk Assessment (SIRA). As another follow-up of a received ASR and ERC assessment, the risk analysts can ask the flight crew to write a so-called 'share your experience' report for the safety publication for the flight crew community.

In two monthly meetings, the safety department and safety representatives from other departments in the so-called Safety Action Group (SAG) meeting discuss reactive, pro-active or predictive risk assessment reports and trend analysis based on ASR data. Managers of the Flight Operations department are members of the SAG. They are the key actors in managing the Operational Performance Conditions of the flight execution process. Currently, the safety department does not present data in any safety management, human performance, or other safety model. This means their safety sensemaking depends on their mental safety models. These managers have no formal safety management and human performance training or education other than safety management process training. They have not recognised the absence of a safety model as necessary, neither have the safety consultants been able to convey the utility of these models.

Actions based on incomplete mental models of safety can, therefore, be ineffective and incoherent. The lack of safety management and human performance models restricts the capability to see different events as connected through a model. The lack of a model could cause managers not to act, while model-based knowledge would suggest otherwise. As anecdotal evidence of the lack of knowledge, a high manager asked me to explain the concept of protection versus production. Most managers in the Flight Operations department are flight crew themselves, and they use their own experiences as a reference in their judgements. Often, own experiences help relate to the operational issue but do not compensate for the lack of safety models. Own experience can be beneficial, but it also makes frequency and impact judgements difficult because of biases (Kahneman, 2011).

The risk analysts present the results of a SIRA as analysed risks in the SAG meetings. Depending on the risk levels stated in the SIRA report, the SAG accepts the risk or mitigates the risks. The risk matrix used in the SIRA process describes for each level of risk the corresponding urgency of action and the level of management involved in accepting the risk. For mitigation, the operational managers responsible for the work activities where the risk is assigned should compile a risk mitigation action plan. The safety department should agree on this plan.

Since the ASR does not prompt the flight crew to report in their ASR, the organisational factors that affected safe performance, a systemic understanding of events is hard to establish. Also, the methods and models used by event and risk analysts do not systematically address systemic safety interdependencies. An issue as operational pressure is hard to address since operational pressure is the consequence of many decisions made in many departments, all culminating in effects on flight execution.

Currently, methods such as the ASR form and the ASR data analysis do not explicitly address the relationship between safety, airline economy, and passenger service. Therefore, they cannot systemically manage the interdependencies between safety and economy and passenger service. Safety is currently mainly managed in a silo, but managers realise that safety is closely related to other topics. As a learning organisation, they found the most effective risk mitigation for bird hits in Entebbe was a flight schedule change. A study showed that the birds have a daily pattern of movement. As risk mitigation, the Network department adjusted the flight arrival and departure times to avoid the largest concentration of birds around the airport. The network department accepted the consequences for the passengers travelling at a less favourable time. Also, they accepted the change of the availability of the aircraft as a resource for the network operation.

Another example of interdependence between safety, economy and passenger service, as reported by a flight crew, is the cost-saving concept of seasonal weight restrictions. The maximum registered take-off weight of the specific aircraft determines Air Traffic Control country's overflight costs. The airline can change these maximum weights on paper, while nothing physical is changed to the aircraft. This paper change reduces the overflight cost. The flight crew reported that this seasonal weight reduction limited him in taking extra fuel, which he desired because of the weather at his destination. The extra fuel margin calculated for this route was limiting the flight crew in his decision-making. This story shows the conflicting goals and the requirements for integrated management of these potential conflicts. The realisation that safety cannot be managed in a silo is growing but has not yet led to changes in the management system.

The processes described above show how data from flight crews are related to operational management actions. This relationship comprises several steps in which data is processed and interpreted. Each step may lead to losing the requisite variety for the management system.

6.2.3 Comparison between the current and desired situation

Operational feedback by flight crew is an essential source of data for the Flight Operations management system. Three related and significant differences between the current and the desired safety management practices driven by flight crew reporting should be eliminated to support more effective safety management and organisational learning. The desired situation should support the organisation's purpose of creating value by providing safe, economic, and passenger-centric transportation experiences. These differences are concerned with:

1. Flight crew as intelligent feedback sensors.
2. Use of models by managers.
3. Integration of safety, economy and passenger in managerial decisions concerning value production.

The first issue to resolve is the omission of using the flight crew as intelligent feedback providers. In the desired situation, opinionated flight crew judgement and expertise complement factual data. A flight crew should be able to describe his sensemaking and decision-making in a way that others can understand. The others, such as colleagues and organisational managers, should be able to learn from pilots' experiences. The flight crew should be able to provide feedback to organisational managers about the quality of the Operational Performance Conditions.

Furthermore, they should be able to describe the applied strategies that were used to handle the reported situation. Current reporting does not include any account of how the flight crew could control the situation. A flight crew might report how the situation was handled, but the subsequent data treatment in the safety department does not support this narrative to be heard by others outside the safety department.

Current data analysis methods are mainly based on data aggregation, combination, and grouping. Using these methods loses the narrative in the ASR form. The analyst only used the narrative to assign categories and classifications. In the desired situation, more people should have access to the raw story of the flight crew. The stories themselves can provide more nuances and insights than classifications can provide.

The trigger for flight crew to report should not be the outcome of an event but the effort that was required to manage the situation. When the flight crew actively had to manage disturbances that could or were affecting the safety, economy or customer experience the workings of the system are revealed and lessons can be learned.

The second issue is the use of more coherent and explicit safety performance models, such as Safety-II, Resilience, Safety Management, Risk Management and Human Performance. Models will guide the selection of data since the data generates information in the models. All people involved with safety performance and safety management are familiar with a minimal set of models in the desired situation. This familiarity helps them see the model aspects issues when they encounter them in actual flight execution and safety management.

The traditional and current approach to safety in airlines is the prevention of undesired events. This approach is implied in SMS regulations and thus required for compliance. This approach is called Safety-I (Hollnagel, 2014b). Safety-II and Resilience Engineering (RE) as described in (Hollnagel, 2013b)(Hollnagel, 2014b) are not yet part of the vocabulary of current SMS methods, processes and data collection. Safety reporting does currently not support data collection for these safety models. In the desired situation, data is collected that is compatible with these safety developments. The lack of explicit safety management models and human performance models does not support systematic data integration, analysis, and sensemaking. In terms of signal-to-noise ratio, the signal refers to the useful information or data being transmitted, while noise refers to any extraneous or irrelevant information that can interfere with the signal (Skyttner, 2005). A model can help to distinguish between the signal and noise, making it easier to separate useful information from irrelevant information. Without a model, it may be more difficult to distinguish between the signal and noise, resulting in a lower signal-to-noise ratio and less accurate information being transmitted. The explicit use of these concepts in SMS design will support analysis, safety sensemaking, and safety interventions. These models should help to provide explanations for the tensions that might occur between the different key performance aspects of safety, economy and passenger service. These explanations should support actionability for managers.

Flight crew know the circumstances can help or hinder them in their job. A particular categorisation of these circumstances creates a language to address the quality of these circumstances. In the current situation, these conditions are only minimally addressed. The working conditions or Performance Shaping Factors (Reason, 1997) should be included in data collection and analysis in the desired situation. Also, organisational managers and especially managers of the Flight Operations department can integrate the concept of Performance Conditions in their decision-making and be more aware of the side effects of their decisions on the Performance Conditions (Groeneweg, 1992).

Concerning the ASR form, specific, model-based questions will reduce the variety compared to open questions about the applied strategy. These models should guide the data selection, collection, and integration. These models allow for narrowing the scope of possible answers into a compatible scope for the selected models. The safety department should also realise that safety models might need updating when new safety science knowledge becomes available. Model updating is a type of double-loop learning (Argyris & Schön, 1978).

In the desired situation, new model-based collected data and analysed data will support the actionability of operational managers. They will be less focused on acting on a single analysed risk issue than in the current situation, but be more proactive by focusing more on common causal factors such as Performance Conditions and the possible undesired interactions of these Performance Conditions.

The third issue addresses the desire for more systemic management of safety in the context of economy and passenger service. In the desired situation, flight crew can report on all events in which they experienced operational disturbances. The flight crew will judge to file a report about operational experiences from which they think valuable lessons for themselves and the organisation can be drawn. These events are always an integration of all aspects. Safety analysts or managers will currently take an aspect perspective 'Safety in a Silo" on these events relevant to their purposes. In the desired situation, the reported operational experiences should be reviewed and discussed from multiple angles to find interdependencies and unintended side effects of organisational decisions.

In the desired situation, organisational models would be available that include operational feedback narratives to get a richer understanding of the value delivery of flights. All operational people engaged in the passenger journey experience can contribute to improving the management system of safe, economical and passenger-centric service delivery. These narratives would also be illustrative of issues found by data analysis since they can provide at least a part of the explanation of why people did what they did.

The Airline Value Production Management model project of this research is a part of the proposed desired situation. This model integrates the perspectives of Safety, Economy and Passenger experience into the concept of value production. The proposed flight crew reporting system is included in this model.

6.2.3.1 Example of actual versus desired situation

In 2010, I had the experience of an actual engine oil leakage. As a captain on a Boeing 777 flight from Manilla to Amsterdam, after 10 hours into the flight while approaching St Peterburg in western Russia, we experienced an engine problem. We had about three hours to fly to Amsterdam. The whole story can be found in Chapter 1. In 2021, I asked an event analyst in the Safety department to search the archives for my original ASR.

The purpose was to show the difference between my ASR event description and a story. This is the ASR event description text:

"During the cruise, after 10 hours, we experienced a low oil quantity. It started with an indication of (4) after 15 min (3) after 25 min (2) after 35 min (1).

The indication stated shown till landing.

We reduced thrust on the left engine below 10.000 ft at EHAM back to normal operation (2 normal operating engines)"

The ASR text is a neutral description, providing almost no learning opportunities. In contrast, the story of this event in Chapter 1 provides much insight into how we as a crew handled the situation. I describe the options we had and the arguments I had for some of the critical decisions. In the story, I include the lessons that, I think, can be learned by the flight crew and by the organisation.

This example illustrates the difference between the actual and desired situation.

6.2.4 Knowledge gaps

The difference between methods and models proposed by relevant sciences and those used in practice can serve as indicators for knowledge gaps. However, I realise that other factors than lack of knowledge are needed to find more complete explanations of the differences between theory and practice. The literature in Chapter 3 review discusses the knowledge gap in science.

The unit of analysis in this critical review of the current processes is not the individual but the groups of people that develop and maintain safety management processes. While individuals may be very educated and knowledgeable, organisational mechanisms attenuate or amplify this knowledge and support or suppress new safety and business management processes. Considering these reservations, I make some claims about the knowledge gaps supported by my own experiences in the safety management domain.

This section will focus on the knowledge gaps that can be elicited from the differences between the current and desired situation.

1. the gap between reporting as compliant practice and reporting as proposed by a science-based constructivist perspective.

2. the gap between current reporting data model methods and the desired reporting data models and methods.

Both gaps have specific knowledge deficiencies, but some deficiencies apply to both gaps. It is vital to realise that innovations in aviation safety management always have to consider compliance. Remaining compliant while innovating is a challenge, and this requirement might hold back some innovations. The gap between the latest ICAO Safety Management Manual and the latest Safety Science SMS theory is significant. A complete analysis of this gap is beyond the purpose of this thesis, but I dare to estimate the gap is about 15 years of research. It is not relevant whether the gap is 5 or 20 years of research. The importance of a considerable gap is that when an airline innovates based on recent research, it will be ahead of the regulations. Being a front-runner in safety management practices may create threats to compliance. The airline management must explain to the regulator the new methods to get an endorsement. Also, airlines often work with partners and innovations in one airline might not be followed by the partner airlines. The differences in methods hinder the exchange of safety information between the partner airlines.

We can describe knowledge gaps between the regulation-based guidance materials and current safety management theory in terms of differences in underlying assumptions. Unfortunately, these assumptions remain often implicit, not only in the guidance material but even in some research. The differences in assumptions between on one side the regulations, their guidance documentation and most current practices, and on the other side safety science developments and this research are found mainly in the following concepts: positivistic versus constructivist, ordered versus complex, quality versus safety, Gaussian distributions versus thick-tail distributions, linear versus non-linear, full knowledge versus limited knowledge, certainty versus uncertainty, average safe versus ultra-safe, Safety-I versus Safety-II, reliable versus resilience.

Current safety reporting and analysis principles based on regulations and guidance materials seem to match a more positivistic background. This research builds on most of the current safety science concepts and a constructivist perspective.

The knowledge gaps have several dimensions. One aspect is the lack of theoretical knowledge that safety managers and experts have, while this knowledge is available in books and scientific publications related to safety science. Another aspect is the lack of knowledge to operationalise the concepts learned from books and publications. As an illustration, there is a desire to include Safety-II and Resilience Engineering concepts in safety management. However, since 2014 when (Hollnagel, 2014b) was published, only a few initiatives have been taken inside several airlines. Moreover, the ICAO regulations (ICAO, 2018a), important drivers for safety management processes in airlines, have not added these new safety science notions in their safety management publications yet.

I should emphasise that the airline in which I conducted this research has shown to walk the talk in its ambition to be a leader in aviation safety. They took the challenge to engage with the regulator to explain their safety innovations, and they accepted that the safety innovations caused differences in best practices.

The first gap: Related to the generic gap, is accepting multiple perspectives and rejecting the idea of a single correct interpretation. The recognition of complexity theory as a useful theory for safety science has not resulted in changes in the underlying assumptions of reporting in aviation. The importance of understanding operators' sensemaking driven by authors like Dekker in (Dekker, 2014b) has been accepted, as evidenced by explanations of human performance in incident investigation reports. The analysis of ASRs and investigations of safety events was my primary job as an incident investigator during the beginning of my research. In the safety office, we were trying to make sense of the reported ASR events. It frustrated me that the information we could derive from the ASR often did not fit our internalised model of human performance and safety management. Based on human factors, system safety and complexity theory, I proposed to extend the reporting possibilities for flight crew as described in this research.

The current reporting system has been operational for over 20 years without significant changes. The assumptions upon which an effective reporting system is based have not been updated. The ambition is to increase the number of submitted reports and increase the safety department's analysis capacity. Safety promotion as a function of safety management has addressed the desire to increase the number of submitted reports, and advertised via messages to flight crew to write safety reports. The safety department sought to increase the analysis capacity through changes in the event, safety, and risk analysts' roles and tasks. Also, data integration and software tool support have become part of development. Those developments continue to be based on the same traditional worldview. We could describe this worldview as having positivistic and objectivist traits (Ferroff et al., 2012). I suggest this background originates from the engineering North American and quality management background of safety management. Anecdotal but illustrative for my suggestion is that several times after I explained my research proposal, I got similar remarks from a senior safety analyst and flight operations managers about the validity of the claims made by the flight crew in the new type of reporting. Managers made remarks such as "Yes, but that is just an opinion of the flight crew. Who knows if the flight crew is correct? ". My answer always was like: "Yes, but these are the people that decide to abort or continue a landing; they are the people that decide to divert to the alternate airport or not. Their opinion is relevant, and we should try to understand them." I always got the impression that they accepted my argument. Sometimes the discussion continued to the problem different opinions may create for the analysis of reports. I then agreed that this was a challenge we must accept.

The second gap: A knowledge gap is the unrecognised importance of models. The requirement for effective management of any system is to have a system model formally described in (Conant & Ashby, 1970). Models help define what data is required and relevant, e.g., human performance and safety management models help define required data sources. These sources may not be readily available yet. Just collecting data under the assumption that big data analytics, machine learning and artificial intelligence will provide sufficient insights is optimistic, if not naïve. Models instantiated with data can bring insight. Without models, data remains data and we cannot transform data into information and knowledge.

The importance of the conversations about the gap between WAD versus WAI is growing. However, attempts to create an understanding of this gap have not resulted in new reporting methods yet. As operational managers of the flight, the flight crew requires supportive working conditions for the challenges they face during their flights. A model of the working conditions, the influences they have on human performance, and the quality of these conditions across different operational situations is not used except for fatigue. Fatigue management regulations resulted in Fatigue Risk Management Systems, which include fatigue reporting and the use of fatigue models. Knowledge of other working conditions classifications such as Performance Shaping Factors (Reason, 1997) and Common Performance Conditions (Hollnagel, 1998) is fragmented. Some managers know of some aspects, but collective knowledge is not combined with the available literature and modelled so that it contributes to safety management. The lack of using these kinds of models makes explanations for the gap between WAD and WAI hard to find. As a result, WAD WAI gap discussions become very opinionated and normative, while these discussions should be part of systemic safety management based on relevant data collected from flight crew reporting.

Current practices show a lack of knowledge about the operationalisation of the concepts of Safety-II and resilience. The ASR data analysis uses only the Safety-I perspective. Undesired events are collected, counted and expressed as rates of the total number of flights. E.g., exposure of events required to estimate the number of successes versus the number of failures is not fully recognised as a valid parameter.

Current safety reporting does not collect resilient performance-related data. They also do not collect the pilot's strategy and resource requirements. The event and risk analysts' current ASR descriptors and event classifications do not contain resilience concepts. Even if the taxonomies currently in use had those concepts, the ASR form does not have data fields for these concepts. Also often when there is a desired positive outcome of an event no ASR is filed leading to an under-representation of resilient performance in the ASR data.

Since the data is not available, the concepts of Safety-II and resilience are not part of the safety management processes and methods. Although safety professionals in the safety department and flight crew instructors have started to talk about these topics, it will take time and organisational learning to include these topics in managing flight operations. This research might be inspirational for the desired progress.

6.3 Why it matters

This research project matters since it contributes to filling some gaps in knowledge and practice. It might help to break the safety performance asymptote (Dekker & Pitzer, 2016).

The gaps that this research is concerned with are:

- A safety science gap, as discussed in the literature review.

  - Research review shows the sparsity of research related to operational feedback from flight crew as a source for learning
- Knowledge gaps existing in airline companies about involving the expertise of flight crew in their operational feedback methods.
  - Current methods and method development are aimed at factual data collection, integration and analysis while leaving out the narratives of flight crew.
- The conversations about the gap between WAD and WAI in flight operations.
  - Only flight crew can explain their trade-offs, resource constraints and sensemaking. Their experiences update the WAI expectations and can inform the management of operational working conditions which shape WAD.
  - For incident and accident investigations, the developed reporting method might be an additional source of information.

The reduction of reporting effectiveness, as argued by (Amalberti, 2001) might be consistent with the plateauing claim of (Dekker & Pitzer, 2016). Amalberti argues that in aviation which he classifies as an ultra-safe system, insufficient incidents and accidents occur to provide an effective feedback signal. This research develops a method that can provide feedback when the conditions challenge the system in maintaining a safe, economical and passenger-satisfactory flight. The flight crew can share their experiences and opinions about what was needed in achieving their safety performance. This research shows the useability of additional data sources that the organisation can use for an effective feedback loop in ultra-safe social-technical systems.

This research is also relevant since it operationalises the concepts of Safety-II and Resilience (Hollnagel, 2013b)(Hollnagel, 2014b) in flight operations in a way that others can easily adopt. These concepts are relatively new, and airlines are searching for methods to adopt these concepts. The methods used in this research can easily be adapted to the local airline situation, and it does not require significant financial investments. Furthermore, an airline can safely test this method while maintaining their current practices, since a failure of the testing does not affect their current practices. A failure would only provide learning opportunities.

This research takes safety out of the silo because it views safety in the context of the economy of flight and service delivery to the customer. This research develops a reporting and sharing method that takes a more holistic approach to flight execution disturbances. The number of learning opportunities increases considerably compared to current practices when the experiences of all disturbances that challenged the flight crew are reported and shared. Recognising safety as a business aspect, as done in my other research project, the Airline Value Production Management model (AVPMM), would benefit from a compatible reporting system. The developed reporting system in this research does not require the use of the AVPMM, but both add value to each other.

Some extensive research projects are funded and managed by EASA in Europe and the FAA in the USA. They aim for these projects mainly at the aviation system or the high-level sub-systems such as Air Navigation Service Providers, Air Traffic Control, and Airlines. This system-level learning from research is generic for an airline company. The research results from this kind of international research might not be relevant for a specific airline. This research project, however, focuses on learning within the specific airline that employs it. Several groups of employees can learn their specific lessons from this new high-variety feedback channel within the airline, including pilots' expertise.

These arguments support the claim that this project fulfils both societal and scientific relevance. The following sections will address the generic and specific solution designs.

6.4 Literature review

The literature can be found in Chapter 3.

6.5 Generic solution

A DSR research aims to arrive at a specific solution for a field problem. The first step is to develop a generic solution that serves as the basis for a specific solution. In the paragraph, I describe the development of a generic solution for the problematic situations I described above. A generic solution composes different requirements that each is necessary and can only jointly be expected to deliver a desired result.

A generic solution should comply with design requirements. The solution's preconditions are often non-negotiable since they involve legal and ethical aspects. The other requirements are less strict and often have multiple potential solutions.

The underpinning of the functional requirements is the theory that I operationalise for practical solutions. The field testing of these theoretical concepts generates learning opportunities for practitioners and scientists.

6.5.1 Introduction

I have used a cybernetic perspective and constructivist epistemology to describe the problematic situation. Using the perspective of purposeful systems, we can describe the type of problem we are trying to solve as a management problem (Beer, 1966). Management is meant here as regulation and not as a group of people with the role of manager. However, the manager's role is typically part of the regulatory function of a regulated system.

To improve the requisite variety of the flight operations management system, the operational feedback of pilots' expertise is critical. The red arrow in the adjacent diagram shows the critical feedback channel.

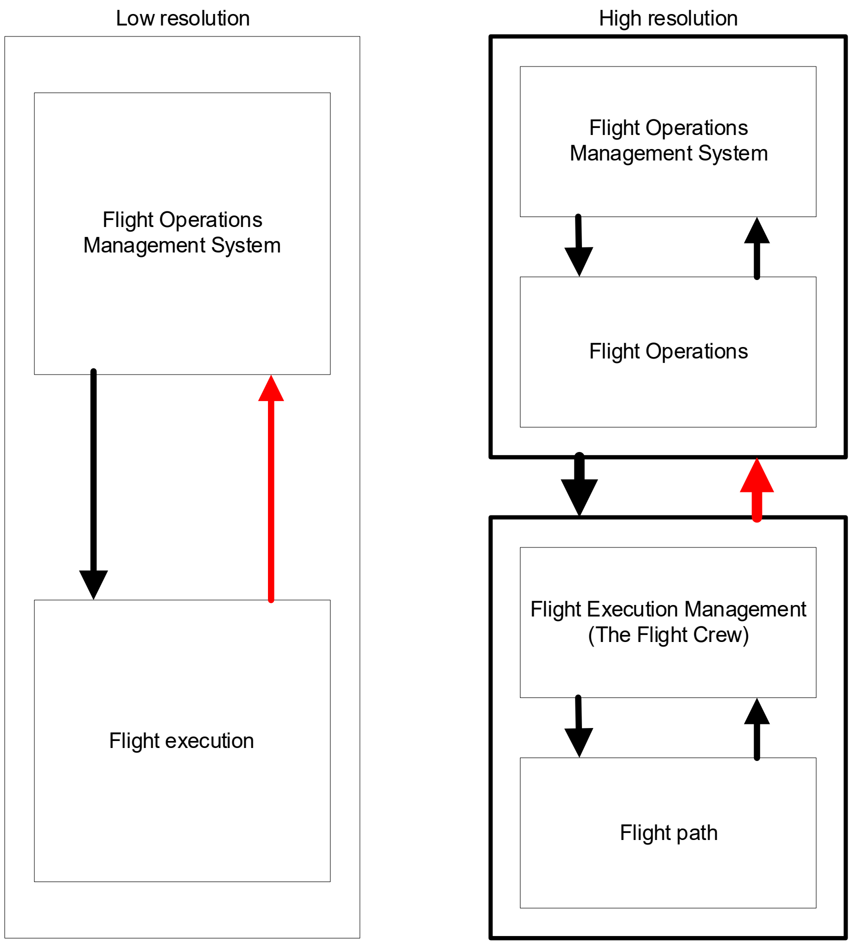


Figure 6-2 Hierarchy of Flight Operations management

Both the low-resolution and high-resolution diagrams show managed systems. Each operational unit constitutes an operation and a management function. In popular language, a doing and a thinking function. One without the other is useless (Beer, 1972). Thinking without doing does not affect the state of affairs, and doing without thinking does not lead to desired results. I describe these concepts in more detail in the theory Chapter 8. A feedback channel from operations to the management function is an essential requirement for every operational unit.

We are discussing managed systems, where the flight crew enacts the management function. The airline has to deliver safe, economical and customer-centric results in a dynamic environment requiring planning and adaptations. Short-term adaptations, during a flight, can be executed by the flight crew, while long-term dynamics require flight operations management to adapt flight operations. This is a simplified diagram leaving out several interactions, such as interactions with the environment. For this specific paragraph, it is unnecessary to show a complete requisite control system.

6.5.2 Problem definition

The problem can be described as: The generic solution for solving the problem of underutilisation of learning opportunities from operational flight events requires rich data on the events. The flight operations management system should receive rich data about the operational events that challenged a safe, economical and passenger-friendly flight. The managers of an operation are the people directly experiencing the disturbances in their operation. They have to manage the critical parameters. Their experiences, judgements, opinions, strategies and lessons learned should be fed back to the higher management layers and peers. From this perspective, flight crew as managers and flight operations managers share a similar position. Each has higher levels of management above itself which shapes their work conditions.

The generic solution is a feedback channel that captures this experience and opinion data, then transmits this data and delivers the data in a format that supports learning through sharing.

6.5.3 Design requirements

The generic design should comply with some specific requirements (van Aken & Andriessen, 2011). These requirements are compiled by the researcher, the domain experts, and the organisational managers. Furthermore, the generic solution should be adaptable to a specific context, allow an intervention in an organisation, create action, and be assessable.

6.5.3.1 Preconditions

The generic design solution should not conflict with regulations applicable to the domain of application. It should also agree with the ethical standards for research. Furthermore, it should not conflict with social agreements within the organisation and legal agreements between stakeholders such as labour unions.

6.5.3.2 Functional requirements

Using a cybernetic perspective on the problem to be addressed, I describe the problem in terms of a feedback system, an essential component of a management system. The feedback system should be requisite (Ashby, 1956) or at least as requisite as possible, given the regulatory constraints. The collected data should be as rich as possible to support learning from events, and the data should be shared with as many people as possible who are involved in flight operations. Finally, the data should be easily understood and actionable by the readers of the data. These functional requirements are described by Beer (Beer, 1979) and expanded upon by (Türke, 2008) as:

- **Channel capacity**; is the ability to convey, in due time, relevant distinctions to actors to allow them to recognise the system state and possible changes. In other words, the variety the channel can handle. In popular language, but under-specified, the channel must have sufficient bandwidth capacity.
- **Transduction capacity**; is the capability of encoding and decoding information when it changes mediums. Requisite variety should not be lost, e.g., when a message is translated into another language or is changed from spoken to written. The Chinese whisper game where one person receives and sends a short

message to the next person, and at the end, the message differs greatly from the initial message illustrates the transduction problem.

- **Change / Transformation capacity**; is the capability to introduce new distinctions and potential choices for the actors engaged in the interaction. In other words, the information must create insights and support the generation of changes. This means the properties of the information receiver, such as their background, should be considered to prevent the loss of variety.

The red box in the diagram below shows the three requirements. This is a model of a basic operational unit (Beer, 1979). It shows the interactions between the environment, operations and management. Clemson in (Clemson, 1991) added the notion of mental models to illustrate the required knowledge for the management function to understand and act in a requisite manner. Beer (Beer, 1979) uses this model to state his 'First Principle of Organization'. This principle describes how managerial, operational and environmental varieties, diffusing through an institutional system, tend to equate. The variety exchanges should be designed to equate with minimal damage to people and cost. For this thesis, this can be rephrased as minimal damage to Safety, Economical and Customer experience.

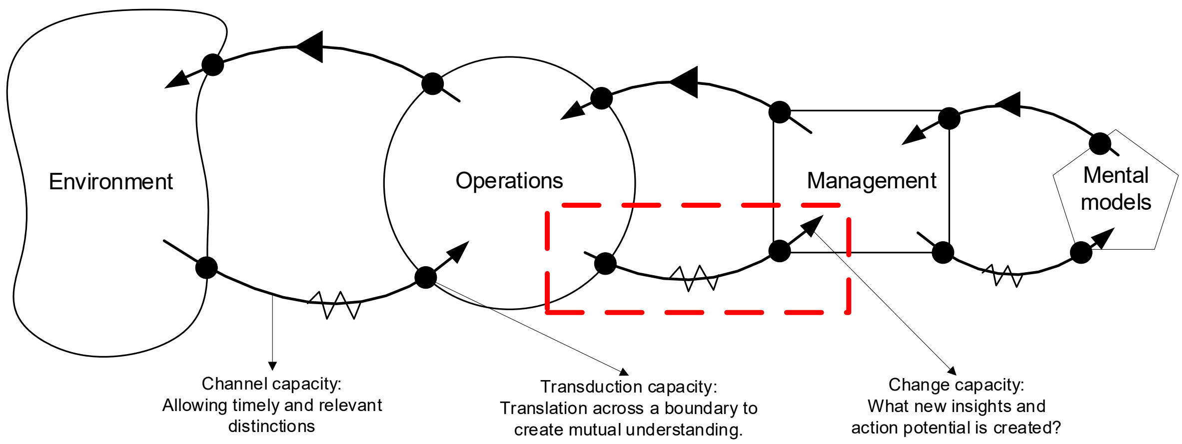


Figure 6-3 Generic Basic Operational Unit adapted from (Beer, 1979) and (Clemson, 1991)

The environment has a higher variety than the operations, which has a higher variety than the management function. For a requisite management system, variety has to be attenuated and amplified. Beer argues the need for variety attenuation for the variety flowing from the environment to operations and the variety flowing from operations to management (beer, 1972). Without variety attenuation, the operations and the management function would swamp in variety, unable to remain in control. Variety from management towards operations and from operations towards the environment must be amplified to ultimately balance the varieties to achieve the requisite variety.

An additional functional requirement based on cybernetics is that the tool should maintain a sufficient variety of the pilots' data. Sufficient here means that each report should be informative and not just a database entry to be used in counts and statistics. Informative as a requirement depends on the reader of the data. Most readers of the data are expected to have sufficient background knowledge of flight execution and aircraft procedures.

The signal-to-noise ratio (S/N) is a measure of the strength of a signal in relation to the amount of background noise. It is closely related to the law of requisite variety (Ashby, 1956). A high signal-to-noise ratio indicates that the desired signal is stronger than the background noise, making it easier for the system to distinguish and respond to the intended input. A low signal-to-noise ratio, on the other hand, means that the background noise is stronger than the desired signal, making it more difficult for the system to accurately respond.

To adapt to its environment, a feedback system must have a high S/N so that it can effectively filter out unwanted or irrelevant inputs and respond to a wide range of inputs (Ashby, 1968). This is consistent with the law of requisite variety, as the more variety of responses a system has, the more adaptable it is.

This concept is important in fields such as telecommunications, signal processing and control systems where the ability to distinguish a signal from noise is crucial for the system's functionality.

The airline management that I consulted, informed and who agreed with this project did not require other functional requirements beyond my proposal, except for one aspect. They desired this project would learn lessons for the development of Air Safety Report 2.0. However, they did not further specify what kind of lessons other than what kind of questions gave interesting data and which did not.

Furthermore, to support proactive safety management and an understanding of how the operational systems work, patterns of behaviour across events rather than causes for individual cases should be evaluated (Hollnagel, 2014b). The tool should be able to provide data for pattern analysis.

Along similar lines Woods (Johannesen et al., 2012) proposes new forms of feedback to support the organisational complexity absorption capacity. He suggests increasing complexity can be balanced by improving feedback. The feedback should contain event-based, context-sensitive and related data elements to capture relationships and patterns.

6.5.3.2.1 Model-based

The tool should capture essential aspects of human performance and safety management data, which were unavailable otherwise. The tool should complement the ASR report data and capture the pilot’s experiences. The tool should also be usable, independent of the ASR.

I determined that the questions in the tool for the flight crew should be model and theory-based. The models should be derived from safety science concepts and allow the flight crew to share their experiences, sensemaking, decision-making, trade-offs, goal conflicts, lessons learned, advice, and opinions.

The data should allow an understanding of how the flight crew achieved flight operational resilience and what strategies the crew used to maintain control over the safety economy and passenger experience. In addition, an extract of this data should be as much as possible (considering regulation and privacy issues) shareable with the colleague flight crew and other airline employees and managers to support as many learning opportunities as possible from single events.

6.5.3.3 User requirements

The aim was a user-friendly tool that requires minimal effort from the flight crew and delivers maximum data. This is a critical balance because the flight crew judges the benefits of using the tool against the required efforts.

The tool should:

- Be readily available for the flight crew to allow them to use it whenever they had the desire.
- Be easy to install and use and as much as possible self-explanatory.
- Capable of partial data entry so the flight crew could continue at any later moment.
- Require a minimal number of data fields to be entered. The tool should not force the flight crew to answer all questions in the tool.
- Require the flight crew to enter only the data that could not otherwise be collected. A minimal number of data items are required to be able to identify the flight in other databases. Other flight-specific data can then be collected in these databases, such as flight times and flight plan data.
- Explain to the flight crew the benefits of using the tool and inspire them to be as complete as possible.

6.5.3.4 Operational requirements

The operational requirements are concerned with the technical features of the tool solution. Several stakeholders had their requirements.

- The managers of the Flight Operations department required that the tool should not interfere with the routine work of the flight crew.
- The managers of the safety department required that the tool should not interfere with the ASR procedures.
- The agreement with the flight crew labour union required data privacy, data protection and user protection like the agreements made between the airline and the union concerning the ASR.

- The airlines' IT and data standards required compliance with personal data and employee data standards such as the European Data Protection Regulation (GDPR).

Because I anticipated feedback on the tool design and operation, it should be possible to update the tool without user interference automatically.

Since the tool should be usable during flight, conditions permitting, it should be operable without an internet connection.

The tool is a company-specific test application and should not be available to others outside the company. Although the content is not in conflict with any regulation, no one outside the company is needed for the experiment; thus, as a principle, it is best to restrict access to the tool to only company employees.

6.5.3.5 Design limitations

I choose to be independent of the IT department of the airline. This allowed me to stay in control and responsible for the development of the tool. My software development capabilities determined some of the design limitations. Airline managers did not specify any design limitations.

6.5.4 Design results

The design should create learning opportunities for both practices in the organisation and science knowledge development.

Users will be confronted with questions about topics that they recognise, but the structured approach of the topics will be new. The explanation of each section of the tool will show the user an operationalisation of a safety model or theory. This feature of the tool might provide the user with implicit learning about safety theory.

The sharing of the collected data should support the flight crew to improve the management of their flights and should support managers to support the flight crew in managing their flights.

6.5.5 Design statement

Using the Context, Intervention, Mechanism and Outcome (CIMO) logic as proposed in DSR (van Aken & Andriessen, 2011) I compose the following design statements:

For a generic operational context: The learning from operational events can be improved by providing means to the operator to share their stories, opinions and lessons, which can be shared with other employees and organisational departments to learn from these operational events.

For a commercial aviation context: The learning from operational flight events can be improved by providing means to the flight crew to share their stories, opinions and lessons, which can be shared with other flight crew and airline organisational departments (flight operations management, flight crew training safety department) to learn from these operational flight events.

6.6 FlightStory as a specific solution

A specific solution to the field problem is based on choices made in the solution space of the generic solution. Choices are concerned with concepts, types of operationalisation and implementations. These choices have to result in a specific solution that could be built, tested and evaluated. In the following paragraphs, I will explain and argue about my choices for my specific solution.

I will describe the development of FlightStory in this section. FlightStory is a means for the flight crew to share their operational experience and lessons learned and to provide their judgement of the operational performance conditions quality as experienced during the event.

6.6.1 Introduction

In principle, many specific solutions are possible that adhere to the requirements of the generic solution. The preconditions, user and operational requirements do not provide specific criteria for the design decisions and do not reduce the solution space very much. The functional requirements, together with my choice of a cybernetics and constructivist perspective, reduce the solution space considerably. In the literature review and problem knowledge gaps sections of the thesis, I have described the void of other research concerning safety management from this cybernetics and constructivist perspective. The design and evaluation of this specific solution have, therefore, scientific relevance.

The functional requirements implementation for the specific solution requires primarily scientific arguments. The other requirements can be adhered to after the choices for the functional requirements have been made. That is why I start with the functional requirements as used for the FlightStory development.

6.6.2 Functional requirements implementation

The diagram below shows a part of the basic functional operational unit (Beer, 1979). The full model is shown above. It shows how an operation influences and is influenced by an environment. The same applies to the interactions between operations and management. This model can be applied at any level of analysis deemed useful. E.g. inside a flight, where flight crew work under the captain's authority, or flight execution, where flights are conducted under the management of the flight operations department, or both the ground and flight operations reporting to the airline's operations management team.

We can view a flight crew who submits a FlightStory, as indicated in the red box in the diagram below, as providing feedback from operations to management.

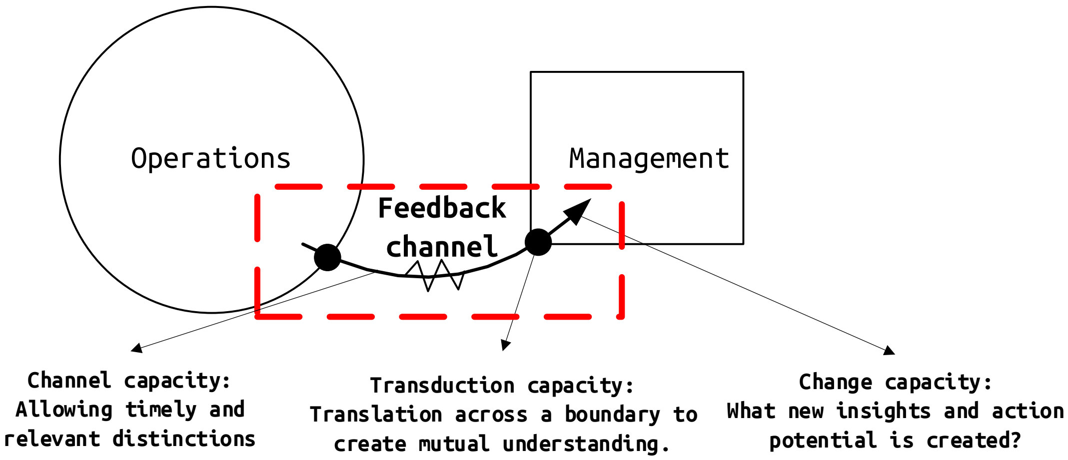


Figure 6-4 Feedback channel capacities

The FlightStory app needs to fulfil all the requirements of the three capacities. I will discuss the operationalisation for each requirement.

Channel capacity is described as the ability to convey, in due time, relevant distinctions to actors to allow them to recognise the system state and possible changes (Türke, 2008)). The time aspect is related to the dynamics of the system under consideration. Here, the system in focus is the flight operations management system and not only an individual flight since FlightStory is aimed at organisational learning of individual flight events. The dynamics of the changes are determined by the rate of change introduced by flight operations management. Changes introduced by flight operations management are driven by compliance, adaptations to changes in the environment, and system optimisation. The effects of the changes as experienced by the flight crew are fed back with FlightStory. Since every flight crew on every flight can submit a FlightStory, one requirement for timeliness is fulfilled. The other requirements are timely FlightStory review, sharing and analysis. In principle, the time from data submission to data availability to flight operations managers can be daily, depending on the availability of the safety analyst to execute the data collection process as agreed with the union. The flight crew can receive the stories and lessons learned, collected in a FlightStoryBook every week during an automatic update of their company iPad. The FlightStory solution is adequate in terms of timeliness. For urgent safety issues, the standard ASR and incident reporting processes are available. There is currently no intention to replace this process with FlightStory but in the future, a kind of ASR2.0 will include effective parts of FlightStory.

Another timely related notion is that of some minimal frequency of reporting. If the flight crew only report extreme events, the reporting frequency would be very low. The frequency of occurrence of extreme events is too low to generate sufficient feedback reports for an effective management system. The flight crew are requested to submit a FlightStory when their expertise is needed to handle an operational situation. Safety-related events and any event that challenged the safety, economy, or passenger experience essential variables can provide lessons. Based on my experience as a flight crew member, I estimate 1 FlightStory per 25 flights. For the airline organisation, that would add up to between 3000 and 10000 stories per year.

The willingness to report is another critical factor. The airline should nurture a reporting culture (Reason, 1997)(ICAO, 2018a). FlightStory differs from other reports since it explicitly requests the expertise of the flight crew and their views. This aspect of FlightStory might inspire the flight crew to submit FlightStories.

The requirement for relevant distinctions is fulfilled by the topics and issues addressed in the FlightStory app. Relevance must be evaluated in relation to the effective and efficient management of flight operations to support safety, economic, and passenger-centric flight execution.

Relevant distinctions or relevant data is that what will inform the flight operation management and safety management system. Relevant data will fit the models in use in the management systems. This is illustrated in the model of the Generic Basic Operational Unit. As noted in the description of the problematic situation, the people operating the management system should be educated to recognise that safety and human performance models are important. These models should be made explicit, discussed, and updated. The FlightStory is designed to match some recent relevant safety science models. This will be made explicit in the section where I explain the form details.

Each section of FlightStory data will be discussed to argue the claim that most, if not all, relevant distinctions are covered. Screenshots of all FlightStory pages are presented in the appendix.

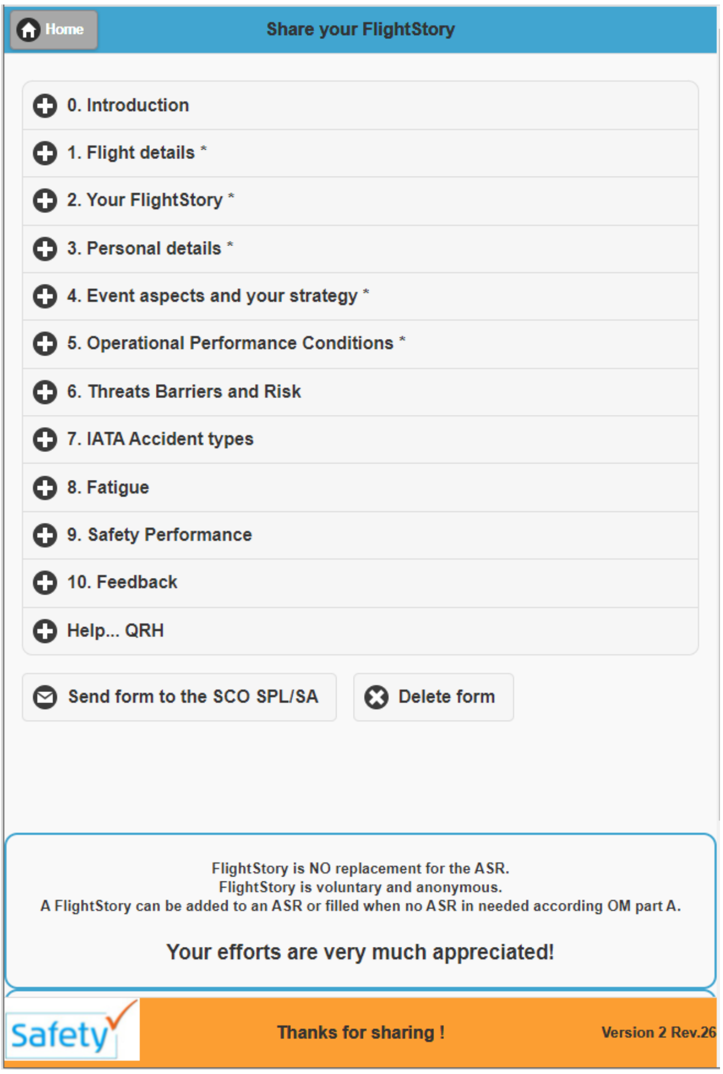


Figure 6-5 Main screen of FlightStory as shown on company iPad

Section 0. Provides an explanation of the tool and guidance for usage.

Section 1 provides entry fields for the flight number, date of departure, departure and arrival airport and aircraft type. This data enables a unique identification of the specific flight required for data linking in the organisational data warehouse.

Section 2 provides input fields for the story itself as told by the flight crew to other flight crew, title and keywords.

Section 3 provides non-privacy-related input fields about the flight crew submitting the FlightStory. This data provides insight into the perspective of the storyteller.

Section 4 provides entry fields to collect event aspects and the employed strategies to handle the event. This section is based on Safety-II, Resilience and Viable System Model concepts.

Section 5 provides the flight crew with a way to evaluate and assess the quality and adequacy of the performance conditions relevant for the management of the event. I derived these Operational Performance Conditions from Human Performance models.

Section 6 provides generic bowtie model data fields. The safety department can use this data to verify for completeness the flight operations bowties.

Section 7 provides the flight crew with a selection of possible worst credible accident scenarios from the event. These answers can be used to relate the stories to the flight operations bowtie models.

Section 8 provides the flight crew with a set of questions, similar to the fatigue reporting form. Fatigue is an important human performance topic. Through this compatibility, FlightStory can add to the fatigue risk management system.

Section 9 provides the flight crew and expert judgement on safety performance. This performance measure is based on Viable System Model performance concepts.

Section 10 provides the flight crew with the fields to express their view on the FlightStory project

Section Help QRH provide help and tips when the user experiences problems with the app.

The send form button triggers the app to encrypt the data and compose an email. The encrypted data is put in the body of a mail. The user only has to press Send from the email app.

The notes section is based on operational requirements composed by the union, and the safety department is clearly placed on the main screen.

Version info. As a developer, I can check the version of software maintenance and updates.

A complete design description can be found in the following paragraph after I have discussed all design requirements.

6.6.3 User requirements implementation

The following implementation decisions were based on the user requirements mentioned above.

- The only viable solution is a software solution since a paper form needs too many additional arrangements, such as making it available in the cockpit, and routing the completed form to the safety department while keeping the content hidden. Furthermore, a paper form as a solution would also conflict with other requirements.
- The flight crew carries a personal electronic device supplied by the company. This iPad contains all required airline, aircraft and navigation documentation. The company has a paperless cockpit policy, and the iPad is their implementation of this

policy. FlightStory as an app on the iPad also provides the user with the ease of keeping the app up to date. The specific software implementation as a web app means the app can be automatically updated when needed.

- The user requirement for ease of use includes that the flight crew should not be required to enter data that the back office can collect via other means. The back offices can complement the FlightStory data to increase the richness of the data and to allow to make more relevant distinctions. Without data enrichment, the information content of FlightStory itself can be better evaluated. This approach would also keep the FlightStory project independent of other data streams in the SMS. Therefore, we evaluated FlightStory without adding extra data from other sources.
- For a valid story from a data collection perspective, the user has to answer a minimal number of answers for a useful FlightStory. The app warns the user when required data is missing. Only items in sections 2 and 3 are required to submit a minimal FlightStory.
- The tool has an introduction section inviting the flight crew to contribute their experiences and opinions. I explain how the flight crew has unique data for the organisation from which many stakeholders can learn. Promotional texts are also part of the FlightStoryBook that the flight crew automatically receive on their iPad as part of their professional operational support documents.

During the app development, I shared initial versions with colleagues during flight and in the safety department. Their comments were used to fine-tune the design.

6.6.4 Operational requirements implementation

The following implementation decisions were based on the operational requirements mentioned above.

- I took several actions to incorporate the operational requirements. In the publication's introduction, I emphasised that a contribution to FlightStory was voluntary. Also, on the app's main screen, a highly visible note shows that FlightStory is voluntary and anonymous. The note also contains the information that FlightStory does not replace the ASR. The stakeholders agreed with these texts.
- The chosen software solution allowed me to control user access fully. This was implemented by using the company email address as a requirement to receive a token to access the FlightStory web form. When entering the website, the user has to request a token to proceed. The user was warned when (s)he did not use an iPad and the Safari browser. This token could only be sent to a company email address. By entering the token, the users accessed the FlightStory web form. The software would then prompt the user to save the app to their iPads home screen, since this feature is only available on the IOS Safari browser. Each step in the installation had an explanation to guide the user.

- Both the union and representatives of the employees agreed to maximise data security of the form data. The FlightStory website, where the user gets the form, does not collect any data. Furthermore, the iPad has its own security, which has also been accepted for other company documents. This means that an incomplete FlightStory on the iPad is sufficiently secure. When the flight crew submits a FlightStory to the safety department, it is secured. It has a two-step AES encryption with a random and public key to encrypt the data before it is placed in the body of a mail. If the mail were sent to another email address, the data would be encrypted and thus unreadable.
- According to the standards of the ASR, the FlightStory data is handled in the safety department, as agreed with the pilot union. All shared data is de-identified. A privacy assessment was made with support from the company's privacy office, which resulted in a compliant process according to GDPR.

6.6.5 Design limitations implementation

A Progressive Web Application (PWA) using HTML, CSS and JavaScript is a suitable software development framework for software applications that run on an iPad and appear as a native IOS app. This solution allowed me to provide the web-App to the flight crew without using the Apple AppStore. Furthermore, by using Service Workers, a browser software technology, the app would also operate without an internet connection. Since I would build the tool myself and have no experience with native IOS programming, the web-App was the only choice. I built a website where the flight crew could load anonymously the app on their iPad after a security verification.

To provide a familiar user experience to the flight crew, I used the very popular user interface JavaScript libraries jQuery and jQuery Mobile. These tools allowed me to design an interface with a form layout that was self-explanatory.

6.6.6 FlightStory design as a specific solution

In this section, I will give a complete description and argumentation for the FlightStory design implementation.

Sensemaking and storytelling inspire the development of FlightStory. This field of research can be traced back to the 1970s (Dervin, 1998). Weick in (Weick et al., 2005) developed applied sensemaking concepts to understand how organisations develop and maintain high reliability in complex environments. Kurtz and Snowden in (Kurtz & Snowden, 2003) included complexity theory concepts explicitly to their sensemaking approach. Complexity theory assumes that it is not a priori possible to know all the issues and relations in a complex system. Also, no claim can be made to pose the only correct view of a complex system. Sometimes in organisations, managers use power to push their view of the system forward as the most relevant view. However, according to complexity science, the manager's view is just another view. Since we cannot know a priori in a complex system all essential aspects, issues, notions or concepts, I use many open questions. E.g., the story keywords are in free format, and I use no taxonomy because the taxonomy is reducing variety and is never complete. In the data analysis, methods such as semantic distance can be used for group keywords.

The form also contains factual data questions such as departure airport and date. These questions have the simplest format for user convenience.

When questions are model-driven, they may be closed questions, category selection questions, or scale types of questions. The intention is that the safety management and human performance models, as mentioned above, are instantiated with data provided by the flight crew.

There are many types of questions and formats of answers, e.g., free text, category selection, slider, radio button, and multiple options. The selection of question-and-answer type in the form determines what data is collected. The collected data shapes the information it can provide to the readers. Therefore, the choice of question-and-answer type must be executed considering the distinctions it can provide in the analysis.

I will show the FlightStory question form section by section. Obvious and self-explanatory data fields will not be discussed.

6.6.6.1 Section 0, Introduction.

This section explains the purpose of FlightStory and provides guidelines for filling out the form.

At the bottom of each page is the next button to step to the next question page for user convenience.

0. Introduction

Dear Colleague,

FlightStory does not replace the ASR. An ASR remains required as per OM part A.

To further improve our flight operations we need your feedback. The KLM ISMS is largely dependent on your reports. In the actual flight execution you experience the consequences of decisions made by KLM departments under all sort of conditions. Your feedback can help us all to learn.

Pilots as Intelligent Feedback Providers

FlightStory is a way to share your story about an interesting operational event. A kind of 'Share Your Experience' app. You can tell your story also in cases where you don't think an ASR is applicable. Every year the KLM safety department SCO (SPL/SA) receives many ASR's. Most of which describe the event in a plain and factual manner. But we also want to hear about your experiences and opinions about the operational conditions and how you handled events. The intention is that we can learn from each other's experiences. We hope to get a better insight in how flight disturbances are handled. At the same time we expect to get a better understanding about which aspects of the operation can be improved.
Many parties will benefit from your story: your colleagues, flight operations management, training, ground operations, dispatch and safety management.
The story form will be sent to a secure KLM site under control of the safety department SCO (SPL/SA). The form does not store any personal details from you other that what you enter in the form. The story will be reviewed and if needed cleaned from personal details or inappropriate language before making the story available for sharing.

We are working on a story sharing method so you'll have always access, also during your flight, to relevant stories for your own flight's Threat and Error Management. The more you share the more you will receive. Your contributions are welcome and your efforts are very much appreciated!
The first time you fill out a FlightStory form will probably take you around 25 minutes. However, once you get familiar with the way the form is set up and the questions that are asked, it will take up less of your time. In addition the form may act as a helpful tool in debriefing the event within the crew.
Sometimes the app can be a little slow to refresh a screen or respond to a button. Sometimes you have to wait a few seconds to get the desired response from the app. Small automatic updates of the app may be distributed and you'll be informed by the app when this occurs.

Guidelines:

When you fill out an ASR and FlightStory, you can tell your story and then copy paste into the ASR. Please tell your story in a way in which your colleagues can learn from it. There is no need to write your story in the ASR and in FlightStory. If you fill out both you can copy paste your story from the ASR to the FlightStory form and add details to the story to make it more informative.
Fill out the form in the sequence of the question numbers. Please use appropriate language and do not enter privacy sensitive data.
You can send the story after question 5 however you can also postpone sending the form until you have time to answer all the questions. All your entered data will automatically be saved until your send or clear the form. Your feedback is very much appreciated !

This project is planned to last about half a year. Your cooperation is voluntary and appreciated. If this method of evaluating events turns out to be successful a next version of this app will be developed. At the end of the form you can provide feedback about this app.

When you encounter problems please contact arthur.dijkstra@klm.com.

Thank you for sharing your experience and providing a learning opportunity.

Next

FlightStory is a pilot project by the SCO SPL/SA for KLM Flight Operations. (Version 2 Rev.19)

Figure 6-6 FlightStory app Introduction screen

6.6.6.2 Section 1. Flight details

The page contains factual questions required to allow linkage of the specific flight to other data sources. In this linking, the privacy regulations and union agreements should always be adhered to.

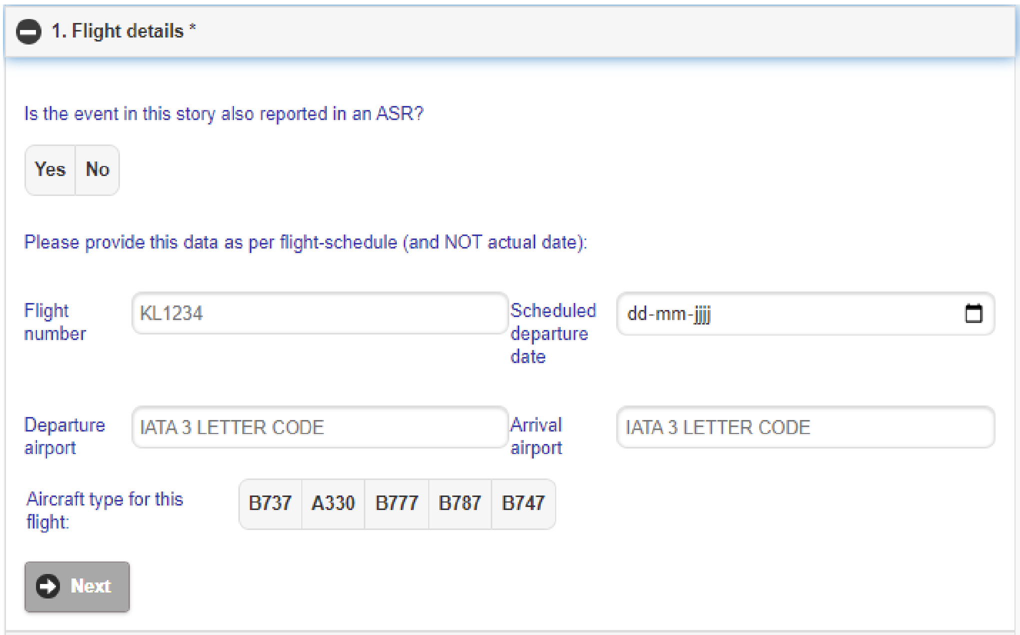
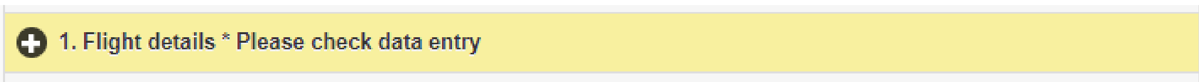


Figure 6-7 FlightStory app Flight details screen

The actual date might differ from the scheduled date because of delays. For data linking, the scheduled departure date is more convenient.

The section header will be coloured yellow if the section is closed and not all required data is submitted.



6.6.6.3 Section 2. Your FlightStory

This is the main page for collecting the experience of the flight crew. I phrased the main question in a specific manner (Snowden, 2002). The storyteller needs to know how much is known by the receiver of the story to judge the level of detail that should be included in the story. The question states that the storyteller describes his story to a colleague. This means the story receiver is well informed of the operational standard, norms, procedures, habits and culture and that these need not be explained in the story. The storyteller is triggered to include some topics in the story. These triggers are based on generic management principles about recognising a threat or deviation and deciding on what and how to respond. How this sensemaking and decision process evolves allows the reader to understand the local rationality. Establishing local rationality is critical in understanding events and accidents (Dekker, 2014b). A better understanding of how flight crew make sense is important for training, data presentation and operational support design.

The trigger for the flight crew to describe how he could create success invites him to think about the strategy the crew used to cope with the disturbances. This is a type of Safety-II approach to collect, analyse, understand and share successful strategies.

Generally, in a Safety-I and traditional ASR approach, no interest is given to how the flight crew achieved success.

The question for a descriptive title for the story follows the story. A title is more descriptive after the story has been written because the writer has reflected on the event than before the story has been written (Snowden, 2002). In my experience as a safety analyst in the safety office, many ASR titles were very short, often just one or two words. Such short titles do not allow to make useful distinctions between nearly similar titles and require the analyst to read the story to get a richer picture of the event.

In addition, the flight crew can provide up to four free text keywords. No taxonomy is used to capture a maximum variety of keywords.

Then two questions are posed which require reflecting on the event. This reflection is essential for learning and is often part of the non-obligatory flight debriefing after the event. In addition, sharing this lesson is relevant for the colleague flight crew since they might draw a similar lesson.

The proposed organisation's lesson from this event is unique data from an insider who was at the event and even responsible for handling the event. Such advice should be taken very seriously and would otherwise not be available.

The language used in the answers on this page is the same as used by other flight crew and Flight Operations managers.

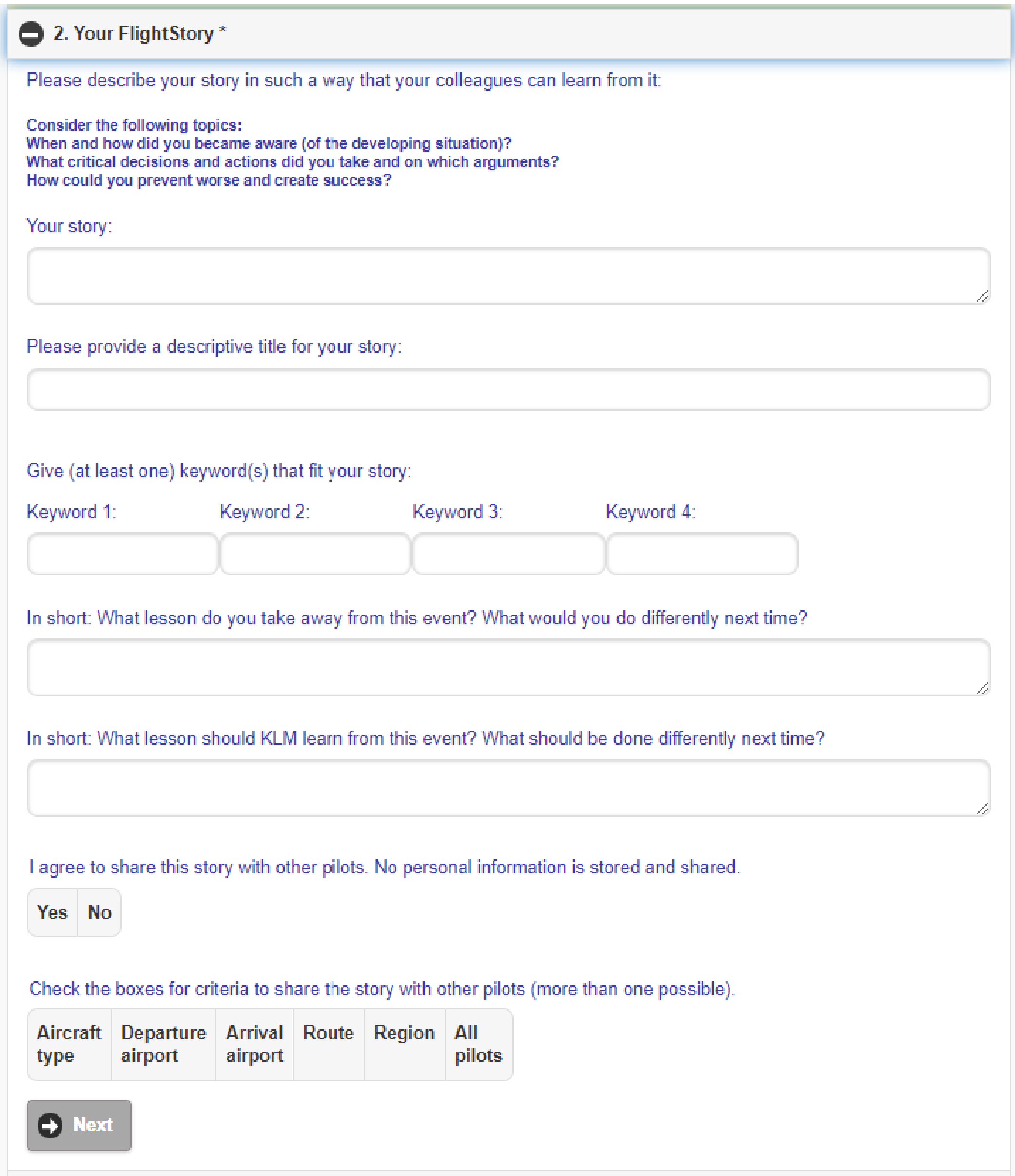


Figure 6-8 FlightStory app Story prompting question

The answer to the last questions can help to filter stories for their relevance to particular situations. E.g. during a flight to New York, the North Atlantic (region), the route and Airport related stories are most relevant and can be filtered with this data.

The user will get a warning when some of the required data is missing.

6.6.6.4 Section 3. Personal details

The answers to these questions provide data on some characteristics of the FlightStory writer. The first answer is crucial because it provides insight into the roles and mindset of the crew. The function and experience answers allow the analysis of the story data based on these differences. Flight crew instructors have shown interest in searching for differences in event handling between low and high-experienced flight crew.

The questions about feeling remembrance of the vent will reveal some emotional data (Snowden, 2002). Events with a high emotional impact must be selectable in the analysis tool because they could show a serious risky event.

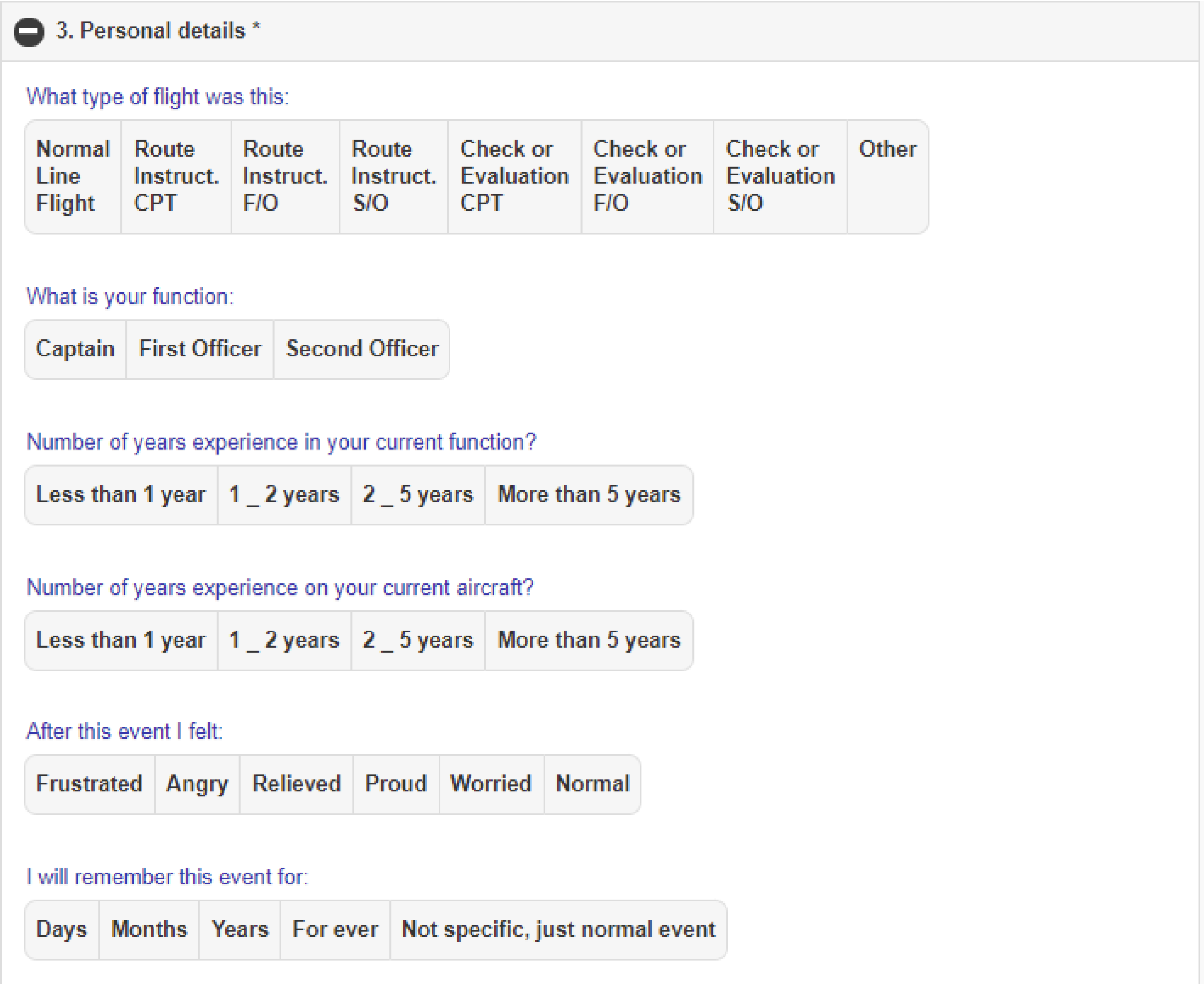


Figure 6-9 FlightStory app Personal details screen

The sub-section is related to variant flying. Many flight crew on the Boeing 777 and Boeing 787 fly both types mixed. As part of the risk mitigation of variant flying, these answers are relevant.

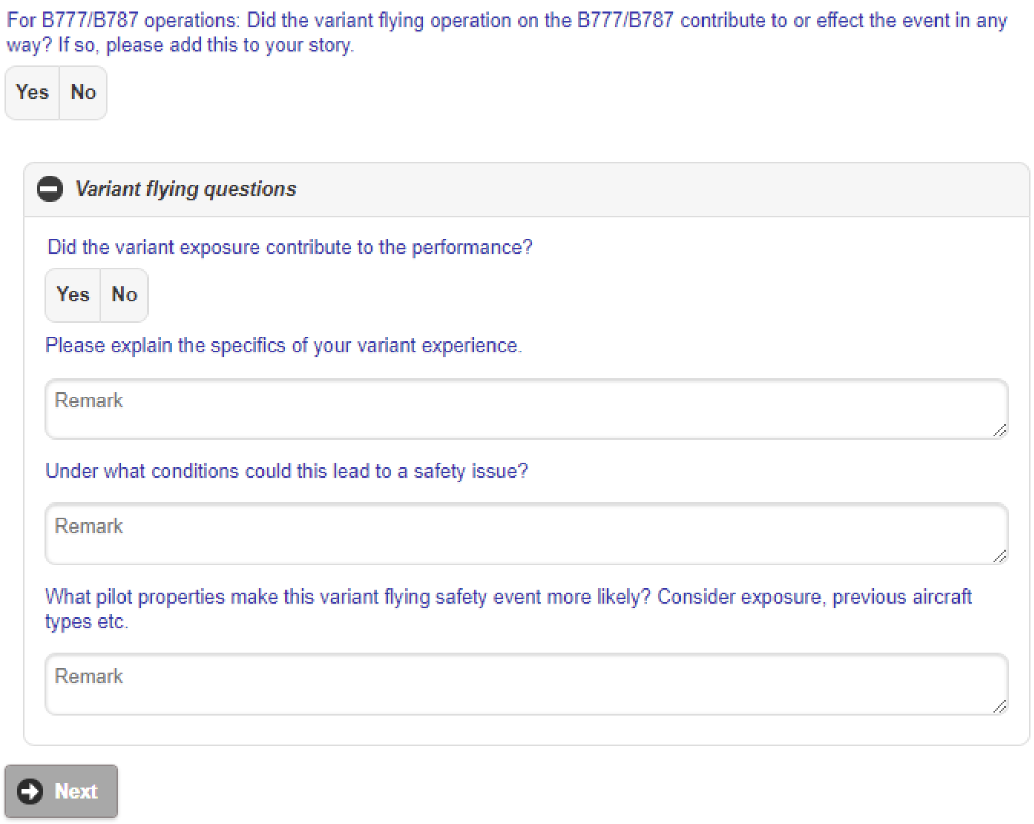
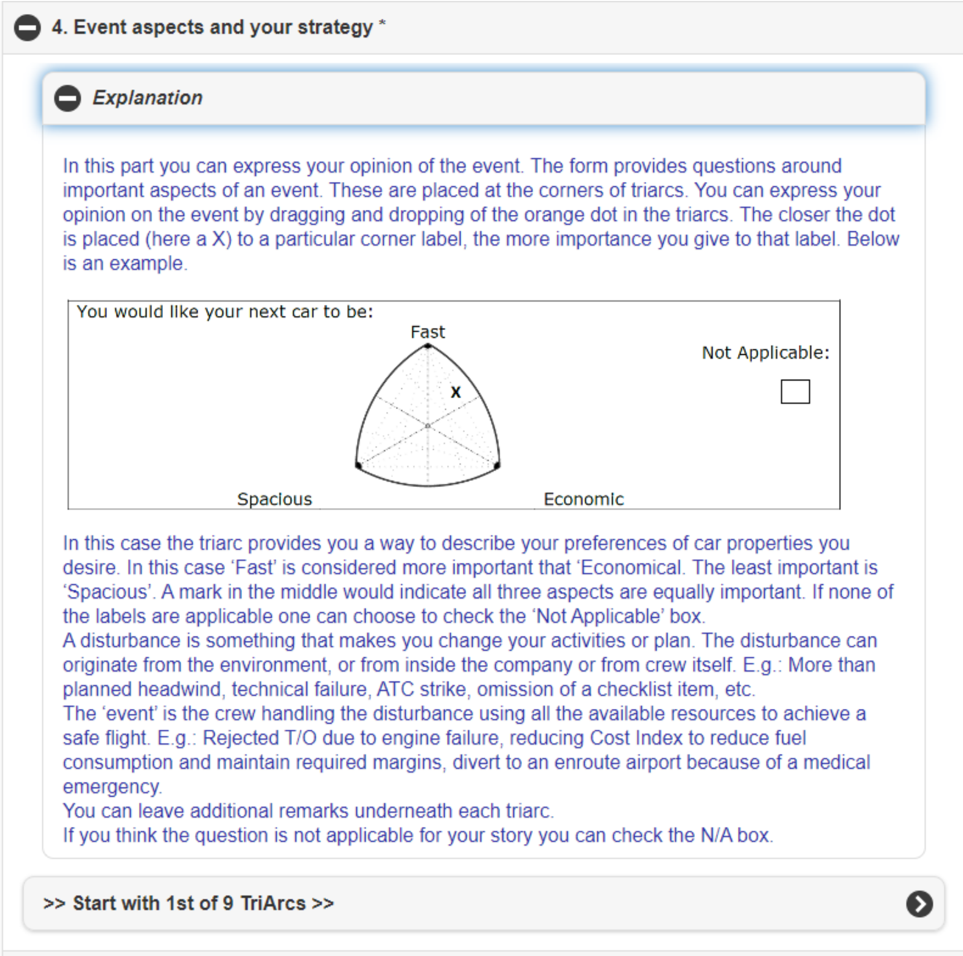


Figure 6-10 FlightStory app Variant Flying questions screen

6.6.6.5 Section 4. Event aspects and your strategy

This section is maybe the most innovative. I based the questions on resilience, Safety-II and viable system theory. Each question will be discussed.

I wrote an explanation for the user to describe the principle of this specific type of question and how to answer it.


4. Event aspects and your strategy *

Explanation

In this part you can express your opinion of the event. The form provides questions around important aspects of an event. These are placed at the corners of triarcs. You can express your opinion on the event by dragging and dropping of the orange dot in the triarcs. The closer the dot is placed (here a X) to a particular corner label, the more importance you give to that label. Below is an example.

In this case the triarc provides you a way to describe your preferences of car properties you desire. In this case 'Fast' is considered more important that 'Economical. The least important is 'Spacious'. A mark in the middle would indicate all three aspects are equally important. If none of the labels are applicable one can choose to check the 'Not Applicable' box.
A disturbance is something that makes you change your activities or plan. The disturbance can originate from the environment, or from inside the company or from crew itself. E.g.: More than planned headwind, technical failure, ATC strike, omission of a checklist item, etc.
The 'event' is the crew handling the disturbance using all the available resources to achieve a safe flight. E.g.: Rejected T/O due to engine failure, reducing Cost Index to reduce fuel consumption and maintain required margins, divert to an enroute airport because of a medical emergency.
You can leave additional remarks underneath each triarc.
If you think the question is not applicable for your story you can check the N/A box.

>> Start with 1st of 9 TriArcs >>

Figure 6-11 FlightStory app tri-arc question explanation

The format of this question is based on (Keidel, 1995), (Allen & Goldsby, 2007) and (Klein et al., 2011). I call these shapes tri-arcs because the distance from each point to the corners is part of an arc. This distance shows the relative importance of each concept or value stated in the corner. In a triad, the distance from a point on an opposite side changes to that point when the point is moved along the edge. A mathematical compensation can be calculated, but I preferred a correct interpretation for the user. This kind of question required special custom JavaScript development, and in a software educational publication, I found a developer who has built a prototype for me in JavaScript and HTML.

The method for answering this tri-arc type of question is new to most flight crew. In the tri-arc diagram below, I show how, by using touch, the user drags the dot to a location in the tri-arc. The flight crew will often choose the location to drop the dot carefully. The curved line from the drag point to the drop location shows the judgements the user makes when moving the cursor to the position representing the judgments about the relative weighting of the corner concepts. Research (Snowden et al., 2011) has shown that respondents using the tri-arcs used more time and consideration on where to place the mark than when the question uses two-point scales. A tri-arc signifying space is richer than a two-point scale, and also, more two-point scales than tri-arcs would be required to get the same amount of data. When desired, the flight crew can add remarks to their answers.

Each of the nine tri-arc questions will have one dot showing a FlightStory. When the number of dots in each tri-arc increases, patterns will emerge. The stories that are part of a pattern can then be read to increase an understanding of the story. I explain this further in the paragraphs about the analysis tools and intervention report.

Snowden (Mosier & Fischer, 2011) suggests two options for designing relevant labels for the tri-arcs. The first is searching for culturally established organisational constructs, and the second is to design a set that makes relevant distinctions visible. I used the following steps to specify the concepts labels:

1. Identify the concepts in the field of safety, safety management and resilience by clustering subjects, behaviours, and decision points from a priming set of narratives and literature.
2. Choose the key concepts that relate strongest to resilience and Safety-II.
3. For each key concept, create a tri-arc with balanced negative or positive labels, since the idea is to force trade-offs between corner concepts.

The concepts are based on a review of Resilience Engineering (RE) (Hollnagel et al., 2007), Safety-II (Hollnagel, 2014b) and Management Cybernetics literature related to the Viable System Model (VSM) (Beer, 1979). Both fields of theory align well, as argued in (Dijkstra, 2007). The tri-arc questions cover the concepts of the four cornerstones or essential capabilities (Hollnagel, 2013b) for resilience performance, to monitor, to anticipate, to respond and to learn. They also cover the essential functions of the VSM, norms and values, strategy, operations management, audit, coordination and implementation (Beer, 1994). I explain these topics more in the theory chapter. The following questions using key concepts were designed while considering the user's requirement of a minimal set of questions:

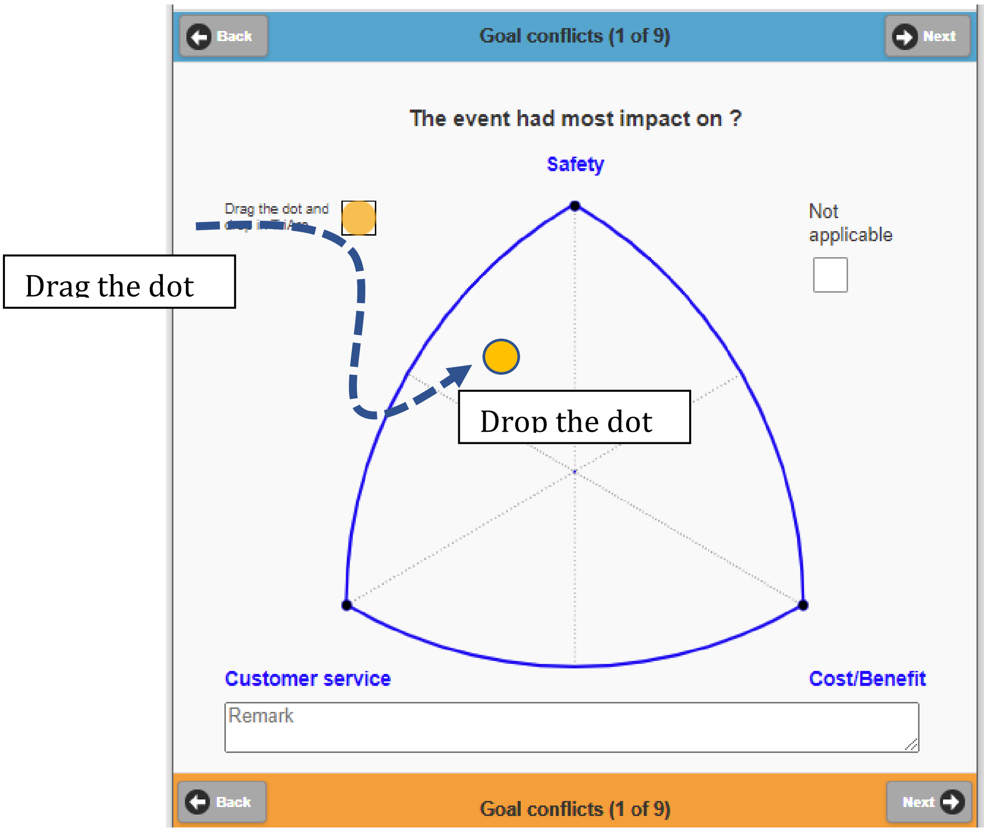


Figure 6-12 FlightStory app tri-arc example

The following tri-arc questions are discussed without a screenshot since they are similar to the first tri-arc question.

Tri-arc question 1:

Goal conflicts: The event had most impact on?

tri-arc corner labels		
Safety	**Cost / Benefit**	**Customer service**
Type of concept		
VSM: Essential variable	VSM: Essential variable	VSM: Essential variable
Explanation		
This question concerns the core of flight execution. These three essential variables define the operational performance criteria. The flight crew recognise these variables as core values and stated in the Basic Operating Philosophy of the flight operations department. This research takes the perspective that flight crew manage these interdependent variables. This perspective provides a richer picture than the perspective of safety in a silo, as if there are no interdependencies. Because each variable is essential, FlightStories related to challenges to manage each of the variables are relevant. Stories concerning goal conflicts and trade-off decisions provide a more holistic view of flight execution.		

Tri-arc question 2:

Source of disturbance: The source of the disturbances or threats that caused the event came from?

tri-arc corner labels		
Outside KLM	**Inside Flight**	**Outside flight but inside KLM**
Type of concept		
VSM: Source of disturbance	VSM: Source of disturbance	VSM: Source of disturbance
Explanation		
After the flight crew has indicated which essential variable was under threat, it is relevant to know the source of the disturbance or threat. The different sources provide relevant distinctions for supporting the management capacity for handling these disturbances or reducing or even removing the disturbance.		

Tri-arc question 3:

Complexity of event: To handle this event we had to deal with:

tri-arc corner labels		
A single factor	**Many interacting and interdependent factors**	**Many, but independent factors**
Type of concept		
VSM and RE	VSM and RE	VSM and RE
Explanation		
Both VSM and RE recognise the importance of complexity theory in handling disturbances, goal conflicts and trade-offs. The answer to this question reveals the perception and assessment of the flight crew and should be considered when evaluating responses and decisions.		

Tri-arc question 4:

Control aspects: We could respond to the situation because:

tri-arc corner labels		
We had clear targets, norms and/or limitations	**We had buffers, margins or alternative options**	**We had anticipated**
Type of concept		
VSM	RE	VSM and RE

Explanation
These questions concern situational control aspects. It combines RE and VSM concepts. Each of the three concepts can be the most relevant for a specific control challenge. The VSM is very explicit about norms and limitations since they provide closure for achieving requisite variety. In RE, this aspect is not explicitly addressed, while the buffers, margins and alternative options are explicitly mentioned in RE literature. Anticipation is explicitly a concept in RE and VSM. Each control aspect requires operational support from the flight operations management system.

Tri-arc question 5:

Resilience aspects: We could keep control of the situation because:

tri-arc corner labels		
We could monitor relevant or critical issues/values	**We could change our plan**	**We were able and ready to respond**
Type of concept		
VSM and RE	VSM and RE	VSM and RE
Explanation		
These questions address both VSM and resilience capabilities. The dynamics of a disturbance can be too high or too low to be noticed in monitoring. High dynamics of the event may make it impossible for the flight crew to change their plans or to respond in time to the event. The failure of the monitoring function, for whatever reason, technical, human or a combination, will affect the performance of the other two capabilities execution. Remarks by the flight crew or parts in the story can be informative about the dynamics and readiness of the crew and the consequences for the event handling. This question completes the VSM and RE concepts.		

Tri-arc question 6:

Core competencies: The competency we needed most to control the event:

tri-arc corner labels		
Leadership and Teamwork	**Flight Path Management**	**Application of Procedures**
Type of concept		
ICAO Crew core competencies	ICAO Crew core competency	ICAO Crew core competency
Explanation		
This is a selection of three core competencies as published by ICAO regarding flight crew training (ICAO, 2013a). The ICAO Core Competencies answers are helpful for the Alternative Training and Qualification Program (ATQP) development. FlightStory provides feedback to update an understanding of how the flight crew applied core competencies in actual cases. I		

added this question after a discussion with the Head Of Training of the airline. In the ICAO publication, Flight Path Management is divided into manual flight and automatic flight. This distinction is not sufficiently relevant for an extra question. The three selected core competencies were chosen because they are the most distinct, which better fits the pilot's perception of these core competencies.

Tri-arc question 7:

Response resource: We could handle the event by using:

tri-arc corner labels		
Standard Operating Procedures	**Improvisation**	**Advice from others such as (Dispatch, Maintenance etc.)**
Type of concept		
Methods	Knowledge	Outside support
Explanation		
These concepts are related to the type of response to a disturbance. The method to apply a response can be pre-planned and covered in a procedure by the aeroplane manufacturer or by a procedure developed by the company. The crew is expected to apply these procedures when required, and this is part of the Work-As-Imagined by Flight Operations Management and training. The description of the flight crew of how they actually handled the event provides insights into Work-As-Done. This question is crucial in the conversations around WAD-WAI. The story itself and the other answers provide a rich picture of this gap.		

Tri-arc question 8:

Learning: This event:

tri-arc corner labels		
Had some surprises	**We were not trained for but knew from experience**	**We have been trained for**
Type of concept		
VSM and RE	VSM and RE	VSM and RE
Explanation		
This question addresses the completeness of previous training. The perception of the event and the ability to relate that perception with previous training and experience is queried. The answers can reveal gaps in training both to the topic of training and the possible desire for training. For example, an event handled without training but handled by previous experience might need less attention than an event with surprises for the crew.		

Tri-arc question 9:

Who should learn: Who should learn most from this event?

tri-arc corner labels		
Flight crew	**Others outside KLM**	**KLM operations and management**
Type of concept		
VSM and RE	VSM	VSM and RE
Explanation		
This question addresses who, should learn most from this event. The answer can be read as a suggestion on where to find system improvements. The flight crew that answer that the flight crew should learn most from the event can be considered critical of their own performance. This specific answer allows the flight crew to show that they, in their own perception, failed to be effective in handling the event. The phrasing of the question was designed in such a way that being critical of their own performance did minimal harm to the pilot's professional image.		

Tri-arc answer analysis: Each question provides a part of the description and explanation of how the flight crew handled the event. For FlightStory data analysis, a team of experts can query the tri-arcs and search for patterns. The combination of the answers to this set of tri-arc questions provides unique data that has not been collected before. It is expected that the answers to these questions will generate new relevant insights for airline management and can support safety research because these questions are safety model-driven.

6.6.6.6 Section 5: Operational Performance Conditions

As managers of the flight, the flight crew should preferably have requisite control over the effects of disturbances on the flight. Their capabilities and the working conditions shape their requisite variety. Only the flight crew can analyse their performance of their flight in handling the disturbance. They can make the judgement to what extent their capabilities and working conditions were adequate for managing the event.

Work conditions concern the research area of Human Performance. Reason in (Reason, 1990)(Reason, 1997) describes Human Error Probability and latent conditions in relation to Safety Management. He elaborates on the relationship between organisational decisions and operational failures to the extent that he coins the term organisational accidents.

In (Johannesen et al., 2012) the flight crew are described as practitioners at the sharp-end, while managers are part of the blunt-end of operations. They made this distinction because explanations for decisions, adaptations, trade-offs at the sharp end are shaped by decisions made at the sharp end.

Since it is now clear context matters, the question is how to define the contextual and organisational factors. Several options for a set of factors are available, and I will discuss each of them for its suitability in the FlightStory concept.

First, the set of classifications related to Human Reliability Analysis (HRA) in terms of Human Error Probability. Based on error type as defined by Reason (Reason, 1990). Based on Reason, Groeneweg (Groeneweg, 1992) developed the Basic Risk Factors (BRF) as part of a questionnaire instrument to detect latent failures. The Performance Shaping Factors (Swain, 1989) is a similar set of factors developed to explain and estimate HRA and HEP. A comparable concept is that of the safety delivery systems (Ale et al., 2008), which also aimed to estimate HEP. The purpose of FlightStory is not related to error probability, but to conditions shaping performance in general; therefore, these classifications are less suitable.

Hollnagel describes the development of the second generation of Human Reliability Analysis (HRA) methods (Hollnagel, 1998) as a step away from 'human error' and human information processing models. He argues in (Hollnagel, 1998) Cognitive Systems Engineering (CSE) models are useful for their predictive and analytic capability of human performance because they account for the context of the activities. He also adopted a pragmatic approach to defining his context classification. Furthermore, the performance conditions are related to control modes which can be related to a full-scope performance description, not just negative but also positive. Based on these arguments, I started with the Common Performance Conditions (CPC) (Hollnagel, 1998) as a set of contextual organisational factors suitable for a linkage between FlightStory, Flight Operations management and Safety Management. The CPC and BRF categories have much overlap. I preferred the more generic performance considerations of the CPC than the BRF, which are more specific risk-based.

A first trial with the standard set of CPCs showed a difficulty for the flight crew to operationalise the generic language of the CPCs to their operational context. In a second iteration, I rewrote the CPCs into a suitable language for the flight crew. I added and refined some categories that are of specific importance and used a language that was more concretely related to flight operations. Due to the changes to the CPCs, I now refer to them as Operational Performance Conditions (OPC)

6.6.6.6.1 Viable System Model resource bargain

In the language of the VSM, the OPC represent a significant part of the so-called resource bargain homeostat (Beer, 1972). The resource bargain is an ongoing interaction between operational system units that implement the systems purpose, i.e., flight execution and the Operational Management System. The interaction is about desired performance as formulated by the Operational Management System and the required resources as required by the operational unit (the flight). In this homeostat, an operational unit, in this case, a flight, feeds back its evaluation of the conditions under which the requested performance has been delivered. These conditions are delivered by the Operational Management System. Since I built the AVPMM on the VSM logic, FlightStory can be integrated with the AVPMM. The resource bargain homeostat has a specific place in the AVPMM interface.

Based on the premise that the VSM provides the required functions for a requisite control system, a low variety resource bargain interaction reduces the requisite variety of the management system. Current ASR reporting does not include resource bargain elements which can be nominated as a missing link from the VSM perspective.

In the theory chapter, I will further explain this homeostat in the context of the complete VSM.

6.6.6.6.2 Operational Performance Conditions questions

The screenshot of the app shows an explanation of this section of the form. Each question has a short explanation. In each question, the reference is made to 'this event'. This is the event about which the flight crew has written the story. The flight crew can select a rating and provide additional text for more information.

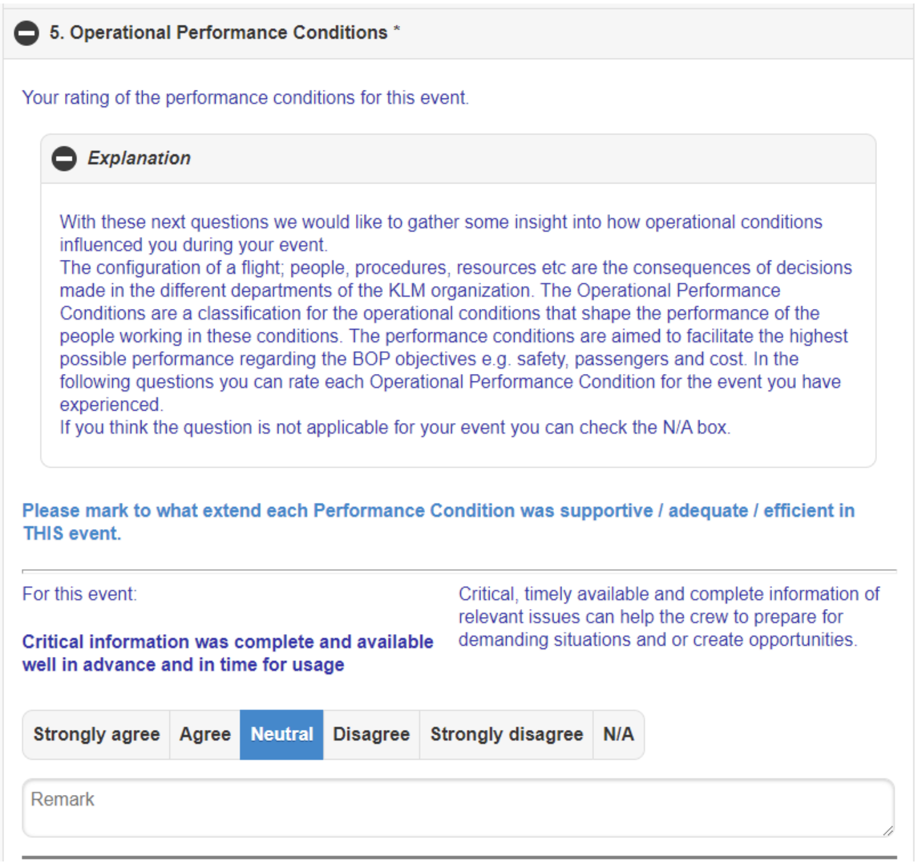


Figure 6-13 FlightStory app Operational Performance Conditions

Each of the questions below has a similar user interface.

Description	Explanation	Rating scale

Critical information was complete and available well in advance and in time for usage	Critical, timely available and complete information on relevant issues can help the crew to prepare for demanding situations and/or provide information about opportunities.	Strongly agree, Agree, Neutral, Disagree, Strongly disagree, N/A
Critical information was usable and accurate for usage	Critical information was precise, easy to use and understand and helped the crew prepare for demanding situations and or create opportunities.	Strongly agree, Agree, Neutral, Disagree, Strongly disagree, N/A
Training	The level and adequacy of relevant training, in relation to this event.	Very adequate, Adequate, Neutral, Inadequate, Very inadequate, N/A
Experience	The level and adequacy of relevant operational experience in relation to this event.	Very adequate, Adequate, Neutral, Inadequate, Very inadequate, N/A
Communication within crew or company: Quality, use of language and effectiveness	The efficiency and effectiveness of communication, both in terms of timeliness and adequacy between relevant parties. This refers to the technological aspects (equipment, bandwidth) and the human or social aspects.	Very effective, Effective, Neutral, Ineffective, Very ineffective, N/A
Communication with other parties outside company: Quality, use of language and effectiveness	The efficiency and effectiveness of communication, both in terms of timeliness and adequacy between relevant parties. This refers to the technological aspects (equipment, bandwidth) and the human or social aspects.	Very effective, Effective, Neutral, Ineffective, Very ineffective, N/A
Tools (software): easy to use and good ergonomics	User-friendly and intuitive tools which prevent errors and support performance.	Very easy, Easy, Neutral, Difficult, Very difficult, N/A

Tools (software): adequacy for purpose	Adequate and effective tools which prevent errors and support a good performance.	Very adequate, Adequate, Neutral, Inadequate, Very inadequate, N/A
Procedures and policies: applicability, availability and completeness	The availability of procedures and policies (operating and emergency procedures). Only workable and adequate procedures and/or policies support performance.	Very adequate, Adequate, Neutral, Inadequate, Very inadequate, N/A
Interruptions, disturbances	A workflow that is disturbed or interrupted by others such as ground crew, ATC or cabin crew can affect essential tasks. Large disturbances may need to reorganise and adapt work.	No disturbances, Minor disturbances; no effect, Some disturbances; we handled easily, Disturbances affecting workflow somewhat, Disturbances requiring work to be adapted, N/A
Goals: number of (temporal) conflicting goals to satisfy	The number of tasks (a) crew member(s) had to attend to and the rules or principles (criteria) for conflict resolution. Clear rules for conflict resolution may significantly support performance.	Far fewer goals than capacity, Fewer goals than capacity, Goals matching capacity, Some more goals than capacity, Far more goals than capacity, N/A
Availability of time and related workload	The time available to carry out a task. Lack of time, even subjective, is likely to decrease performance. Lack of time may be due to too many goals but can also occur for other reasons.	Ample time; low workload, Enough time; low workload, Time matching normal workload, Insufficient time; high workload, Very insufficient time; very high workload, N/A
Fatigue and circadian rhythm (WOCL)	Lack of sleep and whether or not a crew member had adjusted to the current time (circadian rhythm (WOCL)) influences performance.	Well rested, Rested, Neutral, Somewhat fatigued, Very fatigued, N/A
Crew collaboration quality Crew Resource Management	The quality of the collaboration among crew members, including the overlap between the official and unofficial structure, level of trust, and general social climate. This comprises the effects of crew resource	Very efficient, Efficient, Neutral, Inefficient, Very inefficient, N/A

	management, as well as people's enthusiasm for work.	
Organisational support and quality	The quality of the roles and responsibilities of team members and people that support and influence the operation such as operational management, support offices, etc. Think about their safety culture, attention and service for the flight in relation to this event.	Very adequate, Adequate, Neutral, Inadequate, Very inadequate, N/A

Figure 6-14 Operational Performance Conditions questions

The data evaluation will reveal the usefulness of these questions for each of the stakeholder groups.

6.6.6.7 Section 6. Threats Barriers and Risk

I added this section to collect data from the flight crew regarding threats and barriers. This section is less important and could be deleted in the next iteration to shorten the form and answering process. The intention is to use the answers to verify the completeness of the flight operations bowties that the safety department recently developed.

Another purpose of these questions is the relationship between threats and the Threat and Error Management concept. Although we realise how problematic the concept of error is, this TEM concept is well known among flight crew. They have had training in applying this concept and therefore they can make their own analysis of their event handling through the lens of TEM via these questions. The flight crew should not answer this question before the story is told because it will influence their perception of the event and the story might become a threat and barrier description. Such a story might suffer from a simplistic serial barrier event consequence exposure (Dekker, 2004). The flight crew can describe three threat barrier combinations in the form, but this is not required.

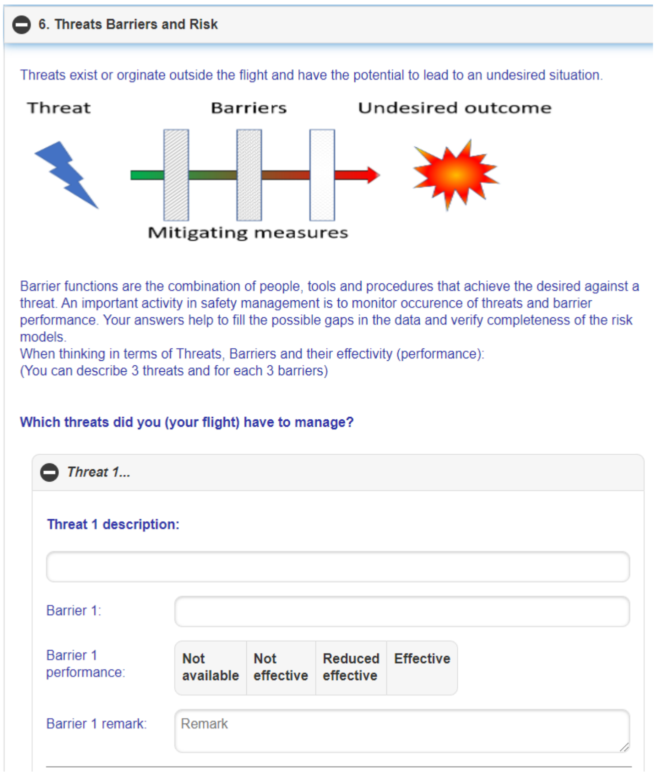


Figure 6-15 FlightStory app Barrier and Threats explanation

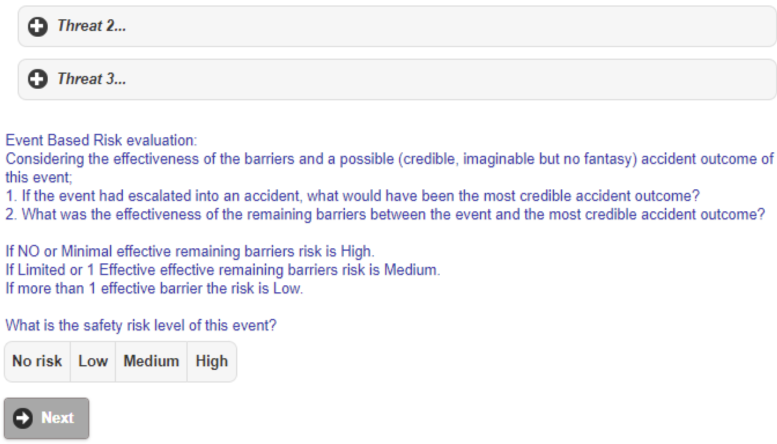


Figure 6-16 FlightStory app Risk explanation

The question about the risk level is designed to find gaps between risk as assigned by the safety office and risk as assigned by the flight crew. A large gap would be interesting to find and understand. This answer will probably have a high correlation with the emotion-related answers.

6.6.6.8 Section 7: IATA Accident types

This section was added to relate the FlightStory to the bowtie model accident scenarios that were developed in the safety department. Each flight operations bowtie model has, as an ultimate consequence in one or more of the IATA accident types. The answer to this question shows the worst credible accident scenarios as judged by the flight crew themselves. In current risk analysis procedures, these worst credible accident scenarios are selected by the risk analyst for ASR information. It should be realised that the risk analysts have fewer data available for their credible accident scenario judgements than the flight crew. This combination of story and bowtie scenarios will be informative for the bowtie models' accuracy, richness, and resolution.

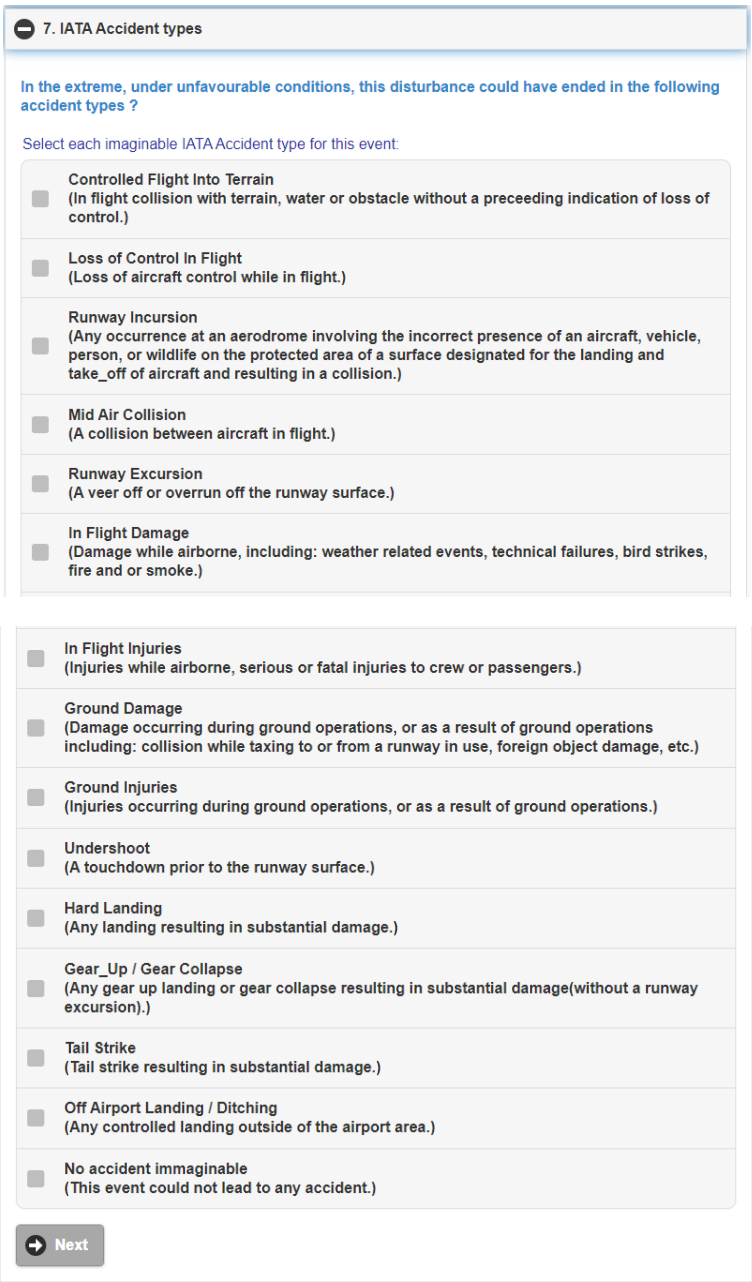


Figure 6-17 FlightStory app IATA accident type questions

6.6.6.9 Section 8. Fatigue

This section covers the fatigue questions as required for the Fatigue Risk Management System. The fatigue specialist has composed these questions, and these can be found in the FlightStory form and the ASR. A general fatigue question is also part of the OPC questions.

8. Fatigue

The description of your fatigue

Explanation

For this event:

Fatigue contributed to the event

Refers to contribution of (possible) reduced performance during the duty, or commuting after duty.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A

Remark

For this event:

What description fits best with your sense of fatigue when the event started:

Fatigue can be recognized by physical and cognitive signals. Physical signs: fidgeting, rubbing eyes, yawning, frequent blinking, staring blankly, long blinks, difficulty keeping eyes open, head nodding. Cognitive signs: increase in slips, increase in memory lapses, impaired attention, impaired memory, irritability and short-temperedness, reduced communication, impaired problem solving, increased risk taking, impaired situational awareness

Completely exhausted	Extremely tired, very difficult to concentrate	Moderately tired, let down	A little tired, less than fresh	OK, somewhat fresh	Very lively, somewhat responsive but not at peak	Fully alert, wide awake	N/A

Remark

For this event:

Fatigue training

The level and adequacy of relevant training, in relation to fatigue.

Very adequate	Adequate	Neutral	Inadequate	Very inadequate	N/A

Remark

For this event:

Impact of roster

If applicable, please indicate which of the following roster-elements contributed to the experienced fatigue.

(More than one selection is possible)

Early start(s) (before 06:00)	Late finish	Night flight (after 21:00)	Passing timezones	Early late transition	Swift E/W W/E changes	Duty length	Nr of Duty days	N/A

Remark

For this event:

Sleep or rest at layover

Refers to quantity and quality of sleep during layover.

Very adequate	Adequate	Neutral	Inadequate	Very inadequate	N/A

Number of hours of sleep

0 to 2 hrs	2 to 4 hrs	4 to 6 hrs	6 to 8 hrs	More than 8 hrs	N/A

Remark

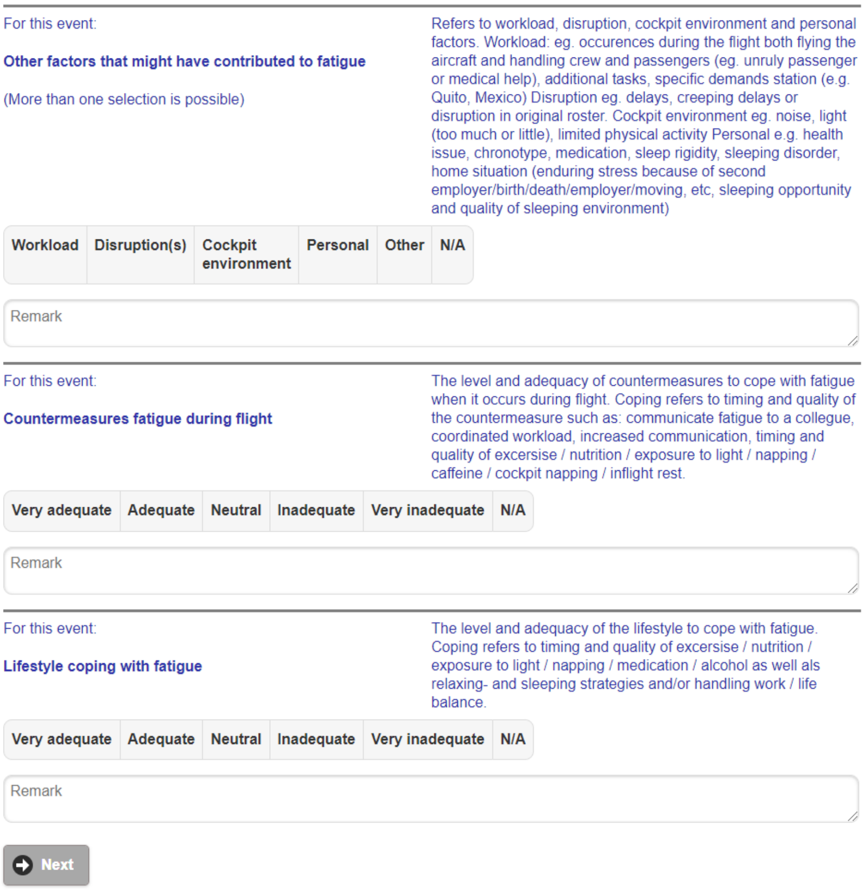


Figure 6-18 FlightStory app Fatigue questions

6.6.6.10 Section 9: Safety performance

This section is not a primary question. It is related to the concept of performance, as suggested by Beer for use in the VSM. The purpose of the question is to test whether the pilot's safety performance judgements can be used to aggregate safety aspects.

Beer defines three activity characteristics (Beer, 1972) of an operational unit. These are:

- Actuality: "What we are doing now, with existing resources, under existing constraints."
- Capability: "This is what we could be doing (still right now) with existing resources, under existing constraints, if we really worked at it."
- Potentiality: "This is what we ought to be doing by developing our resources and removing constraints, although still operating within the bounds of what is already known to be feasible."

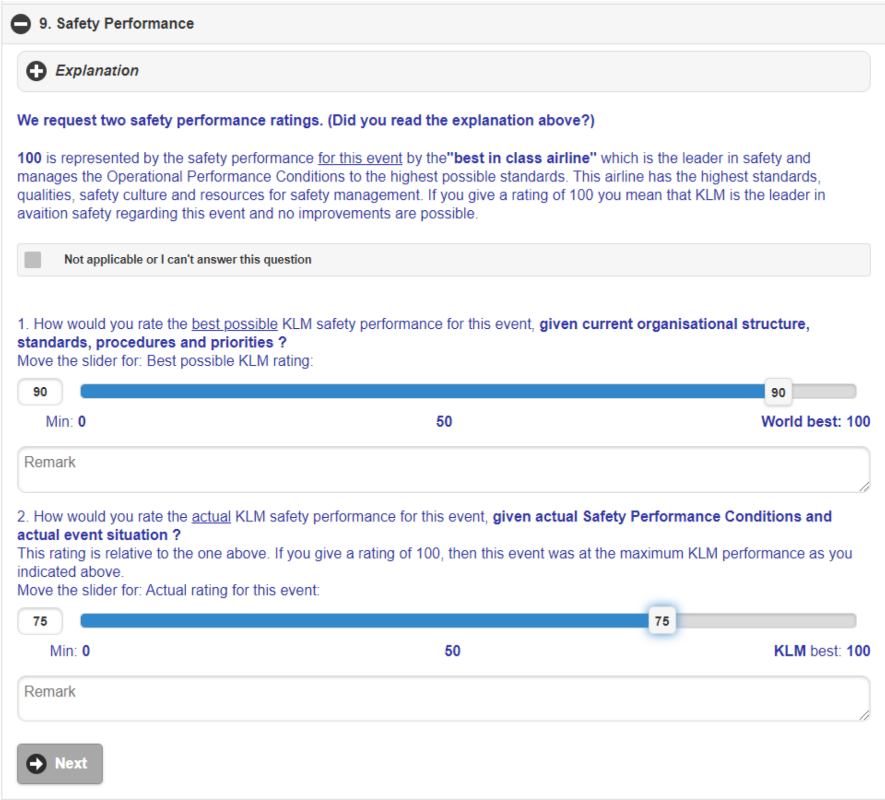


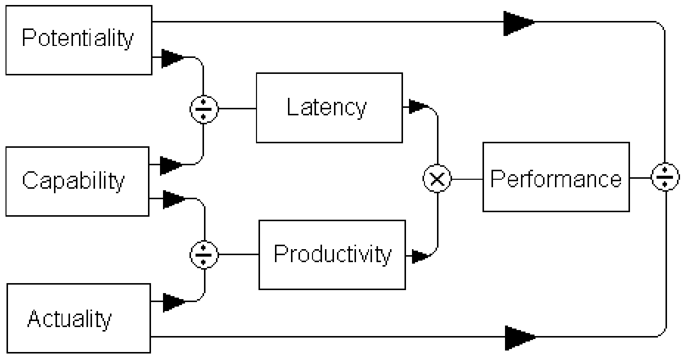
Figure 6-19 FlightStory app Safety performance

Beer adds to these three values the ratios between them. He defines them as follows:

- Productivity: is the ratio of actuality and capability;
- Latency: is the ratio of capability and potentiality;
- Performance: is the ratio of actuality and potentiality and also the product of latency and productivity.

Based on these concepts, the answers from the flight crew can provide a safety performance value. Potentiality is set at 100, as explained in the question. This is the best-in-class airline as judged by the flight crew, and it means it is not a hypothetical condition for which we cannot find an example. The capability is the answer the flight crew gives with the selection of the first slider. Here, the flight crew judges how well the airline can handle the specific event as compared to the best in class.

The second slider provides the flight crew with a way to rate their own crew performance relative to the best company performance. The current shown values would then result in a safety performance of 0.75:



100		
	0.9	
90		**0.75**
	0.83	
75		

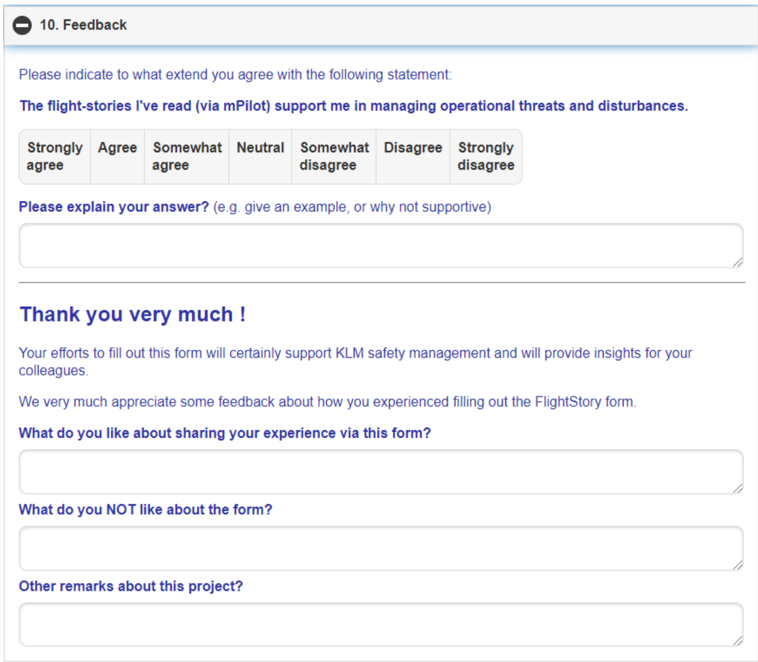
Figure 6-20 Based on Nick Green, Performance ratios (Beer, 1972)

The usability of this metric has to be evaluated. The question itself is quite abstract, which may lead to misinterpretation, which reduces the usability of the answers. The Capacity and Actuality of flight crew judgements can be used to calculate Beer's performance ratios and relate them to the OPC evaluations and the credible accident scenarios. This data collection can contribute to use the OPC evaluations as proxies for accident propensities as part of risk management. The answers can also be correlated to other answers, such as the risk level assignment and the tri-arc about who should learn most of the event.

I have found no scientific reference for this approach to safety as a capability and safety performance. The FlightStory evaluation will give indications about the effectiveness of this implementation of this concept.

6.6.6.11 Section 10: Feedback

The flight crew can use these questions to provide feedback on the form. These are open, free-text questions to prevent variety reduction in the answers.



10. Feedback

Please indicate to what extend you agree with the following statement:

The flight-stories I've read (via mPilot) support me in managing operational threats and disturbances.

Strongly agree	Agree	Somewhat agree	Neutral	Somewhat disagree	Disagree	Strongly disagree

Please explain your answer? (e.g. give an example, or why not supportive)

Thank you very much !

Your efforts to fill out this form will certainly support KLM safety management and will provide insights for your colleagues.

We very much appreciate some feedback about how you experienced filling out the FlightStory form.

What do you like about sharing your experience via this form?

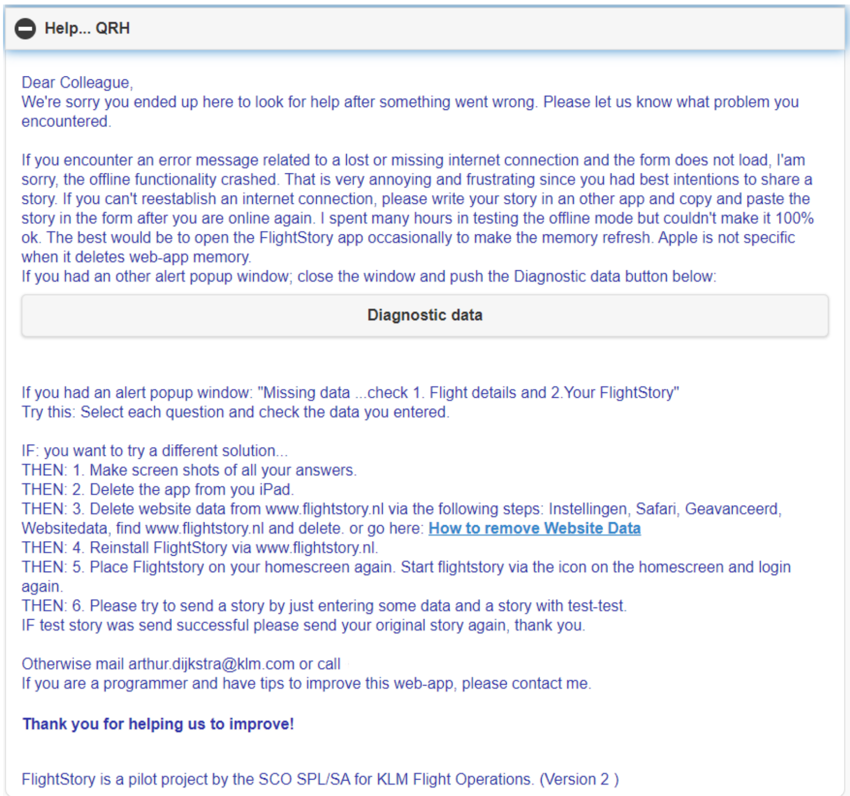
What do you NOT like about the form?

Other remarks about this project?

Figure 6-21 FlightStory app User feedback

6.6.6.12 Section Help...QRH

This section is to help the user when a problem occurs. QRH means Quick Reference Handbook as this is used as part of aircraft operations documentation.



Help... QRH

Dear Colleague,
We're sorry you ended up here to look for help after something went wrong. Please let us know what problem you encountered.

If you encounter an error message related to a lost or missing internet connection and the form does not load, I'am sorry, the offline functionality crashed. That is very annoying and frustrating since you had best intentions to share a story. If you can't reestablish an internet connection, please write your story in an other app and copy and paste the story in the form after you are online again. I spent many hours in testing the offline mode but couldn't make it 100% ok. The best would be to open the FlightStory app occasionally to make the memory refresh. Apple is not specific when it deletes web-app memory.
If you had an other alert popup window; close the window and push the Diagnostic data button below:

Diagnostic data

If you had an alert popup window: "Missing data ...check 1. Flight details and 2.Your FlightStory"
Try this: Select each question and check the data you entered.

IF: you want to try a different solution...
THEN: 1. Make screen shots of all your answers.
THEN: 2. Delete the app from you iPad.
THEN: 3. Delete website data from www.flightstory.nl via the following steps: Instellingen, Safari, Geavanceerd, Websitedata, find www.flightstory.nl and delete. or go here: How to remove Website Data
THEN: 4. Reinstall FlightStory via www.flightstory.nl.
THEN: 5. Place Flightstory on your homescreen again. Start flightstory via the icon on the homescreen and login again.
THEN: 6. Please try to send a story by just entering some data and a story with test-test.
IF test story was send successful please send your original story again, thank you.

Otherwise mail arthur.dijkstra@klm.com or call
If you are a programmer and have tips to improve this web-app, please contact me.

Thank you for helping us to improve!

FlightStory is a pilot project by the SCO SPL/SA for KLM Flight Operations. (Version 2)

Figure 6-22 FlightStory app User help

This concludes the description of the FlightStory app and the explanation for the specific design.

6.7 Implementation of intervention

The implementation went through several phases.

6.7.1 FlightStory 1.0 trial

As an initial test in 2014, FlightStory I made available to the flight instructor flight crew only. This group comprises about 200 flight crew who perform regular flight, route and simulator training and checking. About half of the group is short-haul flight crew (flights less than 4 hours), and the other half is long-haul flight crew (usually longer than 4 hours).

Their training managers invited the instructor flight crew to share their experiences with FlightStory. In a letter to the instructor flight crew, the purpose, the installation procedure and the working of the app were explained.

This flight crew sample sufficiently represents the entire group of flight crew since they operate on regular line flights with regular (no training) colleagues.

6.7.1.1 Try-out reporting rate

After the experiment ran for six months, 25 FlightStories were submitted. Ten FlightStories were short-haul related, and 15 were long-haul. A submission per flight rate is hard to determine since individual flight crew schemes showing actual flight and simulator working periods are not available for this research. A rough estimate would be based on the following assumptions: flight crew perform simulator training and flights at about a 50/50 rate. Thus, three months of flight means for a short-haul flight crew about 100 flights. For 100 flight crew, this totals to 10000 flights. This makes the response rate in the order of 1 in 1000 flights for short-haul. On the other hand, 100 long-haul flight crew fly about 2500 flights in three months. Hence, the response rate is in the order of 1 in 150 flights.

6.7.1.2 Summary trial

The flight crew's responses show a desire to improve safety by sharing and learning. The stories and their titles show trade-offs and goal conflicts, the typical arena where Resilience Engineering is applicable. Event descriptions that contain context and participants' opinions show insights that would otherwise be unavailable for safety management purposes. Some of the remarks from the feedbacks section were:

- “A way to improve safety and awareness without the need for an ASR.”
- “I can give more background information, which is important with human factors.”
- “I have to get used to the tri-arcs. But I can imagine it can give valuable information to fill them in, since you are forced to think about aspects you didn't think of beforehand.”
- “Too labour some”
- “Good plan, but should be more simple. Terms used too theoretical for flight crew.”

- "This is important! Sharing brings this experience to all! We can all benefit from this report. I also learn from it by sending the report."

Based on this feedback, I improved the app interface and the distribution method and made the OPC language simpler and adapted it more to flight operations. In addition, I made the FlightStoryBook as a tool to make all stories available for all flight crew. I wrote a Python script to select the flight details, the story, the lessons and the keywords from the database. This selection was used to create a pdf programmatically. After new stories were received and reviewed, a new FlightStoryBook for the flight crew was updated each week with the iPad update cycle.

These responses provided a sufficient indication that a next iteration where all flight crew, training, Flight Operations managers and Safety Management could benefit from the new insights has the potential to improve organisational learning.

6.7.2 FlightStory 2.0 app distribution to flight crew

In July 2020, the agreement between the flight crew union, the safety department and the Flight Operations department was signed. After I uploaded the final FlightStory version to the web server, I invited the flight crew via a news article in the company NewsApp in July 2020.

In March 2021, all parties agreed to an extension of the trial period until the end of the year. The text of the invitation and extension can be found in the appendix.

For data privacy reasons, limited data regarding visits to the FlightStory website is available. Therefore, it is not possible to know how many flight crew have loaded the app on their company iPad. The survey results will give some guidance to make an estimate.

To increase the group of FlightStory users, a poster was placed in every training simulator briefing room in June 2020. I designed the poster to show the relevance of flight crew feedback via FlightStory. Each of the groups mentioned in the poster will be part of the evaluation of the FlightStory project. In addition, the Head of Training invited all instructors in his July newsletter.

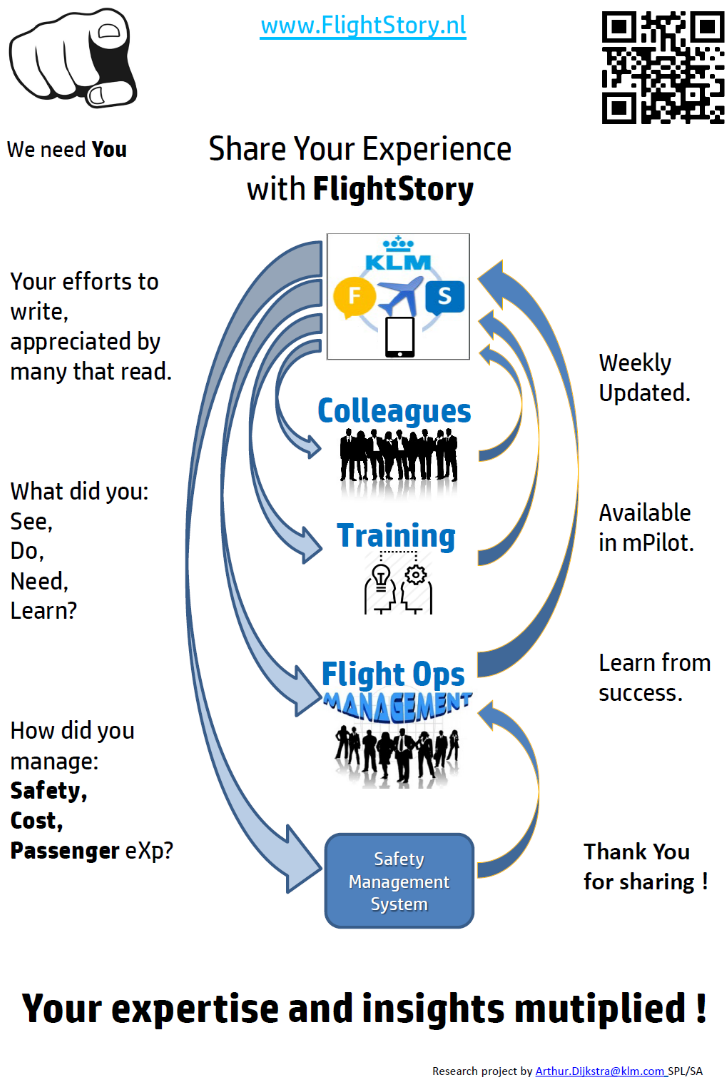


Figure 6-23 FlightStory flight crew invitation

6.8 Evaluation of FlightStory intervention

The general process of DSR (van Aken & Andriessen, 2011) and the related Epistemological Analysis (Xiao & Vicente, 2000) is followed in this research project to achieve relevance and rigour of the research results. The evaluation should provide usable results that can be used by other researchers to conduct further research and airline practitioners to adapt or develop similar tools. The DSR research process is aimed at achieving this purpose. For completeness, some specific criteria described in mixed method research literature will also be evaluated.

To validate the research results, the researcher should protect the internal and external validity of the research findings (Creswell & Creswell, 2017). Internal validity refers to the degree to which the research can draw correct inferences from the data while external validity refers to the degree to which research results can be generalised to other settings.

6.8.1 Internal validity

Threats to internal validity can arise from many factors (Creswell & Creswell, 2017). History or external disturbances can affect the experiment. Since the FlightStory experiment is tightly connected to the normal work of flight crew even the pandemic or labour union issues did not invalidate the concept but probably only the number of participants was affected.

- Maturation of the participants that could affect the experiment was not a factor in this research since it lasted about a year.
- Regression to the mean of the evaluation results is no threat when the results remain stratified in relevant groups (experts and managers and departments) and not aggregated in one group. For the flight crew group evaluation, most questions are not scales but categorical and these are not sensitive to this threat.
- Mortality or drop-out of flight crew participants was mitigated by having access to the complete flight crew population.
- No selection of participants for FlightStory was made. All flight crew were invited to participate and to share their FlightStory and fill out the evaluation survey. Since participation was voluntary, there is always some sort of self-selection. The more enthusiastic flight crew interested in new projects as well as the instructor flight crew have participated in the project by sharing a FlightStory. The willingness to report is also known as reporting culture and does not invalidate the FlightStory data relevance, but a low quality of reporting culture reduces the number of reports and completeness of the reports. Improving reporting culture is a topic of constant attention in a SMS.
- Cross-contamination between flight crew is considered low since flight crew-to-flight crew communication occurs before, during, or after a flight and other pandemic-related topics were much more discussed than the FlightStory project. Some cross-contamination between the expert groups and manager groups might be related to the evaluation surveys might have taken place, but again considering the circumstances, other topics were much more urgent and important than this project.
- There were no compensatory effects, where participants either submitters or non-submitter of a FlightStory get an unequal reward. Nobody except the researcher was aware of who had submitted a FlightStory or an evaluation survey. This fact together with the fact that stories were anonymously shared prevented compensatory rivalry between participants.
- The nature of the project, the voluntary submitting of flight operational experiences, made it insensitive to gaming or testing the method. During the review of the stories, I suspected a few stories were shared for the purpose of trying the app and method, but that had no negative effect on others. The experience of submitting a FlightStory makes the evaluation survey submitted by the experimenter more reliable.

Based on the arguments above, I assume internal validity has sufficiently been addressed and protected to draw valid conclusions from this project.

6.8.2 External validity

Threats to external validity can arise from several factors, such as participants, the uniqueness of the situation and the timing of the experiment (Creswell & Creswell, 2017).

- The participants' characteristics as a threat to external validity is mitigated because the participants of the experiment are members of the same groups that would be the actual users of FlightStory and receivers of FlightStory data. Furthermore, the access to over 2500 flight crew who could take part voluntarily to the experiment also mitigated this threat. The participation of managers was limited to the ones that I personally contacted and to who I showed the data and explained examples of the relevance of the data.
- The setting for the experiment as a threat to external validity was mitigated because the flight crew used the FlightStory app as part of their normal work and related to their normal actual work. They could complete a FlightStory form in the cockpit, at home, or during a layover in a hotel. They used their actual iPad which is also used for other actual flight crew tasks, such as filling out an actual Air Safety Report. Only the procedure to get the app on the iPad was a procedure outside the company software installation procedure, but the install procedure used regular iPad features. This procedure might have reduced the number of participants.
- The timing of the experiment was unfortunately during the COVID pandemic. Aviation and the airline experienced severe economic stress and even fears for bankruptcy. Airlines had to reduce their workforce and fears for layoff and big pay cuts reduced the interest in innovation projects. During the experiment, the number of flights was reduced to 10 or 20 percent of the normal capacity. Many flight crews made so few flights they had to regain recency in the simulator before an actual flight. The timing of the experiment most likely affected the number of participants, but the concept was not negatively affected. In some sense, the timing created an opportunity because FlightStory is better suited to report non-normal flight operation conditions than the regular reporting methods. That is one reason managers promoted the use of FlightStory. When aviation and airlines are returning to normal operations the FlightStory concept will not be invalidated because safety and operational reporting remain a part of normal flight crew work.

Based on the arguments above and considering the research steps of DSR that have been followed, I suggest that external validity to the extent that the research results can be generalised to other airline companies can sufficiently be achieved.

6.8.3 FlightStory evaluation design

The purpose of the survey is to compile answers to answer the research question which has been stated as:

RQ 1.1 To what extent can pilots' flight operational experiences feedback:

- Support self-reflection and learning from own events?
- Support flight crew to flight crew learning?
- Support flight crew training?
- Support the management of flight operations?
- Support Safety Management?
- Provides insights for Safety-II and resilient performance?

Each sub-question addresses a specific feedback loop that receives FlightStory data for its specific role in supporting and improving flight operations. The contribution of FlightStory to the learning from operational events in the four feedback loops will be evaluated. The four stakeholder groups are flight crew, flight crew training department, the Department of Flight Operations and Safety Management System. People from these groups will be requested to cooperate in the evaluation.

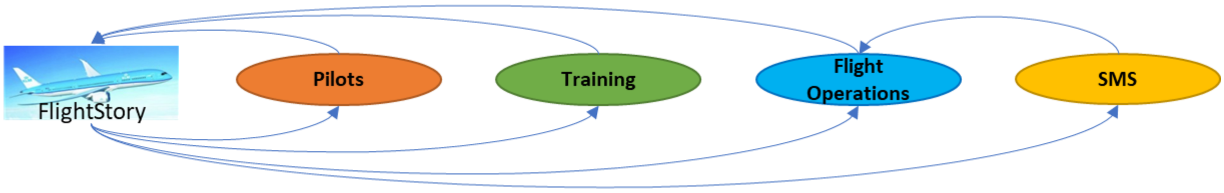


Figure 6-24 FlightStory feedback loops

Cybernetic requirements for effective feedback and control systems include channel, transduction and change capacity. The concepts are described in the paragraph that describes the generic solution for the described problem. In short, these requirements are concerned with maintaining requisite variety in a control loop. Control in the context of flight operations must be read as influencing since, in systems with high complexity, a notion of direct control is problematic. The requirements include the transduction from the pilot's experience to the data in a FlightStory, the amount of variety that can be captured by a FlightStory and the degree to which FlightStory data can inform the flight crew and people involved in training, the Flight Operations and SMS. FlightStory data by itself or connected to other sources to enrich event descriptions, should inform the people, mostly managers, to take effective action in supporting flight operations. The survey should cover these requirements.

The timing of the evaluation coincided with the COVID pandemic and a reorganisation process in the airline. The consequence is that all managers are saturated with work and that, although they are interested, they are unable to make much time available for the evaluation of a research project. It was impossible to make a group appointment for a focus group discussion and evaluation.

Given these circumstances, I developed a survey with supporting informative material such as a PowerPoint presentation and a recorded video demonstration of the analysis dashboard. In this material, I explained the purpose of the project and how the stakeholders can analyse the data with the analysis dashboard that I built for this purpose. I have also conducted one on one live demonstrations of the analysis dashboard upon request using Microsoft Teams.

The respondent contribution was voluntary, with no rewards other than appreciation of the researcher. Each respondent could complete the survey at his or her own moment in time and takes as long as desired. The respondent could request support for clarification from the researcher.

I designed three evaluation surveys which were answered by three groups, namely regular line flight crew, experts from safety and training and managers from the Flight Operations department and the Safety department. The choices for these people assure coverage of every learning loop by competent individuals.

6.8.3.1 FlightStory survey for flight crew

The flight crew survey data collection is mainly focused on one of the four learning loops, the loop that involves peer-to-peer learning as shown in the diagram above.

The flight crew were invited via company news magazine and the flight crew Yammer group to complete a web form survey. The survey was made with Microsoft Forms in the company's Microsoft Office environment to which every employee has secure password-protected access.

The topics in the survey include the aspects that are required for submitting useful FlightStories.

- Knowledge of the availability of FlightStory.
- Knowledge of the purpose of FlightStory.
- Whether the flight crew could install the app on their iPad.
- Whether the flight crew was willing to submit a FlightStory.
- Whether FlightStory was easy to use.
- Whether the flight crew thinks a FlightStory form requests useful information.
- Whether the flight crew thinks the sharing of FlightStories can provide useful lessons.
- Suggestions for improving peer-to-peer learning.

Each question had either a five-point scale from Strongly Agree to Strongly Disagree or some categories covering the range of possibilities. Every scale question was accompanied by an open question to explain their answer or to make a remark.

6.8.3.2 FlightStory survey for experts

In total, three groups of relevant experts were invited to complete the expert surveys.

- Risk Analysts: These people work in the safety department either full-time or part-time. The half-time risk analysts are flight crew (captains and co-pilots) for the other half of their employment. They all conduct accident, incident, and risk analyses related to flight safety. They analyse and report on air safety report trends.

- Business Flight Crew Safety: These people are flight crew and work for the Flight Operations department. They are the liaisons for the safety department. They have frequent contact with the risk analysts with whom they conduct the two weekly fleet safety action group meetings.
- Training experts: These people are all flight crew and are involved in flight crew training by training content development, instructor training, and flight crew examinations.

The experts contributed to two surveys.

- The first was a review of every question in the FlightStory app and the operationalisation of the concepts in every set of questions. This added up to 60 questions, which could be answered by a 5 point agreement Likert scale and complemented with a remark or explanation. For every unique question in FlightStory compared with the current ASR, the judgment was asked whether that question should be part of the next development of the ASR. Based on these answers, it is simple to provide a ranking of the questions that should be part of the next development. The survey had an introduction and explanation and some ethical notes such as anonymity.
- The second survey included specific questions about each learning loop as illustrated in the picture above and a general question. This added up to 14 questions, each with a 5 point agreement Likert scale and a sub-question for an explanation of the answer.

FlightStory app expert questions:

- Explanatory introduction to a group of questions
- Relevance of the individual question
- Relevance of a group of questions
- Degree in agreement to add the specific topic to the current reporting tool

This part of the survey contained 54 scale questions accompanied by 54 open questions to elicit an explanation.

FlightStory concept expert questions:

- Type of data that is collected and to what degree insights into the sensemaking of the reporting flight crew are supported by the FlightStory questions and the format of the questions.
- The importance of flight crew judging the Operational Performance Condition of the event they are reporting about.

- The learning potential for other flight crew reading the stories and the lessons learned.
- The learning opportunities for training experts to find relevant topics for flight crew training.
- The insights Business Flight crew Safety can gain to support the managers of the Flight Operations department in their role to support flight operations.
- Their judgement on the potential for learning by Flight Operations managers from FlightStories.
- Their judgement on the learning potential by risk analysts and SMS processes from FlightStories.
- The extent to which data about Operational Performance Conditions and Operational Strategies (tri-arcs) are relevant for Safety Management, including a Safety-II and Resilience perspective.
- The supposed actionability of FlightStory data
- Their judgement about taking the lesson learned from FlightStory into the next iteration of operational reporting developments.

This part of the survey contained 17 scale questions accompanied by 17 open questions to elicit an explanation of their answer.

Before they completed the survey, I had spoken to all of them explaining the project and making sure they had no further questions.

6.8.3.3 Safety managers and Flight Operations managers' survey

The survey for managers contained the same concept questions as the expert's survey covering all learning loops. Using the same questions for both the experts and managers has the advantage that answers can be compared. Each research question is covered by one or more survey questions.

RQ	Learning loop	Survey questions	FlightStory question by question review by experts
All	General improvement of the feedback system and supporting all learning loops	1, 2, 3, 13	
A	Flight crew self-reflection and evaluation	5	
B	Flight crew to flight crew	4	
C	Flight crew to flight crew training	6	
D	Flight crew to Flight Operations management	7, 8, 10, 11, 12	
E	Flight crew to Safety Management System	7, 9, 11, 12	
F	Flight crew provide Safety-II and resilience insights	1, 4, 6	Story, tri-arcs: 20, 21, 22, 23, 24, 25, Statements: 27, 28, 29

Table 6-1 Mapping learning loops with research questions

	Survey question	RQ
1	FlightStory collects 'warm' (human) rich data that provides insight into the sensemaking of the flight crew and how they viewed and understood the interdependencies between event facts to provide a systems view of the event more effective than ASR 1.0, TR and FDM.	All
2	FlightStory offers suggestions, free text keywords and personal lessons learned, supporting the flight crew to tell his story in such a way that others can learn from it, more effective than ASR 1.0, TR and FDM.	All
3	FlightStory supports the flight crew to give his judgement about Operational Performance Conditions more effective than ASR 1.0, TR and FDM.	All
4	By sharing (via mPilot) the stories and lessons learned, FlightStory provides learning opportunities for other FLIGHT CREW from operational events more effective than ASR 1.0, TR and FDM.	B
5	By filling out the questions (such as the story, the critical events, the lessons learned, the operational strategies (tri-arcs), the Performance Conditions) in a FlightStory, the submitting flight crew(s) are supported in taking a reflective view on their own performance, enhancing their own learning process more effectively than ASR 1.0, TR and FDM.	A
6	FlightStory provides the data for training experts to find learning opportunities for FLIGHT CREW TRAINING more effective than ASR 1.0, TR and FDM.	C
7	FlightStory provides the data for Business Flight crew Safety and supports Flight Operations Management in improving operational support for flight operations more effectively than ASR 1.0, TR and FDM.	D, E
8	FlightStory provides the data items for Flight Operations Managers and for other Managers of operational departments to learn from operational events more than ASR 1.0, TR and FDM data.	D
9	FlightStory provides data for Risk Analysts, Safety Consultants, and Safety Management System processes to learn more from operational events than can be learned from ASR 1.0, TR and FDM data.	E
10	FlightStory provides more actionable data, for Flight Operations Managers and for other Managers of operational departments than ASR 1.0, TR and FDM data. Actionable data provides immediate and specific insight and guides decision making and can be acted upon.	D
11	(SCO) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Safety Management to support Flight Operations. (FO) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Flight Operations.	D, E
12	(SCO) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Safety Management to support Flight Operations. (FO) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Flight Operations.	D, E
13	We should implement the lessons from the FlightStory project in e.g. ASR 2.0.	All

Table 6-2 Mapping research questions with survey questions

Due to lack of time, I did not explain the AVPMM to the managers and therefore the linkage between FlightStory and the AVPMM was not directly surveyed in the managers' group. The low number of respondents relative to the number of managers that were invited illustrates the difficulty I had getting managers motivated to complete the survey and addressing the AVPMM and one-hour explanation would have reduced the number of participants even more.

6.9 Evaluation of FlightStory survey responses

Three groups accepted the invitation to voluntarily contribute to a FlightStory evaluation. The flight crew answered some questions online, and the experts answered in a Word document. This section presents the survey results.

6.9.1 Flight crew survey responses

The flight crew were invited to complete the survey via the company's news app and the Yammer app in the Flight Operations group. For a period of 4 months, the survey was available. This first month 80% of the responses was received. In total 159 responses were received and the Yammer annunciation with the link to the survey has been viewed 847 times. 75% = 635 The flight crew community that was invited to participate in the FlightStory was about 2300.

The data shows:

1	How familiar are you with FlightStory?	Count	%
	Sorry, never heard about it	31	19
	I heard about it but that is all.	59	37
	I looked at the App page but did not install it	17	11
	Sorry, I've looked at the App page but did not install it.	7	4
	I've the App but I've not submitted a FlightStory yet.	39	24
	I've submitted a FlightStory	6	4

Table 6-3 FlightStory Flight Crew survey question 1 data

The interpretation is that when we assume that the Yammer users are representative of the total of the flight crew population and that flight crew who had the app would complete the survey then (39+6)/635 * 2300 = 162 (7%) flight crew. During a random check at the flight crew centre where I asked the flight crew if they had installed the app 10% had FlightStory actually on their iPad. This makes the estimate that between 160 and 230 flight crew actually installed FlightStory on their iPad to cooperate with the project.

Of the 69 respondents that had heard about FlightStory, 43 (62%) answered they heard about FlightStory in the company's NewsApp, 7 (10%) heard about it from a colleague and 14 (20%) heard about it from other sources. These 69 also completed the follow-up questions which are shown, with the answer percentages in the following table.

	Count answers	Strongly Agree%	Agree %	Neutral %	Disagree %	Strongly Disagree%
I know what the purpose is of FlightStory.	69	20	61	17	1	0
I could complete the install of the FlightStory app on my iPad.	69	30	43	19	1	6
I've seen the app and I think it is easy to use.	69	9	27	43	12	9
I've seen the app and I think the FlightStory form requests useful information.	69	7	27	55	7	3
I am willing to submit a FlightStory when I experience an interesting operational event.	69	17	40	26	13	3
I think the stories we share can provide useful lessons.	69	29	52	14	1	3
Sum percentages		112	250	174	35	24
Agree versus Disagree		362		174	59	

Table 6-4 FlightStory Flight Crew survey answers

The data shows:

- 81% of the flight crew say they know the purpose of FlightStory but a few of the free text comments show FlightStory is assumed to only be for the pilot's peer-to-peer sharing. Apparently, the other three purposes have not been recognised.
- That regarding use friendliness of the app
    - the install procedure could be completed by 73% of the flight crew.
    - the ease of use had 36% agreement while 21% had a disagreement.
- 57% of the flight crew agreed to share a story while 16% said to be unwilling. Too much work has several times been mentioned as an obstacle to use the app.
- 34% see the usefulness of the requested data while 10% disagree. An increase in appreciation of the usefulness of the data could increase the willingness to submit a FlightStory.
- An overwhelming majority of 81% agrees that useful stories can be shared by FlightStory. The disagree answers were provided by a flight crew who could not find the shared stories on the iPad and the other was a manager who also commented about the large amount of work to complete and submit a FlightStory.
- A few flight crew provided most of the (strongly) disagree answers.
- Overall, there was a ratio of agreement versus disagreement of about 6 to 1.

The responses from the flight crew show a willingness to cooperate and a potential for more cooperation if the app is simple to instal and use, completing a FlightStory does not take too much time and the stories are easy to find in a user-friendly manner on the iPad.

6.9.2 Responses from experts about FlightStory app questions

In the table below the experts' judgements are summarised. The data did not allow to analyse the difference between the expert groups. Two groups had only three experts.

The order of the rows is based on the level of agreement about the question of whether the specific question should be part of ASR 2.0. The higher the score, the stronger is the advice to include the question is ASR 2.0. Where ASR 2.0 is the next iteration of combining ASR 1.0 with the lessons from FlightStory. The score is the sum of two times the number of answers with Strongly Agree added to the number of answers with Agree minus the number of answers of Disagree minus two times the number of answers with Strongly disagree. The weight difference between the Strongly Agree and Agree does not make a difference in the order of the results, it only provides somewhat more resolution. The number of answers is the count of the answers by the experts.

		FlightStory		ASR 2.0		Safety-II Resilience	
Survey Quest	Quest Type	Score	Nr answers	Score	Nr answers		Description of survey question
11	Safety	10	10	12	10		The function of the flight crew submitting the FlightStory provides useful (but not sufficient) indication for the point of view of the story teller and answers given.
7	Safety	17	10	11	10	Yes	The personal lesson provides useful information for all the readers of FlightStory data.
35	OPC	14	10	11	10		This question addresses a required Operational Performance Condition.
37	OPC	14	10	11	10		This question addresses a required Operational Performance Condition.
38	OPC	14	10	11	10		This question addresses a required Operational Performance Condition.
42	OPC	14	10	11	10		This question addresses a required Operational Performance Condition.
45	OPC	15	10	11	9		This question addresses a required Operational Performance Condition.
8	Safety	14	10	10	9		The suggested KLM lesson provides useful information for KLM managers.
39	OPC	14	10	9	10		This question addresses a required Operational Performance Condition.
3	Design	12	10	8	7		A minimal set of data items is requested to identify the flight and aircraft type.

4	Safety	12	10	8	9	Yes	The question and considerations to solicit the story from the flight crew gives effective guidance to the flight crew to tell a story that others can learn from.
16	Safety	13	10	8	7		The answer to this question provides useful data to learn about variant flying issues.
36	OPC	14	10	8	9		This question addresses a required Operational Performance Condition.
44	OPC	14	10	8	10		This question addresses a required Operational Performance Condition.
46	OPC	11	10	8	10		This question addresses a required Operational Performance Condition.
47	OPC	11	10	8	10		This question addresses a required Operational Performance Condition.
33	OPC	12	10	7	10		This question addresses a required Operational Performance Condition.
41	OPC	14	10	7	10		This question addresses a required Operational Performance Condition.
53	Safety	13	10	7	9		These questions address the possible reasons for the existence of fatigue for this event.
6	Design	7	10	6	10		Free-format keywords provide a more accurate categorisation than when the user has to select from a pre-defined list.
24	tri-arc	11	10	6	10	Yes	This tri-arc allows the user to express information resources used for the handling of this event.
40	OPC	14	10	6	10		This question addresses a required Operational Performance Condition.
18	tri-arc	12	10	5	9		This tri-arc allows the user to express the balance between Safety Cost and Customer for this event.
19	tri-arc	9	10	5	10		This tri-arc allows the user to express the source of the disturbance or threat for this event.
25	tri-arc	12	10	5	10	Yes	This tri-arc allows the user to express the resilience and control aspects of this event.
34	OPC	11	10	5	10		This question addresses a required Operational Performance Condition.
5	Design	9	10	4	7		The request for a descriptive title after the story has been told will ensure a title that fits the story.

14	Safety	7	10	3	10		The emotional state of the flight crew submitting the FlightStory provides a useful (but not sufficient) indication for the point of view of the storyteller and answers given.
23	tri-arc	7	10	3	10	Yes	This tri-arc allows the user to express the critical competencies for this event.
26	tri-arc	12	10	3	10		This tri-arc allows the user to express who should learn from this event.
43	OPC	11	10	3	10		This question addresses a required Operational Performance Condition.
20	tri-arc	10	10	2	10	Yes	This tri-arc allows the user to express the complexity of this event.
21	tri-arc	6	10	1	10	Yes	This tri-arc allows the user to express the resilience and control aspects of this event.
22	tri-arc	4	10	1	10	Yes	This tri-arc allows the user to express the resilience and control aspects of this event.
51	Risk	0	10	0	10		It is informative to compare the risk rating differences between the crew assigned risk and SCO assigned risk.
52	Accident Cat	0	10	0	10		This flight crew judgement about a credible accident scenario (helpful in connecting bowties to the stories) is more accurate than a judgement made by an event or risk analyst in the safety office.
9	Safety	2	10	-1	7		This are sufficient and required criteria for sharing a large list of FlightStories.
15	Safety	3	10	-1	10		This answer by the flight crew submitting the FlightStory provides a useful (but not sufficient) indication for the emotional impact the event had on the flight crew, which helps to judge the severity of the event.
50-A	BowTie	5	10	-3	9		This set of bowtie elements provides useful data to review the completeness of the bowties as designed by the SCO.
57-A	Perf	-5	10	-6	9		The ratio of the actual performance and the potential performance gives useful data about the safety improvement that can be made and the importance of the lessons learned.
56	Perf	-4	10	-7	10		The pilot's expert judgement about the potential safety

							performance for this kind of event KLM is useful data.
57	Perf	-5	10	-8	10		The pilot's expert judgement about the actual safety performance for this kind of event KLM is useful data.

Table 6-5 FlightStory Experts survey data

Some remarks about the results in the table:

- The results show that the categories of OPC have received a high score, which means the experts' advice these questions to be part of future developments.
- The highest ranking in the FlightStory score is the question asking the flight crew to give the personal lesson of the story event.
- All the tri-arc questions have also a positive advice to be a part in ASR 2.0
- Some tri-arc questions are more preferred than others.
- The design questions are also related to the content of the question and not only the design of the form. Some form design remarks were made in the free text responses from the experts.
- The three performance type of questions have received the lowest score. While this question addresses the capacity to maintain a safe situation, which is a new framing of safety, the score is low. I think the combination with potentiality and actuality in the question created confusion about what it was about. I would test this question in a different format with more explanation of the type of the desired answer in a next iteration.

The topic of objectivity versus subjectivity is mentioned 14 times in the expert judgement remarks such as "Quite subjective, what one considers as high can be seen by others as low." and "Subjectiveness of this item might be considerable.". In most cases, when this is addressed, subjectivity is seen as negative or problematic and the answers are often to disagree. This seems in tension with the highest score of the question posed in the FlightStory app about the personal lesson that the flight crew draws from the event. The topics where some experts assume a correct or more accurate value judgement or calculation can be made, subjectivity can be problematic. Especially in remarks of the lowest scoring questions about safety performance, remarks are made about the problem of subjectivity. The experts do not rate the flight crew who fill out a FlightStory as experts for this kind of judgements. Maybe in their view, a flight crew is not automatically a risk analyst, and that statement would make some sense.

Some remarks are made that a trained investigator can make better judgements about questions such as probable accident category, the relevance of a story, and the reason for a response at a particular position in a tri-arc question. This expert judgement might be correct if the trained investigator was on the particular flight and had the same information as the crew. Since this is not the case and the investigator in the office with only an ASR, or even with a FlightStory, the investigator lacks contextual information and has to make a judgement based on limited data.

Several respondents remarked about the tri-arc questions that the information is important for safety management but there was a concern that these questions might take too much time for the flight crew to answer them.

Some remarks were made related to the design of the FlightStory form:

- Some question statements are rated as Disagree or Strongly Disagree but the question should still be in ASR2.0. This means the question is ok but it should be asked in a better way.
- A free format keyword is seen as problematic:" This might need a trial phase. I can't tell how many descriptions will be used. The more there are, the less useful in my opinion."
- Some answers seemed to assume FS would remain a separate reporting tool: "To much detail for a 'simple' ASR but useful for an in-depth FlightStory", "This is a typical question for FlightStory and not an ASR. For filing or reporting an ASR, the tools are already in place to share your feelings.". The specific questions at which these remarks were made were not recommended as part of ASR 2.0.
- Several remarks were made about the length of time required to fill out a FlightStory. One respondent made explicit that an ASR2.0 should be quick and short on European flights with sometimes 4 stretches a day.

Some remarks revealed the experts did not fully consider the features and potentials of the FlightStory analysis dashboard and the possibilities of modern software analysis tools. I had added a link to a video about the FlightStory analysis dashboard that I had built, but we had not further discussed the possibilities of analysis techniques.

6.9.3 Responses from experts and managers about FlightStory support for learning loops

It took little effort to get cooperation from the experts. I had spoken to 14 experts, and 13 delivered their responses. Several emails and online meetings were needed to get sufficient cooperation from both the safety and flight operations departments. Although there was sufficient interest, the situation in the company due to the COVID pandemic required a lot of their time and attention. In the end, 3 safety managers and 4 Flight Operations managers completed the survey.

The invitation to complete the survey was sent to managers in the safety department, the Flight Operations department, training and safety experts. All invitations included a PowerPoint presentation and a link to a video with explanatory material and a demonstration of the analysis dashboard which held actual FlightStory data submitted by regular pilots executing regular passenger flights during the experiment period. In the event of doubt, the participants were invited to call me. I spoke to 18 of the 20 respondents to explain the purpose of the survey.

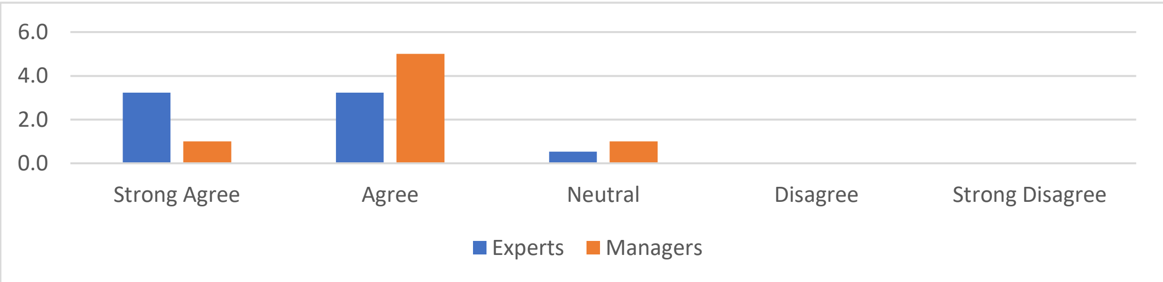
Demographics of the respondents:

Type	Function / Role	Invited	Total respondents	Flight crew	Years in company avg (std dev)	Years in relevant role avg (std dev)
Experts	Training	5	4	4	26.3 (5.6)	12.2 (5.6)
	Business Flight crew Safety	3	3	3	24.3 (4.0)	7.7 (4.7)
	Risk Analysts	6	6	4	19.2 (8.4)	8.8 (6.9)
Managers	Flight Operations department	19	4	4	21 (5.2)	10.7 (5.7)
	Safety department	6	3	2	22.7 (10.2)	6.3 (2)

Table 6-6 FlightStory respondents demographics

All the participants agreed with the ethical aspects, but one manager stated that he was not sufficiently informed about the purpose of the survey.

Q1: Statement:
FlightStory collects 'warm' (human) rich data that provides insight into the sensemaking of the flight crew and how they viewed and understood the interdependencies between event facts to provide a systems view of the event more effective than ASR 1.0, TR and FDM.

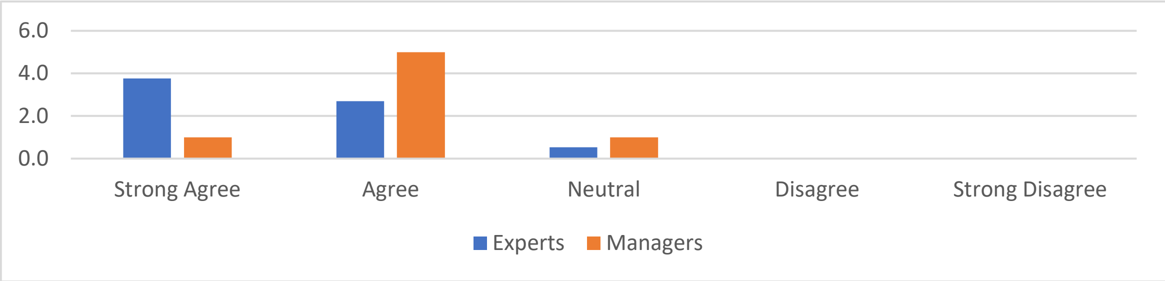


Thematic analysis:
R2 is concerned with the willingness to report, not just the willingness to fill out a FlightStory.
S2 refers to the differences in reporting system and that Flight Data Monitoring is very different from reporting personal experiences.
The others mainly agree about the benefit of collecting personal flight crew experiences and opinions as compared to the ASR, which is mainly factual

The answers to this question are relevant for: RQ 1.1 A, B, C, D, E

Q2: Statement:

FlightStory offers suggestions, free text keywords and personal lessons learned, supporting the flight crew to tell his story in such a way that others can learn from it, more effective than ASR 1.0, TR and FDM.



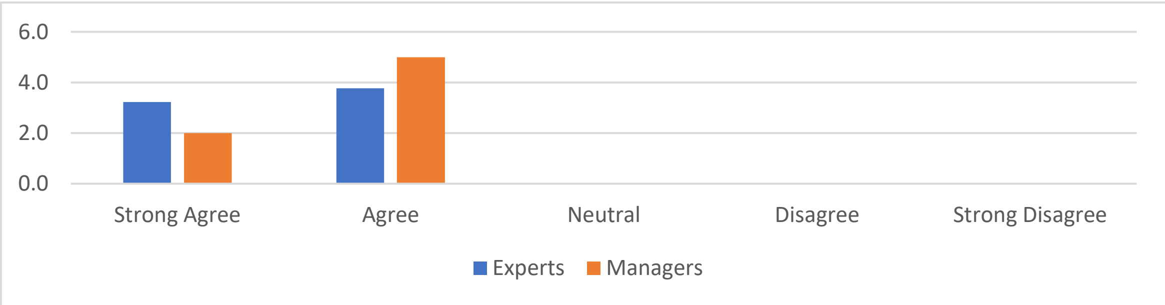
Thematic analysis:

Some remarks are made in agreement with the statement such as: the relevance of context, crew perspective, self-reflection. These are reporting topics that FlightStory enables in contrast to the current ASR and TR.

A remark for the neutral judgment is the similarity that an Event Analyst should give the correct labels.

The answers to this question are relevant for: RQ 1.1 A, B, C, D, E

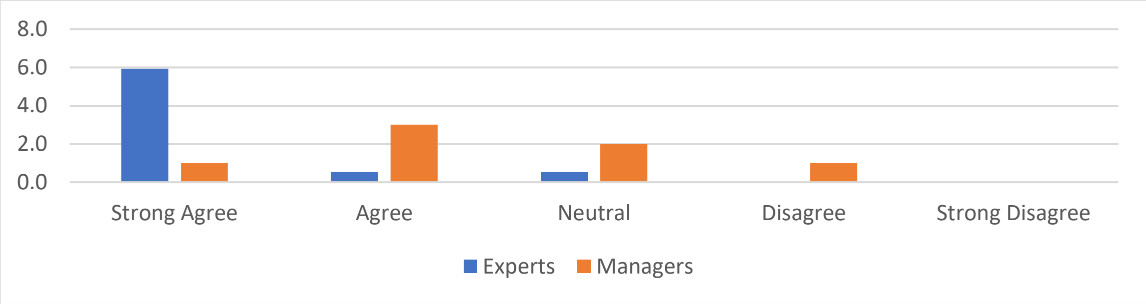
Q3: Statement:
FlightStory supports the flight crew to give his judgement about Operational Performance Conditions
more effective than ASR 1.0, TR and FDM.



Thematic analysis:
All are in agreement. Some remarks are made that the current reporting is not made for collecting OPC. One remark concerns the correctness of the flight crew judgement of the OPC and that a verification might be required before the data is shared.

The answers to this question are relevant for: RQ 1.1 A,B,C,D,E

Q4: Statement:
By sharing (via mPilot) the stories and lessons learned, FlightStory provides learning opportunities for other FLIGHT CREW from operational events more effective than ASR 1.0, TR, and FDM.

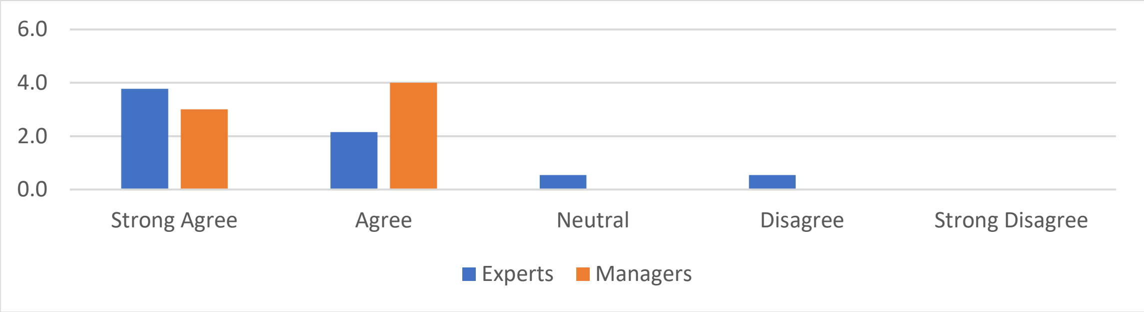


Thematic analysis:
This question has some more spread in the agreement with the statement. A disagree, a neutral and one agree judgement are based on the argument that the story text might be too comprehensive for the most flight crew.
Two are concerned with the possibility the crew might draw conclusions that are valid for them but wrong or undesirable from a manager's perspective.
Most experts strongly agree and provide arguments for their judgement, such as . “In an ultra-safe system, there is only so much one can experience oneself, reading stories about how other crew struggled or succeeded in dealing with a particular safety issue is helpful. It identifies knowledge gaps and possibly best practices how to deal with similar situations. Current feedback mechanisms require active time investment of crew to look up ‘share your experience’ stories that are easily hidden in the amount of irrelevant information distribution by modern communication tools. Lessons learned should be brought to crew in an easily accessible form, such as the FlightStoryBook, i.s.o. logging into a company's portal and getting lost in an extreme amount of other and notably outdated information. When the amount of FlightStories increases, the presentation may require further thought to ensure that relevant stories remain quickly accessible.”

The answers to this question are relevant for: RQ 1.1 B

Q5: Statement:

By filling out the questions (such as the story, the critical events, the lessons learned, the operational strategies (tri-arcs), the Performance Conditions) in a FlightStory, the submitting flight crew(s) are supported in taking a reflective view on their own performance, enhancing their own learning process more effectively than ASR 1.0, TR and FDM.



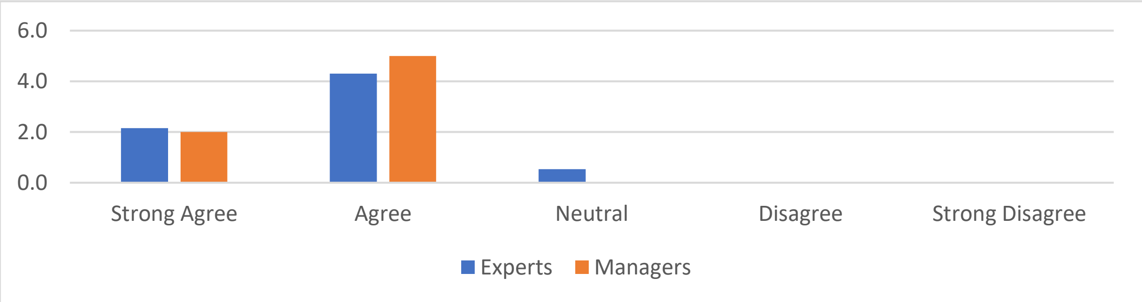
Thematic analysis:

Most are in agreement. Remarks are made about the mainly factual statements in the ASR, which lack context and sensemaking. Remarks were also made about the guidance the FlightStory form and sequence of questions gave to the flight crew to reflect and include factors in the report that might have been omitted if FlightStory did not address them. The disagreeable judgement is based on the suggestion that the line of thinking of the flight crew might not follow the way the questions are asked. The neutral judgement says that it's hard to tell and that it depends on the flight crew.

The answers to this question are relevant for: RQ 1.1 A

Q6: Statement:

FlightStory provides the data for training experts to find learning opportunities for FLIGHT CREW TRAINING
more effective than ASR 1.0, TR and FDM.

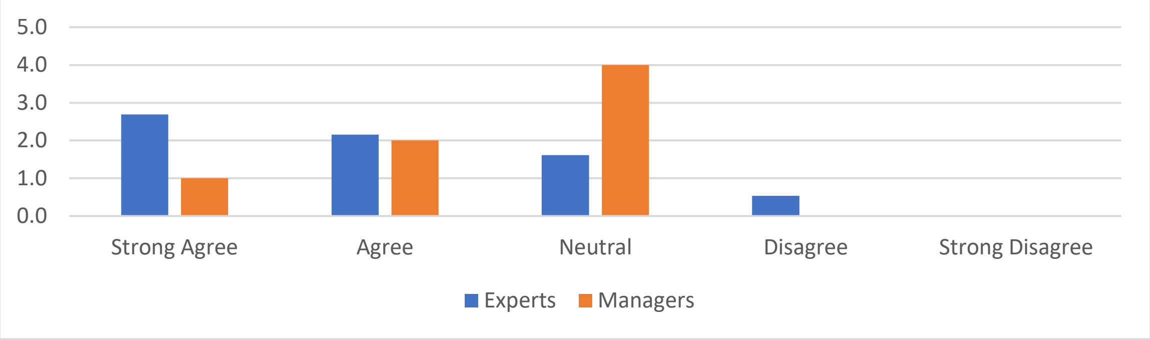


Thematic analysis:

Most agree that flight crew training can benefit from FlightStory data. Some say training topics are easier to find; others say the sensemaking information is useful for training development.

The answers to this question are relevant for: RQ 1.1 C

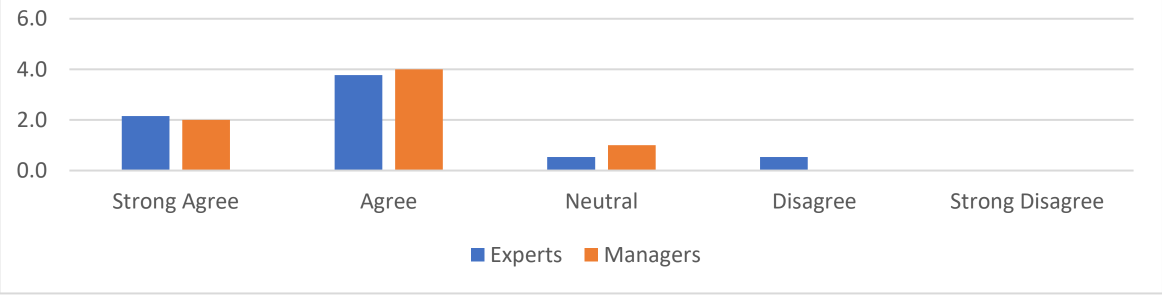
Q7: Statement:
FlightStory provides the data for Business Pilots Safety and supports Flight Operations Management in improving operational support for flight operations more effective than ASR 1.0, TR and FDM.



Thematic analysis:
Most experts agree that flight operations management can benefit from FlightStory data, in particular the business pilots who's job it is to inform Flight Operations managers. However, the managers are less convinced about the benefit than the experts. The disagree statement is related to the current lack of a process to implement the FlightStory data in the safety meetings. Some respondents who answered neutral indicated that FlightStory is just one of the data sources used by Flight Operations management.

The answers to this question are relevant for: RQ 1.1 D, E

Q8: Statement:
FlightStory provides the data items for Flight Operations Managers as well as for other Managers of operational departments to learn from operational events more than ASR 1.0, TR and FDM data.

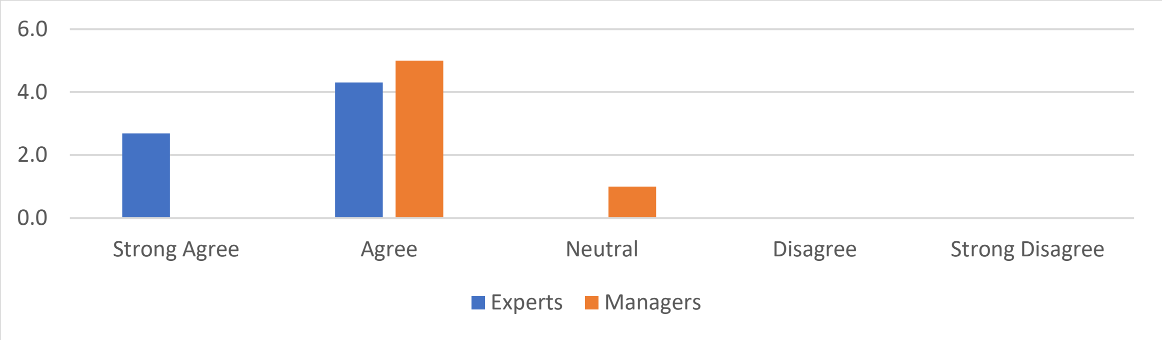


Thematic analysis:
Most agree that flight crew training can benefit from FlightStory data. The disagree judgement is based on the lack of integration of FlightStory in the current work processes and the current low number of submitted FlightStories. A remark is made about how FlightStory can show the difference between Work-As-Done and Work-As-Imagined and how beneficial this is for managers who think flying is just following the procedures in the book. Some remarks are made that outside the Flight Operations department readers may not fully understand the story from the flight crew perspective.

The answers to this question are relevant for: RQ 1.1 D

Q9: Statement:

FlightStory provides data for Risk Analysts, Safety Consultants, and Safety Management System processes to learn more from operational events than can be learned from ASR 1.0, TR and FDM data.

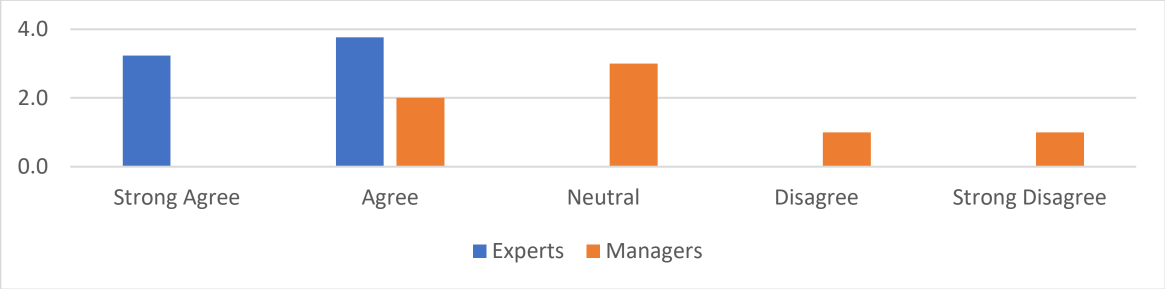


Thematic analysis:

Nearly all respondents agree that Safety Management can benefit from FlightStory data and refer to the benefit of contextual info. The neutral response states that Risk Analysts and Safety Consultants do not need to learn. This remark is maybe triggered by the format and syntax of the question because the respondent agree FlightStory is a more elaborate source of data. One expert suggests FlightStory data can collect Safety-II data.

The answers to this question are relevant for: RQ 1.1 E

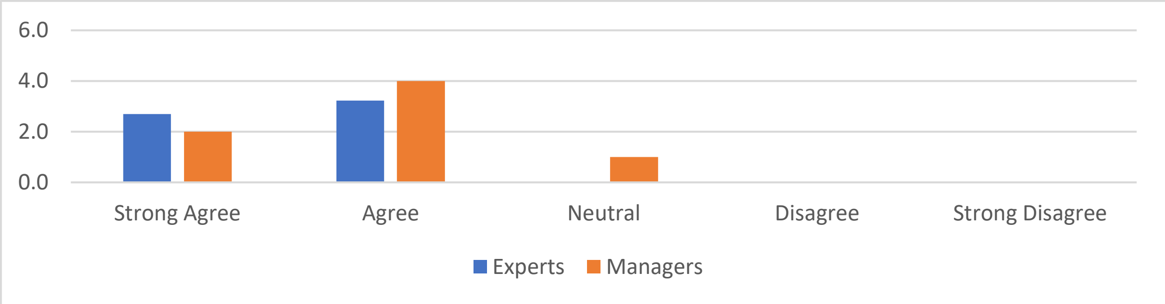
Q10: Statement:
FlightStory provides more actionable data, for Flight Operations Managers as well as for other Managers of operational departments than ASR 1.0, TR and FDM data. Actionable data provides immediate and specific insight and guides decision making and can be acted upon.



Thematic analysis:
Most experts agree Flight Operations managers will receive more actionable data from FlightStory data. It is interesting to see the managers seem to have less agreement.
The Strongly disagree judgement is based on an argument that decision making should follow the SMS process.
The disagree statement is more principled by stating that data should always be interpreted and this is no different for FlightStory data.
A neutral judgement by a manager respondent stresses that FlightStory provides other actionable data and not necessarily more actionable data.
A manager's neutral judgement is explained by: “As FS gives more opportunity to enter more subjective data, it can also be “tainted” by random personal events which perhaps do not institute a trend. As a manager, my job is to observe trends and act upon them where necessary. FS must have much data entered to avoid one-off events becoming events which create un-proportional follow up. The other refers to the requirement to have a trend in data before action is needed.”

The answers to this question are relevant for: RQ 1.1 D

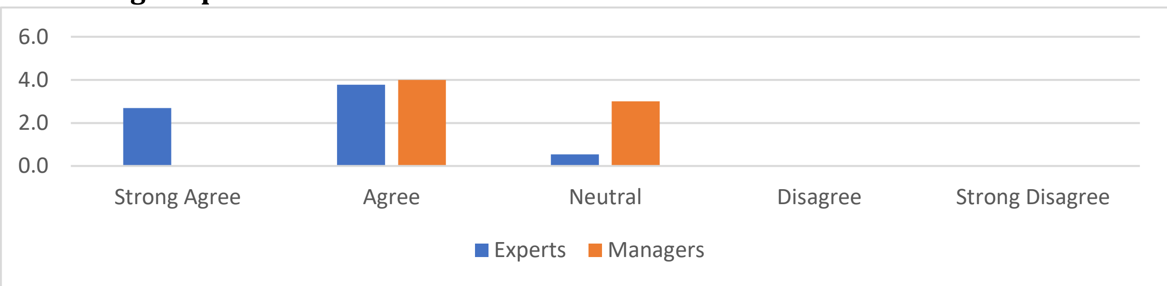
Q11: Statement:
(SCO) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Safety Management to support Flight Operations.
(FO) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Flight Operations.



Thematic analysis:
Nearly all experts agree that OPCs are relevant to both Safety Management and Flight Operations management. One judgement is neutral with the remark that a judgement cannot be made because of unfamiliarity. Few comments are made, but one expert explains why OPC data is important and stresses that FlightStory is the only tool that collects this data in a systematic way.

The answers to this question are relevant for: RQ 1.1 D, E

Q12: Statement:
(SCO) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Safety Management to support Flight Operations.
(FO) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Flight Operations.

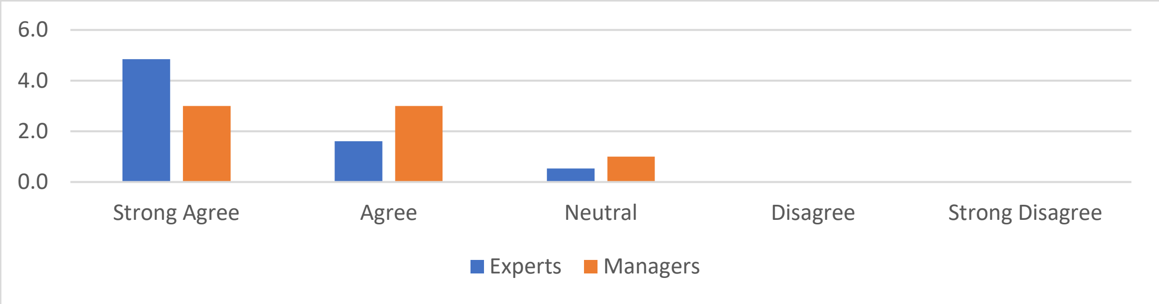


Thematic analysis:
Most experts agree that the Operational Strategies captured with the tri-arcs are important. The experts are more convinced than the managers. A possible explanation for this difference is the unfamiliarity of the managers with the theoretical underpinning of the Operational Strategies. However, these remarks do not support or refute this hypothesis. No negative remarks are made about the graphical properties of the question type.

The answers to this question are relevant for: RQ 1.1 D, E

Q13: Statement:

We should implement the lessons from the FlightStory project in e.g. ASR 2.0.



Thematic analysis:
Nearly all agree that the lessons from FlightStory should be used for further reporting developments. Several remarks are made about the process of filling out a FlightStory, such as "hassle-free and quick to fulfil.".

The answers to this question are relevant for: RQ 1.1 A, B, C, D, E

Q14: **Please provide any remark you find relevant for this project:**

- I like…

-F1. the concept.
-F2. I like the fact that FlightStory underlines other factors than FDM, ASR 1.0 and TR. I like the dashboard.
-F3 The extra info obtained from Flight Story.
-F4. The reflective part, and more story line of the FS in contrast to the ASR, FDM and TR process.
-S1. The video with explanations, short and to the point.
-S2. Visualisations in the reporting environment are very intuitive.
-S3. - the focus on the human operator, based on the fundamental idea that operations personnel are professionals. - the fact that this project actually adds new knowledge to the field of safety management, and that it has been validated in practice.

-I don't like…

-F1. the feeling that it could be time-consuming for input and output. If we can deal with this, expectations and engagement by and for flight crew could be improved.
-S1. Dash boarding need attention. Now the weighing is done with tri-arcs by the reporter. This is subjective and not independent. I would suspect this has to pass Risk Analysts for validation before an item is actionable for a SAG or management. The current version shows what employees think about an event. This involves a personal judgement. Collected this gives a view of how people in the operation look at things. This is Raw Data. To make it actionable, is has to be filtered by objective criteria.
-S2. The lengthiness of reporting; the opposite is visible in the new seamless flow reporting; make it as hassle-free as possible. FS still requires quite a bit of time.
-F2. The fact that for flight crew, it is time-consuming filling out Flight Story. On the EUR operation, there is hardly time available in between flights. Also, the risk assessment by the crew itself should be taken with a pinch of salt. And the fact that not all key competencies are taken into account (that might, however, make it even more time-consuming to fill out).
-F3. That only very few people have actually used it. The thinking behind is excellent, but the operational part just doesn't match the effort flight crew and managers are willing to put into this.

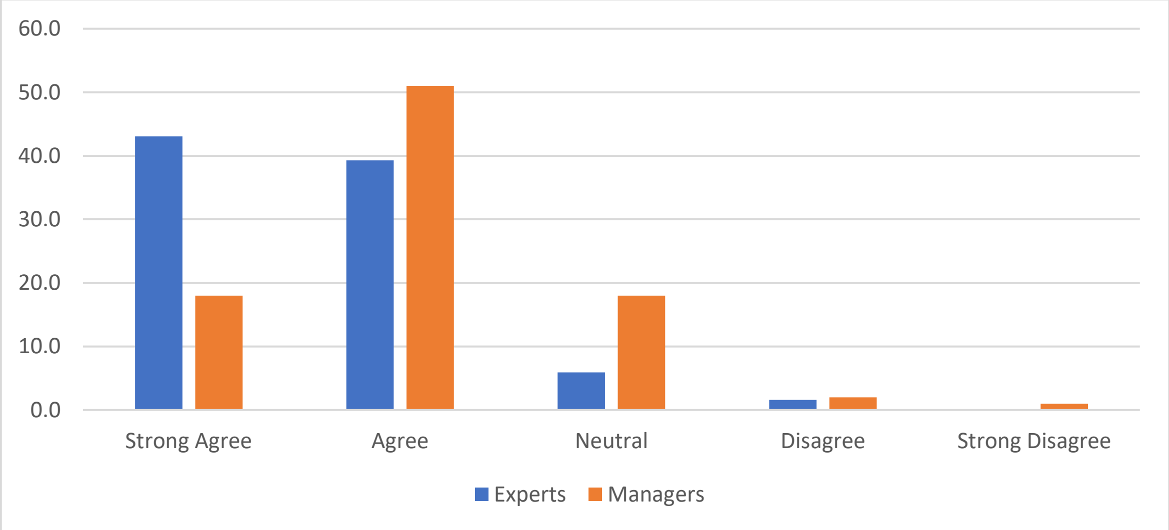
-F4. Multiple reporting lines about the same event.

-Other:
-S1. Nice and complete overview of Safety, Cost and Customer. It connects to the risk framework RAF/RMS, but the data is not analysed and prioritised, this would we a next step.
-T4. I think it's important that all units in FO agree on a united vision of importance of this subject and that it can become a tool for everyone working in FO.
-F3 Reported he was not satisfactory informed about the purpose of the survey.
-F3. I have a lot of respect for Arthur for his limitless efforts to bring Flight Story to a success.

6.9.4 Evaluation of responses: Similarities and differences between experts and managers.

The answers of 13 experts and 7 managers are aggregated into two groups. A pure quantitative analysis of only the Likert scale questions would involve the topics of statistical methods, such as specifics of statistical significance and whether to use parametric or non-parametric methods. When the group sizes of 13, 7 and 20 are combined, some quantification can be argued for. However, most of the respondents have added free text explanations to their Likert scale answers, allowing a richer analysis than just a quantitative one.

Normalised totals of all survey questions



Since this research is executed in an actual airline context and aims to improve and develop feedback from flight crew, the FlightStory intervention is tested, bringing this progress. In the survey questions, the current situation is compared with a new situation where FlightStory is fully implemented.

While taken together, the answers show both groups agree that FlightStory brings progress, the individual answers with the free text remarks allow a more nuanced description of the responses.

Notable similarities in responses:

- The normalised summed totals of each answer show for both groups a high agreement among the respondents that FlightStory will improve the feedback loop.
- Both groups appreciate the context descriptions of events.
- High agreement can be found in question 3 about data about Operational Performance Conditions.
- High agreement can be found in question 6 about data for flight crew training.
- High agreement can be found in question 8 about data for managers of Flight Operations and other operational departments.
- High agreement is about implementing the lessons learned from the FlightStory project in question 13.
- Both groups have concerns about the lengthiness of filling out a FlightStory form and the time to read the stories.
- Both groups refer to the processes of collecting and disseminating feedback data and that FlightStory sharing, as executed by this project, extends the current data analysis and sharing processes.
- Both refer to the gap between Work-As-Imagined and Work-As-Done as revealed by FlightStory and how the stories can explain the why of crew decision-making and actions taken.

Notable differences in responses:

- Some experts refer to the limited knowledge Flight Operations managers have of safety management concepts, such as OPC. Their lack of knowledge could be confirmed by their answer that the FlightStory data does not deliver actionable data. The largest difference between the answers of the experts and managers is about the actionability of FlightStory data in question 10. Obviously, knowledge is required to understand how the FlightStory data concepts can be operationalised into specific topics in Flight Operations. Question 12 with the tri-arcs about operational strategies shows a higher appreciation by the experts, which might be based on their higher expert knowledge of safety concepts than the managers have. On the other hand, experts might not see the organisational consequences of intervention actions, which is why they might be overly optimistic about the possible actionability of FlightStory data.
- The managers refer more often to the processes of safety management for data analysis and dissemination and how FlightStory goes partly outside these established processes. The sharing of stories directly without workload for the Safety Department is not referred to as an efficient method for learning.
- Some experts have made remarks about their preference to receive a lower volume of reports (such as FlightStories) with high informational content than more reports with little informational content such as many ASRs. These remarks

are made because there is scepticism against a Safety Management target of increasing numbers of submitted ASRs.

- Although I stated in the introduction that the respondent should consider enough new FlightStories every month, some used the low number of FlightStories received during the trial as an argument to be less optimistic about the potential benefits.
- In both groups' responses, reference is made to the property of FlightStory that it presents a subjective point of view. While there is an appreciation of the flight crew member presenting his or her point of view, there is also a concern. That concern is mostly expressed by the managers. Some remarks in this group seem to indicate a more positivist worldview, where it is possible to determine the correct aspect of the story. It is then suggested that the correct view, classification or judgement is not determined by the flight crew but by people in the Flight Operations or Flight Safety department.

Table with references to others than the flight crew for validation or verification of the FlightStory data:

Experts	Managers
To my opinion 'free text' keywords is similar to current ASR/TR reporting. It is up to the Event Analyses to give the correct labels. What a flight crew thinks is important does not always have to be safety-wise important.	Agree, because of the factors mentioned in statement 2. However, in my opinion, the organization has a responsibility to 'check' the judgement since the FlightStories are published 'unfiltered' on mPilot. Again, it does provide learning opportunities, but are there chances that crew's perception, however true that is to that crew, is too coloured and gives the wrong conclusions and thus 'negative learning'? As FS gives more opportunity to enter more subjective data, it can also be "tainted" by random personal events which perhaps do not institute a trend. This would suggest that an analysed risk is determined without the SMS involved in prioritising and ready is for assessment by SAG. Now the weighing is done with tri-arcs by the reporter. This is subjective and not independent. I would suspect this has to pass Risk Analysts for validation before an item is actionable for a SAG or management.

Each group has their expertise, role and responsibility and therefore a complete overlap should not be expected. The differences could be a reason to have a group conversation but that is beyond the scope of my single iteration of this research.

The bottom line for this research is that FlightStory provides a positive development and they agree the lesson should be used for improving current reporting methods.

6.9.5 Evaluation of actual FlightStory data

The FlightStory version 1 trial resulted in 25 submitted FlightStory forms. I have no data showing that a pilot submitted more than one FlightStory. The FlightStory version 2 project resulted in 23 submitted FlightStory. Data shows two pilots each submitted 2 FlightStories.

The sections below show the useful themes and types of lessons that can be extracted from FlightStory data. Flight crew training in terms of the Advanced Qualification Program, can benefit from FlightStory data because the pilot statements provide valuable insights into real-world experiences and challenges faced by flight crew, which can be used to enhance and customize training programs. By analysing these statements, airlines can identify areas for improvement and tailor their AQP training to address specific operational needs.

6.9.5.1 Thematic analysis of FlightStory keywords

The 48 submitted FlightStory provided a list of free-format keywords. Every FlightStory got at least one keyword and most got three keywords. In total 120 keywords were given resulting in the following themes:

1. Automation, Technology, and Equipment:
    - Autopilot, LNAV, FMS faults, TCAS, EGPWS, cockpit layout, and maintenance-related issues.
2. Environmental Awareness:
    - Turbulence, gust, windshear, weather forecasting, runway conditions, and weather-related risks.
3. Crew Resource Management and Workload:
    - Workload, fatigue, rest schedules, focus, and cabin crew coordination.
4. Communication, Coordination, and Decision-making:
    - ATC interaction, ground personnel coordination, information sharing, and risk management.
5. Training, Standard Operating Procedures, and Human Factors:
    - Adherence to SOPs, effective communication, skill development, and human error management.

These themes map well, which shows consistency, with the following lessons as suggested by the flight crew submitting a FlightStory.

6.9.5.2 Lesson for the organisation

20 of the 23 pilots answered the FlightStory version 2 form question: “What should KLM learn from this event? What should be done differently next time?”.

After analysing the statements made by the airline pilots, I have identified several key themes that emerge as potential areas for organizational learning and improvement within the aviation safety domain. These themes are:

These themes are related to organizational activities such as training, operational support, and resource provision:

6. Training and skill development:

- Enhancing the realism and relevance of training scenarios to better match real-life experiences.
- Providing training on specific technical aspects, such as GS interceptions and upset/UAS recovery.
- Incorporating CRM training that focuses on leadership, minimizing distractions, and clear communication.

7. Operational support and communication:
    - Improving coordination and communication between different teams, such as flight and ground crew, dispatch, and maintenance.
    - Ensuring relevant information is shared with and accessible to all parties involved in the operation, including digital communication tools and documentation.
8. Resource provision and management:
    - Providing necessary resources, such as aircraft maintenance manuals (AMMs) and bus equipment lists, to support decision-making and problem-solving.
    - Ensuring the accuracy and reliability of critical documents, such as load sheets and runway surface condition matrices.
9. Risk management and decision-making support:
    - Encouraging proactive identification and mitigation of potential safety risks, such as challenging destinations, weather variances, and critical equipment status.
    - Supporting flight crew assessments and providing guidance on risk management decisions.
10. Crew resource management and awareness:
    - Reinforcing the importance of crew roles, responsibilities, and vigilance during different flight phases.
    - Encouraging awareness of geographical position, threat factors, and the importance of double-checking relevant data.
11. Organizational learning culture:
    - Fostering an environment that encourages continuous learning and improvement, based on feedback from pilots and other crew members.
    - Implementing changes to improve aviation safety and operational efficiency in response to lessons learned from pilots' experiences.

By addressing these themes, the organization can learn from the pilots' experiences and implement changes that will contribute to improved aviation safety and overall operational efficiency.

6.9.5.3 Lessons for flight crew

23 of the 23 pilots answered the FlightStory version 2 form question: "What lesson do you take away from the event? What would you do differently next time?

After analysing the statements made by the airline pilots regarding the lessons, they learned from the events they experienced, I have identified several key themes that can serve as valuable insights for pilots themselves. These themes are:

1. Situational awareness and anticipation:
    - Expecting the unexpected and being prepared for various contingencies.
    - Considering factors such as cabin crew rest periods, fuel distribution, and aircraft limitations.
2. Communication and collaboration:
    - Maintaining open communication with all parties involved, including ground staff, dispatch, and cabin crew.
    - Being proactive in discussing potential issues, such as contingencies on arrival or adverse weather.
3. Decision-making and critical thinking:
    - Trusting instincts and intuition when faced with uncertain situations.
    - Weighing the risks and benefits of different courses of action, such as fuel reserves and diversion planning.
4. Technical knowledge and understanding:
    - Continuously learning and understanding aircraft systems, limitations, and procedures.
    - Recognizing the importance of knowing and applying the guidelines from the FCOM and other resources.
5. Stress and workload management:
    - Acknowledging the impact of stress on decision-making and performance.
    - Focusing on the task at hand, such as checking take-off performance, without letting external factors like time pressures interfere.
6. Self-reflection and personal growth:
    - Reflecting on personal limitations and areas for improvement.
    - Identifying opportunities for growth, such as speaking up as a second officer or improving communication during high-stress situations.
7. Adherence to procedures and safety protocols:
    - Following established procedures and making use of available resources, such as the Non-Normal Situations (NNS) tool.
    - Ensuring proper cockpit preparation and double-checking performance data, even during seat changes or other transitions.

By focusing on these themes, pilots can apply the lessons learned from their experiences to improve their individual performance and contribute to overall aviation safety.

6.9.5.4 Safety, economy and customer thematic analysis

Based on the keywords and lesson statements provided by the pilots, we can analyse and categorize the themes into safety, economy, and customer satisfaction. Here's a thematic analysis of these three key areas:

Safety:

- Training: Emphasis on adequate training and continuous learning, including handling emergency situations, automation dependency, and effective communication.
- Standard Operating Procedures (SOPs): Adherence to SOPs and incorporating lessons learned to improve safety-related procedures.
- Crew Resource Management (CRM): Enhancing teamwork, coordination, and communication among crew members to manage workload and ensure safety.
- Automation and Technical Issues: Addressing issues related to autopilot, LNAV, FMS faults, EGPWS, TCAS, and other systems to ensure safe and reliable aircraft operation.
- Weather Awareness: Improved understanding and management of weather-related threats such as turbulence, windshear, icing, and low visibility conditions.
- Fatigue and Workload Management: Ensuring that crew members are well-rested and that workload is manageable to prevent human errors and safety lapses.

Economy:

- Fuel Efficiency: Optimizing fuel consumption through accurate fuel distribution, proper loading, and efficient flight planning.
- Maintenance and Dispatch: Streamlining communication and coordination between ground staff, maintenance, and flight crews to minimize delays and optimize aircraft availability.
- Resource Management: Ensuring optimal utilization of resources, such as aircraft, crew, and ground support equipment, to maximize operational efficiency.
- Decision-making: Enhancing decision-making processes to balance safety, operational efficiency, and customer satisfaction.

Customer Satisfaction:

- Communication: Improving communication between flight crew and passengers, particularly in situations involving delays, diversions, or other disruptions.
- Cabin Comfort: Ensuring a comfortable cabin environment by addressing issues related to temperature control, cabin lighting, and public address systems.
- Flight Experience: Enhancing the overall flight experience by reducing distractions, managing workload, and providing a smooth, safe journey for passengers.
- Timeliness: Reducing delays and cancellations through efficient resource management, better coordination between departments, and proactive handling of potential issues.
- In summary, the thematic analysis of the keywords and lesson statements highlights the importance of addressing safety, economy, and customer satisfaction as interconnected aspects of airline operations. By learning from

these insights, the airline organization can continue to optimize its performance and create value for all stakeholders.

This analysis shows FlightStory data provided by pilots addresses the three key factors for value production.

6.10 Answers to research questions

To answer the research question, the flight crew, experts, and managers' surveys must be combined, therefore questions related to a specific part of the research question are grouped.

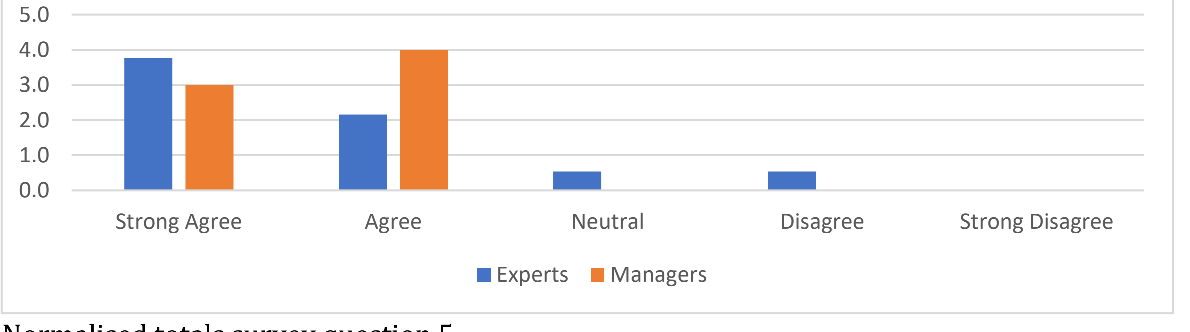
I will argue that the results of the evaluation lead to level 3 and 4 strength of evidence (see Chapter 5) claims about the efficacy of the FlightStory intervention. The survey questions were designed to answer the research questions and to find lessons for practice and add knowledge to the scientific domain.

6.10.1 RQ1.1 A: How does FlightStory support flight crew self-reflection and evaluation?

To answer this research question, the answers to the specific questions below by the experts and managers can be used.

A: FlightStory improves the flight crew own learning loop.

By filling out the questions (such as the story, the critical events, the lessons learned, the operational strategies (tri-arcs), the Performance Conditions) in a FlightStory, the submitting flight crew(s) are supported in taking a reflective view on their own performance, enhancing their own learning process more effectively than ASR 1.0, TR and FDM.



Normalised totals survey question 5

- Most are in agreement. Remarks are made about the mainly factual statements in the ASR which lack context and sensemaking. Remarks are also made about the guidance the FlightStory form and sequence of questions give to the flight crew to reflect and include factors in the report that might have been omitted if FlightStory did not address it.
- The disagree judgement is based on the suggestion that the line of thinking of the flight crew might not follow the way the questions are asked.
- The neutral judgement remarks that it is hard to judge and very personal for each flight crew.

Nearly all respondents confirmed the claim in the statement. The Disagree judgement has a remark describing a possible situation where "The way questions are asked do not necessarily follow the line of thinking of the concerned flight crew." Unfortunately, this argument does not explain why flight crew learning does not occur when the questions do not match the line of thinking. Neither does the remark explain why ASR can provide more reflection and learning.

18 answers of the 20 respondents confirm that filling out of a FlightStory form helps the flight crew to reflect and evaluate his handling of the event and thereby supports learning. FlightStory is therefore an improvement of the current reporting practices.

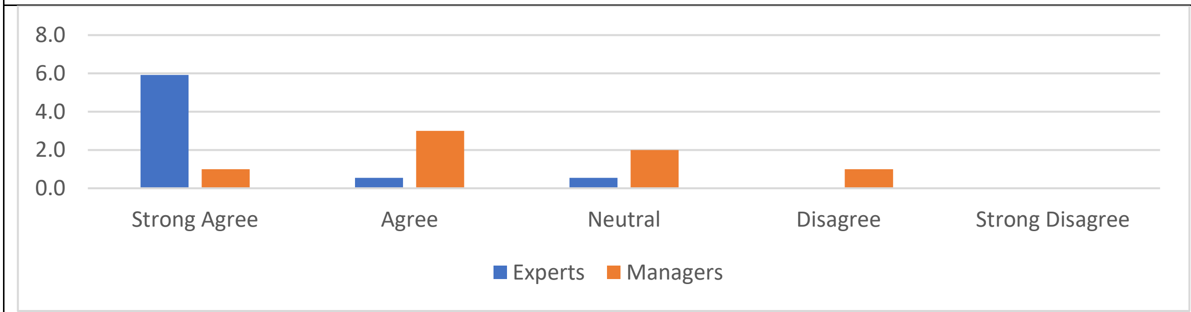
The thematic analysis of the FlightStory data provides evidence for the claim and the analysis provides types of lessons the flight crew identified themselves.

This answer can be argued to have descriptive, theoretical, indicative and causal levels of strength of evidence. The fact that FlightStory was operational, that the respondents have read the stories and that some of the experts have written a story a causal level of strength can be claimed.

6.10.2 RQ1.1 B: Does FlightStory support flight crew to flight crew learning?

To answer this research question two data sources are available. The experts' and managers' survey addresses the research question directly. This group of 20 people consists of 18 flight crew which have direct operational experience and user experience with the FlightStory app the FlightStoryBook with stories. This makes that in total 87 flight crew have provided their responses as shown below.

B: FlightStory improves flight crew to flight crew learning
By sharing (via mPilot) the stories and lessons learned, FlightStory provides learning opportunities for other FLIGHT CREW from operational events more effective than ASR 1.0, TR and FDM.

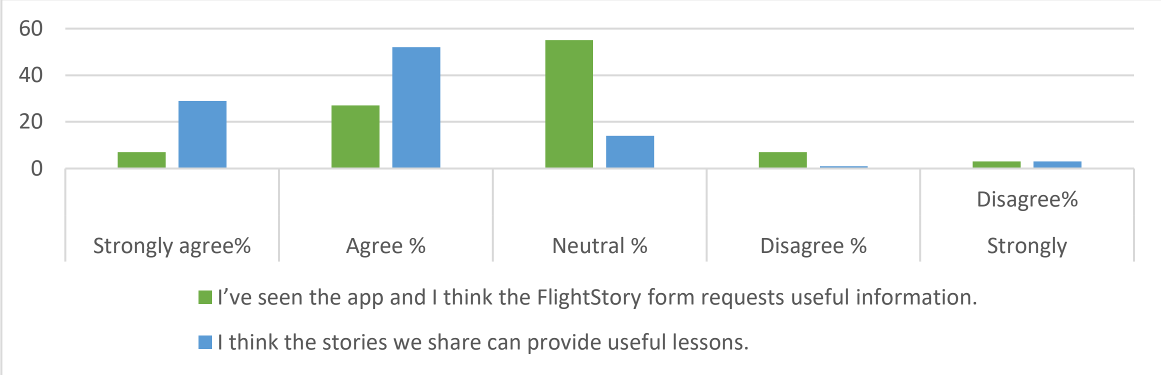


Normalised totals survey question 4

This question has some more spread in the agreement with the statement. The disagree judgement and a neutral are based on the argument that the story text might be too comprehensive for most flight crew.
Some critical manager remarks:

- "Could be, but not sure. It will take time and effort for flight crew to read and understand. Will they take the time for this?"
- "Again, it does provide learning opportunities, but are there chances that crew's perception, however true that is to that crew, is too coloured and gives the wrong conclusions and thus 'negative learning'?"
- Disagree because "Text is too comprehensive; I fear that only very few people would actually read the entire stories every time."

FlightStory flight crew survey. 69 answers.



None of the flight crew has added a useful remark.
Flight crew remarks Useful lessons:

- Several flight crew refer to the Share Your Experience story told by a flight crew about his event, for which he has also submitted an ASR. As a follow up of an ASR, these stories are written on the request of the safety department.
- Some refer to the time needed to read a story.
- Most like to read flight crew stories and lesson learned.
- A Strongly disagree answer is about the unavailability of the stories on his iPad and thus not relevant for this research question. Other Strongly disagree or Disagree have not made a remark.

Both data sources show basically a similar picture which confirms that FlightStory does support flight crew to flight crew learning. The responses to survey question 4 show a high agreement among the experts. The line flight crew survey shows two questions that are relevant for this research question although the second (blue) question is more relevant than the green question. The (green) question about the type of information collected by FlightStory has a high percentage of Neutral answers and about a ratio of three to one that are more in agreement than in disagreement. The more relevant blue question shows a nine to one ratio of agreement that FlightStories can provide useful lessons.

It should be noted that the flight crew answering these questions had actual access to the FlightStoryBook the story-sharing document on the pilots' iPads.

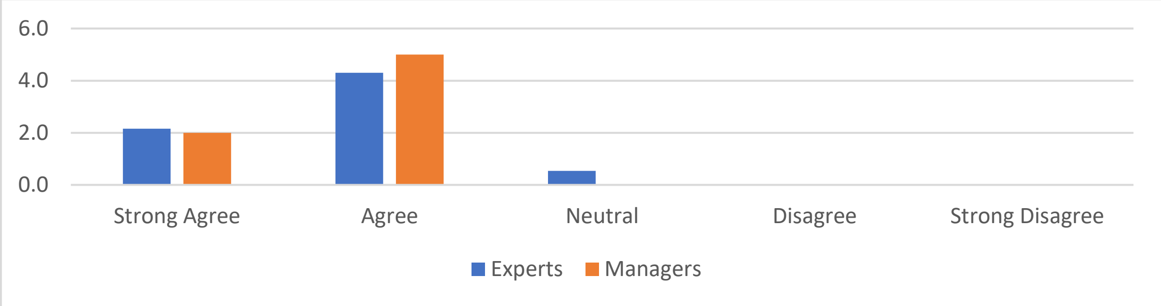
The conclusion is that this research question can be answered in the affirmative that flight crew can, by writing and sharing FlightStories, provide learning opportunities to other flight crew.

This answer can be argued to have descriptive, theoretical, indicative, and very likely causal levels of strength of evidence. The fact that FlightStory was operational, that the respondents had read the stories, and that some of the experts had written stories and agreed to the statement, a causal level of strength can be claimed.

6.10.3 RQ1.1 C: Does FlightStory support flight crew training?

C: FlightStory improves for flight crew training

FlightStory provides the data for training experts to find learning opportunities for FLIGHT CREW TRAINING more effective than ASR 1.0, TR and FDM.



Normalised totals survey question 6

- Most agree flight crew training can benefit from FlightStory data. Some say training topics are easier to find, other say the sensemaking information is useful for training development.
- An expert remarks, low frequency high quality data is better suited to identify conflicting goals or other organizational issues. The first hand assessment of suboptimal performance conditions is preferable to interpret assessment resulting from low-quality reports.
- An expert remarks, "I don't believe that the scenarios derived from FlightStory will be more effective than other sources. I think it would be another effective source. In the end it only matters to talk about the effectivity of barriers (or risk controls) no matter the source or outcome. Also, the fact that the flight story dashboard is currently better suited for providing data in an effective matter than how ASR data is currently presented may have to do with the inadequacy of the current ASR program."

This research question matches the survey question. Two flight crew training experts, who are also flight crew, answer Agree and the other two answer Strongly agree. These experts have also written and read FlightStories, which allow them to be based their survey judgements on actual experience.

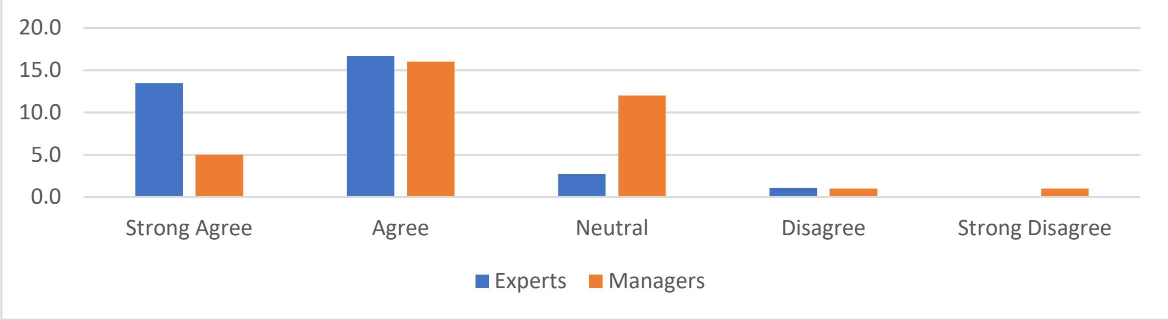
The thematic analysis of FlightStory data show themes that are relevant for training development and especially the Advance Qualification Program for pilot training.

The conclusion is that this research question can be answered in the affirmative that FlightStory provides more effective learning opportunities than current ASR, TR and FDM.

This answer can be argued to have descriptive, theoretical, indicative and very likely causal levels of strength of evidence. The fact that FlightStory was operational, that the respondents have read the stories and that some experts have written a story, and agreed to the statement, a causal level of strength can be claimed.

6.10.4 RQ1.1 D: Does FlightStory support the management of flight operations?

D: FlightStory supports the management of Flight Operations



Normalised totals survey questions 7, 8, 10, 11, 12

- Most agree flight operations management can benefit from FlightStory data in particular the business flight crew whose job it is to inform Flight Operations managers. The managers are less convinced about the benefit than the experts. The disagree statement is related to the current lack of a process to implement the FlightStory data in the safety meetings. Some respondent who answered neutral indicate that FlightStory is just one of the data sources used by Flight Operations management.
- Most agree flight crew training can benefit from FlightStory data. The disagree judgement is based on the lack of integration of FlightStory in the current work processes and the current low number of submitted FlightStories.
- A remark is made about how FlightStory can show the difference between Work-As-Done and Work-As-Imagined and how beneficial this is for managers who think flying is just following the procedures in the book.
- Some remarks are made that outside the Flight Operations department readers may not fully understand the story from the flight crew perspective.
- Most experts agree Flight Operations managers will receive more actionable data from FlightStory data. It is interesting to see the managers seem to agree less. The Strongly disagree judgement is based on an argument that decision making should follow the SMS process. The disagree statement is more principled by stating that data should always be interpreted and this is not different for FlightStory data. A neutral judgement by a manager respondent stresses that FlightStory provides other actionable data and not necessarily more actionable data. The other refers to the requirement to have a trend in data before action is needed.
- Nearly all experts agree OPC are relevant for both Safety Management and Flight Operations management. One judgement is neutral with the remark that a judgement cannot be made due to unfamiliarity.
- Few remarks are made but one expert explains and stresses the need for OPC data and that FlightStory is the only tool that systematically collects this data.
- Most experts agree the Operational Strategies captured with the tri-arcs are important. The experts are more convinced than the managers. A possible explanation for this difference is the unfamiliarity of the managers with the theoretical underpinning of the Operational Strategies. No negative remarks are made about the graphical properties of the tri-arc question type.

To answer this research question, responses to survey questions must be combined. Each of the individual questions is reviewed above.

The first question to consider are the responses to survey question 7: “FlightStory provides the data for Business Flight crew Safety and supports Flight Operations

Management in improving operational support for flight operations more effective than ASR 1.0, TR and FDM." has received mainly agreement.

The second question to consider are the responses to survey question 8: "FlightStory provides the data items for Flight Operations Managers as well as for other Managers of operational departments to learn from operational events more than ASR 1.0, TR and FDM data." has received also received mainly agreement.

The third question to consider is survey question 10: "FlightStory provides more actionable data, for Flight Operations Managers as well as for other Managers of operational departments than ASR 1.0, TR and FDM data. Actionable data provides immediate and specific insight and guides decision making and can be acted upon." has received mainly agreement.

The fourth question to consider is survey question 11: " (Safety Managers) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Safety Management to support Flight Operations. (FO managers) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Flight Operations." has received mainly an agreement

The fifth question to consider is the survey question 12: "(Safety Managers) The feedback about the Operational Strategies (tri-arcs) is very relevant to my role in Safety Management to support Flight Operations. (FO managers) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Flight Operations. "has also received mainly agreement.

Two of the three disagreeing judgements have remarks made by the respondents that are related to the fact that FlightStory is currently not part of the current process and will not fit into some of the current processes. Although the remarks are valid, they are not very relevant to the research question under consideration because the processes can be easily adapted to accommodate the FlightStory data.

Most of the neutral answers are provided in survey question 7, which concerns the Business Pilots Safety. Two of them answered "strongly agree" and the other has answered "agree." This means the others, not being Business Pilot Safety, were not as positive towards FlightStory data as the BPS themselves. This observation reduces the importance of at least five neutral responses for this research question.

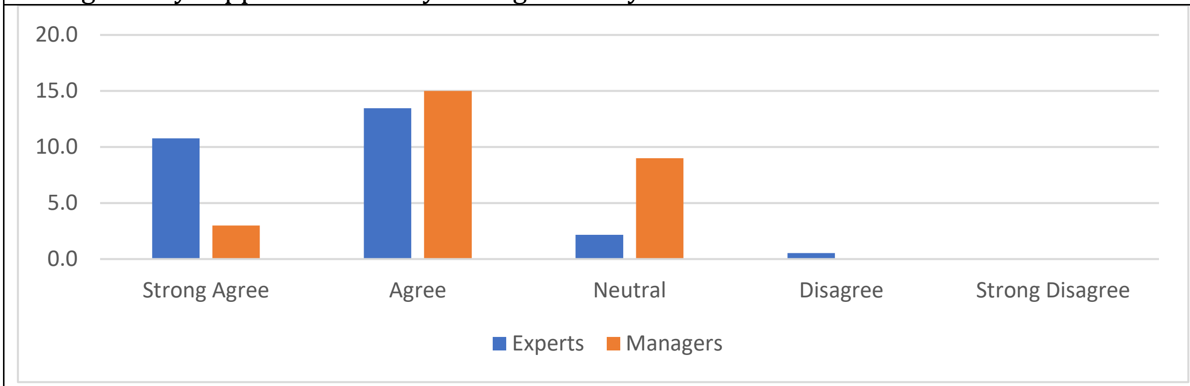
The thematic analysis of the FlightStory data shows lesson for the organisation and issues that are the responsibility of the Flight Operations department. The context, provided by the story, supports actionability on the issues.

Based on the combined survey responses and the arguments provided above, the claim can be made that this research question can be answered in the affirmative, meaning that FlightStory data does support the management of Flight Operations.

This answer can be argued to have descriptive, theoretical, indicative and very likely causal levels of strength of evidence. The fact that FlightStory was operational, that the respondents have read the stories and that some could imagine the benefit of FlightStory data over current practices provides an argument that a for a very likely causal level of evidence.

6.10.5 RQ1.1 E: Does FlightStory support Safety Management?

E: FlightStory supports the Safety Management System



Normalised totals survey questions 7, 9, 11, 12

- Most agree flight operations management can benefit from FlightStory data in particular the business pilots whose job it is to inform Flight Operations managers. The managers are less convinced about the benefit than the experts. The disagree statement is related to the current lack of a process to implement the FlightStory data in the safety meetings. Some respondent who answered neutral indicate that FlightStory is just one of the data sources used by Flight Operations management.
- Nearly all respondents that agree Safety Management can benefit from FlightStory data and refer to the benefit of contextual info. The neutral response states that Risk Analysts and Safety Consultants do not need to learn. This remark is maybe triggered by the format and syntax of the question because the respondent agree FlightStory is a more elaborate source of data. One expert suggests FlightStory data can collect Safety-II data.
- Nearly all experts agree OPC are relevant for both Safety Management and Flight Operations management. One judgement is neutral with the remark that a judgement cannot be made due to unfamiliarity.
- Few remarks are made but one expert explains and stresses the need for OPC data and that Flight5Story is the only tool that systematically collects this data.
- Most experts agree the Operational Strategies captured with the tri-arcs are important. The experts are more convinced than the managers. A possible explanation for this difference is the unfamiliarity of the managers with the theoretical underpinning of the Operational Strategies. No negative remarks are made about the graphical properties of the tri-arc question type.

To answer this research question, 5 responses to survey questions must be combined. Each of the individual questions is reviewed above.

The first question to consider is the responses to survey question 7: “FlightStory provides the data for Business Pilot's Safety and supports Flight Operations Management in improving operational support for flight operations more effective than ASR 1.0, TR and FDM.” has received mainly agreement.

The second question to consider are the responses to survey question 9: "FlightStory provides data for Risk Analysts, Safety Consultants, and Safety Management System processes to learn more from operational events than can be learned from ASR 1.0, TR and FDM data" has received one neutral judgement and for the rest, all agreements.

The third question to consider is survey question 11: "(Safety Managers) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Safety Management to support Flight Operations. (FO managers) The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Flight Operations." has received one neutral judgement and for the rest all agreements.

The fourth question to consider is survey question 12: "(Safety Managers) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Safety Management to support Flight Operations. (FO managers) The feedback about the Operational Strategies (tri-arcs) is very relevant for my role in Flight Operations. "has received three neutral judgements and for the rest, all agreements.

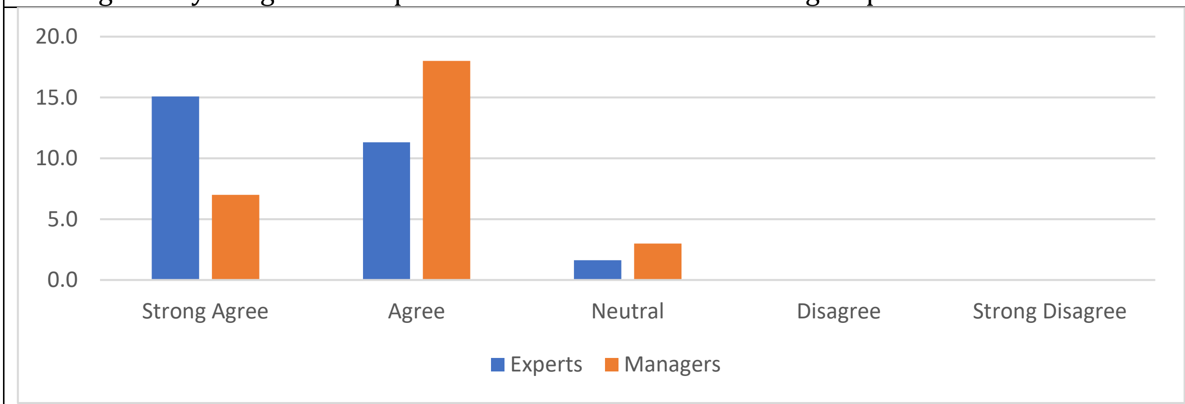
The thematic analysis of FlightStory data shows issues related to risk management with credible potential accident outcomes. Furthermore, this data provides coping strategies for disturbances (Safety-II).

Based on the combined survey responses and the arguments provided above, the claim can be made that this research question can be answered in the affirmative, meaning that FlightStory data does support Safety Management.

This answer can be argued to have descriptive, theoretical, indicative, and very likely causal levels of strength of evidence. The fact that FlightStory was operational, that respondents had read the stories, and that some could imagine the benefits of FlightStory data over current practices all contribute to an argument for a very likely causal level of evidence.

6.10.6 RQ1.1: Does FlightStory makes step forward in flight operational feedback?

All: FlightStory is a general improvement of the current learning loops.



Normalised totals survey questions 1,2,3,13

- An expert is concerned with the willingness to report, not just the willingness to fill out a FlightStory.

- A manager refers to the differences in reporting system and that Flight Data Monitoring is very different from reporting personal experiences.
- The others mainly agree about the benefit of collecting personal flight crew experiences and opinions as compared to the ASR, which is mainly factual.
- Some remarks are made in agreement of the learning statement, such as: the relevance of context, crew perspective, self-reflection. These are reporting topics that FlightStory enables in contrast to the current ASR and TR.
- All are in agreement. Some remarks are made that the current reporting is not made for collecting OPC. One remark concerns the correctness of the flight crew judgement of the OPC and that a verification might be required before the data is shared.
- Nearly all agree the lessons from FlightStory should be used for further reporting developments. Several remarks are made about the process of filling out a FlightStory such as: “hassle free and quick to fulfil”.

To answer this research question, 5 responses to survey questions must be combined. Each of the individual questions is reviewed above. These are different survey questions than the ones that were used to answer the research question. One could argue that the combination of the answers to research questions 1.1 A, B, C, D, E already answers this broader research question about the improvement FlightStory makes in flight operational feedback. I can, however, present a set of other survey questions that also provide arguments to answer this research question.

The responses to the following research questions add additional evidential support to the answer to this research question.

The first question to consider is the responses to survey question 1: “FlightStory collects ‘warm’ (human) rich data that provides insight into the sensemaking of the flight crew and how they viewed and understood the interdependencies between event facts to provide a systems view of the event more effective than ASR 1.0, TR and FDM..” has received mainly agreement.

The second question to consider is the responses to survey question 2: “FlightStory offers suggestions, free text keywords and personal lessons learned, supporting the flight crew to tell his story in such a way that others can learn from it, more effective than ASR 1.0, TR and FDM. “has received two neutral judgement and for the rest, all agreements.

The third question to consider is survey question 11: “FlightStory supports the flight crew to give his judgement about Operational Performance Conditions more effective than ASR 1.0, TR and FDM..” has received all agreements.

The fourth question to consider is survey question 12: “We should implement the lessons from the FlightStory project in e.g. ASR 2.0.“this has received two neutral judgements and for the rest, all agreements.

The majority of support for the individual survey questions above and the answers to the research questions 1.1.A, B, C, D, and E provide strong support for

the claim that FlightStory indeed provides an improvement in the quality of flight operational feedback.

This answer can be argued to include descriptive, theoretical, indicative, and very likely causal levels of evidence. The fact that FlightStory was operational, that the respondents had read the stories, and that some could imagine the benefits of FlightStory data over current practices, provides an argument for an initial causal level of evidence.

6.10.7 RQ 1.1 F Does FlightStory provide insights for a Safety-II and Resilience perspective?

To answer this research question, some answers from the FlightStory question-by-question survey as executed by the experts have to be combined and considered.

The related survey questions and responses are indicated in the table above in the columns Safety-II and Resilience with a 'Yes' notation. Also, in this survey, some specific questions are about Safety-II, resilience, and WAD-WAI.

The survey responses show the following:

- All specific questions, relevant to this research question get at least six agreements more than the disagreements, indicating a majority agrees that FlightStory provides Safety-II and resilience insights.
- All specific questions, relevant to this research question get a positive score, indicating more agreement than disagreement that the question should be part of ASR 2.0. Some tri-arcs, however, show a low score and get some remarks in the surveys. These tri-arcs may need redesign.
- Three claims related specifically to this research question get high agreement:
    - These tri-arcs answers generate patterns that are useful data to explore operational strategies from a resilience perspective.
    - These tri-arcs answers generate patterns that are useful data to explore operational performance from a Safety-II perspective.
    - These tri-arcs answers provide useful data to explore the gap between Work-As-Done and Work-As-Imagined.

The survey responses also show only agreement for the question in FlightStory that solicits the story from the flight crew and the question about the personal lesson that the crew takes from the event.

Considering these survey responses, we can claim that FlightStory provides insights for a Safety-II and a resilience perspective.

This answer can be argued to include descriptive, theoretical, indicative, and very likely causal levels of evidence. The fact that FlightStory was operational, that the respondents had read the stories, and that some could imagine the Safety-II and resilience insights FlightStory provides, offers an argument for an initial causal level of evidence.

6.10.8 RQ 1.2 How can pilots' flight operational experiences feedback support the AVPMM?

In the AVPMM approach, safety is an aspect of the system and thus a topic in flight, route, region, and network decisions. Safety is managed as an aspect next to the other aspects of the economy and customer experience. As described and explained in Chapter 7 about the AVPMM, these three aspects combined result in a value. The actual value exchange with the customer is executed mainly during the flight for which the customer has bought a ticket. Then, FlightStory is built and designed to feed back the operational data of the flight in this value exchange.

Four arguments will be presented to answer this research question:

- The first argument is that FlightStory does not require the flight crew to report on one individual aspect but to maintain the context of the three aspects. The thematic analysis in section 6.9.5 shows pilots provide relevant feedback for the three key areas of value production. This is different from all other reporting systems. FlightStory recognised the interdependence of the aspects and provides specific feedback opportunities related to this interdependence. This specific feedback option is available through the tri-arcs, which request the flight crew to indicate the goal conflict between the three aspects. This tri-arc has been qualified by the experts as a data point with high informational content and has a large agreement that this question should be part of the next development of the reporting system called ASR 2.0.
- The second argument is based on the AVPMM research-related claim that was examined: "FlightStory supports Value Production Management by enhancing the feedback channel from actual flight operations to management.". During the AVPMM group session, near-real cases and examples were discussed. The claim based on the AVPMM survey responses was supported by descriptive, theoretical, and indicative levels of evidence with a likely level of causal evidence.
- The third is that FlightStory data can be analysed and synthesised for flight, route, region, and network points of view to match the AVPMM hierarchical recursion structure. Safety Management can provide the network safety performance insight that is required for certain AVPMM decisions. The FlightStory survey shows FlightStory is more suitable than current methods for the integrated AVPMM approach.
- The fourth argument is the answers to research questions 1.1 D and, to a lesser extent, E. Safety Management but more importantly for this research question, Flight Operations management would benefit from the FlightStory development. Flight Operations play an important role in the development and operation of the airlines' network related to safety and economy aspects. Therefore, Flight Operations management, informed by FlightStory data, is important for AVPMM.

The first and second arguments are based on features of FlightStory that are not part of the current feedback system and thus unique to FlightStory. These two are important for the AVPMM approach.

This research question can then be answered by stating that, by the integrated reporting of safety, economy and customer experience, FlightStory supports the AVPMM more than current reporting.

The answer has descriptive, theoretical, and indicative levels of evidence. A causal level of strength, which is likely because of the case discussions in the AVPMM group session, needs more development and interventions.

6.11 Lesson learned

A main feature of DSR is to contribute to knowledge development for different stakeholders. This paragraph refers to steps 8 and 9 in the DSR process (van Aken & Andriessen, 2011) and chapter 5 in this thesis.

As a researcher, I can provide feedback to the problem owner in whose domain the research intervention was conducted so that the problem owner can acquire a better understanding of the problematic topics and potentially undertake improvement efforts.

The second lesson can be applied to the knowledge domain chosen for the intervention's design. Closing the design cycle means using the feedback from the group session and survey, in this case, as well as the encounters between the design and practice as carried out in the intervention, to improve the design. The revised design can then be put to the test in real-world settings for the relevance cycle's next cycle (Hevner & Chatterjee, 2010).

A third lesson that can be derived is to increase the science knowledge domain. Closing the loop of the rigour cycle means that the experiences of encounters of the science-based design with the actual problematic situation during the intervention are analysed and fed back into the domain of science (Hevner & Chatterjee, 2010).

6.11.1 Lessons for current practices of feedback systems

Several lessons can be extracted from the project:

- To improve the effectiveness of operational feedback, the organisation must go beyond compliance. This research has shown that much important data is not part of the EASA EU376/2014 reporting format. Below is a table comparing FlightStory with the regulatory standard.

Framework based on (Lukic et al., 2010)	FlightStory	EU 376/2014
Who is learning? This is dependent on the type of information received from the reports and the reports analysis. Learning can occur when safety	Flight crew, Airline departments (e.g. training, flight operations management), Airline's SMS.	Regulatory stakeholders

report abstracts or safety reports analysis reports are disseminated among stakeholders.		
What kind of learning (single loop or double loop) process is adopted? (Argyris & Schön, 1978) The type of information in the disseminated report analysis supports the depth of understanding of the reported events.	Single loop learning based on lessons learned per event. Double loop learning based on reflective answers concerning used strategies in the event.	Taxonomy counts and generalisations provide the learners some insights for single and double loop learning, but not very effective and specific.
What is the nature of the problems causing the incident?	Stories reveal the complexity of factors involved, goal conflicts and trade-offs. Also the effects of Operational Performance Conditions and Operational Strategies	The primary use of a taxonomy with a generic event description are not able to expose the richness of events. This is especially a problem when events are aggregated.
What type of knowledge is involved? Three types of knowledge are relevant for learning: conceptual (know-what-why), procedural (know-how), and dispositional (e.g. attitudes, values, emotions).	Stories and their signification by the reporter provide: Conceptual, procedural and dispositional types of knowledge. Also experiences and expert judgements.	Aggregated event analysis reports can due (to the nature of the disseminated information) provide some conceptual and some procedural knowledge.

Table 6-7 Comparison FlightStory with Regulatory standards

- The project was delayed because, in my view, an overemphasis on process and procedures by some key managers. The FlightStory project faced a two-year delay when an individual in the Safety Action Group argued that the current processes should be improved before the project could commence. I maintained that FlightStory, as a project that operates largely outside of established procedures, was not being accepted. The group ultimately agreed to the delay, and it took me two years to finally secure approval for the project at the meeting.
- To make improvements beyond compliance, an up-to-date knowledge of safety science concepts is required. The organisation should invest in ensuring this knowledge is available in the department.
- The safety knowledge gaps between managers and experts, as illustrated by some responses in the survey, require knowledge sharing between experts and managers. However, this process requires time and priority from both groups, and time is limited. The imbalance between decision power and safety knowledge does not invite innovation initiatives.
- The current focus on organisational structure, processes, and responsibilities can hamper progress when the progress challenges or does not fully fit these structures, responsibilities, and authorities. FlightStory data can be easily reviewed for certain

rules and be distributed to the flight crew without any effort from the safety department. During the project, I did a review of the submitted stories to check no personal data, and no controllable stories or incorrect recommendations were shared. When in doubt, I would consult a BPS. This process of verification and sharing does not fit the current data flow, and that is seen by some managers as problematic, as they stated in the reviews.

- A concern of one of the managers in Flight Operations was that FlightStory would be used as a channel for complaining about all sorts of issues. None of the submitted stories could be classified as a complaint story. Nearly all stories had a positive learning attitude.
- The current ASR can be enriched with some FlightStory items. This change does not require a redesign of the current ASR but only an added section with questions. The experts advise adding questions about the Operational Performance Conditions to the current ASR. These OPC are identified in the new Risk Analysis Framework and Risk Management Strategies as important indicators for which the current ASR cannot provide data. The safety data expert and ASR form developer have been contacted and confirmed that the addition of the OPC is possible without any problems.
- The current Safety Management process culture puts an emphasis on increasing the number of ASR reports. The assumption is that more reports provide more learning opportunities. Although there is some truth to that logic, the content of each report may be more relevant, as shown by the FlightStory project. I would suggest inviting the flight crew to provide a rich description of the event beyond just a short factual description.

6.11.2 Lessons for next iteration of the FlightStory design

The two design statements were formulated as:

- For a generic operational context: The learning from operational events can be improved by providing means to the operator to share their stories, opinions and lessons, which can be shared with other employees and organisational departments to learn from these operational events.
- For a commercial aviation context: Learning from operational flight events can be improved by providing means to the flight crew to share their stories, opinions and lessons, which can be shared with other flight crew and airline organisational departments (flight operations management, flight crew training safety department) to learn from these operational flight events.

The first lesson is that the design statement as formulated above does not need a revision based on this iteration of the design.

The second lesson is that the FlightStory question-by-question expert review shows some questions in FlightStory should be changed or deleted. The experts have not suggested any new questions to add to the FlightStory form. The experts' evaluation provides the data to make improvements for a next design of FlightStory.

6.11.2.1 Requirement's implementation evaluation

The following feedback regarding the implementation of the user-, operational requirements, and design limitations from the submitted FlightStories was received:

Operational requirements implementation: The tool and process were compliant with the operational requirements.

Design limitations: With the help of some friendly colleagues, I developed all software including a data analysis dashboard. Without these skills, this project would not have been possible. The organisation might need to consider to what extent software development issues might restrict the innovative capacity of new tools and methods. I suggest considering an open-source development concept where all company employees can contribute. There is an enormous capacity in the people which might become available with an adequate approach.

User requirements implementation: Some improvements should be made in the next iteration of development.

- The software tool availability should be reconsidered. Installing the app on the iPad was an extra step that made people less likely to participate.
- The flight crew survey remarks showed they preferred the tool to be part of the standard collection of software and should not need an extra installation of the software.
- The survey results show the flight crew should not be required to enter any data fields that can also be collected in the back office to reduce the time needed to fill out a form. Some of the FlightStory data entries can be removed when the automatic data enrichment is achieved.

I did receive a few requests for software support. All issues were fixed in a day and bugs in the software did not affect the project.

The FlightStory sharing method, which is currently a pdf with internal links, should be changed into an app with a richer interface to select and find relevant stories. The FlightStoryBook was effective for this experiment but should be changed for the next iteration. User requirements for the sharing part should be developed.

6.11.3 Contributions to science

This research contributes in several ways to knowledge development and scientific research. The answers to the research questions provide firm claims that can be scrutinised, argued and built upon in further research. These answers could be described as contributions to scientific knowledge. My unique position in the airline as a safety investigator, airline captain, and researcher and the access I had to all topics and people has hopefully resulted in a research project that other researchers can build upon. That would be a rewarding result for my work.

Science has a role to play in initiating, developing and supporting airline operations to mature beyond the minimum standard of compliance. The FlightStory project evaluation shows that a compliant reporting system has many shortcomings. The design of the current regulatory ASR format does not consider the multiple feedback loops that can benefit from operational feedback reports. The FlightStory literature review shows (safety) science can find challenges to developing reporting beyond compliance.

A difference in preference for subjectivity or objectivity is illustrated in some of the survey responses. More managers than experts referred to the lack of objectivity or verifiability in some FlightStory answers as problematic. The notion that various aspects of flight operations, or any complex system, can be examined from multiple perspectives, which may sometimes appear contradictory, is not always fully appreciated by all managers. Progress can be hampered by unrealistic requirements for objective and hard data therefore science has to find ways to close or bridge the gap between safety science knowledge and organisational process decision authority. Maybe research will reveal that only regulations for minimal safety education for persons with a safety responsibility will be effective to close the gap.

In my advertisement for the project, I attempted to emphasise the importance of the role of the flight crew as feedback providers for the rest of the organisation. I think I was not able to provide many of the flight crew with this perspective. This touches upon what is called "reporting culture." Since most of the FlightStory data has been categorised as highly relevant, maybe new persuasion communication for reporting can be considered.

One of the arguments used to help the flight crew overcome the burden of reporting is the extensive use of their feedback. In addition to all the feedback loops I have researched; more research can be done to increase the utilisation of pilots' feedback data. Suggestions are:

- Flight crew career development. E.g., each flight crew can collect stories of desired and undesired event handling as an element in their career development.
- Flight crew route training. According to the survey findings, completing a FlightStory contributes to self-reflection on one's own performance, thereby facilitating discussions during line training.

FlightStory collects data about a number of different topics such as the story, the lessons, operational performance conditions, applied strategies, fatigue and safety performance. A FlightStory data set provides researchers with a huge number of research possibilities of which I here suggest a few:

- Analyse relationships such as between the OPC, applied strategies and lessons learned.

- Analyse applied strategies and safety performance judgements.
- Combine experience on type and in career with above analysis.

FlightStory data is valuable from a safety-II and resilience perspective as the flight crew only submit stories that they believe to be significant and they share data that on sensemaking, strategies and decisions. The sample collected by FlightStory is not representative of average flights, but instead focuses more on the tails, which are instances where the crew had to actively manage to maintain control. This sample provides a better understanding of the crew's resilience potential and the effectiveness of applied strategies, making it more valuable than data from normal flights without challenges. Anonymized FlightStory data would be a highly sought-after resource for researchers.

Furthermore, the FlightStory tri-arcs provide the resilience and control concepts to express the safety-II or resilience capabilities. Further research can be built on this research and find a language that fits the operational flight crew and the researchers.

I hope this research project, which fills part of the knowledge gaps as identified by the literature review, will be a stepping stone for more research that both supports an airline organisation in implementing the findings and further develops the concepts because people operating at the sharp end have much knowledge and expertise to share.

Chapter 7: Safety as Aspect of Airline Value Production Management

This chapter starts with a field problem description. This will be the basis for describing knowledge gaps. This is followed by an explanation of the relevance of the design and evaluation of an intervention. The intervention will be an evaluation of a model for business and safety management decisions by managers in an airline company. Thereafter, an analysis of the survey will provide lessons for practice and contributions to science.

7.1 Introduction

"The Purpose of a Business is to Create a Customer." Peter F. Drucker, 1954

A business organisation can survive for as long as it can sustain a value exchange with its changing environment. An airline company can survive as long as passengers are willing to buy tickets. This logic provides a basic argument for a Value Production Management perspective on the network airline business(Brewis et al., 2011).

The purpose of the organization must be clear (Malik, 2011), this requirement thus also applies to an Airline business. The purpose defines the context to evaluate the relevance of events, actions, and plans. The purpose should provide closure for all possible actions into desired actions.

A stated airline's purpose is to "create memorable experiences." This high-level abstract description guides employees' actions and decisions but is in most situations underspecified. The prerequisite to delivering the purpose can be specified by the notions of economy, since an organisation must over time be sufficiently profitable; safety, since without sufficient safety, the airline's reputation goes down and passengers may avoid the airline; and customer service, since the service offering to the customer is critical in creating a memorable experience and a ticket repurchase intention.

An airline's business management model must be able to integrate safety with other business values. This enables the balancing of essential variables such as production, cost, and safety. In daily practice of flight execution, safety is a priority, but not the only one. Flight crew achieves to optimise economy of flight and customer experience as long as the flight is considered safe. For the daily practice of network operations, more focus is put on economy and customer connections criteria because the flight and cabin crew are first in line for flight safety. In the daily operation of network development, a next layer distanced from the actual flight, safety, economy and customer experience have different dimensions. At each hierarchical level trade-offs are made. For effective management of these trade-offs, it is necessary to have models (Conant & Ashby, 1970) (Schwaninger et al., 2010) to indicate the variables and interrelationships so that informed decisions can be made.

Following the DSR steps as described in chapter 5, I will provide a problem description, provide a description of a general solution followed by the description of the development of the specific solution. Next, I will execute the experiment, analyse the results and answer the research questions.

In the following paragraphs I will describe the current situation with respect to the requisite variety of the corporate safety management model. I will infer knowledge gaps between exposed knowledge in the current practices and the desired knowledge to improve current practices.

7.2 Problem description and diagnosis

My field problem description is based on my background as a safety researcher, as well as my experiences and discussions with safety and business managers while working as a safety consultant involved in SMS development in the airline.

Problem descriptions in the context of Design Science Research (DSR) can be divided into field problems and knowledge problems (van Aken & Andriessen, 2011). The first idea of the two problem types is used to engage in the practices of an organisation. It is a description of problematic aspects of actual practices in a particular field. The difference between actual practices and desired ones can also be part of the problem description. What is called the problematic situation could also be addressed as a situation that could be improved.

It must be realised that the field problem description is subjective and concerns the perception, interpretation, and assessment of an observer. This realisation is well in line with the management cybernetics tradition of Beer, who states that facts about the nature and purposes of a system are not objective realities (Beer, 1979).

The knowledge problems, or knowledge gaps, are deduced from the field problem and describes the knowledge that is assumed to be necessary to solve the field problem. It is about the lack of knowledge and not about the lack of resources necessary to solve the field problem. The knowledge problem is not about individuals in the organisation but much more about the organisation itself, which has not engaged yet with the topic that I have nominated to be problematic, or the organisation has not yet sufficiently become aware of the problematic situation, or the organisational collaboration has so far been ineffective to solve the problematic situation.

In DSR, the researcher attempts to understand the problem(s) and the origin for their existence. Dealing only with the occurrence of a problem is similar to symptom treatment and does not provide a prolonged solution. The designed solution should involve both origin and occurrence of the problem(s).

The problem that will be addressed:
Lack of effective management of the balance between production and protection. This results in the inability to completely evaluate ongoing operations from an

integrated perspective of safety, economy, and customer service. Resulting in the inability to optimally allocate resources based on safety risk arguments. In general terms, it is the inability to manage the balance between the economy, safety, and customer experience in a context of value production.

7.2.1 Description of the current problematic situation

KLM translates its overall strategy and long-term goals into a so-called Flight Plan (KLM, 2018). The Flight Plan consists of five pillars, being Customer & Product, Network & Fleet, Operational Excellence, People & Organisation and Innovation. Safety is discussed in the chapter on Operational Excellence. Risk appetite as part of Risk Management is described in the chapter on Risk Management and Control. KLM differentiates between four types of risk namely:

- Strategic risk, risk related to the air transport activity,
- Operational Risk, risks related to the operations of KLM,
- Compliance risks, risks related to the non-compliance to applicable laws and regulations,
- Financial risks, risks related to the integrity of finance and reporting.

The risk appetite for Operational risk is expressed as: zero risks in the fields of flight safety and operational safety. Airline accident risk is described as inherent to air transport. It is stated that each Aircraft Operating Certificate holder is required to adopt a predictive and pro-active approach to safety, and this approach is an integral part of KLM's Integrated Safety Management System. KLM aims to enhance its risk and performance-based safety management system by participating in industry-leading initiatives. This will allow risk-based decisions to be made at all levels of the company. For this research, it is interesting to see what is meant by 'all levels of KLM'.

The Control and Monitoring paragraphs of the KLM annual report 2018 describe Safety Management. KLM has set up a Safety and Security Organisation to ensure compliance with the principles of secure, safe and effective operations. At the highest level of the organisation is the Safety Review Board (SRB) chaired by the Accountable Manager, the Chief Operating Officer, and deals with high-level issues. The SRB sets the safety policy and strategic safety directives, including the company's safety goals, and also provides the platform to: (1) monitor the safety and compliance performance against safety policy and objectives, (2) ensure appropriate resources are allocated to achieve the desired safety and compliance performance. The Management Team Operations (MTO) as the corporate Safety Action Group, monitors these. If these goals are being met, the safety risks are identified and whether any necessary corrective action is taken in a timely manner. The MTO comprises heads of operational departments. The responsibility for integrated safety and compliance, including the implementation of mitigations, resides with the Nominated Person or Head of Division and, ultimately, the Accountable Manager, the KLM COO. The corporate Integrated Safety Services Organisation (ISSO) ensures that the measures applied by all the company's entities are consistent. The main objectives of the SRB are the execution, communication and promotion of KLM's Safety Policy and the review of the Integrated Safety Management. The SRB allocates the appropriate resources to ensure the proper execution of safety and compliance. It is important to notice that the departments of Network development and Fleet development do not have their own representatives in the MTO or SRB.

The Integrated Safety Management System Board (ISMS Board) is a strategic meeting and is chaired by the Accountable Manager Air Operator Certificate. The ISMS Board sets policies, procedures and methods regarding the delivery of safety services. Its aim is the continuous development of the ISMS for KLM, KLM Engineering & Maintenance and KLC (KLM City Hopper) and to ensure the effectiveness of KLM's ISMS processes, procedures and methods regarding safety and compliance monitoring. The ISMS board allocates the appropriate resources to ensure the proper execution of safety and compliance monitoring.

Safety & compliance execution is the responsibility of the divisions and business units within KLM to work safely and in accordance with legislation and agreements, as stated in the KLM policy. Advice and support for this responsibility is organised both de-central and central. The Integrated Safety & Compliance Manager (ISCM) within the (de-central) line organisation is responsible for implementing KLM's safety policy and related culture. Each ISCM has a direct line and access to the highest responsible manager in the division or business unit.

ISSO is a centralised independent support department that is in charge of monitoring, measuring, policy, and advice for operational, occupational, and environmental safety and compliance, as well as operational security, and reports directly to the COO. The Integrated Safety & Compliance Manager (ISCM) serves as a liaison between the ISSO and their assigned division/department. They are responsible for ensuring safe and compliant work practices in accordance with corporate policy. The ISCM holds a managerial position within the division/department and can directly communicate with the Post Holder or a member of the SRB, or the Head of Division if necessary.

The KLM Integrated Safety Management Manual (ISMM) states that the ISMS aims for a well-founded balance of production and protection in which the optimal allocation of resources is ensured and an acceptable level of safety performance is maintained. It is the SRB that determines safety goals and initiatives that contribute to the ISMS objective. The ISMS objective is very relevant to this research project. In particular, the ambition to balance production and protection.

However, current safety management and business management practices are unable to operationalise the production-protection balance into variables that can be managed. Although the balance is not explicitly managed, the metaphor is sometimes used in conversations between the safety department and the flight operations department. In these conversations, production is then translated into operational pressure, which can be a safety issue.

The departments outside of flight or ground operations consider safety primarily as a challenge for the operations departments. These more business-driven departments, such as network development and management, consider safety as a problem solved by operations. In network design, the operations departments are involved in the evaluation of a potential new destination. They will assess the operational feasibility and constraints. When the operation is approved by operations, the business departments consider safety to be ensured. The lack of communication between the business departments and the safety department and the fact that safety is not part of the network performance dashboards illustrates this claim.

In 2010, I visited this network development department after an Airbus A330 experienced a high-risk incident during take-off at Entebbe airport in Uganda. I wanted to understand how it was possible that a destination was chosen as part of the network that is located in a bird sanctuary. Bird strikes, which is a collision between a bird and an aircraft, pose a risk to the aircraft. Damage to the aircraft during departure may require the aircraft to return to the airport. This results in delays for the passengers and extra costs on top of the inspection and repair costs. I was told that the sheer complexity of maximising the value offer with the resources, political aspects of overflight rights, labour agreements, aircraft performance etc., was already very high. Adding safety to the multivariable optimisation calculation would make it even more complex. Safety was assumed to be part of flight operations alone. The process for the acceptance of a new destination would therefore lie with the flight operations department. They would have to confirm that operations, as desired by network development, at a new destination could be executed safely. Entebbe had been accepted by the flight operations departments evaluation process and was therefore it became an airport in the network.

Roughly after 2010, driven by the fierce economic competition between airlines, new destinations were sought that were not already international airports. These so-called B airports serve more regional flights than international and transatlantic flights. Examples are Guayaquil in Ecuador, Cartagena in Colombia, and San José in Costa Rica. The strategy followed by network development is to be the first airline at the B airports to serve direct flights to Europe. Adding such an airport to the network increases the origin-destination (O-D) pairs, an important quantitative measure for a hub-and-spoke network. Safety-related features of these B airports include limited runway length, air traffic control that is not used to large aircraft and international radio communication in aviation lingo, limited surface for taxing and parking, and sometimes geographical issues such as terrain. The first international airline at such an airport cannot use the lessons learned from the other international carriers that have already operated at the specific airport. The safety information exchange between local regional and international airlines is often not established at the start of an operation. An extra flight to a destination that is already part of the network has fewer unknowns than an extra flight to a new airport to which no international airlines operate. Without a safety assessment of new airport that makes comparison between airport already in the network possible, no balanced decision can be made. The increased corporate risk and individual flight risk must be viewed in the context of the expected business benefit.

The network as designed will be executed by the network operations processes. Each period, ranging from 3 to 6 months, a new network design published in the timetable is put into operation. The daily operations of the network are managed by the Operations Control Center (OCC). The management of network operations is concerned with network performance. A 2010 review of the network performance dashboard showed no parameter for safety. Safety was part of the network performance meeting as the first topic on the agenda, and this topic was scheduled for 5 minutes. In this practice safety was always a topic in every network performance meeting, but safety was not systematically connected to specific network topics such as flight or route performance. Performance was defined in terms of on-time departure and arrival performance. Furthermore, safety, expressed by some analysis of Air Safety Reports and Flight Data Monitoring was not a deliverable from the safety department towards network operations processes and, therefore, safety could not be managed as an aspect of network performance.

During one of my talks with a network performance manager, I asked if they had any insight into the safety performance of the worst performing stations in the network. He said they has not. They would have to ask the safety department for a station or flight safety report, but that was not customary. The logic is that as long as the safety performance is acceptable as judged by the safety and flight operations department, safety is not a criterion for network performance.

Another observation is that safety is predominantly managed in a silo. In risk management and when searching for safety recommendations as part of an incident or accident investigation report, as part of the SMS processes, there is no standard process for considering risk reduction measures by adapting, e.g., a flight schedule. Neither are there instructions for considering the impact of safety driven changes on cost, network and passenger experience. When one of the aspects is an obvious part of the issue, then that aspect will be addressed but not as part of a systematic process step.

In summary, the problems in the relationship between safety and business management:

- Safety is mainly managed in a silo. Several divisions, such as finance and network development are not directly connected to the ISMS structure. The corporate SAG is not really corporate but covers only the operational divisions of the organisation
- The difficulty of operationalising the production-protection balance to be able to manage this balance effectively and efficiently.

- When safety is not an aspect of network performance, network optimisation does not include safety and network management cannot manage and thus a balance between safety and business value.
- The standard risk management process does not consider the possible solution space for risk reduction offered by network, route, flight or customer experience changes.

7.2.2 Explanation of the current situation.

In this section, I will propose several explanations for the current situation of airline safety management and its integration into the business aspects.

The complexity of a network full service airline is high (Trapote-Barreira et al., 2016)(Wittmer, Bieger, & Müller, 2011). The costs of managing complexity are also high (Trapote-Barreira et al., 2016). Therefore, an airline's management is constantly trying to reduce complexity to reduce costs. How complexity is reduced and handled is crucial and not a simple task.

A first observation is the lack of an explicit model, except for an organogram that covers all organisational activities and processes. Given the fact that the airline has survived for a hundred years, the functions for viability must be working. This is achieved by the many different incomplete and buggy mental models with different perspectives that are connected by managers and employees in their discourses and meetings. Most models are concerned with departmental activities and processes, while in the field of operations, interdepartmental models are also used for the processes of ground operations and flight operations. The organisational structure with highly specialised professionals has led to a degree of silo mentality. The required coordination actions and meetings between departments to make the interfaces between them effective and efficient caused much discussion. The introduction of the ISSO as a corporate safety department, reporting directly to the COO, was a logical step to cohere the safety management processes in each specific division, but this has not (yet) led to a business integrated safety management approach.

Fierce competition between the airlines has driven down the profits. Increase of wages and fuel prices causes internal discussions about the available resources. Resources for the development of safety management must compete with arguments about achieving and maintaining compliance. Airlines are exposed to many and frequent audits. Audit findings by regulators or IATA Operational Safety Audit (IOSA) can immediately endanger the business activities of an airline. Therefore, resources for compliance are easier to make than arguments for investments for further safety enhancements, while safety is assumed to be at an already high level.

Furthermore, great efforts are needed to implement the SMS regulations and to be compliant. The organisational effects of this implementation also require attention and, thus resources. New roles, responsibilities, accountabilities and functions require new formal SMS processes. The new SMS regulations may result in any degree of the bureaucratisation of Safety (Dekker, 2014). Unfortunately, compliance pressure has resulted in strict safety management process execution where effectiveness and adequacy of these processes are sometimes traded against compliance.

Traditional SMS outputs are not suited for anything other than operational departments such as flight and ground operations. The transduction of safety insights into information that fits the requirements of departments such as network development and aircraft fleet development needs investments in time and money and the creation of a shared understanding of safety and the business. The literature shows that safety is not yet a factor in network flight time scheduling. Due to the nature of safety data management in terms of confidentiality and anonymity, it is only the safety department that has access to it. Therefore, safety data has traditionally been stored in a safety silo. Safety reports are only shared with operational departments that are directly involved in flight and ground operations. A development is to build a safety data warehouse where safety data is enriched with other operational data. The driver is the desire to recreate the operational context of the safety events. This development paves the way to further involving businesses in the safety aspect of their activities and processes. But only the safety department is the likely initiator for this outreach since they own the safety data. Because of the constraints of resource issues mentioned above, developments regarding safety as a business aspect are not a first priority.

Additionally, developing safety as a business aspect requires a shared model of how safety is created. This model is not further developed by the organisation beyond the belief that several departments are important for safety. These departments are Flight Operations, Ground Operations, Engineering & Maintenance and Inflight Services. Further specification of what these departments deliver to the actual flight execution is not part of an explicit model of how safety is created. The concept of organisational factors (Reason, 1997) that shape operational performance is not developed beyond fatigue, training and experience.

Current practices of network development involve some operational assessment of a potential new network destination airport. In ICAO Safety Management (ICAO, 2018a) terms, this is a kind of predictive safety management. Once the operation into and from this airport is acceptable, and the airport has become part of the network, the safety and operational issues are not part of the network performance dashboards. Pro-active Safety Management, the discovery of issues before actual problems or incidents occur, is not yet part of network performance management. The safety department does not yet deliver a full operational safety performance report for each airport, route, or region. Such a report would group all safety data per flight, route and airport to be compatible with a network performance view of the network. In incidental cases, re-active safety management was employed as a follow-up of an incident such as Entebbe or, after a serious risk issue has been discovered. Re-active safety risk mitigations can include network schedule changes and extra resources, such as an extra flight crew, to reduce fatigue.

The tradition of separating specialist work into specialised departments has a tendency to create silos of decision making, optimization, data collection, and analysis. The silos must be connected to allow integrated safety management. The lack of silo connectivity is one of the reasons safety is not yet integrated with economy and customer satisfaction. The latter two are already managed in a more integrated manner. The Entebbe example above shows how safety was not an aspect of the network design. Safety management was operating more than a sub-system and as a problematic consequence, sub-optimal decisions at network design level could be made.

The focus on risk management as a pillar of the ICAO SMS has led to the interest on risk modelling. The development of bowties by the UK CAA bowties has made the bowtie a sort of standard in aviation. The initial introduction of the bowtie, did not result in the involvement of the wider organisation to enhance safety management. The implementation of the bowtie in aviation safety management requires a lot of effort. Firstly, the standard bowtie model is not suitable for a complex system as airlines operations and flight execution (Leveson, 2021). Secondly, the bowtie as a risk model is limited in explaining how safety is created. In the safety department we have developed a sequel to the bowtie, referred to as bowtie 2.0 which relates the blunt end of the organisation to the elements that jointly deliver the barrier functions. Bowtie 2.0 solves most of the limitations of bowtie 1.0. The difficulty of risk modelling, as well as the effort put into it, has slowed interest in extending the risk model into the economy and customer satisfaction variables.

Another part of the explanation for the lack of integration of safety as a business aspect is the low number of usable research results, especially results that can be applied in practice. This claim is supported by the literature review and the experience I have had in safety management. This knowledge gap will be addressed in the next paragraph.

7.2.3 Comparison between current and desired situation:

In general terms, the challenge for each organisation is to manage itself in a requisite manner. The essential variables of the organisation must be managed within limits to enable organisational viability. The management of the organisation requires a requisite model (Conant & Ashby, 1970). The embodiment of Airline Value Production Management Model (AVPMM) by all relevant KLM actors should achieve requisite variety vis-à-vis the required performance to its environment. The choice of safety, economy and customer service as essential variables managed in the context of value production will be contrasted to the management of the production versus protection balance. Several concepts and some of the logic of the AVPMM model will be used as the requirements for the desired and improved situation.

The desired situation is that variety is divided over management systems in a way that is congruent with the organisation's main activity, value production. This means that value production should be the context for decision making. Furthermore, the AVPMM logic will serve as an organising principle for structuring problematic issues.

The ideal situation is for organisational decisions to be made in a value production context in which the essential variables are made explicit and operationalized. This should result in the ability to allocate resources optimally, where optimal is defined by safety, economy, and customer service criteria, all of which combine to produce value. Safety should be a component of network performance that supports the ISMM's optimal resource allocation (people, aircraft, etc.). The options for proposing network schedule changes, such as changes in arrival or departure time and aircraft type, should be included in the safety risk analysis. In the ideal situation, optimal resource allocation should take into account all recursions (network, region, route, and flight) as well as all aspects: safety, economy, and customer service. My intervention will put the AVPMM's support for resource allocation decisions over routes in relation to the value they produce to the test.

The MTO serves as the corporate SAG for safety management. In my opinion, the name "corporate" is incorrect because departments such as finance, fleet, and network development are not included in the corporate SAG. The current SAG, in my opinion, should be renamed Operations SAG, and the new corporate SAG should include all divisions and departments because they all affect safety, economy, and customer experience. This step toward expanding the ISMS would make it obvious to discuss topics like occupational safety when purchasing new aircraft. It would also be more obvious to review the safety aspects of network development. The ISMS, like finance and customer service, would then be an aspect management system. These three aspects would necessitate a new type of meeting for each recursion of the AVPMM, i.e. a meeting attended by representatives from each essential variable. In such a meeting, for example, the balance between safety, profitability, and customer satisfaction on a specific route would be discussed. Routes with high safety risks and low or negative profitability could be proposed. The resources used for these routes could be better used for other routes. Thus, resources could be optimally used for value creation while maintaining a balance of safety finance and customer service. This approach would be two steps beyond production and protection management:

- The first is that production is replaced by economy and customer service. These are easier to operationalise and are familiar topics in the company.
- The second step is that the context is value production, operationalised by the recursions of network, region, route and flight.

7.2.4 Knowledge gaps

The difference between methods and models proposed by relevant sciences and those used in practice can be used to identify knowledge gaps. It is recognised that other factors other than a lack of knowledge are required to find more comprehensive explanations for the differences as mentioned previously. The review of literature discusses scientific knowledge gaps.

A more generic gap in Safety Management knowledge has been described in chapter 2. In this section, the gap related to the AVPMM will be discussed.

The SMS processes, often developed by managers themselves, have both advantages and disadvantages. Structure and process are fine as long as the outcome is relevant to the next management level. If, for instance, a risk expert's opinion can't be taken into account by the process, the organisation is dumbing itself down. The focus on compliance and process is a threat to safety intelligence(Dekker, 2014).

Possible sources for knowledge increase are scientific publications in journals, books by safety scientists, and articles in aviation magazines. The accessibility is in the form of articles, books, and journals. Journals have two problems for safety practitioners, namely accessibility and applicability. A journal subscription is frequently required for access to the journal, which airlines typically do not have due to a cost-benefit analysis, if considered at all. Thus, journal articles in the public domain are the only available for airline safety employees and managers. Research articles normally don't provide the desired solution to the " 'silver bullet" of safety management challenges. The transfer from scientific safety knowledge to actual safety management practices requires educated readers working in safety management and researchers that understand the needs of actual safety management practices. An example of this knowledge gap is the pile of safety science articles about the problems of the risk matrix and the wide application of the risk matrix in safety risk management. There are a lot of books on safety and safety management, but it takes time to read them, and time is valuable. Often, it is problematic to translate the concepts into the new safety management practices.

Against this background, it seems natural that innovations in safety management come from safety professionals. The proposals for improvements and innovations should then be accepted and accommodated by safety managers. The research I've conducted and other innovations not discussed in this thesis are examples of these kinds of innovations. The acceptance of the innovation proposals is dependent on factors such as: to what extent can the safety expert explain the proposal so it is understood, but also to what extent does the safety expert understand the safety management issue from a safety manager's perspective. Safety managers tend to be very focused on process, much more than experts, who are more focused on content. The challenge is to accommodate both views.

This was the context in which I as a DSR researcher had to make my research proposal. I explained the AVPMM and its logic and purpose to the Vice President of the ISSO. The concepts in the AVPMM, such as recursions, essential variables, the need for a model, and aspect versus sub-system, I guess were new to him, but he understood my explanation. The Plan-Do-Check-Act model is used in safety management processes, but the limitations of this model are not well known. The VSM as a multi-layer super PDCA was a new insight for them. Also, safety as an aspect system instead of a sub-system was a new insight that seemed to make sense when I explained my view. He reacted positively but asked for a 1-page summary. I used two sides of an A4 to explain my three topics. He then promised to offer and explain my project to the COO of the company.

Although the word system is used frequently, such as in safety management systems, this does not mean many systems' theoretical concepts are known and used. A discussion with safety managers about the SMS boundary as an important system theoretical concept created confusion. Furthermore, just because managers manage does not imply that they have sufficient explicit knowledge of management science to assist them in finding management solutions to problems. A specific lack of knowledge is related to the law of requisite variety (Ashby, 1960) and what this means for the control functions in a management system (Conant & Ashby, 1970)(Beer, 1972). Testing a process of management of a process for requisite variety is not a normal practice.

The explicit need for modelling is also not known by managers. Adhering to the requirement for modelling (Conant & Ashby, 1970), models would serve as issue resolution since it serves to make the partial and faulty mental models into shared explicit more complete models (Türke, 2008).

Risk management as an ICAO SMS pillar plays an important role. The standard practices in risk management across the airline industry involve accident scenario risks expressed in a risk matrix. Risk expressed in this manner does not support effective discussions about route selection, the topic of my intervention. The risk matrix is widely used in airline operations but has been heavily criticised in safety science publications (2023c). The limitations of the risk matrix are to some extent recognised in practice by risk analysts but not addressed in the ICAO SMM. A risk based comparison of routes can be done via risk ratios based on risk proxies. Risk ratios can be shown in increasing or decreasing risk order. The risk can be calculated on the occurrence of a proxy event, e.g., fatigue reports or unestablished approach reports. The proxy serves as an indicator for one or more accident types. Since accidents are so rare, the use of proxies is useful. This new development in risk management is closing a knowledge gap, but it is only effective when put into practice.

I have never seen in any safety publication or heard in any safety related meeting a reference to the Rasmussen and Svedung hierarchy which shows nested levels of decision making ultimately shaping the context and content of work (Rasmussen et al., 2000). Another example where the need for a model is not realised is the need for a model of safety creation. Such a model would support cross-silo discussions about safety and provide logic for collecting safety-related data. Compliance driven safety data collection does not promote further development in data collection. The realisation of a model of safety creation has not yet been recognised. A safety influencing factor, such as network scheduling, the topic of the other project, has not been considered, which is indicative of a knowledge gap.

The need to nominate essential variables is not widely discussed throughout safety management. The flight operations department has safety, cost, and passengers nominated as critical variables to be managed by the flight crew. This line of thought is not explicitly extended beyond the flight operations department. These variables are not further used as an organising principle for data analysis and flight evaluation.

The knowledge gaps between daily safety management practices and (safety) science are considerable. A learning attitude, as exemplified by the cooperation on this research project, is required but not sufficient for the gap to be reduced. To achieve a world-class safety management system that goes beyond compliance, the organization must employ experts who can assist in creating tools and techniques. This is necessary to fulfil the safety vision set by the executive management.

7.3 Why it matters

The relevance of research can be expressed in the context of either the general society or science. Since much research is publicly funded, some accountability towards the public is created. The Evaluation Research in Context (ERIC) (van Drooge et al., 2010) has developed standards to evaluate societal relevance. According to their definition, societal relevance is measured by how much research advances knowledge about how societal practices, like industry, develop and the objectives they seek to realise, as well as how it helps to solve issues and problems.

The Design Science Research (DSR) employed in this project matches up well with this notion of societal relevance by the research element of ‘cycle of relevance’ (van Aken & Andriessen, 2011) (R. Hevner, 2007).In this cycle, the match between needs, concerns, and problems in the environment relative to science, is evaluated to ensure the relevance of research results for the public and or organisations.

The relevance, in terms, of usability, problem-solving and improvements, of the AVPMM project for aviation safety management can be argued for by:

- The project builds on existing attempts to extend safety management across the entire organisation. In (Stolzer et al., 2008) Yantiss proposes an integrated-Airline Management System: “The *Integrated*-Airline Management System is simply a term applied to the integration of all management systems within an airline. The foundation is the executive leadership and corporate governance of the airline that is supported by documenting the roles and responsibilities of corporate officers, the functions of each operating division or group, management review/decision processes, and the integration of multiple work activities. It describes the relationship and operational responsibility of each supporting management system within the overall enterprise.” This may sound as a desirable way forward, but it has not been achieved by any airline organisation according to the literature review.

- This project will reduce the gap between safety management and business management. While in safety management the business activities are reduced to 'production', without being more specific, in business management e.g. network performance management, safety is accepted as a given, as a fulfilled precondition. The consequence is that dependencies between business activities and safety are not effectively monitored and managed.
- The project proposes a new way of reducing complexity that is compatible which numerous structures in the airline company and is therefore easily recognised by airline managers. Based on my conversations with safety managers in other companies and my participation in research projects like the project for Advanced Safety Management Systems as part of the European Future Sky Safety research, I contend that the field issues identified are not particular to the airline industry and are prevalent in other airlines organisations. Therefore, the generated knowledge might have wider potential, which contributes to the relevance of this research.
- The project has operationalised the concepts in a software model that can be employed in the airline when actual data is used. The problem with the simplistic model of production versus protection is its oversimplification. In general, managers cannot operationalise this model into their actions and the safety department does not report in terms of this model. This project shows a possible way forward.

The rigour cycle of DSR ((van Aken & Andriessen, 2011) should ensure the application of scientific methods and principles but also the relevance for science of this research project. Relevance for science can be expressed in terms of e.g. validation, falsification, transferability and generalisability. The claim for relevance for science, more specifically for safety science, management cybernetics and DSR, is supported by the arguments that:

- The project develops practices as proposed by regulating bodies such as ICAO, IATA, and FAA, as well as by safety science publications (Reason, 1997)(Hollnagel, 2014b) which suggest that safety management should be integrated with normal business management.
- The literature review shows the gap in research which connects the business with safety. This project, using management cybernetics concepts, builds an integrative model for safety and the business in an attempt to reduce the gap.
- This project uses DSR concepts and methods in a new field of application. Furthermore, three parallel DSR projects are executed, and each contributes to the other projects.

The conclusion can be made that this project fulfils both societal and scientific relevance.

7.4 Literature review

The literature review is described in Chapter 4.

7.5 Generic solution

This paragraph describes the logic for the design of a generic solution for the mentioned problems. The characterisation of the problem will shape the kind of solution that is proposed. Specific operationalisations of the concepts mentioned in this paragraph will be given in the section about the specific solution.

7.5.1 Problem definition

In a single high-level term, the problem could be described as an organisational management information problem. Cybernetics, as a science of information and regulation (Wiener, 1948) independent of the physical embodiment, seems as a relevant body of knowledge to explore since management is in some essence about information and regulation. The more specific field of management cybernetics (Beer, 1981) should then provide the concepts and models for a generic solution.

7.5.2 Design requirements

The generic design should comply with some specific requirements (van Aken & Andriessen, 2011). These requirements are compiled by the researcher, the domain experts, and the organisational managers. Furthermore, the generic solution should be adaptable to a specific context, allow intervention in an organisation, create action, and be assessable.

7.5.2.1 Preconditions

The generic design solution should not conflict with regulations applicable to the domain of the application. It should also agree with the ethical standards for research. Additionally, it should not conflict with social agreements within the organisation and legal agreements between stakeholders such as labour unions.

7.5.2.2 Functional requirements

A high-level, low-detail description of the functionalities of the design is that it should facilitate decision making about network development and management from the integrated perspective of the network, safety economy and customer experience. This decision making occurs on the topics such as destination, time of arrival and time of departure and aircraft type.

- The design should bring (analysed) data from all four areas together to facilitate the conversations between experts in preparing systemic decisions for management.
- The design should support a systems perspective of every network element and essential variable that is required for decision making.

7.5.2.3 User requirements

For this expected design solution, I will be the only operator for the software. I will operate the software to support the network discussions and display the required information requested by the participants.

The data presented in the design will have to match the current formats (in terms of variables, groupings and visualisations) and should match the understanding of the domain experts. E.g., the network and customer experience experts should be able to understand to a sufficient degree a safety performance indicator such as a risk ratio of non-stabilised approaches.

7.5.2.4 Operational requirements

The operational requirements involve both the decision-making as an operational activity and also the software support of this decision-making process.

The flow of the discussion around an issue that I will present cannot be predicted. The tool should be flexible in examining aspects of the cases that will be discussed in the intervention to support the dynamics of the conversation.

The design should clearly visualise a systemic perspective and should be able to change perspective to match the ongoing expert discussion and decision-making.

7.5.2.5 Design limitations

I chose to be independent of the IT department of the airline. This allowed me to stay in control and responsible for the development of the tool. My software development capabilities determined the design limitations. Airline managers did not specify any design limitations.

7.5.3 Design results

The solution that I propose is a functional management system. A functional system description is invariant and independent of the physical implementation of the system. I offer no proposals for any specific departmental structural implementation of the airline organisation. Many implementation options are possible and exemplified by the different departmental structures of Air France, Lufthansa, KLM and British Airways. However, the management functions that their different implementations have to bring alive are invariant from a cybernetic perspective.

I've described the problem as a lack of integration of safety into all corporate decisions while using value production as context. The main characteristics of the problem are:

- In a commercial organisation.
- Management of complexity.
- Information and regulation.

Since the purpose of the proposed solution in this project is to evaluate a high-level management system by providing some executive managers with specific information in a specific context, I consider psychological and sociological factors out of scope. These two factors are required for an effective management system, but they are not sufficient. Effective collaboration requires also shared backgrounds, which can be enhanced by a management information model (Türke, 2008). This is where I focused on with this project and it may reduce the knowledge gaps in this area since little research is executed in the field of management of business integrated safety management, as shown in the literature review chapter.

The concepts (further explained in the theory chapter) that I considered for an effective management model:

- The Law of Requisite variety (Ashby, 1956) asserts that only variety can destroy variety (Ashby, 1958). This means that the controller of a system, which is similar to the management of a system, must have sufficient actions to oppose external disturbances which can push the essential variables outside their desired bandwidth.
- Essential Variables (Ashby, 1956) are those variables that must be kept within limits to sustain the survival of the system. Body temperature is an example of an essential variable for the human body system. Safety, economy and customer experience can be proposed as essential variables. These essential variables must be managed in an integrated manner to prevent issues such as local optimisation, which reduces overall performance (Espejo & Reyes, 2011). For a commercial organisation to survive, it must maintain a value exchange with its environment. To maintain a sustainable value exchange, the organisation must maintain its essential variables within limits (Beer, 1984).
- Distinctions and differences that make a difference are useful notions to decide what to be explicit about. Making distinctions (Brown, 1969) is the primary operation of perception creation (Türke, 2008).
- Complex system: a description of a system with many elements which have a changing number and changing nature of relationships. Complexity and variety are closely related since a system with high complexity also has high variety.
- The Viable System Model (VSM) is a requisite fractal-like management control system, which has sufficient and required control functions to manage essential variables within limits in a changing world.

The requirements for a requisite management model are that it indicates, by making distinctions, the differences that make a difference, the state and the change of the essential variables and their influences.

Management is here understood as coordinated actions to achieve the survival of the organisation or in terms of various engineering to maintain the homeostasis, or variety balance, between the system and its environment.

Management decisions need a frame of reference without which issues remain undecidable. The context for a commercial organisation can only be the context that is about the topics that ensure the organisational survival. These topics are, in my view, the services that the organisation delivers to its environment and reward the organisation for. I use the context of value exchange based on the work of Brewis for British Telecom (Brewis et al., 2011) and Hoverstadt, a cybernetics consultant and writer (Hoverstadt, 2011). Using this logic, the organisation should produce value, and therefore it needs a value production system.

Now that we have established the need for requisite variety and value production, we can argue for a requisite value production management system. The VSM fractal-like properties provide these requirements.

An important step is to decide about the logic for balancing the variety between environment and organisation. The VSM feature of recursions allows distributing variety of different types. Each recursion can handle its own type of recursion-specific variety. At a recursion, it is in principle possible to distribute variety over sibling systems, systems at the same recursion but a different characteristic. Hoverstadt (Hoverstadt, 2011) describes four primary complexity drivers for primary activities: Geography, Technology, Customers and Time.

At each recursion, a meaningful translation of the essential organisational variables must be made (Kingston-Howlett, 1996). Suppose that economy is selected as an organisational essential variable, then at a recursion defined by geography, a different economy aspect of the economy essential variable is chosen than at the recursion defined by technology. In the next section, I'll explain different aspects of safety at different recursions.

Implementing the AVPMM can be done in different ways. Different technological implementations are possible, but the system is not just the IT part; it is the people discussing their issues, making sense and agreeing on decisions, all supported by an implementation of the project model. This should be a first step in model-based management (Schwaninger, 2015). Management of the model itself will create more effective conversations. It should be recognised that the usefulness of a model is not a function of how accurate its representation of an "objective" reality is, but how helpful it is in coordinating the ongoing actions of people (Espejo, 1990).

7.5.4 Design statement

For a design statement, I use the Context, Intervention, Mechanism and Outcome (CIMO) logic as proposed in DSR (van Aken & Andriessen, 2011). A specific design statement is an operationalisation of a general design statement: "In this Context of problems, the use of this Intervention, these Mechanisms will achieve these Outcomes."

In this complex organisation with some silo characteristics, the intervention with a (Network, Safety, Economy, and Customer experience) Integrated management system, will support more effective cross-silo conversations and multi-variable optimisation to enhance network performance management and ultimately improve resource utilisation for value production.

7.6 Airline Value Production Management Model as a specific solution

The specific solution is an operationalisation of the generic solution in terms of a network full-service airline.

The problem that will be addressed is the lack of adequate management of the balance between Network, Safety, Economy, and Customer in the context of Value production.

The decision context for the essential variables is the value production of the organisation. An organisation seen as a complex adaptive system can be modelled as systems embedded in systems. A logic to define systems is value production. A system or Value Production Unit (VPU) provides the context for decisions about the essential variables. A VPU unfolding (systems in systems) of a network airline (like British Airways, Lufthansa and Air France-KLM) can be done as follows: at the highest recursion is the network, then the network comprises regions (Europa, USA etc.), each region has routes (New York Chicago etc.) and each route has a flight (KLM641). Each recursion in this hierarchy maintains the same dimension of value offering to the market. More arguments for this separation in recursions will be provided below in the sections explaining each layer.

One could argue that the model should have one more recursion namely the recursion of a passenger seat (or a stowage space in the cargo hold) since that is the recursion of the value exchange between the specific customer and the company. Since my main focus is flight safety, the safety of the aircraft and not the safety of specific cabin seats I have decided to stop at the recursion of the aircraft. The model provides the capabilities to extend in the future is desired.

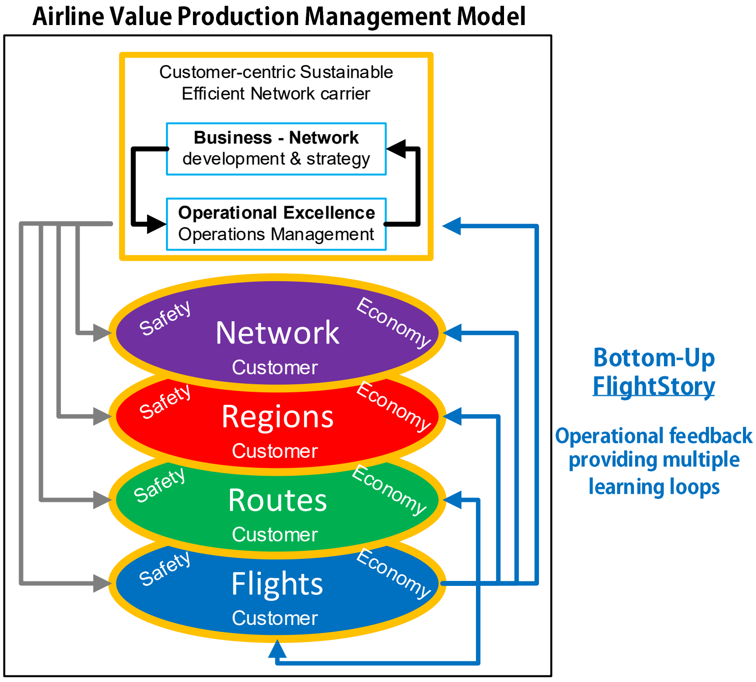


Figure 7-1 AVPMM 4 recursions

The Network, Region, Route, and Flight VPUs provide the context for integrated management of the essential variables. The Flight recursion is embedded in the other three recursions, which means that the performance of the flight VPU is strongly influenced (can be modelled by the Safety Delivery Systems) by decisions in the three other, higher recursion VPUs. The performance factors of the flight can be modelled by the Common Performance Conditions (CPC) (Hollnagel, 1998). The coming together of the factors that produce the flight must be managed and may not be left unattended, or safety events are likely to occur. The management of the CPCs must be part of business cases and decisions, or suboptimal decisions will be made. For e.g. opening a new route that can only be operated safely by extra flight crew training and extra operational support equipment without taking the costs for these safety measures into the business case may lead to an overall unprofitable route. While for strategic market reasons, an unprofitable temporal route may be acceptable, at some point, a route should be adding value.

7.6.1 Essential Variables

The Essential Variables (EV), as defined by Ashby (Ashby, 1956) are a specific class of variables that must be maintained within limits to remain viable. The application of the concept of EV for organisations has been researched by Malik (Malik, 2013), a student of Stafford Beer in his management science publications. Based on his research into hundreds of companies, Malik has proposed a generalised set of EVs that he calls the Central Performance Controls (Malik, 2013). Based on empirical research, he claims that topics unrelated to these controls cannot be justified.

Since I use a systems cybernetic approach to Safety Management, I apply the Ashbian concept of EV. Furthermore, research by Malik (Malik, 2011) has shown the operationalisation of EV is possible in a wide range of organisations. The ICAO, EASA, and IATA regulations and guidelines refer to Safety Management as a means to balance production versus protection. When viewing protection and production as essential variables, the requisite variety of the combination of these variables should also be considered. Obviously, two variables as EV have less requisite variety than more EV. A set of three EV has much more variety since it allows to distinguish topics and issues that should be resolved to maintain viability. From one possible trade-off with two variables, there are minimal three trade-offs with three EVs. This increment is needed to support the operationalisation of the EV into meaningful concepts for people in the organisation. In actual practice, the captain of a flight is supported by an operating philosophy to balance safety, cost and passenger needs. With a slight generalisation into safety, economy and passenger service, these three EVs can better be operationalised for the whole airline company.

One might argue why not take even more EVs than three since that would increase even more the variety of topics and issues to be discussed. My arguments against going beyond these three EVs are:

- In principle, things should be kept as simple as possible, but not simpler than that. This means that effective management requires the capacity to make a requisite number of distinctions. More is not needed and would require a larger than needed management system, which increases the cost that would be hard to endure in the fierce completion in the airline business.
- Based on the principle mentioned above, we should research the effectiveness of four EVs if three are not requisite. Progressing from three to four could be part of organisational learning but currently, it would complicate the model and the project more than it would increase its usefulness.
- The three EVs that I nominate are, in some sense, already used in parts of the organisation and the generalisation and application to the rest of the organisation seem possible. Four or more EVs would be new for all employees, which creates possible confounding effects for this research.

For my specific solution, I will explain and argue to use of the three EVs of safety, economy and customer service in the next paragraphs.

7.6.2 Safety as Essential Variable

For the specific operationalisation of Safety in the context of this network airline, three types of safety are recognised. These are Operational Safety, Occupational Safety and Environmental Safety. **Operational Safety** in this airline concerns the safety of all the activities and processes related to the operation of an aircraft on the ground and in the air. It includes ground operation safety and flight operations safety. During ground operations, it involves aircraft servicing, loading, fuelling etc. During flight operations, it

involves the operation from gate to gate and the prevention of damage of the aircraft. The ICAO includes the prevention of harm to people related to flight execution.
Occupational Safety is defined in this airline as all tasks, procedures, processes and policies to ensure safe and compliant conditions regarding human beings, including personal safety. It includes physical and psychological safety and health effects, both short-term and long-term.
Environmental Safety encloses all tasks, procedures, processes and policies that ensure the surrounding environment, including workplaces, is safe and compliant. This includes emissions (e.g. CO_2), soil and groundwater protection, use and transport and storage of dangerous and hazardous substances and goods.

In this thesis: Safety = $f\ (S_{Operational}, S_{Occupational}, S_{Environmental})$

In general, when the word safety is used, a combination of the three safeties, operational, occupational and environmental, is meant. In a specific context, it will be obvious which specific type of safety is addressed. For this thesis, the focus is on Operational Safety and, more specifically, Flight Safety.

After a review of different safety definitions, as proposed by safety scientists, it will be concluded that no specific safety definition is required as the basis for a safety index. Limiting the safety perspective to one single definition will unnecessarily limit the safety perspective. However, the safety definition in use in an airline company can affect the specifics of the airline's SMS activities.

7.6.2.1 Flight Safety

A short description of the concept of safety will be introduced in this section. Further elaboration can be found in the theory chapter.

A definition of an issue has consequences for how the issue is addressed. A definition of safety will lead to a particular approach to safety models and methods. Hollnagel has introduced two approaches to safety called protective safety as Safety-I and productive safety as Safety-II (Hollnagel, 2017). Since protective safety focuses on preventing adverse outcomes, mainly by managing risks, safety competes with productivity (Hollnagel, 2014b). Safety-II changes safety management from a focus on how things can go wrong to productive safety and a focus on how things can go well (Hollnagel, 2017). Both views are complementary. Hollnagel states that typical performance is continuous rather than discrete, so proposals for improvements refer to a broad spectrum of performance rather than single instances.

7.6.2.2 Flight execution Safety Essential Variables

In principle, safety is assured when the safety EV of the operational processes (ground and flight) are within limits. In general, this means no harm to people or damage to aircraft. The Flight EV are variables that are required for the people in the aircraft and variables related to the structural integrity of the aircraft and to the aerodynamics of the flight. Each IATA category accident can be expressed as one or more EVs out of limits.

Two main high-level flight interdependent management functions to maintain safety essential variables within limits are:

- Flightpath management. The management of the aircraft trajectory both on the ground as in the air. Normally this involves both flight crew working together using procedures and tools such as flight director, auto flight crew, auto throttle and navigation computers. Effective Flightpath management must prevent the EV of Angle Of Attack, Flight envelope parameters, and Distance to Other Objects to remain within limitations.
- System Configuration Management. This is the management of aircraft systems, which, when correctly managed, provide protection for the liveability of passengers and flight crew. These are systems e.g. cabin pressure and temperature.

In actual line flying operations, the flight crew executes these management functions to optimise for safety (EV within limits), cost (minimal time), customer service (on time, comfortable, keeping passengers informed etc.)

Evaluating the performance of the integrated management of safety, economy and customer requires some criteria. The concept of a Safety Index is used to evaluate safety performance. There is a considerable amount of research on safety performance indicators ((Hale, 2009), (Roelen & Klompstra, 2012)) and for the purpose of this project, it is sufficient to only give some suggestions on how a safety index could be compiled.

A Safety Index can comprise some combination of analysed and registered SMS data such as Air Safety Reports, Flight Data Monitoring events, Threat Occurrence frequency, Safety Barrier performance, Risk Ratios etc. Especially the risk ratios combine data based on the concept of Safety-I and Safety-II. Data related to failures and success of threat handling are useful to compare between Flights, Routes and Regions. Depending on the level of recursion at which the Safety Index is presented, a particular composition of the Safety Index is required. At the recursion of Flights, other data is relevant for the composition of the SI as compared to, e.g. the recursion of the Network. At the Flights recursion, the Safety Index must be specific for flights and airports, while this is not required at the recursion of the Network. Some data can be aggregated, e.g. the number of hard landings, while other Safety Index components at a specific recursion cannot be simply aggregated into something meaningful such as sums of analysed risks which have different units of risk, e.g. per flight hour and per flight under specific conditions.

A Safety Index, S-index, can be compiled, which requires by itself a project, and multiple solutions are conceivable, but this is out of this project's scope. In this project, Safety Index is used with values that have some face validity.

7.6.3 Economy as Essential Variable

The financial aspect of an airline business can easily be argued to be an essential variable (Tolkin, 2010). Financial variables such as solvency, liquidity, and operating margin. create threats to the airlines' survival when these variables go outside limits (Holloway, 2008).

To compare Safety, Economy and Customer indexes, to decide on resource allocation in terms of flight frequency, destinations and other network value production criteria, it is out of scope to develop a specific Economy Index for this project.

For an evaluation between two routes, we can assume that all costs remain the same except for some operating costs (fuel, ATC overflight) but that the revenue can significantly differ. Revenue differences must be evaluated against safety and customer for a value-based decision. For this project, the concept of an economy index, E-index, is scaled to a range of +10 to -10.

7.6.4 Customer Experience as Essential Variable

Part of the airline's strategic goals in 2019 is to be “most customer centric” airline, with a strong focus on customer intimacy. To manage this ambition, the airline creates customer and market insights by tools for brand performance monitoring, campaign tracking, local customer research, and customer feedback such as Net Promoter Score (NPS) (Parniangtong, 2017).

For this project, it suffices to compare some kind of aggregated score, C-index, of customer feedback information per flight, route, region and the overall network. For the project, this C-index is scaled to a range of +10 to -10.

7.6.5 Essential variable operationalisations per recursion

Since each recursion is instantiated with viable systems which all have the combination of Safety Economy and Customer as EV, each recursion will be discussed separately. Each recursion has its own specific operationalisation of these three EV. Data for each recursion can comprise different types of aggregation or recursion specific data. Aggregations can be sum, counts etc. At each recursion and each system in focus the aggregation is specific and provides specific information. At each recursion, specific useful system properties may become available which do not exist at lower recursions. For example, a turnaround time, the time between arrival and departure of an aircraft at an airport, does not exist on the recursion of the Flight but it originates at the recursion of Route and can be relevant a higher recursion.

The description of the EVs starts with the Flight, the lowest level of the recursions, as the actual activity that executes the value exchange with the customer.

7.6.5.1 Flight: Safety, Economy and Customer operationalisation

Flight as the lowest level of recursion for this project is identified by a single flight from origin to destination, with a possible stopover at an intermediate airport. In many performance analyses, the flight from an origin to a destination, with no intermediate stop, is a useful unit of analysis (Cook & Billig, 2017).

Safety: Flight safety, in terms of maintaining the flight safety essential variables within limits as described in the paragraph above, concerns a focus on an individual flight. It differs from the Route of Regional safety notions because the scale increase with each step up in the recursions.

Economy: An economic indicator per flight is assumed as useful EV. The assumption is made that the airline's revenue management department in consultation with other departments can design an Economy Index per flight considering the requirements to compare flights. A flight E-index is probably based on an aggregation of individual customer ticket prices.

Customer: The monitoring of customer satisfaction score per flight is already common practice. For this project, the assumption is made that the airline's customer relations department in consultation with other departments can design a Customer index, C-index, per flight to compare flights on the aspect of customer satisfaction.

7.6.5.2 Route Safety, Economy and Customer operationalisation

The Route recursion comprises all the flights between an origin and destination. A route system such as AMS-JFK-AMS (Amsterdam-New York vice versa) is an aggregation of Flights including all the ground operations processes concerned with arrival at JFK and departure for AMS. In the Route recursion, it becomes apparent that Flights have interdependencies. A delayed arrival at the destination may lead to a delayed departure. Since on-schedule operations are important for customers and airline processes, these dependencies may cause tensions and may lead to trade-offs. Increasing flight plan aircraft's speed will lead to more fuel consumption, leading to increased operating cost, thus reducing economical margin, but satisfying the customers' expectation of on-time arrival.

Flights can be executed by two, three or four flight crews, depending on the agreements with flight crew unions and aviation regulations. Every three or six months, a new timetable is compiled. The timetable is an operational planning for the network to optimise resources such as aircraft and crew usage. A scheduled time between two airports can be just around a two to three-flight crew or around a three to four-flight crew limit. In these cases, increased flight speed can reduce the flight time to just below the limit for an extra flight crew. The increased fuel cost for the extra speed is lower than the cost increase for the extra flight crew. Since conditions change, traffic at airports, weather, technical issues etc, executing flights on schedule can become difficult, especially since flight time margins can be minimal.

The frequency of Flights can be several a day or only once a week. Also, different aircraft types can operate on one Route. E.g., the morning flight can be a B777 and the evening flight can be a B787. Many combinations can be found in an attempt to optimise resource usage.

Safety: The tension between time table scheduled flight time and actual flight plan flight time may lead to operational pressure. This on-time performance pressure can have undesired side effects on ground operations safety and flight safety. FDM data of excess flight speeds may not be understood at the recursion of the Flight but may be understood in the context of a Route.

Economy: The cost aspect of operating a flight becomes different in the context of a route. High-speed flight, increasing the operating cost due to increased fuel usage may become acceptable for the outbound flight because on-time arrival is important because the return flight can then also be executed according to schedule.
Passenger tickets are mostly based on a return flight, which is like a route price. It is common practice for the airline to design Route economic performance indications, therefore an assumption that an E-index for Route is possible is justified.

Customer: Based on the aggregation of Flight customer index data, the Route customer index can be calculated. For simplicity, in this project, customer experiences on connecting flights at outstations are not considerate and this does not reduce project validity.

7.6.5.3 Region Safety, Economy and Customer operationalisation

The Region recursion comprises all the Routes in a geographical region. For strategic network development, Regions make sense because they are markets with their own specificities. Also, Flights on Routes in Regions can share specificities that make grouping them in Regions a useful way to group variety. Specificities include operation over large isolated areas towards South America, operating over mountainous areas towards Far East South, operating over areas with specific regulations such as China or areas with reduced Air Traffic Control capabilities such as Africa.
Also, ground operations and aircraft maintenance may be different in different Regions, making it useful to cluster common areas.

Safety: Safety data via e.g. ASR about regional topics such as ATC problems in China, huge fun balloons in South America, volcanic activities in Middle America, Afghanistan overflight or Africa Air Traffic Control issues make more sense at the aggregated Region level than when viewed per route or per flight. From a Safety Management perspective, the Region perspective is used when e.g. airlines are investing in relationships with Chinese authorities and discuss topics such as route development, flight contingency procedures, air traffic control issues and aeroplane diversion procedures. When mutual understanding increases, more flight execution efficiency can be achieved and at the same time safety risk reduces. For example, when a destination is closed for weather (e.g. poor visibility) a flight has to divert to an alternate airport. Communication problems with Air Traffic Control might increase flight time and thus decrease fuel quantity, which will put extra pressure on the crew, which can be a safety issue.

Economy: Economic performance indicators per Region are already compiled for network strategic insights, therefore, the E-Index for a Region is considered being a relevant type of measure.

Customer: Regions with common customer characteristics are important for strategic network developments and are already complied, therefor the C-Index per region is seen as a relevant concept.

7.6.5.4 Network Safety, Economy and Customer operationalisation

Network is considered as the highest recursion. It comprises nested viable systems such as Regions, Routes and Flights. All data from lower recursions can be aggregated to the recursion of the network. New system dynamics become apparent at the network since it influences all Region, Route and Flight operations but is also influenced by these recursions, especially by the issues that cannot be resolved at lower recursions and are pushed upwards to a higher recursions. The network gains most of its value by transferring passengers at the hub station Amsterdam Schiphol. The hub operations performance is critical for passenger and luggage connections, where missed connections require costly recovery actions and dissatisfied customers. Flight crew on European flights also transfer from aircraft to aircraft at the hub. Crew and aircraft changes require attention, often under time constraints and causing operational pressure.

At the network recursion, regional performances can be compared and lessons, be it Safety, Economy or Customers from one region, can be evaluated for applicability to other regions.

Safety: For a network airline, its network structure and network operation are crucial to maximise its value offering to the market. The network design seeks to maximise economic utility by managing its network. This includes new destinations, dropping non-viable destinations and designing a network operations schedule with optimal use of resources (people, aircraft etc.). Network operations and management, which includes all these activities, obviously has a safety aspect. In other words, the configuration of the network sets a base risk for flight operations safety.

Destination selection is an important factor in the network base risk. Network operation into a destination such as Entebbe in the middle of a bird sanctuary has shown the safety aspects. Bird hits after take-off resulted in aircraft damage, return to the airport and the need for maintenance repair. Next, to the direct costs of these repairs, indirect network disturbance damage was caused because passengers could not make their connections.

The combination of destination, time of operation and type of aircraft should be evaluated on safety risk and be part of the business case before any change in network design. If safety is excluded from the network business case, it is not possible to choose a lower safety risk destination when money-wise both are equal. Without safety as an aspect of the business case, it is not possible to evaluate the balance of potential revenue and safety risk. A low revenue potential and high safety risk new destination is probably not a wise business decision.

The expansion of the flight network aims to identify new business opportunities through the development of secondary airports that have yet to be integrated into the international flight network. These airports often have flight operational challenges such as terrain, marginal runway and apron facilities, local air traffic control and traffic speaking their national language and less experience with international heavy aircraft. Examples airports are: Quito in Ecuador, Cali in Columbia, Split in Croatia, San Jose in Costa Rica. Sometimes specific arrangements have to be made with the local aviation authorities and airport to make a desired operation possible (e.g. special take-off and departure procedures). A flight safety risk evaluation of the operation to and from these secondary airports is required, and the costs of mitigating measures to reduce risk should be part of the destination business plan. Without this integrated view, an airline might execute a risky operation on a low revenue airport.

Economy: A Network economic perspective is very important and is therefore compiled on a regular basis. The index used for this project is assumed to be acceptable as a concept for network managers. The index is an aggregation of the values at the lower recursions.

Customer: A Network customer satisfaction perspective is very important and is therefore compiled on a regular basis. The index used for this project is assumed to be acceptable as a concept for network managers. The index is an aggregation of the values at the lower recursions. At the network recursion, regional performances can be compared and lessons from one Region can be evaluated for other regions.

7.6.6 Value index based on Safety, Economy and Customer

The Value index is a function of the Safety, Economy and Customer indexes. Every system on every recursion has a performance expressed in terms of indices for each of the three essential variables. The indices have a value between -10 and +10. This range is considered being adequate for the project because every index can be normalised to this range. The weighting of each essential variable is important since it drives business decisions about flights, destinations, etc., decisions about the optimality of resources usage. The method to find optimality is for the organisation to decide. The weighting of the essential variable plays here an important role. For an actual implementation of this model, the weighting coefficients functions for Safety, Economy and Customer should be based on analysis, expert judgement and business strategies. For this project, the weighting of Economy and Customer was regarded as equal to each other over the full range from -10 to +10 and was assumed to be 1. For strategic decisions, a negative Economy or Customer index may be acceptable. However, a negative Safety Index is very critical and should not occur. The risk and safety management strategies will determine the acceptability of specific safety performance indicators. For this project, the weighting of safety becomes higher when the index becomes negative. An exponential weighting factor for the safety index is shown in the figure below. The weighting below complies with the required logic and is for illustration purposes only.

$$f(\boldsymbol{Value}) = (Eindex * Economy) + (Cindex * Customer) + \ (0.885 + 1.093 * e^{-0.328Sindex}) * Safety$$

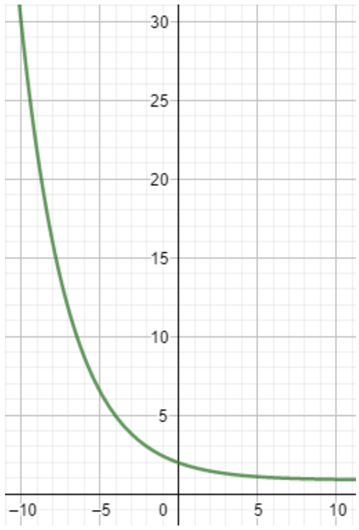


Figure 7-2 Safety element of Value

7.6.7 AVPMM implementation in software

The purpose of the intervention is to evaluate the improvement of the decision-making process regarding the optimal usage of resources in the context of value production. In less formal words: to what extent does this model help to manage network performance based on Safety, Economy and Customer criteria. Current methods for this type of decision making do not include the Safety component. Safety is assumed to be at a 'satisfactory level' in network decisions. In other words, risk is assumed to be acceptable and therefore not part of the network resource optimisation equation.

The AVPMM, based on the Viable System Model (VSM) ((Beer, 1972), uses the logic of value production to define recursions and Value Production Units (VPU) as Operational Units. Each Operational Unit is a Viable System and requires the VSM based required and sufficient management functions.

The software model allows to navigate through the structure of the VPUs. Each VPU can be made a System in Focus. For each System in Focus, the parent recursion and child systems are visible. Because the System in focus has direct interactions with the systems above and below, these interactions can be shown in the panels of each VPU.

The screen structure is invariant for every System in Focus. Every screen contains data panels for every VSM communication channel. For this intervention, most panels are filled with example data. Data can be any type that can be displayed on a display ranging from tables, text, graphs, enclosed websites, links to websites, etc. A perspective selector allows to view data in the panels from the perspective of Value, Safety, Economy or

Customer. This feature allows to zoom in on a perspective while staying in the context of the value production, to support conversations to understand, decide and learn.

The software runs on a windows computer, but can run on any platform, build in Web2py, a Python web framework. Most of the server and data structure programming for the VPU navigation system was done by my brother, Richard Dijkstra, using some ideas from Steve Brewis, while I designed and built the rest of the software, such as the interface and data visualisations. The interface for the screen display is constructed using JavaScript jQuery UI. The visual representation of data is created using the Bokeh server and Dash, which are both data visualization libraries in Python. The data for these visualizations is easily obtainable from an Excel spreadsheet for easy testing and configuration purposes.

The software model is developed to support as much as possible an effective model through which to manage a system, to comply with the Conant Ashby theorem (Conant & Ashby, 1970), and to be a requisite model, by using the VSM concepts, to comply with the Law of Requisite Variety (Ashby, 1956)(Ashby, 1958).

Figure 7-3 AVPMM Software interface

7.6.8 AVPMM Software screen Interface components

Data panels are grouped according to the drawing of the VSM model by Stafford Beer, which has a standard layout. The environment is always shown on the left, and the recursions are vertical. Furthermore, in Beer's drawing, the management system functions are always depicted at a similar location. This convention is also used in the screen layout to facilitate the transfer from theory to practice in using the VSM.

> The environment of the organisation is shown on the far left. Top left is concerned with stakeholders and environmental forces that can influence the

organisation in a positive or negative way. Left top is concerned with the 'Future', left bottom is concerned with the 'Now'. These panels have sub panels available for data related to possible issues.
Left of the navigation interface, panels for data related to the interaction the System in Focus has with the Environment. The top panels are again related to the 'Future' and the lower panels are related to the 'Now'. These panels have sub-panels for the different type of interactions.
The centre panels are for navigation and panel size configuration. Panel size can be adjusted to facilitate conversations.
The right-hand panels are all related to the inside of the organisation. There is a panel group for each of the VSM functions. Each function group has sub-panels for specific interactions between the management system functions.
At the top, a row of buttons allows to select a perspective. Each perspective is an aspect system of the whole system. A change in perspective allows to discuss some value issue from that specific selected perspective.
Details of all the sub-panels can be found where the details of the VSM are explained.

Data visualisations, figures and text are used to illustrate and explain the specific parts of the model.

In the panel for data related to the interaction with the environment (left of centre, lower panel), box plots are used to show the value exchange performance for each VPU at the currently selected recursion, in this case, Regions.
Regions can be compared and outliers, either in positive or negative value exchange performance, can easily be found by hovering over the outlier dots of the box plots.
Value exchange performance of sub-systems (Routes) of the current System in Focus Europe (EUR) are show in the lower set of box plots. This configuration of the plots allows to compare and drill to lower recursions based on the unfolding discussion of the participants.
Each drill to a lower recursion shows new details specific for that System in Focus.

The **VPU navigation system** is made to move between different System in Focus. The screenshots show the Network as recursion and System in Focus. The blue text can be selected for navigation towards higher recursion Company or to lower recursion Routes. At the recursion Network there is only one system with the same name Network but in the company this system is referred to as Passage.

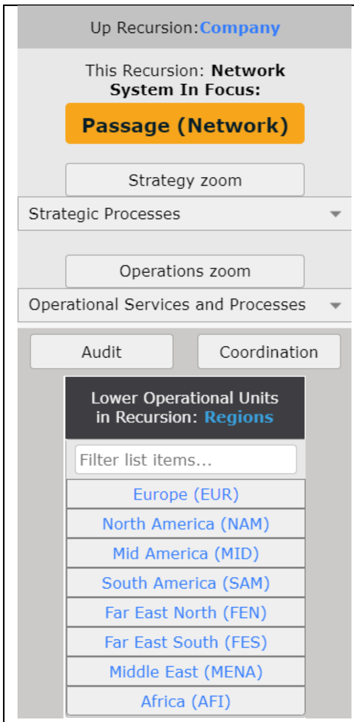
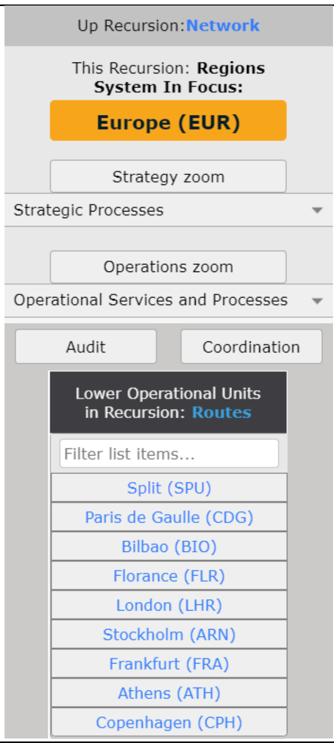
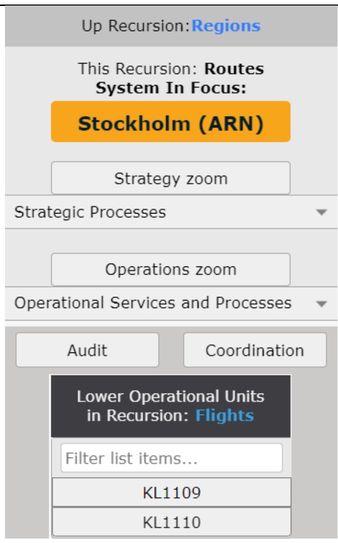
<table>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recursion: Network
System in Focus: Network</td>
<td>Recursion: Regions
System in Focus: Europe (EUR)</td>
<td>Recursion: Routes
System in Focus: Stockholm (ARN)</td>
</tr>
<tr>
<td colspan="3">After selecting the button with the text Europe (EUR) the interface changes from the left to the right screenshot, to navigate downwards.
The blue Network button on the top of the right screenshot can be used for navigating to the higher recursion Network. To navigate from Europe to Paris CDG as System in Focus the use must select the respective button on the middle screen.
Note: Passage is used a company name for what is called Network in this project.</td>
</tr>
</table>

Figure 7-4 VPU model navigation

To illustrate a particular use case, the model is used to navigate from Network, to Europe, to Split SPU to KL1945. First, the Values perspective is used and later the perspective is switched to Safety, Economy and Customer.

The model is in Value perspective. These buttons can be found at the top of the interface of the model.

Figure 7-5 AVPMM perspective selection

Figure 7-6 AVPMM Value perspective system in focus

While at this recursion of Europe (EUR) the panels on the right-hand side of the centre show more detailed data to provide a first step in understanding the value exchange performance shown on the left of centre. In the shown examples the panels below show the individual Safety, Economy and Customer indexes that combine into the specific value performance for this System in Focus.

Figure 7-7 AVPMM Aggregated Value perspective

The above two visualisations show a negative value index of BIO and SPU. The visualisation above shows the negative Safety index for both these airports, explaining the negative value index. A drill to SPU or BIO is needed for a further explanation for this performance. For this example we navigate to the VPU SPU.

Below the left visualisation shows the Value performance. The upper plot shows the overall performance and the lower plot shows the performance per flight. Because of the limited data set, no full box plot is shown. The inbound flight (fake data) KL1945 has the lowest Value index. The lower right visualisation shows how the value for SPU is composed of Safety, Economy and Customer indexes per Flight. Here it becomes obvious the KL1945 has a low Safety performance.

Now the model allows to change the perspective on Safety to get a better understanding of the Safety performance of SPU.

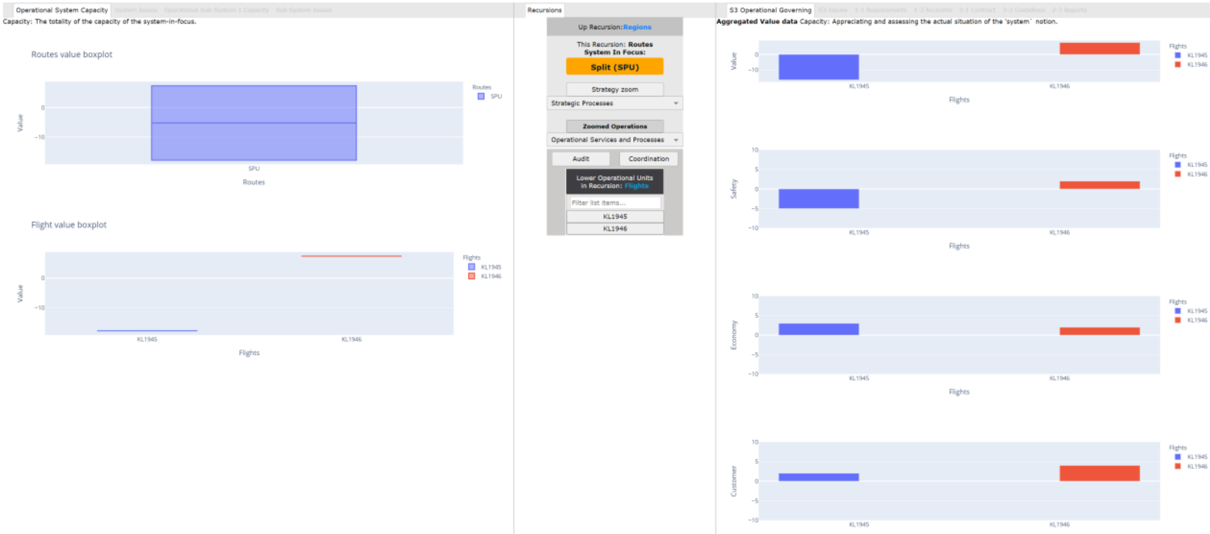


Figure 7-8 Zoom in to negative Value issues

The perspective is now selected into Safety to get more Safety data available.

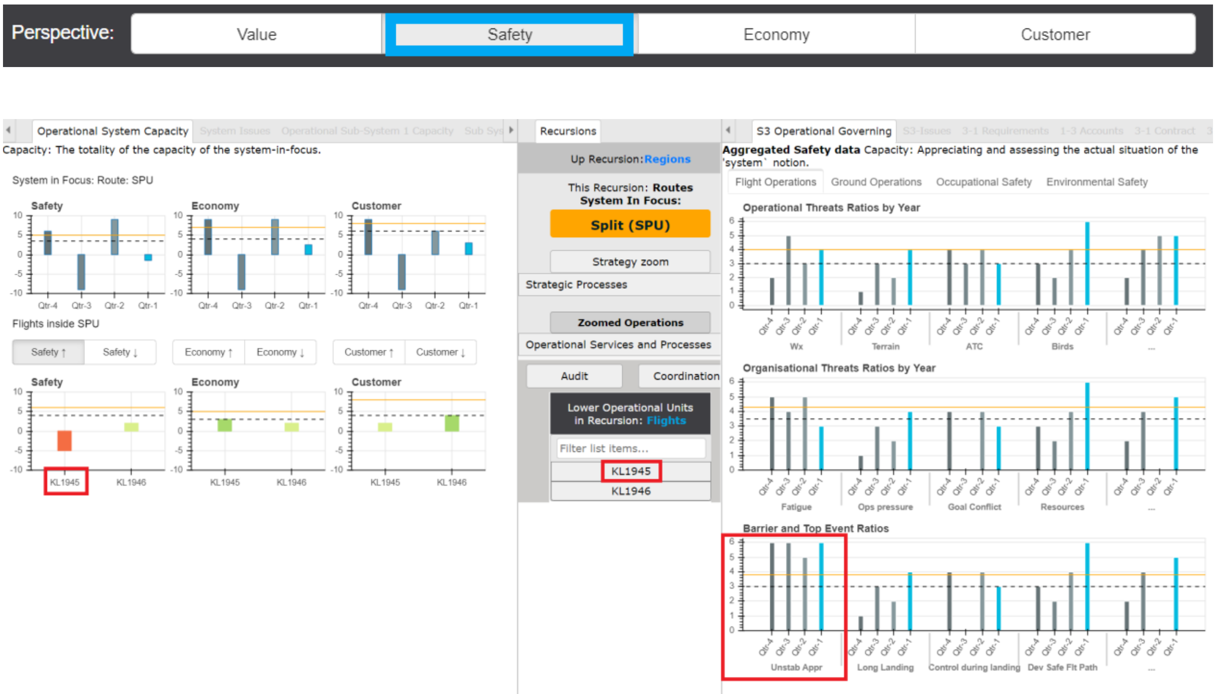


Figure 7-9 Zoom in to Safety issue

The **aspect Safety perspective** is a kind of drill down into a specific data set, but in this model the context of the specific aspect data is still Value.

The left panel (Operational System Capacity) upper visualisation shows the three essential variables (aspects) of Safety, Economy and Customer for this System in Focus.

For each variable, a performance graph over the last year is shown with some specific details regarding e.g. targets and margins.

In the left panel (Operational System Capacity) lower visualisation aggregated data for each lower recursion for each aspect. Buttons to order (from low to high or high to low) the lower recursions within each aspect support ranking lower recursion based on each aspect. This facilitates to find easily e.g., the lowest Safety performing Flight.

The right panel (S3 Operational Governing) shows four tabs with Safety data visualisations regarding Flight Operations, Ground Operations, Occupational Safety and Environmental Safety all related to the current System in Focus. Each tab can provide specific data visualisations. The Flight Operations tab shows quarterly ratio data related to operational threats, organisational threats, barriers, and top events. The operationalisation of the safety concepts should be aligned with the concepts used in the Safety Management System processes. In this case BowTie related concepts were used.

A Safety analysis of this System in Focus: SPU shows a low Safety performance for KL1945 in the left panel. In the right panel we can find an explanation for the low Safety performance. The number of Unstabilized Approach for this flight is high (shown inside the red square). Further analysis would show that, in this period, because of the wind direction and wind strength, a special final approach to landing procedure for this Flight was flown, leading to more unstabilized approaches. This finding can lead to a discussion regarding safety risk and value production for this Flight and Route. For this discussion, network managers would be interested in changing the aspect view.

The **aspect Economy perspective** is a kind of drill down into a specific data set, but in this model the context of the specific aspect data is still Value.

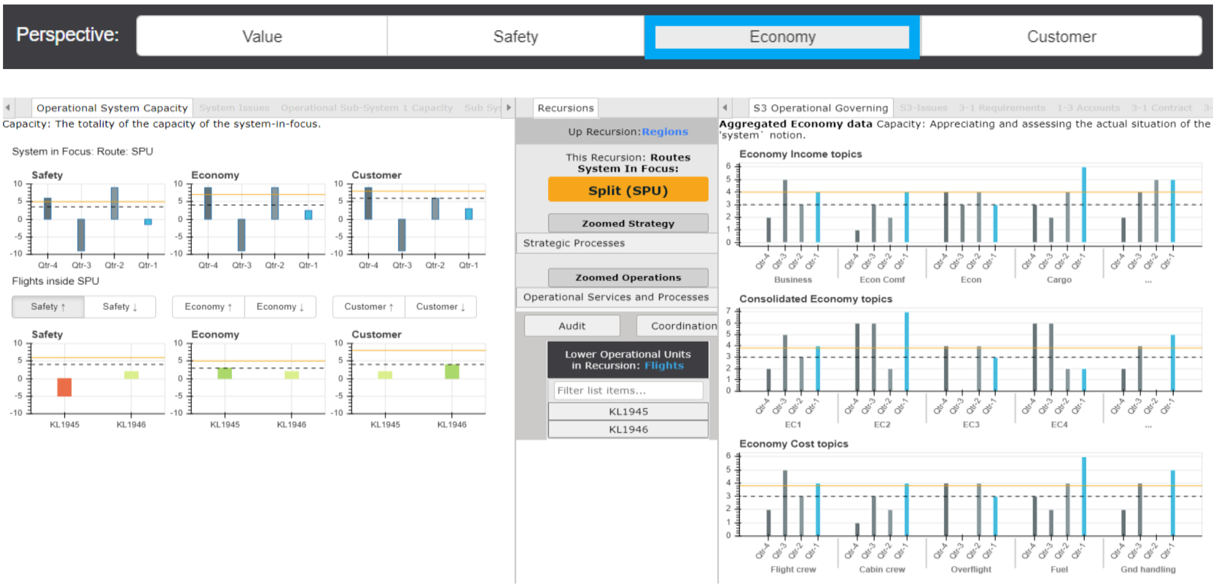


Figure 7-10 Economy perspective

To further enhance the richness of the evaluation of SPU the AVMP allows to switch to the **aspect Customer perspective** as a kind of drill down into a specific data set, but still in the context of Value.

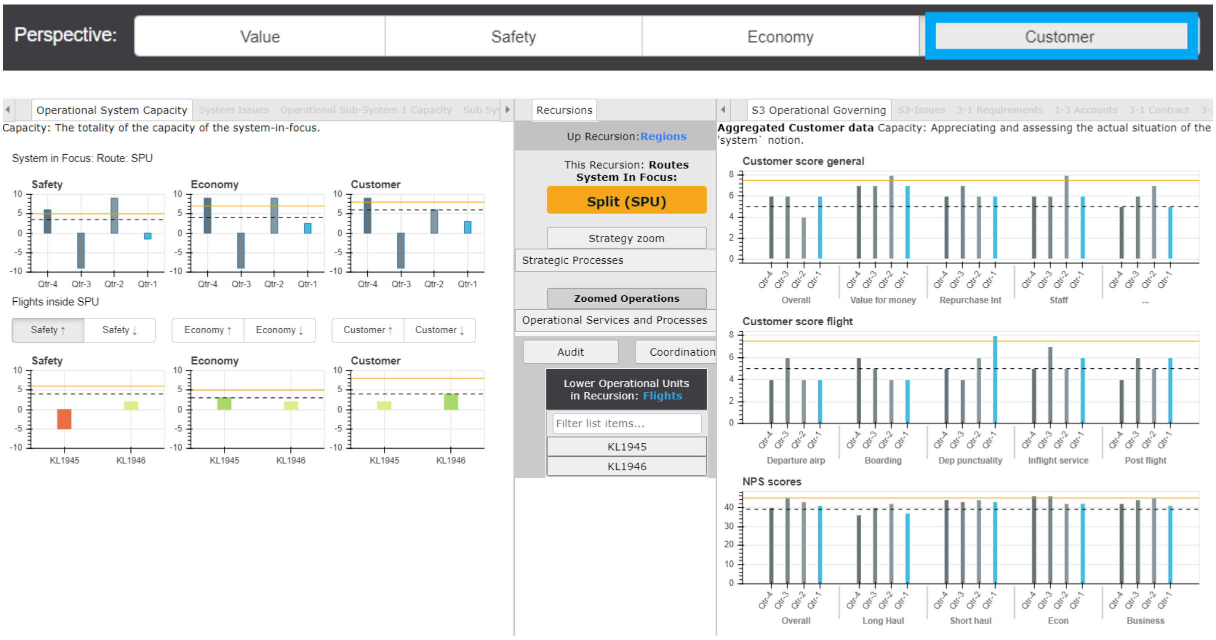


Figure 7-11 Customer perspective

Specific features to enhance Value Production conversations

Below the System in Focus is the Region of North America (NAM) with the aspect perspective Safety and specific Occupational Safety. The Routes are ordered from high to low Safety performance. Safety performance is shown via Risk Ratios, a high level view, allowing to compare Safety performance relative to the other VPU on the same recursion. Outliers in Risk Ratio should be analysed very carefully. A Risk Management Strategy may advise limiting the differences in Risk Ratio since some Flights (or any other recursion VPU) might be far riskier than others.

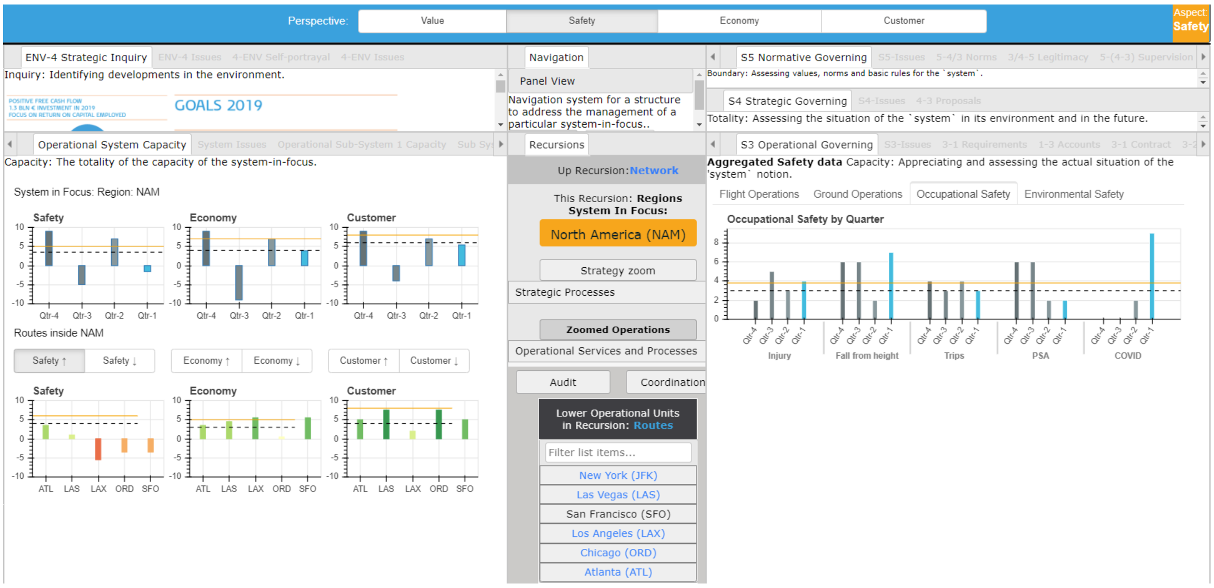


Figure 7-12 Resource allocation conversation support

Below the System in Focus is the Region of Mid America (MID) with the aspect perspective Safety.

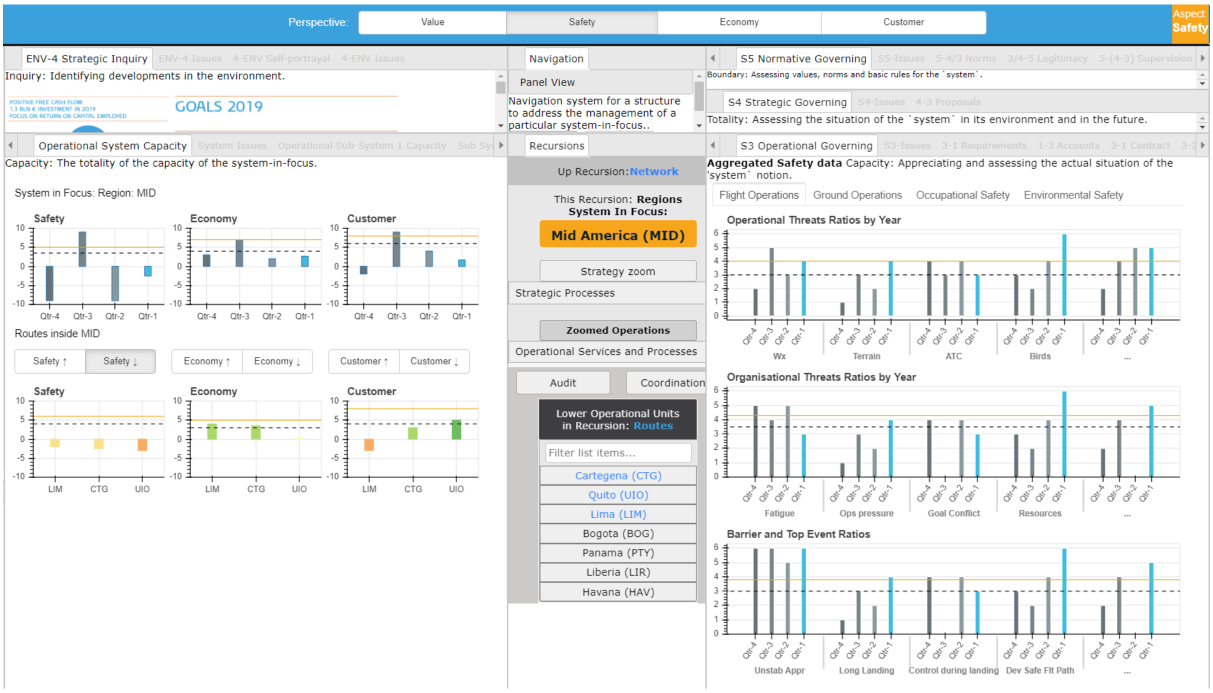


Figure 7-13 Region VPU Safety performance overview

The right panel shows the concept of the Common Performance Conditions (CPC) (Hollnagel, 1998). These are shown in the panel which holds the VSM system 3 to system 1 communication. The channel concerning the resource bargain in the VSM language. Here the discussion about desired performance as expressed by system 3 and the required resources to deliver this required performance by the systems 1 is resolved (Beer, 1994). This is explained in more detail in the theory chapter. For this project, I use the CPCs as representing the resources. In the FlightStory project, the flight crew, the managers of the Flight, provide feedback on the quality of the provided resources. An example of flight crew feedback is shown here. The quality of the resources shapes the performance of the VPU (e.g. Flights) and enriches the discussion of Value Production performance and the aspects of Safety, Economy and Customer.

Summary of navigating the Airline Value Production Management Model

The AVPMM software allows to navigate from recursion to recursion, from System in Focus to System in Focus to evaluate Value Production performance. At any System in Focus of interest, the perspective can be changed from Value to Safety, Economy or Customer. In any perspective, relevant data is visualised with interactions, to allow an interactive discussion and evaluation of any aspect performance in the context of Value production. These model features allow and support more integrated managerial sensemaking an decision making.

7.7 AVPMM group Intervention

For the research design part of the data collection, I will consider the objective of the data collection, the possible methods for data collection and the sources for data collection.

Since the purpose of the intervention is to test and evaluate the design against the research questions and design statement, the evaluation method should be considered. It should be realised that the setting of the research, in an airline company during the COVID pandemic, can put constraints on both the intervention and the evaluation of the intervention.

7.7.1 Evaluation considerations for the intervention

DSR requires a sound evaluation, otherwise it must conclude with only theorising about the utility of design artefacts, with an assertion that a new technology ‘works’ with no evidence that it does (Venable et al., 2016). DSR assessment serves a larger purpose than in 'regular' design practice since it is framed by research goals. Evaluation is focused on assessing the artefact in the context of the usefulness it brings to its context in an ordinary design project without scientific goals (Hevner & Chatterjee, 2010), call this the relevance cycle. In a design science project, assessment must take into account the design and artefact in relation to the knowledge it adds to the knowledge base (Hevner & Chatterjee, 2010) calls this the rigour cycle. Because a build-and-evaluate cycle aims to give both environmental utility and additional (new) knowledge, the evaluation strategy must consider both the artefact usefulness and the quality of the knowledge outputs. Because of the twin aim of assessment, it must be relevant, rigorous, and scientific if DSR is to live up to its name as "science." Furthermore, the validation of DSR intervention's results is more pragmatical than explanatory (van Aken & Andriessen, 2011). The traditional gold standard for controlled experiments of

Randomised Control trials is not possible in this research type and setting so another approach is needed to achieve reliable results.

Considering the two types of evaluation and two settings (Venable et al., 2016) propose a four- step process for choosing an approach for a particular DSR project. The four steps which are proposed are: (1) explicate the goals of the evaluation, (2) choose the evaluation strategy or strategies, (3) determine the properties to evaluate, and (4) design the individual evaluation episode(s).

The goal of the evaluation includes rigour, which means the evaluation must establish the efficacy of the intervention and the effectiveness. Efficacy is established when the outcome is based on the artefact being tested and not some other confounding variable. This can easiest be achieved in an artificial, controlled setting. Effectiveness is established when the artefact in the intervention works in an actual, naturalistic situation.

Regarding the evaluation strategy, my research is a single iteration of design and intervention, there is no need to conduct separate formative and summative evaluations. The type of research leads to what (Venable et al., 2016) call a 'Quick & Simple' evaluation strategy, which has low social and technical risk. The other three evaluation strategies they suggest a "Human Risk & Effectiveness", "Technical Risk & Efficacy" and "Purley Technical Artefact" involve more iterations in the design and development process and for that reason they do not fit well with my research.

The evaluation results of the properties of the AVPMM should help to answer the research questions and design statement. These are centred around integrating safety management and network performance management.

7.7.2 Organisational constraints for intervention and evaluation

Given the multidisciplinary nature of the research, topic experts from different departments are needed. Since interaction between the experts in the conversations about scenarios, these people should preferably meet all at the same time. In agreement with the VP of the ISSO, I wrote a letter to the COO to explain my plan and requested from him support and suggestions for executive managers to contact from the relevant department. I added the table below for clarification.

KLM Department	Job description	Focus group role
Network	Manager	Value strategy Network development strategy
Network	Expert	Network development, destination criteria
Safety	Manager	Safety management strategy
Safety	Expert	Safety performance
Economy	Manager	Economy management strategy
Economy	Expert	Economy, network performance
Customer	Manager	Customer service strategy
Customer	Expert	NPS score

Figure 7-14 Focus group participants

The data for the scenarios being discussed during the intervention could be like actual data but not actual data. Having seen the formats of the different data visualisations in network, economy and customer management summaries, I could mimic this data presentation with values fitting the scenarios.

The software was in my own control, so I had no organisational dependencies, to design, build and maintain the AVPMM application.

7.7.3 Focus group intervention

The gathering and analysis of data can be performed in several ways, according to the goals of the study being conducted as well as the research method being used(Dresch et al., 2014).

Semi-structured and in-depth interviews can be performed in groups, with one or more interviewer's asking questions and recording replies from a group of participants. The phrase "group interview" refers to any semi-structured and in-depth interviews performed with two or more interviewees. The phrase focus group, on the other hand, refers to a particular sort of group interview. The subject to be investigated in this kind is specified and explicitly defined, and the researcher's function is to assist or encourage conversation among participants rather than to lead or be the focal point of interaction (Saunders et al., 2019).

Given the complexity of the research topic, the organisational constraints and resource limitations, it was not possible to use actual information and make actual decisions using the AVPMM approach. That is, however, not very problematic because if it were possible, then the intervention and evaluation depend on the actual issues at hand and this might not be the type of cases where the integrated approach could show its benefit. Simulating safety and network decisions in a setting with experts and actual historic cases that required the integrated approach would be more effective and efficient for addressing new insights proposed by the AVPMM approach. Focus group discussion, as opposed to more traditional procedures like individual interviews and surveys, allows investigating topics that aren't well understood or have been little researched yet. The key feature of a single focus group is the interactive discussion of a topic by a collection of all participants and a team of facilitators as one group in one place. This is the most common and classical type of focus group discussion. It has been widely used by both researchers and practitioners across different disciplines(O Nyumba et al., 2018).

Given the evaluation aspects above, a naturalistic setting of the focus group intervention followed by a survey for each member was the best possible choice. The circumstances of the COVID pandemic put a constraint on face-to-face meetings and the among of time the participants could make themselves available for the project.

7.7.4 Before intervention focus group preparation

The steps for the focus group research design include the:

- Objective of the study
- Possible participants
- Suitable location

The COO forwarded my request to three Vice Presidents of departments that he judged to be best suited for my research project. The first was the department involved in the commercial aspect of network development. This department considers subjects such as the operating costs and the revenue. This department proposes new destinations and closes destinations from a commercial perspective. The second department is responsible for the operational feasibility of the planned network. They are concerned with the required resources for the execution of the planning, but also with the operational and safety aspects of each timetable flight. This department has frequent contact with the flight operations department. The third department is concerned with the customer's experience of the service delivery. They conduct research on customer understanding and customer satisfaction.

I provided a further explanation of my research project for each of the three VPs. They then provided me with a contact detail of managers that reported directly to them. These managers were willing to have a Teams meeting so I could explain the purpose of the research and the kind of expertise I was looking for. Each of the directors was willing to cooperate and provided the contact details of an experienced colleague of them.

For two participants for the safety aspect in the focus group, I requested a current and former risk analyst who are also flight crew. The former risk analyst has also been chief pilot of an aircraft type. This means he has been a member of the management team of the flight operations department, which is a very suitable background for representing the safety and operations perspective in the focus group discussions.

As a preparation for the group session, I had a Teams meeting of about one hour with each of these eight people. I presented slides to explain my project and the objective of the focus group meeting. I could answer all their questions to the extent that they felt sufficiently prepared for the session.

The meeting restrictions due to COVID were getting less stringent, and all agreed to meet in a very large meeting room in the head office.

The planned focus group participants were:

- Two experts from the department of Network Planning: one director, Network Planning and a Network Planner.
- Two experts from the department of schedule development and distribution; one Schedule Development lead and one Schedule Development planner.
- From the department of Customer Insight; one director Customer Insights and one director Flights and Partners.

- From the safety department: one senior risk analyst and one former risk analyst and former chief pilot of the Flight Operations Department.
- A research assistant and myself.

My role, was the moderator or 'facilitator'. These two labels emphasise the dual purpose involved in running a focus group, namely to keep the group within the boundaries of the topic being discussed and generate interest in the topic and encourage discussion, while at the same time not leading the group towards any particular opinion (Saunders et al., 2019). I was assisted a PhD candidate and MSc Communication Science, who knows my research topic well.

7.7.4.1 Focus group session presentation

I prepared a PowerPoint slide presentation to introduce and explain the research and guide the conversations. The following topics were in the presentation: welcome, agenda, who is who, explanation of the AVPMM, protection versus production, safety as sub-system versus safety as aspect system optimisation, flight scenario related to fatigue, flight scenario related to bird hit, FlightStory as data source for AVPMM.

7.7.4.2 Focus group discussion topic: Production versus Protection

This first part of the discussion was related to the research question:

> **RQ 2.1 How can the AVPMM improve the management of production-protection?**

The link between production and protection was the first item to be discussed during the focus group discussion. ICAO proposes a high-level model that introduces the concept of a Safety Space to explain an organisational management challenge (ICAO, 2018b). The model depicts the conflict between bankruptcy, which indicates financial failure, and catastrophe, which indicates a failure in terms of safety. As a result, I wanted the focus group to talk about how useful this two-variable ICAO model is in comparison to the AVPMM model's Safety, Cost, and Passenger elements. These specific research questions addressed the decision support these models can offer for the kinds of decisions these people make.

7.7.4.3 Focus group discussion topic: Network performance management decisions

The second part of the focus group discussion would be related to the second and third research questions:

> **RQ 2.2 How can the AVPMM improve Network Performance Management?**

In the second section of the group discussion, I presented a model of safety as sub-system and as aspect system. In the safety as sub-system approach, safety is taken to be either acceptable or not acceptable. In the safety as aspect system, safety is a topic in more business decisions. At the end of this topic I asked the group to answer the specific questions related to this research question shown in the section 7.7.7.

RQ 2.3 How can the AVPMM improve 'optimal resource allocation'?

After this section, we would discuss two scenarios. The first scenario was very recent and related to a very long flight and the safety risk of flight crew fatigue. All participants except for the Customer experts, this scenario was known. We would also discuss the handling of a fatigue case. The risk analyst and Flight Operations Manager that handled this case were in the group. They could describe how the safety issue was managed and what the impact was on the economy aspect of the flight. The second scenario was about an airport with frequent bird hits and in 2010 a serious incident occurred as a consequence of a bird hit. This was the incident of which I was one of the investigators and which I describe in my investigator's story in the first chapter. The scenarios served as cases where safety is a very visible issue and how that would shine a light on possible differences between safety as sub-system or safety as aspect system. I wanted the group to consider the solution space for safety issues for both approaches.

7.7.4.4 Focus group discussion topic: FlightStory integration with AVPMM

The last part of the group session discussion would be related to the possible benefits of FlightStory data for the AVPMM. I explained to the participants that flight crew were invited to submit a FlightStory whenever one of the service delivery aspects was challenged by the conditions and had operational consequences.

I would provide some samples of actual collected FlightStories which had issues related to a diversion and extra fuel policy and another related to passenger concerns affecting crew behaviour in a safety event. Some questions about FlightStory as operational audit and value delivery feedback channel were to be considered.

The final topic I wanted to address was to what extend the participants would support a trial period of several months for working with the AVPMM concepts.

I had prepared other Network Management cases might the opportunity arise to discuss them:

- Compare a short list of possible new destinations on the safety aspect.
- Find low-performance stations based on economy and customer experience and use the safety aspect to determine the possible closure of a station
- Possible flight operational pressure as experienced by the crew because of scheduled flight time minimisation by flying higher cost index.

Two weeks before the group meeting, the participants received a 25 slide presentation, and that introduces the research and explains the concepts. The participants were asked to consider cases from their own domain that could be discussed in the group session.

A week before the group session, I send the participants an explanation of the ICAO production-protection model. The explanation comprised the ICAO explanation from the ICAO SMS manual and two pages from the Reason book (Reason, 1997) explaining the relationship between production and protection.

7.7.5 Ethical considerations

Focus group methods raises ethical issues that are unique from those posed e.g. by one-on-one interviews (Sim & Waterfield, 2019). Due to the unpredictability of the conversation and interaction that will follow, the main problem in getting consent is offering a clear picture of what will happen in the group. Consent might be difficult to get since it is perceived as a means of setting acceptable expectations in the person. The participant's ability to withdraw permission is more difficult than in one-on-one interviews. Because the researcher has limited control over what participants may later disclose outside the group, confidentiality and anonymity are potentially problematic and therefore participants must trust one another to act as agreed. During the first information session I held with each of the participants and at the start of the group session, the following points were addressed and agreed upon.

- Voluntary cooperating allowed withdrawing.
- Agreed to record the session for research analysis purposes and store the file in a safe place and delete after the research is completed.
- Anonymity will be maintained in the report because no specific names will be mentioned.
- Confidentiality is agreed between the participants.

7.7.6 Report of the actual Focus Group meeting

The planning for the actual face-to-face meeting took three months. Finally, on 17 December 2021, the focus group session took place from 10:00 to 12:30. A few days before the meeting, one expert of the Network Planning had to cancel the group meeting because of more urgent actual flight schedule issues.

I made the following excerpt based on the video recordings.

7.7.6.1 Introduction

We confirmed the ethical agreements during the introduction. All the participants gave a brief overview of themselves, their jobs, and the goals of the department in which they work.

FlightStory was introduced as a method for improving operational feedback. The Net Promoter Score (NPS) that passengers provide after the flight was introduced, and that NPM data could be interesting data for the AVPMM, similar to FlightStory. Indeed, I had already incorporated this information into the model. Because of cultural differences between passengers, the concept of passenger journey measurements was explained, as well as how data should be interpreted in the context of a region, route, or flight.

The group discussed the significance of on-time departure and arrival and how it influences operational decisions. According to passenger experts, on-time departure is more important to passengers than flight crew believe. Flight crew priorities on-time arrival, but passengers appear to have a different perspective.

It was explained that while flight crew are willing to optimise their flights for on-time arrivals, this can be difficult sometimes. A short turn-in to final for landing, for example, will be appreciated by the company and the passengers, but it may increase the flight risk to an undesirable level. It all depends on the circumstances. The phrase "never compromise on safety" was explained as not being as absolute as one might believe. Flight operations, for example, are more dangerous in stormy weather than in sunny, no-wind conditions.

The conclusion was that flight crew and flight operations consider all shades of safety, whereas other departments assume safety is not really an issue because the Flight Operations department has accepted the route.

It was explained that the choices for destinations, the planned arrival and departure times, and the type of aircraft determine the minimum airline risk. Airline risk increases when more challenging destinations are added to the network, such as Kathmandu in Nepal.

The notion of safety, cost and customer as used in flight execution as a frame of reference for the captain makes also sense at the recursions of route, region and network. Some examples were discussed to get an understanding of these notions and how they could relate.

I explain how my background is Safety Management and how this research is an attempt to connect to the business to try to support the airlines' ambition to have an industry leading integrated SMS. I explain how we in risk management as part of safety management are considering the other aspects of Economy, Customer and Network. I am challenged that I suggest safety is the most important. This is followed by discussing how the aspects are interdependent and together create value. I explain how the value concept integrates the three aspects and that the challenge is to maximise value. When the aspects are combined, we might have a larger solution space for issues. Sometimes it might be more effective to operate by daylight and thus reducing risk by adapting the schedule. The risk management strategies are explained, especially that concentrated risk should be avoided. The group discusses that risk management concepts, such as threats, can be recognised in each aspect. Concern is expressed that each department will strive to maximise its own value. It is agreed that the maximisation of value leads to the question to answer the question “what is in it for us” as company instead of department.

7.7.6.2 Focus group discussion topic: Production versus Protection

Because Value Production must be managed, a management system is required. The AVPMM is then explained. The software model is briefly explained. It is recommended that you think in terms of functions rather than departments. The next challenge would be figuring out how to put these ideas into action. The question of how Value is operationalised is raised. Is it possible to do this in Euros? There is agreement that this is problematic, and one reason is that a human life may have to be expressed in Euros for the safety value. To make the value judgement, my suggestion is to use expert and data support agreement. This is problematic, according to an expert, because changing one variable causes other variables to change, and using subjective group norms instead of numbers obscures the dynamics. Following that, there is a discussion about the importance of numerical unity. According to an expert, reducing outliers for each value is a viable option. Several people agree that determining a value in each domain will be difficult. I explain that sitting around a table and discussing dependencies in a regular meeting structure is already a step forward. I propose we make judgement calls and decide on how to maximise value as a group of experts. Because the discussion came to a halt, it appeared that this idea had been accepted by the group.

The management dilemma when safety meets the rest of the organisation was then discussed using the model of protection versus production. The model was interpreted in a variety of ways. The problem of the boundaries was one of the issues. Other issues included the operationalisation of production in a specific case, scale, conceptual versus optimalisation, and the fact that production and protection are not always in conflict. Both models may be correct, but which one is more useful? The ICAO conceptual model is useful at a high level, but it is less useful as a steering model.

The group agreed to answer the questions on a later day after the session because the discussions took longer than expected.

7.7.6.3 Focus group discussion topic: Network performance management decisions

Following the break, I explain that with my research, I am attempting to take a step forward compared to the current state of network performance management in the airline. The current processes for selecting new network destinations and managing the existing network are discussed. The experts explain the conflict that exists between a route's commercial and operational feasibility. They use a specific discussion between these departments as an example. There is no joint search for the best solution, according to the remark. According to one expert, the culture is not to sit together, but rather for each department to "work in isolation". Several group members that communication between network planners, schedule developers, and flight operations is ineffective, resulting in potential opportunities being lost. There are two examples given. An expert inquires as to what makes up an acceptable level of safety. I explain that the limits are determined by expert judgement and agreement on a case-by-case basis. The idea of improving departmental communication is supported by the group. The tension between commercial and operational is how one expert describes his observation. Another expert describes the interaction between the two network departments as "extremely intense," they have daily contact, such as when attempting to gain 7 minutes of flight time. A network review is shared between departments twice a year, according to an expert, but the safety department is not one of them. Network people like clear safety boundary limits there are already many trade-off variables.

The handling of the Entebbe case in 2010 contrasts with how the new approach would handle this case. A case about a different destination was also brought in to support the argument for more open and effective communication. It would be extremely beneficial if people could express their concerns in Euros. More effective communication, according to the general consensus, can improve current practice. Unfortunately, the current departmental-oriented culture is not conducive to a more integrated approach, as it is stated.

A specialist notices that during a risk analysis there is no indication of the commercial significance. Another observes that he believes each case has commercial significance. He is told that not all commercial cases are the same. The route that is discussed had a very high commercial value. The safety department was not aware of that. This raises the question if the safety department should take commercial value into consideration. An expert explains that the risk mitigation may be more expensive for profitable routes, e.g., add an extra flight crew.

A comment is made about the importance of data transparency because not very department wants to share their data. Both the safety and commercial departments are cautious with whom to share data. Maybe the commercial department is more restrictive in sharing data than the safety department, since safety data is made anonymous when it leaves the department. Another says that data should not be used against individuals.

7.7.6.4 Focus group discussion topic: FlightStory integration with AVPMM

The last topic in the session was a short explanation about FlightStory as a value delivery feedback system. I explained the tri-arc about safety, economy and customer as an illustration of the integrative approach, which made some to utter an appreciative response.

The session was ended with a proposal for the process to answer some questions.

I had planned for the experts to answer some questions, but during the session it was agreed that thoughtful answering these questions would take too much time. We agreed I would send the questions after the session with a summary of discussions as a reference together with a video explanation of FlightStory.

7.7.7 AVPMM evaluation design

The initial version of the AVPMM evaluation questions was part of the group session presentation, which you can find in the section above. There I also provide the logic for the questions in the survey, which are designed to collect data for grounding answers to the research questions.

Because of the limited time in the group session, it was decided to send the evaluation questions to the participants after the session. Based on the discussion, I could make some updates to the questions. I made them somewhat simpler and put more emphasis on the comparison between the current situation and the proposed new situation when using the AVPMM.

The following survey question statements were developed which could be answered on a 5 point scale from fully agree to fully disagree.:

1 **The three variables, safety economy and customer as used in the Value Production Model, provide us as an airline more guidance in managing our activities than the ICAO two variables Production-Protection model.**
This question addressed research question 2.1. The purpose of the question is to find out to which extent the ICAO model can be operationalised in a way that it helps decision-making related to either safety or to production. The AVPMM has more specific variables and might thus be easier to fit a decision context.

2 **The current practices resemble more safety as a sub-system approach where safety is treated as binary (safe or not-safe) than safety as an aspect where safety is more nuanced and completely integrated (right picture).**
This question addresses the current practice of safety as a sub-stem with a possible future where safety is managed as an aspect-system in the context of Value Production. The safety as aspect-system has the consequence that safe gets out of the silo, which means the other aspects will encounter a more nuanced and conditional view of safety and risk as opposed to the traditional binary safety view. The answers to this question can be informative for research question 2.2 and 2.3.

3 **When safety is added as a criterium to Network Performance some network decisions become more informed.**
This question addressed the topic of a richer appreciation of network performance as suggested by the AVPMM and in research question 2.2. Maybe some answers would be informative for research question 2.3. The AVPMM software model can demonstrate an analysis of the network in finding value production problems. These problem scenarios showed various ways to improve network performance such as changing arrival and departure times, changing crew composition and support for the choice which station to delete from the network by considering the difference between safety performance of different stations which perform equally poor in terms of economy.

4 **The integrated and interactive approach suggested by the Value Production Model provides a more effective and efficient method for finding conflicting issues and risk reduction options than current practices.**

This question addresses the wider solution space for optimisation. The integrated way is contrasted with the current more reductionist approach for which research questions 2.2 and 2.3 seek an improvement. Some specific scenarios will be used as examples. The experts will be familiar with or can easily relate to the scenarios because they are based on actual events. Some of the arguments in the answers will be based on actual experiences, which is a useful addition to hypothetical arguments.

5 **I advise to senior management to develop a trial for a more interactive cooperation between the three aspects and network based on the Value Production Model concept.**
This question will reveal to what extent the experts see benefit the AVPMM and are supportive of integrating the AVPMM based ideas, such as a more safety integrated approach to network design and management. The answers can inform research questions 2.1, 2.2 and 2.3.

6 **FlightStory supports Value Production Management by enhancing the feedback channel from actual flight operations to management.**
This question is focussed on research question 1.2 about the added value of FlightStory to the AVPMM. Current reporting is not as integrative as FlightStory and is much more fact-based and related to fixed predetermined categories. The FlightStory narrative that can address the three essential aspects and the opinion and advice from the flight crew based on actual flight experiences can be informative for other organisational departments than the departments that receive the current Air Safety Reports of factual Inflight Reports. FlightStory would be a new data item for most of the experts in the group.

7.7.8 Individual survey for focus group members

As agreed during the group session the participants would answer the questions after the session. I added to the questions the presentation we had discussed and complemented it with some highlights of the group discussion which I compiled from the video recordings. I also added a 14 minute video recap of the session in which I show the presentation and provide comments based on the discussion and explain the questions. I also added a link to a video in which I explain the FlightStory project.

7.7.9 AVPMM Focus group survey results

The complete set of answers with all arguments provided by the respondents can be found in the appendix.

7.7.10 Unplanned intervention

Two events can serve as a type of validation of the relevance and applicability of the concepts used in this project during the final stages. The model was appreciated in structuring topics of possible concern in two encounters with managers dealing with the early stages of the Corona crisis. It began with a call from a safety manager, a member of the Corona Crisis Team, around 20:00 on a Friday evening. He wanted to talk about the impact of corona on the organisation, the people, and network flight operations, among other things. For all the topics that were now unstructured and difficult to oversee and address, he needed some sort of organising structure. First, we talked about how one or more bowtie models could be used to organise the topics. This is the risk model in use, so it's a logical choice to think about. However, a bowtie model did not provide him with the necessary topic structuring. I explained my proposal for an organising principle of topics and possible problematic issues while sitting behind my computer with the AVPMM model on my display. I described the AVPMM's logic as a way to distribute variety across different recursions. Variations in the environment that impact the organisation, such as corona effects on passengers and employees, as well as new regulations from countries and aviation authorities that affect flight execution, are also modelled in the AVPMM and can be evaluated at any time when the model is live with actual data. After just over an hour on the phone, the logic was clear to him, and he acknowledged that this method of organising the topics made a lot of sense to him. I also sent him a screenshot of the model, and he thanked me for introducing him to this method of modelling his difficult subjects.

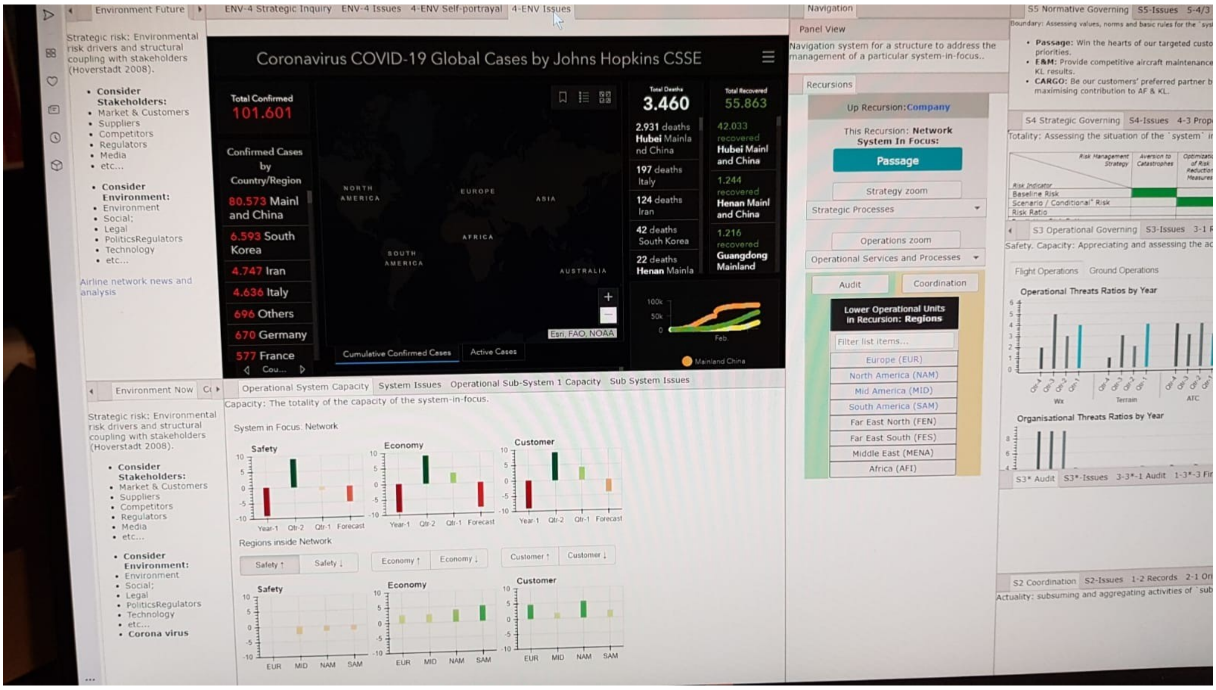


Figure 7-15 AVPMM screenshot

To further support the operationalisation of the AVPMM model for COVID-19 issues, I built the topic matrix below. This excel sheet has rows with recursions, Network, Regions, Routes and Flights. Per recursion, I address the degree of control over the main processes Ground Operations, Flight Operations and Engineering and Maintenance. These processes drive the value creation, they are the production processes for the airline. Process control, in combination with the required resources and materials for the production processes, is under the influence of the environment, which is shown on the left-hand side of the AVPMM to show that they should be considered for strategical and operational topics. In the matrix, I mention these stakeholders in the columns to create a topic matrix where each possible combination is represented by a cell. For a complete systematic evaluation of possible issues, all cells should be evaluated. The matrix is not safety specific but value production oriented and can be viewed from the aspects of safety, economy and customer service.

Topic matrix

Consider for each cell the threats, barriers, margins, buffers and flexibility capacities (and opportunities)

			External Related parties (StakeHolders)					
			Pressure groups	Media	Regulators	Competitors	Suppliers	Market / Customers
		Flight						
	Control over own activities	Ground						
		Maintenance						
		OCC						
Network	Resources	Ground						
		Flight						
		Maintenance						
		Catering						
	Materials	Fuel						
		AC servicing						
		Flight						
	Control over own activities	Ground						
		Maintenance						
		OCC						
Region	Resources	Ground						
		Flight						
		Maintenance						
		Catering						
	Materials	Fuel						
		AC servicing						
		Flight						
	Control over own activities	Ground						
		Maintenance						
		OCC						
Routes (O-D)	Resources	Ground						
		Flight						
		Maintenance						
		Catering						
	Materials	Fuel						
		AC servicing						
		Flight						
	Control over own activities	Ground						
		Maintenance						
		OCC						
Flight	Resources	Ground						
		Flight						
		Maintenance						
		Catering						
	Materials	Fuel						
		AC servicing						

Figure 7-16 Topic Matrix based on AVPMM

With the description above, I sent this matrix to the VP of the ISSO and my safety manager. His appreciation and expected benefit of this approach to structuring the COVID impact can be deduced from his request to make me available for office work. This happened over the weekend and I was scheduled to fly on Monday. The VP of the ISSO requested to Chief Pilot of the B777/B787 to replace me with another captain so I could continue work based on these models. Unfortunately, no replacement was available, so I had to fly. On Monday, a team was built to work on bowtie modelling of the COVID impact. My safety manager, with whom I had spoken on Friday and who also received my topic matrix, was part of the Safety Issue Risk Analysis (SIRA) team. The following bowtie model shows how the use of the topic matrix structured the risk scenarios developed by the SIRA team. A validation of the usability of the topic matrix can be inferred from the bowtie. Below is the actual bowtie after the first day of development by the SIRA team.

<table>
<tr><th>English translation of the blue threats</th><th></th></tr>
<tr><td>KLM employee in NL or abroad are unable to work. Governmental restrictions or fear of infection.

Governmental restrictions on flight execution and passenger flows.

Failure of critical infrastructure such as airports, air traffic control, etc.

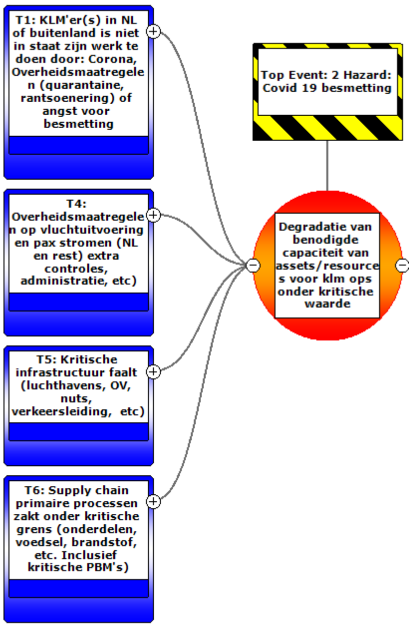
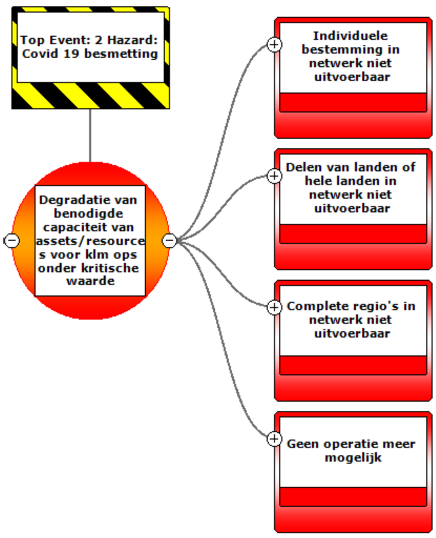
Supply chain resources below critical limits (fuel, food, parts and personal protective equipment)</td><td>
</td></tr>
</table>

Figure 7-17 Threats in BowTie model based on Topic Matrix

<table>
<tr><th>Consequences</th><th>English translation of red consequences</th></tr>
<tr><td>
</td><td>Operation to individual destinations is not possible.

Unable to operate to countries or parts of countries in the network not possible.

Unable to operate to regions in the network

No network operations possible</td></tr>
</table>

Figure 7-18 Consequences in BowTie model based on Topic Matrix

Without my presence in the SIRA team because I had to fly, the team, together with my safety manager, could adopt the ideas from the topic matrix. This shows the usability, applicability and relevance of this new way of thinking, as confirmed by my safety manager, with actual organisational challenges and thus as a kind of validation of the AVPMM.

7.8 Evaluation of AVPMM intervention

For evaluating the DSR intervention of the AVPMM, I was very fortunate to have access to a group of experts that are actually involved in these topics in the airline company. They have an average of 7 years' experience in the specific domains, which means they qualify as experts.

The survey was narrower than I had intended. The AVPMM solution developed included an operational software model capable of displaying Value Management scenarios. The software model enabled the discovery of Value issues and the zooming in on them from a value, safety, economy, or customer perspective. In an evaluation, I intended to demonstrate the capability of multiple perspectives. A group evaluation of a broader software model would take at least two hours. Unfortunately, the organisational conditions limited my time, so I limited myself to the six survey questions.

The survey questions were not answered during the group session because it would have taken too long, and the participants preferred to finish the survey after the session. I included the survey in the email, as well as my notes from the group session, and a FlightStory explanation video for those who were unfamiliar with the FlightStory project. This method of working gave them more time to become acquainted with the new concepts and time to reflect and think. They could spend as much time as they wanted answering the questions. I believe that this procedure gave the participants more time and more data so that they could answer the survey questions more informed and confidently, and their answers thus better represented their expert judgement.

Since the company was experiencing an existential threat because of the COVID situation I was limited to a single focus group session. More sessions with other groups were impossible. I do not expect other focus group sessions would have resulted in very different answers for the network, economy and customer experience topics. In the safety and flight operations domain, I was lucky to have the best informed experts. Other participants from safety and flight operations would be fewer experts and consequently would have required much more explanation to avoid answers based on unfamiliarity with the subject.

In my opinion, the way this survey is conducted provides adequate support for making some claims that contribute to scientific and practical progress in this field.

7.9 Evaluation of AVPMM responses

Depending on the rigour of the testing of a new design, evidence claims can be made. Strong evidence for a design is to test a design artifact in actual operations. The nature of the AVPMM as a research topic makes it impossible to test in actual airline network management decision making. A suitable alternative is to have the people that execute the actual operations available for some simulations and case discussions. A version of a focus group expert elicitation was used to collect evidence about airline network decision-making aspects based on the principles of the AVPMM.

I will argue that the results of the evaluation lead to level 1, 2 and 3 strength of evident (see Chapter 5) claims about the efficacy of the AVPMM intervention. The survey questions were designed to supplement the focus group statements to answer the research questions. The intention is to find lessons for practice and add knowledge to the scientific domain.

Respondent	Aspect	Department	Years in KLM	Years in relevant departments
1	Netw	Network Schedule	20	4
2	Netw	Network Schedule	22	6
3	CX	Customer & Market Insight	23	12
4	CX	Customer & Market Insight	20	3
5	E	Network commercial	11	7
6	S	Flight Operations and Safety	31	7
7	S	Safety	25	10

Table 7-1 AVPMM respondent demographics

7.9.1 Evaluation of AVPMM responses to question 1

In a section above, the design of the evaluation was presented and the following question was composed:

1 **The three variables, safety, economy, and customer, as in the Value Production Model, provide us as an airline with more guidance in managing our activities than the ICAO two-variable Production-Protection model.**
This question addresses the research question 2.1. The purpose of the question is to find out to what extent the ICAO model can be operationalised in a way that it helps decision-making related to either safety or production. The AVPMM has more specific variables and might thus be easier to fit into a decision context.

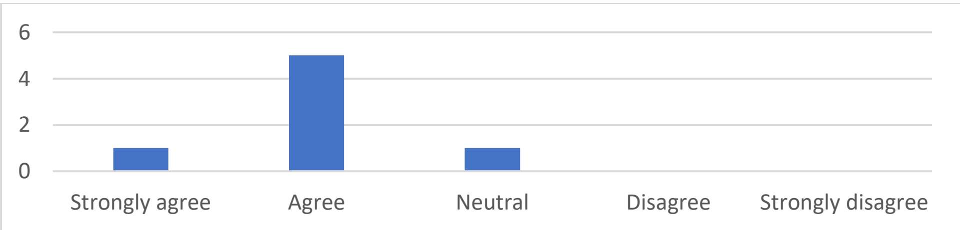


Figure 7-19 Evaluation of AVPMM responses to question 1

Question 1 answers Thematic Analysis:

The ICAO model is viewed more as a high-level conceptual model. It could accommodate the customer variable when the customer value is converted into an economical value.

Three responses related to viewing the customer variable as an economic value. Seven remarks are related to the three variables in the AVPMM model because it provides more specificity, which is seen as a benefit. Two responses are concerned that in theory this might look easier than it will be in practice and that it will be hard to define metrics.

Evaluation:

The desire for simplification was shown by three experts, who suggested that the customer experience variable could be part of an economy variable. One expert who initially suggested this simplification also stated that explicit passenger experience data, possibly collected with FlightStory, would be useful for analysing the future revenue impact of, e.g., flight delays. The conclusion was that customer experience as a separate variable makes sense providing a richer optimisation area. In general, the higher resolution of three variables and the alignment of each variable with airline departments was appreciated and judged useful. A single expert answered "Neutral" while all others agreed with the presented statement. There seems to be a general agreement that the AVPMM is more useful for these experts than the ICAO model. Maybe the presentation of the full AVPMM model caused some undesired anxiety for the experts because of the initial perceived complexity of the model. The notion of recursions is not as relevant to this question as the presentation of the three variables of safety, economy, and customer experience as an alternative to the two-variable production-protection model of ICAO.

Conclusion:

The focus group participants' answers provide support to the claim that the AVPMM three-variable model is more supportive for airline management than the two-variable ICAO model at:

Level 1, descriptive strength for the potential of efficacy because the participants understood the description of both models.

Level 2, theoretical strength for the theoretical and promising efficacy because the participants discussed the pro and cons of both models and could articulate why they agreed with the statement as posed in the question.

Level 3, a somewhat indicative strength for the model to be effective because the group discussed the lack of resolution for the ICAO model for specific cases of decision-making. The merging of economy and customer removes differences that may make a difference in, e.g. service delivery.

Level 4, operational strength is not shown yet.

7.9.2 Evaluation of AVPMM responses to question 2

In a section above, the design of the evaluation was presented and the following question was composed:

2 The current practices resemble safety more than a sub-system approach where safety is treated as binary (safe or not-safe) than safety as an aspect where safety is more nuanced and completely integrated (right picture).
This question addresses the current practice of safety as a sub-system with a possible future where safety is managed as an aspect-system in the context of value production. Safety as an aspect-system has the consequence that safety gets out of the silo, which means the other aspects will encounter a more nuanced and conditional view of safety and risk as opposed to the traditional binary safety view. The answers to these questions can be found in the information for research questions 2.2 and 2.3.

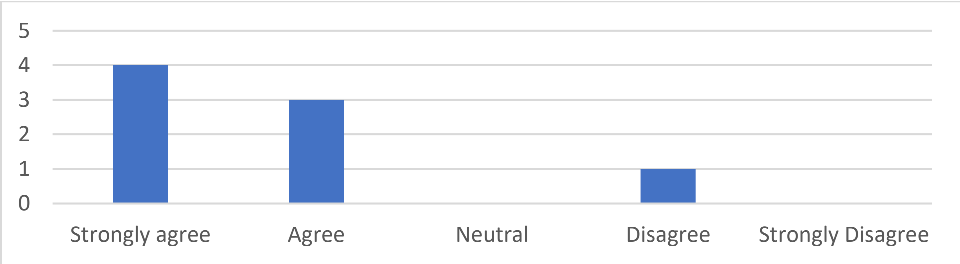


Figure 7-20 Evaluation of AVPMM responses to question 2

Question 2 answers Thematic Analysis:

In general, most are positive about a more inclusive treatment of safety. Most group members agree the current situation can be described as a safety as a sub-system approach. Outside the safety department, there is a rather simplistic view on safety. Some assume it is either safe or not safe, others realise safety is a distribution and as long as a minimum acceptable level of safety is maintained (by the Flight Operations and Safety departments) other departments can see safety as binary. The treatment of safety as an aspect system is seen by most as a step forward from current practices with a caution that poor safety should not be traded against high economy or customer values.

Evaluation:

This question revealed a large difference in the approach to safety of each department. Safety and operational experts have a nuanced view of safety and risk. Especially in flight operations, the aspect of safety is more present. The safety department's view has still been very much like safety in a silo, but a change has been started to consider the other domains in risk analysis and management. The schedule planners, who have regular contact with flight operations people, realise the nuances of safety but take safety for granted once flight operations have agreed to operate a particular flight. The network planner department, which is often in consultation with the schedule planners, has a more binary approach to safety. They currently do not actively involve safety as a key performance indicator, since safety is seen as a sub-system and managed by flight operations.

Most participants agreed that an integrated safety as an aspect system approach to finding optimal solutions is preferred, with the caveat that safety should not be traded off against economy or customer value. The development started by this research to consider the other domains in the newly developed risk analysis framework and risk management strategies by the safety department illustrates the perceived benefit of safety as an aspect system.

Conclusion:

The focus group participants' answers provide support to claim that the safety as aspect system approach has benefits relative to the safety as sub-system approach.

Level 1, descriptive strength for the potential of efficacy because the participants understood the differences between the two approaches.

Level 2, theoretical strength for the theoretical and promising efficacy because the participants could also relate their work to both approaches and they could discuss the differences of the models related to conversations between the departments.

Level 3, indicative strength for the model to be effective because the group discussed the optimisation of solutions for network decisions when safety was treated as an aspect system.

Level 4, operational strength is beginning to show in the new risk analysis framework and risk management strategies processes which are agreed by the COO of the company.

7.9.3 Evaluation of AVPMM responses to question 3

In a section above, the design of the evaluation was presented and the following question was composed:

3 **When safety is added as a criterium to Network Performance some network decisions become more informed.**

This question addressed the topic of a richer appreciation of network performance as suggested by the AVPMM and in research question 2.2. Maybe some answers are informative for research question 2.3. The AVPMM software model can demonstrate an analysis of the network in finding value production problems. These problem scenarios demonstrate various ways to improve network performance, such as changing arrival and departure times; changing crew composition; and supporting the choice of which station to delete from the network by considering the difference between the safety performances of different stations that perform equally poorly in terms of economy.

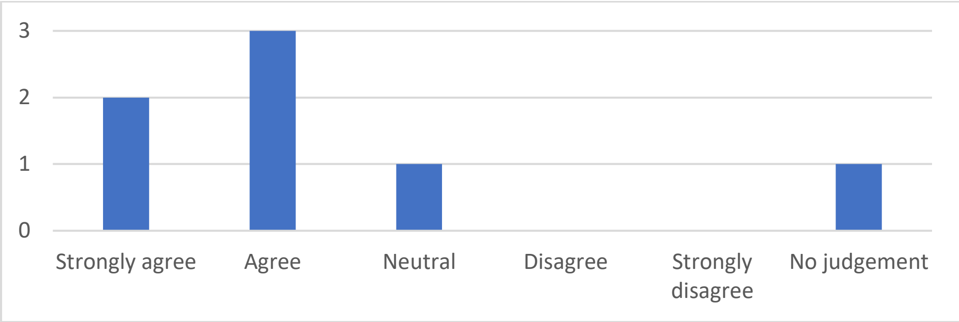


Figure 7-21 Evaluation of AVPMM responses to question 3

Question 3 answers Thematic Analysis:

Some say network decisions can be more informed. One says he thinks safety is already part of network performance, but it could be improved, just like cross-domain communication can be improved. Integration can bring improvements and a richer picture, but should not slow down network competitive response time. A warning is given that safety might be viewed as the dominant factor because the AVPMM originates from the safety domain. New network decisions are possible when, e.g., a low-profitability airport is also a high-risk airport. Safety could also be the determining factor for two new routes that have equal expected profitability.

Evaluation:

This statement addresses the first step in integrating safety as an aspect of network decisions. The next step of aggregating the three variables into a value is discussed in the next question. There was mostly agreement in the group that some network decisions, such as opening and closing of routes or airports, and network schedule changes, become more informed when safety is added as an aspect of network performance. A network manager considers safety already a part of network performance, but the current network performance graphs and reports do not include safety performance, and the safety department does not provide regular data to the network department. The view that safety is already a part of network performance might be based on the idea that safety is assured above a minimum desired level as long as flight operations will execute these flights. Another network manager gave examples of recent network decisions where both safety and economy played crucial roles. These examples illustrate the suggested benefit of safety as a network performance aspect.

The safety and flight operations experts had a strong agreement. The safety expert could explain how the concept of risk as a distribution and how risk can be conditional on circumstances. This approach can help to decide which station to close when both have stations equal low economic and customer performance. The richness of understanding safety and risk nuances seemed to align with the agreement on the statement. Further group discussions are needed to discover the possible benefits of network performance management.

A customer expert did not provide an answer to this question since he declared not to have sufficient expertise to make a judgement. This honesty and self-judgment improve the validity of his answers and show the pleasant professional and inclusive atmosphere of the meeting.

Conclusion:

The focus group participants' answers provide support to the claim that some network decisions become more informed when safety is added as a network performance criterion.

Level 1, descriptive strength for the potential of efficacy because the participants understood the proposed development.

Level 2, theoretical strength for the theoretical and promising efficacy because the participants could also relate their work to both approaches and they could discuss examples of possible conflicts between network decisions and safety.

Level 3, indicative strength for the model to be effective because the group discussed the optimisation of solutions for network decisions and reference was made to actual network decision cases.

Level 4, operational strength is not shown yet.

7.9.4 Evaluation of AVPMM responses to question 4

In a section above, the design of the evaluation was presented and the following question was composed:

4 **The integrated and interactive approach suggested by the Value Production Model provides a more effective and efficient method for finding conflicting issues and risk reduction options than current practices do.**
This question addresses the wider solution space for optimisation. The integrated way is contrasted with the current more reductionist approach, for which research questions 2.2 and 2.3 seek an improvement. Some specific scenarios will be used as examples. Because the scenarios are based on actual events, the experts will be familiar with them or can easily relate to them. Some of the arguments in the answers will be based on actual experiences, which is a useful addition to hypothetical arguments.

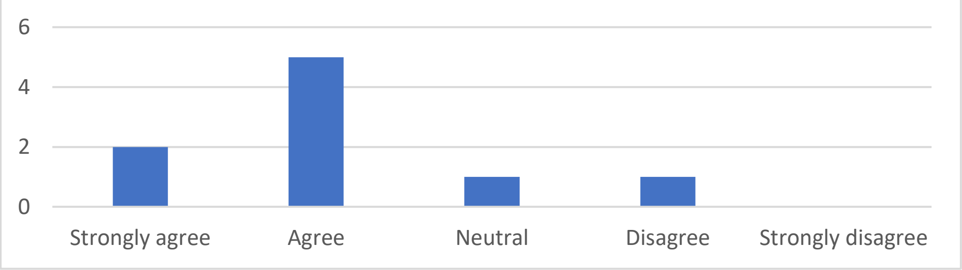


Figure 7-22 Evaluation of AVPMM responses to question 4

Question 4 answers Thematic Analysis:

Most respondents agree, considering these two outlier cases specifically, to expect an increase in effectivity and efficiency to find better value-optimised solutions. However, caution is expressed not to trade safety for the economy and customers. Sub-optimised solutions might be chosen without a value and integrated perspective. Both examples of high-risk cases were discussed, and it was agreed that the lack of an integrated approach led to sub-optimal decision making. In one case, the route was cancelled while not all options were searched exhaustively, and in the other case, the decision making for schedule changes to reduce risk took far longer than desired.

Most participants agreed that the AVPMM approach would lead to more effective decision making, with some reservations since not all information about the cases was known.

Evaluation:

One step beyond including safety as an aspect system is the aggregation into value and the consideration of the AVPMM. Due to the circumstances, I could not explain as much as I desired about concepts integrated into the workings of the software AVPMM. The consequence was that the specifics of the AVPMM, such as e.g., finding value production issues, were not sufficiently explicitly discussed. I had, however, two actual cases that could be discussed to verify the possible added value of using the AVPMM concept.

Two actual cases served as useful experiments to discuss the AVPMM approach. While not all information was known it was assumed that a AVPMM approach would result in more prompt and more informed decisions. The group participants expressed their understanding and agreement. The Entebbe bird hit case was an inspiration for this research.

Conclusion:

The focus group participants' answers provide support to the claim that the AVPMM approach provides more effective and efficient support for finding conflicting issues and risk reduction options than current practices do.

Level 1, descriptive strength for the potential of efficacy because the participants understood the main concept of the AVPMM.

Level 2, theoretical strength for the theoretical and promising efficacy because the participants could also relate their work to the model and they could discuss the differences between current practices and the practices proposed by the model.

Level 3, indicative strength for the model to be effective because the group discussed and agreed the two actual cases could be managed more effectively when the AVPMM concept would have been used. Specific solutions for each case were discussed and most agreed that these solutions would have led to a more favourable outcome of the decisions than those that were actually taken.

Level 4, operational strength could have been shown with actual data and actual value production issues.

7.9.5 Evaluation of AVPMM responses to question 5

In a section above, the design of the evaluation was presented and the following question was composed:

5 **I advise to senior management to develop a trial for a more interactive cooperation between the three aspects and network based on the Value Production Model concept.**
This question will reveal to what extent the experts see the benefits of the AVPMM and are supportive of finding ways to integrate the AVPMM-based ideas, such as a more safety-oriented approach to network design and management. The answers can inform research questions 2.1, 2.2, and 2.3.

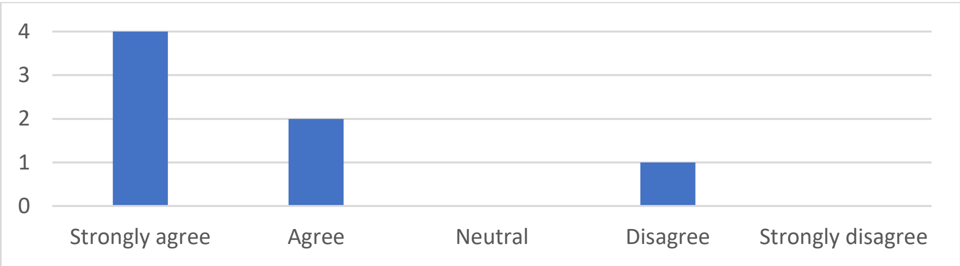


Figure 7-23 Evaluation of AVPMM responses to question 5

Question 5 answers Thematic Analysis:

Most respondents are positive about developing a trial to learn more about the integrated approach. A caution is given again not to trade safety for other aspects. Advice is given to consider relative indicators, e.g., a route's safety performance based on safety proxy indicators. It is suggested that, depending on the issue under discussion, other departments can be added to the conversation.

Evaluation:

These answers to this question show the perceived potential of the AVPMM. All participants are in favour of conducting a further experiment. One participant emphasised safety should not be traded directly against customer and/or economic decisions, but he supported an integrated approach.

This question had the most “strongly agree” answers, showing a positive attitude towards further learning and development of the AVPMM approach. Most experts clearly see potential for the AVPMM approach.

Conclusion:

The focus group participants' answers provide support to the claim that the AVPMM approach provides more interactive cooperation between the three aspects and network based on the Value Production Model concept.

The hierarchy of strength of evidence is not suitable for this claim. Because of the support for the trial of using the AVPMM approach, we can conclude most participants have considerable confidence the AVPMM can bring desired improvements relative to current practices. All previous questions gave level 3 support for the evidence that the AVPMM will provide the basis for a step forward in the development of network and safety management. Based on the responses, I infer most participants expect to find a level 4 strength of evidence by conducting the trial.

7.9.6 Evaluation of AVPMM responses to question 6

In a section above, the design of the evaluation was presented and the following question was composed:

6 **FlightStory supports Value Production Management by enhancing the feedback channel from actual flight operations to management.**
This question is focused on research question 1.2 about the added value of FlightStory to the AVPMM. Current reporting is not as integrative as FlightStory and is much more fact-based and related to fixed predetermined categories. The FlightStory narrative can address the three essential aspects, and the opinion and advice from the flight crew based on actual flight experiences can be informative for other departments than the departments that receive the current Air Safety Reports or factual Inflight Reports. FlightStories would be a new data item for most of the experts in the group.

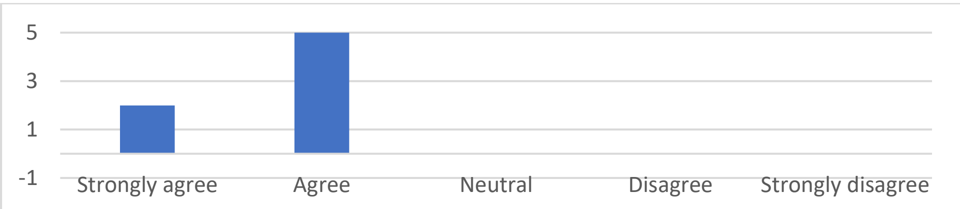


Figure 7-24 Evaluation of AVPMM responses to question 6

Question 6 answers Thematic Analysis:

Most respondents agree FlightStory can have a beneficial contribution. This judgement is for some who are not very familiar with FlightStory and is based on the logic that improved feedback is always better. Others are more specific about the benefits of FlightStory because it has the potential to support organisational learning from the conflicts of the aspects in actual flight operations.

Evaluation:

Two of the experts in this group had actual experience with FlightStory and the insights it can produce. The other had my explanation during the session and on video about the FlightStory concept. I provided them with two examples of actual flight stories that included passenger considerations. Most in the group agreed that improved feedback from flight executions, especially from the integrated perspective as proposed by the AVPMM, is preferred. In particular, the Operational Performance Conditions are mentioned as valuable feedback for which currently no feedback system exists.

The integrative AVPMM Safety, Economy and Customer approach is also a topic in the FlightStory research.

Conclusion:

The focus group participants' answers provide support to the claim that FlightStory, as an enhanced feedback channel, can support the AVPMM approach.

Level 1, descriptive strength for the potential of efficacy because the participants understood the main concept of the AVPMM and FlightStory

Level 2, theoretical strength for the theoretical and promising efficacy because most of the participants could agree that improved feedback channels from flight operations to the organisation are beneficial for learning.

Level 3, indicative strength for the FlightStory to be effective because the safety and flight operational experts had actual experience with the FlightStory app and data and understood the full theory behind the FlightStory concept. They recognised how problematic issues in flight operations can be found with FlightStory.

Level 4, operational strength could have been shown when actual data and actual value production issues were discussed in relevant meetings. Since two of the seven experts had submitted and read FlightStories and were aware of the concepts behind FlightStory, a causal level of evidence can be argued to be likely.

7.9.7 Unplanned AVPMM as Airline Operations Model for supporting COVID risk assessment.

The unplanned intervention was not prepared in any way. The opportunity arose when I was asked to contribute to a brainstorm session to collect all topics that might become issues during the initial stages of the COVID pandemic. I was asked because the specific safety manager knew my ability to scale up and down from network to flight to crew and supporting departments. I explained my AVPMM logic and sent him a screenshot of the software which shows all the relevant aspects, such as operational and strategic threats. I had the impression I could explain the concept in such a way that he confirmed an understanding. The fact that he weighted my AVPMM-based advice as useable is supported by the fact that he explained the concept to the group doing the risk meeting the next day. Also, the VP of Safety assessed my proposal as potentially beneficial because he tried to replace my flight for a day at the office so I could assist with the risk group meeting. Unfortunately, no reserve flight crew was available, so I could not be at the meeting. After my flight, I was able to retrieve the BowTie risk model that had been compiled during the risk meeting. The model showed the elements I had suggested to the safety manager. Apparently, the safety manager has been able to convey my proposals, which is supporting the claim of usefulness and clarity of the model. The fact that the group meeting had accepted my suggestions as presented by the safety manager shows the group accepted these topics and their acceptance is supportive of the claim that these AVPMM-based suggestions were regarded as useful. Given the urgency of the developing COVID situation, relevant experts and managers were at the meeting, and this was not an occasional meeting with occasional attendants.

Since I was not at the meeting, confounding variables may be at play. I don't know if the manager was at the blackboard writing the topics and pushing his own points. He was probably not the person using the BowTie software to build the model, since that is not part of his normal job.

I was unable to investigate and analyse their degree of understanding and their interpretation and judgement of the model beyond the observation that they used it.

Conclusion:

The safety manager, VP safety focus group, and the risk meeting group acceptance of the AVPMM based topics as relevant for a network operations risk assessment supports the claim that the AVPMM supports managing some of the complexity of the network and operations.

Level 1, descriptive strength for the potential of efficacy because the managers and group members seemed to have understood the main topics of concern.

Level 2, theoretical strength for the theoretical and promising efficacy. Most of the participants could agree that improved feedback channels from flight operations to the organisation is beneficial for learning.

Level 3, indicative strength for some of the AVPMM to be effective because, by some form of group collaboration, the group accepted AVPMM-based topics in the risk model. They recognised how problematic issues in flight and network operations can be defined using the AVPMM logic.

Level 4, operational strength might to some degree be claimed since the group, without my direct involvement, used the concepts in a network operations bowtie for an actual qualitative risk assessment.

7.10 Answers to the research questions

This section provides concise answers to the research questions. Richer answers can be found in the section of the evaluation of the expert group responses.

The driving force behind this research is my realisation that (flight) safety can and should be an essential variable in airline management. Safety should be combined with other essential variables to develop the notion of value. Then value production management in a changing world becomes the context for management and operational decision making. An effective management system requires sufficient feedback from actual operations. The match between the management (the airline organisation) and the operational system (flight execution) needs to be connected through effective communication channels. Therefore, I combined both requirements into two research topics into one research project.

The research questions have the structure of a how-to question. This kind of question can be about the design, build, use, evaluate, and implement processes, as well as the operationalisation and use of design artefacts to solve the problems that have been identified.(Thuan et al., 2019).

This research is conducted from within the airline and for the airline. The airline has a history and has developed its own methods and tools and is not beginning from scratch. Since this is a problem-solving research project, the aim is to improve current practices in the airline using a scientific method. Current practices will be used as a reference to make judgements about the progress this research can bring to the handling of problematic situations. When applicable, each answer will contain the strength of evidence that is established by the analysis of the responses and compared to the four levels of evidence (van Aken & Andriessen, 2011) as explained in a previous section.

First, I will address the three sub questions individually and then synthesise the answers to answer the main research question.

7.10.1 RQ 2.1 How can the AVPMM improve the management of production-protection?

The ICAO SMS proposes a metaphor of the balance between production and protection as a management dilemma(ICAO, 2018a). This question will involve a comparison between the AVPMM and the protection-production metaphor. To compose an answer to this question, a group of seven experts was asked the following question: "The three variables, safety, economy, and customer, as in the Value Production Model, provide us as an airline more guidance in managing our activities than the ICAO two-variable Production-Protection model."

The focus group of experts, which included senior experts and director experts, answered predominantly that the three variables of Safety, Economy and Customer experience of the AVPMM are more supportive for airline value management than the two variable production-protection ICAO model because the experts could relate their work more to the AVPMM than to the ICAO model. The operationalisation of the AVPMM variables matches more with the experts' current practices than the ICAO model does.

Furthermore, the experts agreed the AVPMM goes beyond the ICAO safety space toward a richer optimisation challenge.

The AVPMM is more effective for actual integrated airline value management because of the three more easier to operationalise variables, while the ICAO model is probably more effective as a conceptual model for bringing a particular safety risk to the attention of higher and executive management.

The strength of evidence based on the expert responses is descriptive, theoretical, and somewhat indicative.

7.10.2 RQ 2.2 How can the AVPMM improve Network Performance Management?

An important change from the current practice to the AVPMM's proposed practice is to include safety explicitly as a network performance aspect. Two questions were discussed with the focus expert group.

The first question addresses the current practice of safety as mainly a sub-system as seen from the perspective of network management. The consequence is that safety performance is treated as a binary, either sufficient (safe) or not sufficient (not safe). The AVPMM approach makes safety an aspect of the system and thus more part of the decision making in network management.

The second question addresses the increase of network management decision criteria as part of the AVPMM approach. Certain distinctions become visible when adding safety performance for a particular route or flight and allowing new network management decisions.

A specific example is that when using the AVPMM, safety performance becomes available as a criterion to decide, e.g., which airport or route to close for equally poor performing routes or stations.

Both answers provide descriptive, theoretical, and indicative strength of evidence that network performance management can improve by using the AVPMM approach.

7.10.3 RQ 2.3 How can the AVPMM improve 'optimal resource allocation'?

Another important change from current practice and to continue the development from network performance management to value production management is the combination of the three essential variables of safety economy and customer experience into value. In the AVPMM, the interdependencies between the essential variables are integrated managed, and this allows enhanced airline resource management.

Using the AVPMM, airline management can decide about value production issues using a larger solution space to optimise value production. The interdependencies can have an effect, e.g., safety risk reduction can be very effective by flight or route network changes. This feature of the AVPMM has been recognised and is now part of the new airline's risk management strategies. Also, a high yield route allows for more investment in risk reduction measures, such as intermediate stops and extra crew to reduce crew fatigue risk.

By using the features of the AVPMM, such as the context of value production, organisational resource decisions can be improved in relation to value production, which is a richer context than just the production of profitability. Using the AVPMM based on Viable System Model, organisational complexity is more structured to achieve viability.

Both answers provide descriptive, theoretical and indicative strength of evidence that optimal resource allocation can improve by using the AVPMM approach. Six of the seven experts supported the statement to advise the COO to conduct a trial using the AVPMM concepts.

7.10.4 RQ2: How can we develop and use a Value Production Management model for the integrated management of Safety, Economy and Passenger experience for a Network Airline?

Based on the framing of the problematic situation description, in terms of a management problem, I could use cybernetic principles and models to develop the AVPMM. The AVPMM is an instantiation of the Viable System Model, and the organisational complexity is distributed across four unfoldings of recursions using the logic of value production as a recursion criterion. The four recursions provide the context for integrated management of Safety, Economy and Customer experience. The resulting AVPMM does only consider the functional structure of Value Production Management and does not consider the organisational structure. Therefore, the AVPMM has generic properties for network airlines.

Some aspects of the possible usage of the model have been discussed and evaluated by relevant experts. The model can be used to operationalise the ICAO model variables of production and protection in terms of performance indicators that are more directly related to actual main themes in airline management, such as network and customer service development and management.

Another usage of the AVPMM that has been researched, evaluated, and to some degree confirmed is further development of Network Performance Management. Two sequential steps have been researched. The first is the change from safety as a sub-system to safety as an aspect system, which makes safety an aspect of all important topics. The second usage building on safety as an aspect of network performance is the possibility of new network management decisions. Because safety, as a new performance criterion, can now be used to distinguish between equal performing stations or routes.

The third usage of the AVPMM is the most comprehensive and uses the main features of the VSM based AVPMM. It provides a value production context for organisational and operational decisions. A value approach forces an appreciation of all three essential variables and their interdependencies. This approach requires more integrated meetings and decision-making, which was positively received by most experts and tested in some use-cases.

An unplanned intervention showed the AVPMM was used, without my active involvement, to provide a structure for the network operations for a risk analysis of the impact of COVID on the people and resources operating the flight network in the early stages of the pandemic.

Finally, the AVPMM can integrate a rich and high-capacity feedback channel from flight operations. Flight crew can share operational flight experiences with other flight crew, relevant value production units, and organisational departments to support organisational learning. This feedback channel is the other part of this research.

7.11 Lesson learned

A main feature of DSR is to contribute to knowledge development for different stakeholders. This paragraph refers to steps 8 and 9 in the DSR process (van Aken & Andriessen, 2011) and chapter 5 in this thesis.

Lessons can be learned at three levels:

- First, as a researcher, I can provide feedback to the problem owner in whose domain the research intervention was conducted so that the problem owner can gain a better understanding of the problematic topics and potentially undertake improvement efforts.
- The second lesson can be applied to the knowledge domain chosen for the intervention's design. Closing the design cycle means using the feedback from the group session and survey, in this case, as well as the encounters between the design and practice as carried out in the intervention, to improve the design. The revised design can then be put to the test in real-world settings for the relevance cycle's following cycle (Hevner & Chatterjee, 2010).
- Thirdly, lesson can be derived to increase the science knowledge domain. Closing the loop of the rigor cycle means that the experiences of encounters of the science based design with the actual problematic situation during the intervention are analysed and feedback to the domain of science (Hevner & Chatterjee, 2010).

7.11.1 Lessons for current practices

This research has used actual cases and actual experts that are working in the related domains for the evaluation of the AVPMM-based approach. Therefore, the research is relevant for the organisation and can provide some lessons, if not suggestions, to the organisation.

The complexity of all topics and their relationships results in big differences in mental models between the different stakeholders. As a means of variety reduction, for network development and management, safety is delegated to the operational departments with the support of the safety department. The AVPMM provides a shared mental model to align conversations and be more effective in creating an understanding between the stakeholders. The group session has shown how, in a relatively short time, the different domains of safety, flight operations, economy, and customer experience can have effective conversations.

The AVPMM provides, as an organising principle, an enormous capacity for variety absorption and could be used as a structure for integrating dashboards and process management data. The functional AVPMM can serve as a reference for evaluating roles and responsibilities for experts and managers in the different departments. Currently, the boundaries of departments are also boundaries in terms of roles and responsibilities, which are not always beneficial for the execution of processes. Communication from the safety department with the organisational environment is very much through safety and risk reports. The safety consultant capacity in the safety department is not very effectively distributed to other domains because of the current departmental structure and the enactment of safety management. In the AVPMM approach, safety would become an aspect of the system and safety would need to be part of the conversations and decision making. In the group session, the suggestion was made that when a particular high-yield flight with a fatigue issue was handled by a group face-to-face meeting with representatives from the different domains, an acceptable solution would probably have been found. The face-to-face meeting across the different domains follows from the AVPMM functional perspective that requires more effective conversation than is currently in place.

It is very positive that safety as an aspect system, as I proposed, based on this research, is beginning to be recognised in the newly developed Risk Analysis Framework and Risk Management Strategies. Although this approach seems to make sense to the safety governance managers, the implementation is in development and slightly problematic because the new approach challenges the existing safety action group capabilities and authorities, which are mainly based on the current organisational structure.

The expert group sessions have shown the network commercial and planning experts that safety is not binary and that a more nuanced view, e.g., in terms of risk ratios and risk distributions, some new network management decisions become possible. A network safety performance integrated with the current network performance would enable the airline to evaluate its total risk in relation to the other aspects of the economy and customer experience. As said by the experts in the group session, a value perspective makes us work together to optimise towards a shared optimisation as opposed to departmental performance.

Although some recommendations may appear critical of the organisation, I should stress that the attitude towards safety management is always aimed at progress, as illustrated by supporting this research.

7.11.2 Lesson for next integration of the AVPMM design

The AVPMM design is based on the VSM. Due to the circumstances of the pandemic, which caused the limited time of availability of the experts, only a few features of the complete design could be evaluated. For a rigorous evaluation, more time was needed and therefore no sufficient learning could take place to change the design.

In informal meetings with managers, I have demonstrated the AVPMM software model with its features. The conceptual width and depth of the AVPMM required a lot of time to explain. The initial idea was quickly grasped, but to close the gap between their current understanding of models and data dashboards took a lot of time. Given the limited time of availability of the experts, I did not peruse a model review in the expert group session. I presented some navigation through the software value model to arrive at a destination airport and to show the perspectives on the value, safety, economic and customer performance at that destination in a video that I send to the experts for a project description.

The format and data used in the design were not those used by the actual departments and processes. Although experts could understand this format, a subsequent design should ideally hold hypothetical data in the same format as it is actually used.

7.11.3 Contributions to science

This research contributes in several ways to knowledge development and scientific research. The answers to the research questions provide firm claims that can be scrutinised, argued, and built upon in further research. These answers could be described as contributions to scientific knowledge. My unique position in the airline as safety investigator, airline captain, and researcher and the access I had to all topics and people has hopefully resulted in a research project that other researchers can build upon. That would be a rewarding result for my work.

The review of the literature showed that there were gaps in how safety was integrated into business. I called this "Safety as a Business Aspect," and the AVPMM is an example of this. Also, the scientific literature search revealed few publications related to value production in the sense that it is used in this research and only one that was specifically related to value production management and a value production model. This research project contributes to closing some of these gaps and to stimulating subsequent research.

The fact that this research was conducted from within an airline organisation by a researcher that was part of the operation of the airline can provide researchers some insights to calibrate their assumptions about the inner workings of an airline.

When this research enters the domain of science, especially safety science, researchers can find connection points for further research in safety management. This research goes beyond the production-protection relationship between safety and business management and offers an approach that is very general and instantiated for a network airline. The concept of sustained value exchange between an organisation and the environment as a requirement for organisational survival is very general. This notion relates well with the concept of viability of the VSM, and therefore this research also contributes to VSM related research. Operational software-based instantiations of the VSM model are rare, and this implementation has already received interest from VSM researchers.

The AVPMM illustrates how relevant aspects of an organisation can be modelled. The VSM, with all its features, reaches out to scientists who regress to arguments about complexity, that complex systems cannot be modelled. The VSM as instantiated by the AVPMM provide structures and perspectives that allow researchers to see new things that reduce the complexity of their notion of airline safety management and airline operations.

I have found no research that generalises network airlines by describing them as a hierarchical structure of value-producing units. This description is independent of the organisational structure and allows a model for comparing network airlines such as KLM, AirFrance, Lufthansa, British Airways and more. The AVPMM provides a model based on a structure of functions, as a reference for the implementation and management of an organisational structure. The structure of departments, the roles and responsibilities of people are all important to achieving the requisite variety in the functional structure. The AVPMM approach challenges organisational designers to achieve the requisite variety of the essential variables.

The selection of essential variables for an airline company may trigger other researchers to think and argue about this selection. The consequence of choosing safety as an essential variable has the consequence that safety changes from a sub-system to an aspect system. This research shows that safety can become a topic in network development and management decisions making and how the solution space for safety issues changes. This approach breaks down some of the silo aspects of safety management as illustrated by, e.g. the fact that safety is not an aspect of network performance management, and that safety roles and responsibilities change at departmental boundaries. Another example of de-compartmentalisation is that this research has inspired an element of risk management in the airline. Risk is not evaluated only in the context of safety but also how it relates to the aspects of economy, network, and customer experience.

The two cases that had an important safety element illustrated how the solution space for risk reduction increases when a case is evaluated in the context of value production. Network changes can provide a huge benefit for risk reduction. The interdependencies between safety and other business aspects illustrated by these specific examples in this research may provide researchers with stepping stones for more knowledge development of these interdependencies.

The AVPMM research has touched upon FlightStory as a feedback system. The more general and useful for further research point is the notion of an integrated feedback signal. A signal that is not separated at the source into different aspects but maintains the integration of the essential variables and thus maintains a potentially higher informational content for integrated management, such as the AVPMM. In the FlightStory chapter, I will discuss this in more depth.

These items complete my assertions about the contributions to science of my research. Based on the gaps in the reviewed literature, I expect other researchers may find additional research details that can be used in their research.

Chapter 8: Supporting Theory to Answer Research Questions

In this chapter I will present the theoretical concepts that require sufficient understanding by the reader for an effective discourse concerning the research questions and answers. The reader should also consider my assumptions about the ontology and epistemology as relevant for this research and described in chapter 5.6 to understand my frame of reference. The reader is assumed to have a basic understanding of safety management and airline operations.

8.1 Introduction

As I consider the human perspective of both myself, the researcher and the subjects being researched, I also assume that the reader of this work is human. This requires me to be explicit about my worldview or 'Weltanschauung' (Checkland & Holwell, 1998) so that we can start a conversation about the claims I make in this thesis. This research has much to do with managing. I address the management of different kinds of systems, from aircraft flight execution to a network of flights. In his thesis about governance, which can be seen as a type of management (Türke, 2008) describes three fundamental concepts constitutive for a perspective on governance which are: actor, image and system. By gaining an understanding of these concepts, one can comprehend the process by which individuals shape their environment and knowledge of it, specifically how flight crew, managers, and other employees shape their organization and align their goals within relevant contexts. Relevant theories must be identified and discussed to provide sufficient explanation for answering the research questions. These theories are listed below and will be further described in the following sections. The theories are discussed in an order that creates a kind of building blocks, from the basics of human sensemaking to the specifics of safety science.

- Human sense making: In sensemaking, ontology and epistemology are used to understand how individuals construct their understanding of the world and how it is influenced by their beliefs, experiences and context. Sensemaking is a process that deals with the nature of reality and knowledge, not just cognitive process.
- Different descriptions of the nature of the problem domain. Based on different epistemological perspectives different descriptions of a domain can be provided. This section is a preparation for the next two sections.
- The Newtonian-Cartesian worldview is a way of understanding the nature of reality and has been the foundation of modern science and has led to many important discoveries and technological advancements. The universe is thought to be governed by fixed, unchanging laws that can be discovered through observation and experimentation.

- A systems worldview is characterized by an emphasis on the importance of context and how the same system can be perceived differently depending on the perspective of the observer. It also stresses the need to consider the whole system and how it interacts with its environment rather than only focusing on individual parts.
- The concepts of system behaviour and complexity theory are closely related as they both focus on understanding the dynamic and complex nature of systems. Some general concepts will be presented.
- Cybernetics as the science of information and control can be used to analyse and understand the behaviour of complex management systems, such as organizations, and to develop strategies for improving their performance. By identifying the feedback loops and interactions that regulate the behaviour of a system, cybernetics can be used to design systems that are more responsive and adaptive to change.
- Safety science theories concerning organisational accidents (Reason, 1997), human performance and safety as a control issue are relevant for this research's approach to safety as a business aspect. Also, the developments of Safety-II as a view on the broader scope of system performance instead of only the traditional Safety-I approach focussed on failed performance are relevant. The related concept of resilience and resilient system performance will be addressed and is this theory is also compatible with the theories mentioned above.

Many aviation safety publications fail to clearly state their underlying worldview, which makes it necessary to infer it from the content. Regulations and guidelines such as the ICAO Safety Management Manual (ICAO, 2018a) do not typically address worldviews explicitly. It is worth considering whether regulations can be consistent or even conflicting with different worldviews and the assumptions they hold.

8.2 Making sense of the world in order to act

This research, as well as the topic of the research, are human activities at a scale that is meaningful for humans. I will consider the very small, such as quarks and sub-particles as well as the large, such light years and galaxies out of scope when they are irrelevant for our human activities in doing research and our everyday activities.

The theoretical concepts I will discuss should be seen in the context of human activity. This conditioning will help to reduce the required completeness of the concepts I address. Especially regarding the concepts of complexity and causality, I can cut some wicked scientific debated corners that are not relevant for our human activities.

We should consider the temporal dimension of human action. Coined as ‘Muddling Through’ (Lindblom, 1959) we have to accept that we can’t know everything, but we should have sufficient confidence to act and accept the consequences of our actions as inputs for our evaluation and subsequent actions in a continuous cycle and dynamic flow of action.

The acting is aimed at progressing in handling variety in an attempt to survive and improve. For the practitioner achieving results with their actions is often more important than finding the truth or making valid claims. For the scientist, however, priorities are different. Design Science Research aimed at improving, managing Value production in an airline makes internal and external validity relevant but also scientific rigour and coherence. Truth statements are part of the scientific and philosophical debate and are avoided in a pragmatic approach and might not be verifiable because of our human condition (Maturana, 1988). Therefore, I will not attempt to make truth statements and thus I don't have to refute Heinz von Foerster who said "Truth is the invention of a liar" (v Foerster, 1981).

8.2.1 Making distinctions

One of the most fundamental human activities is the making of distinctions (Brown, 1969). The distinctor makes distinctions for his own purpose(Goguen & Varela, 1979). The distinctions available to the distinctor depends on the characteristics of the distinctor and are thus not always available to others with a different frame of reference. People with different epistemological backgrounds will make different distinctions and can argue the utility of the distinctions that have been made. Bateson (Bateson, 1972) suggests "… a difference which makes a difference is an idea or unit of information". The least number of distinctions makes issues as simple as possible but insufficient distinctions. Often the result of oversimplification do not meet the Law of Requisite Variety (Ashby, 1958) and remain problematic. The distinctions I make in this research should enable the management of value with safety, economy and customers' experience as components and allow flight crew to make distinctions that help organisational managers in making useful distinctions.

8.2.2 Ontology

Every research activity is based on explicit and implicit assumptions about the nature of the world and how knowledge and understanding can be acquired. An explication of my assumptions used for this research allows the reader to put my claims in an epistemological frame of reference and question my assertions.

From a critical realist ontological position, there is the postulate of a mind independent and changing world (Bhaskar, 2013). From a constructivist viewpoint, it is more relevant to find out what we can agree upon and how we can achieve our intentions. Due to our human nature, we have limited access to the world around us, which makes it problematic to tell how the world is, independent of our human cognitive and biological system interpretation (von Foerster, 1988). Both worldviews can be reconciled by understanding that scientific knowledge is a human construct, but it is a construct that is based on evidence and is subject to testing and revision, which allows us to overcome the limitations of our individual perspectives and access a more objective understanding of the world.

8.2.3 Epistemology

There are various ways to look at the world to understand what is going on and to find ways to achieve goals. Each perspective highlights some distinctions while concealing others. Aristotle and other great Greek philosophers debated their world views, which included holistic and teleological ideas.

Constructivism is an epistemological approach that differs from positivism. There are significant differences between the two approaches in terms of human understanding and sensemaking. While a positivist assumes that meaning can be found in the world and that the human must capture it, a constructivist assumes that the human takes in data and generates internal information in order to make sense and create a personal understanding.

Aviation safety and airline management include technical, social, and psychological aspects. As a result, aviation is frequently referred to as a sociotechnical system. Each aspect has its own scientific field as well as its own epistemological discourse. Safety science is a multidisciplinary science that involves various scientific fields, resulting in discussions between 'hard-core' engineers concerned with the strength of a wing structure and 'soft' psychologists concerned with the emotional state of flight crew in an attempt to provide a complete explanation for a loss of control in flight accident. Each scientific field has its own dominant worldview regarding the world and making aviation safer.

People with different worldviews make different decisions and, as a result, have different perspectives. In general, multiple perspectives on a topic provide a more complete picture than a single perspective. Depending on the topic, some perspectives have proven to be more effective than others in arriving at an effective solution or intervention. Different perspectives (Dekker, 2015) (Stoop & Dekker, 2012) on accident causation and prevention are debated in science, but an aeroplane accident with casualties ultimately involves physics and biology, with the laws of nature determining an outcome and serve as the judge.

8.2.4 Actor, actions and image

The following is relevant for the description and understanding of the researcher doing his research, but also for the humans in the airline organisation doing their work. I describe some basic concepts that are used in the field of Human Factors.

In CSE the smallest unit of analysis in Joint Cognitive System (JCS) consists of two cognitive systems, such as two people working together or a cognitive system using a tool such as a human using a tool (Hollnagel & Woods, 2005). In management science (Kooiman, 2003) (Türke, 2008) also takes human action and interaction as the smallest unit of analysis. This makes sense, according to Maturana, who describes human among other living systems as organisationally closed (Maturana, 1980). This means humans are information tight and autonomous in creating meaning and this is how I look at the actors in the airline, the employees such as managers and flight crew.

We continuously update our own definitions of situations and form our own ideas about reality. These definitions form the basis for making distinctions and selecting, ordering and interpreting the diversity of our experiences (Kooiman, 2003). No matter what worldview an individual holds, it requires actors who have views of the universe and how they work together to form their world of systems. Actors are living human systems that sense their surroundings in accordance with their internal organisation and behave in accordance with the unique abilities made available by their structure (Türke, 2008). Actors see inputs and respond based on their own reflections and interpretations rather than external stimuli dictating their behaviour. As biologist Maturana describes humans as structurally determined and operationally closed (Maturana, 1988). With structure, he means the composite unity, in other words, a system, consists of components and their interactions. Maturana and Varela (Maturana & Varela, 1987) describe living beings as autonomous and autopoetic systems. An autopoietic system is operationally closed because it is able to act upon the relevant information it receives in such a way that it maintains its own autonomy and identity. It does not need any external guidance or control to function, it operates based on its own organizational structure and principles, it generates its own behaviour and is self-determining. This means living systems produce themselves, they maintain their own organisation, and continuously produce their own images of the world. Their autonomy allows them to disagree with adopted beliefs. Since actors have a limited sensory capacity to perceive the totality of their environment, they can only grasp the distinctions that fit their image. Therefore, one can conclude they cannot identify objective reality since properties of the actor are always present.

Actors frequently find themselves in circumstances where problems need to be solved. A situation's "is-ness"—or what it "is"—is always decided on an individual basis. A situation's "is-ness" develops from the distinctions that a person can and does make, and is therefore based on the actors' experiences (Türke, 2008). All the alternative distinctions an actor can make depends on the actor’s background and this leads to a reduction of the variety of the actors' perceived world. The image an actor hold of the world has always less variety than the world. This means the actor's background determines to what extent the actor can attend to and describe an issue. This follows from a fundamental cybernetic insight that “only variety can absorb variety” (Ashby, 1956). Effective issue resolution requires the actor(s) to employ requisite variety in image creation and thus be able to make sufficient distinctions to make an issue or situation as simple as possible but not simpler than that. The minimum effective simplicity is reached when the actor or cognitive system neglects more distinctions which would lead to over-simplification where differences that make a difference are lost. Requisite variety ends where oversimplification starts (Beer, 1972).

Claims are suggested as the smallest entity of belief and it captures the actors' beliefs and judgements about the world, of "how things are" (Türke, 2008). When actors have no compatible claims, such as when there is a tribal conflict as we sometimes witness in politics, it is very difficult and it takes time and intention to develop compatible concepts. The social activities of actors that have a shared intent, e.g. in a company, can be viewed as attuning actors' backgrounds.

8.2.5 Objectivity and subjectivity

The FlightStory project has been confronted with discussions about objectivity versus subjectivity. I will elaborate on the discussion in the next chapter. In this section I present some of the scientific arguments on subjectivity and objectivity.

Most dictionary entries on objectivity include the notion of free of bias or faithful to facts. Subjectivity as opposite from objectivity includes perspectives, value judgements or personal interest to name a few relevant factors. Maturana in his essay about the ontology of observing (Maturana, 1988), following Kant, explains an objective observation cannot be made without the disregard of the observer. Because the observation is based on the observer's distinctions, this type of objectivity, which he refers to as objectivity without parentheses, is not possible. He contends that everything said is said by one observer to another (one human to another) and that because we speak of objects in language, we cannot speak of the objects as if they are independent of the languages and distinctions made by the observer. We accept human cognition as a biological phenomenon when we put objectivity in parentheses. According to Maturana, scientific explanations, which include explanations made between employees in a company, do not explain an independent world; rather, they explain aspects of our living praxis. With reference to the previous paragraph, this means that actors engage in background attuning to understand each other's reality. Because humans share a similar sensory system for making distinctions, agreement on features of the world should be feasible.

For this research it is not needed to dig deeper in this philosophical debate since the reader should now be aware of the problematic arena of objectivity and subjectivity and realise that in FlightStory the subjective view is desired and this is not problematic as long as we realise this.

8.3 The nature of the problem domain

The nature of the domain and the kind of issues the research is about providing arguments to select an appropriate research paradigm. The research projects are set in the context of network airline operations. Airlines operate all year and 24 hours a day, sometimes in very congested areas and sometimes in very remote areas of the world, all of which are subject to extreme weather conditions. Furthermore, the aviation industry and airlines' economic viability necessitates constant innovation in services and organisational capabilities (Wittmer, Bieger, & Müller, 2011). The dynamics of airline operations are increased by increased connectivity between parties and players, as well as increased data-driven automated decision systems. The modern aviation system's safe and efficient operation requires highly trained personnel who are supported by ideal working conditions.

Relevant aspects, which are already theory loaded, are:

- Is it about components or collectives?
    - Aviation, airlines and flight operations are collectives of people and technology.
- Is it isolated or connected?
    - Elements of these organisational structures are highly interconnected and have interdependencies.
- Is the system static or dynamic?
    - In an ever changing world, economy, customer preference and technology aviation, airlines and flight operations are in continuous change in an attempt to remain viable.
- Is the behaviour of the systems linear and or deterministic, or is it non-linear and or non-determinate?
    - Effects result from combinations of influences which can combine with feedback and feedforward loops. This results in non-linear and non-determinant system behaviour and effects.
- Are we considering different levels of analysis?
    - The research is concerned with the behaviour of individuals such as flight crew and managers, but also with larger systems such as airline routes, regions and network.

The preceding description supports the classification of aviation safety as an open complex adaptive social-technical goal-oriented system in which human sensemaking is critical. Flight crew making operational decisions and managers making organisational decisions affecting flight operations, which is the process of the actual value exchange with the customer, are the focus of this study.

Aspects of the domain of research can be viewed as complex following comparable definitions of complex systems behaviour as defined by scientists in this field: Beer (Beer, 1959) Ashby (Ashby, 1956) Perrow (Perrow, 1984) Hollnagel (Hollnagel & Woods, 2005) (Hollnagel, 2014b) Woods (Woods & Hollnagel, 1987)(Woods, 2006) Dekker (Dekker, 2012)(Dekker et al., 2011) Bar-Yam (Bar-Yam, 2002) and Snowden (Kurtz & Snowden, 2003)(van der Merwe et al., 2019) .

8.3.1 Introduction

In this section, I will provide a brief overview of the development of some sciences and epistemological perspectives that are relevant for safety science and the nature of the problem domain. Please note that this overview will not be exhaustive, but I hope that it will still be useful in understanding the context of the field and my research.

The map of complexity science shows the many concepts, their relationships and influential authors. Different authors may have different views of the development of complexity science, but I expect there is no difference of opinion about the relatedness of the depicted topics.

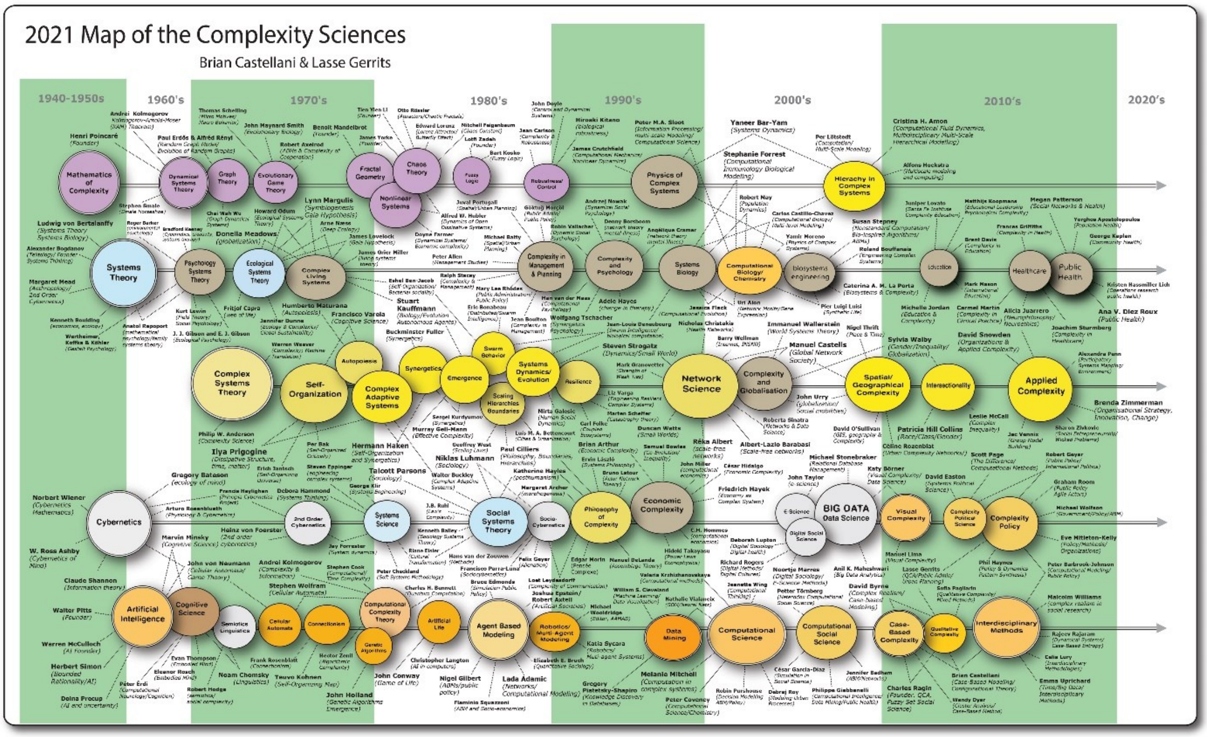


Figure 8-1 Map of Complexity Sciences by Castellani Gerrits 2021 (See appendix)

8.3.2 Two paradigms in science: Reductionism and Holism

Reductionism and holism represent two paradigms or worldviews (Fang & Casadevall, 2011) within science that provide fundamentally different accounts of how to research, interpret and understand phenomenon. Reductionism focuses on breaking down complex systems and phenomena into their individual parts to understand how they work, while recognizing its limitations., while holism focuses on understanding the whole system and its interactions, rather than focusing on individual parts in isolation. This approach emphasizes the interconnectedness and interdependence of all parts of the system, and how they work together to create the overall system.

The term "system" will be used loosely in the following sections, rather than in the strict formal sense of a system as used in systems theory. The concept of a system will be defined more explicitly in the following paragraph. Both paradigms agree that the system is a placeholder for a research topic or phenomenon that researchers are attempting to learn more about.

8.3.2.1 Reductionism

Reductionism is a worldview that focuses on the relationships between concepts, theories, and sciences. In the realm of scientific theories, reductionists argue that a secondary theory should be reduced to a primary science. If a predicate in a secondary science is completely defined in terms of the primary science, it is reduced (Auyang, 1998). Reduced theories, laws, and concepts, as well as the corresponding science, are dispensable according to this logic because the primary science can replace them. In practice this may be mathematically difficult or even impossible to carry out. When reductionism is possible, one could argue whether to call the phenomena described as emergent or not.

There are two types of reduction: homogeneous and inhomogeneous. The reduced theory is a part of the reducing theory in homogeneous reduction. E.g., in physics, the development of Einstein's relativistic theory supersedes Newtonian mechanics. When the special case is dispensed for the broader theory, as in homogeneous reduction, most reductionist arguments are valid. This type of reduction is very similar to William of Occam's principle, which states that things, sometimes referred to as essentials, should not be multiplied unless absolutely necessary. In short this means, take the simplest hypothesis available (Beer, 1979).

The reduced and reducing theories in inhomogeneous reduction cover separate conceptual domains. Frequently, concepts not found in the primary theory are found in the secondary theory. To make this work, logical deduction necessitates terms not found in the premise, necessitating the use of bridge laws to bridge the gap. The primary theory's necessary and sufficient concepts for achieving the bridge function are still being debated. These high standards are rarely met in actual scientific theories (Auyang, 1998).

A hierarchical structure of the sciences, as sometimes proposed in complexity science, ranges from Sociology, Economics, Politics, Psychology, Physiology, Cell biology, Biochemistry, Chemistry, Physics to Particle physics. Each lower level underlies what happens at each higher level in term of physical causation (Ellis, 2004). Inhomogeneous reduction is then reduction across one or more levels of the hierarchy, while homogeneous reduction occurs within one level. For example, a reductionist approach to a biological system would be to consider it being composed of molecules as a suitable focus for analysis.

Homogeneous reductionism is epistemological reductionism that has the potential to be effective, whereas inhomogeneous reductionism runs into the problem of discontinuities between scientific disciplines, as illustrated by the hierarchy of sciences.

Methodological reductionism is an approach to analysing parts of a system in order to gain an understanding of the whole system (Bar-Yam, 2018). The system is broken down into smaller atomic parts in this approach, but the relationship between these parts is ignored. The assumption is that the micro-level properties can explain macro-level behaviour. This approach is similar to Descartes' proposal to divide each difficulty into as many parts as possible and necessary to solve the problem (Fang & Casadevall, 2011).

8.3.2.2 Holism

Reductionism was not the only scientific method. Aristotle already contributed to what is known as holism which means whole, based on the Greek holos. Holism can be seen as an antithesis to reductionism (Klir, 2001). The revival of holism in the 20th century was the result of reductionism not providing sufficient explanation for problems in disciplines such as psychology and biology. The Gestalt theory in psychology, originated in the 1910s, is developed around the notion that a Gestalt is an organised whole whose parts belong together. In biology, the limits of the reductionist approach became apparent in the late 1900s because of an inadequate understanding of biological phenomena. In the 1960s, Smuts in his book Holism and Evolution introduced holistic thinking to understand all levels of nature, from chemistry and biology to the human mind and society. In the 1950s and 1960s, Bertalanffy and Weiss contributed to the further development of holistic thinking about systems thinking. They and other scientist refuted the Cartesian mechanistic metaphor since it reduced biology physics and chemistry (Drack et al., 2007).

In principle, a purely holistic approach is impossible because it is impossible to consider all possible aspects of a topic, situation, or system. Many items are included in the list of all possible assessments, measurements, and classifications for a topic. For example, all physical, chemical, and biological dimensions, as well as all psychological and social dimensions, are included. We must make decisions from this list as researchers, practitioners, and simply as humans. In addition, the human sensory system is reductionistic, and we can only handle a limited number of things at once. As a result, we must consider holistic research as a gradual concept, implying less reductionism (Verschuren, 2001).

We can often see reductionistic and holistic aspects in the research object, research strategy, and research observations with DSR and the social sciences, as shown in the table below.

Research	**Reductionistic**	**Holistic**
Object	Variables, Relations Individual attributes Set of observation units	Patterns, types Group attributes Research unit(s)
Strategy	Decomposition Counting Linear-serial One single method Analytical Deductive	Composition Comparison Iterative-parallel Triangulation Analogous Inductive
Observation	Stimulus-Response Closed, pre-structured Measurement instruments Extensive methods Researcher at a distance Serial	Stimulus free/-weak Open, Unstructured Via research questions Intensive procedures Interacting researcher Parallel

Figure 8-2. Reductionist versus Holistic Empirical Research (Verschuren, 2001).

Reductionism has received a negative connotation among safety en management science authors (Dekker, 2011b), (Larsson et al., 2010), (Gharajedaghi & Ackoff, 1984). Addressing the limitations of a mechanistic cause-effect analysis is frequently used to supplement the argument to explain the limitations of reductionism. Since research topics are always reduced versions of a research question about the universe, I suggest a more nuanced approach to reductionism. In addition, in order to achieve the systems-in-systems-in-systems approach, some reductions must be made. Reductionistic and holistic methodologies can be thought of as complementary approaches to better understanding complex systems. Each approach has limitations, but when combined, they can offer new perspectives.

8.3.3 Causality and explanation

In Western thinking, the relationship between causality and explanation appears to make sense. In many cases, it is assumed that to explain a fact, one must first define its cause. This assumption is overly simplistic, especially in a domain like aviation. The difference between explanations and causes, according to Hollnagel (Hollnagel, 1994), is the difference between knowledge and certainty. Knowledge is a prerequisite for taking action, whereas certainty is a mental state. People in high-risk industries want to know how and why accidents happened. Hollnagel explains that the construction of a cause is model dependent and describes some issues with the implicit or metal model of accident causation used in accident investigations (Hollnagel, 2002). The model used in accident reports is frequently implicit, resulting in debate and disagreement. This highlights the need for this theory chapter to be somewhat more explicit about causality and explanation.

(Ellis, 2008), (Woodward, 2021)(Kistler, 2021)(Paoletti & Orilia, 2017) argue top-down or downward causation is a relevant and valid concept of causal influences from higher levels to lower levels. Information control, feedback, and selection are examples of top-down causal influences in a complex system where complexity arises from the interaction of all modes of causation. Ellis in (Ellis, 2008) summarises that same-level causation is where the action is, bottom-up causation enables it to happen, and top-down causation decides what happens. Physics provides necessary but not sufficient conditions to explain outcomes. It provides the possibility space for what happens but does not fully explain the outcome (Ellis, 2016).

Top-down causality and bottom-up causality are two different ways of understanding how systems and phenomena function and change. Top-down causality refers to the idea that higher-level systems and phenomena influence and shape lower-level systems and phenomena. The existence and nature of top-down causality is part of a current ongoing debate in science (Carroll, 2016). On the other hand, bottom-up causality refers to the idea that lower-level systems and phenomena influence and shape higher-level systems and phenomena. Together, they provide a more complete understanding of complex systems and phenomena, which enables better problem-solving and decision-making.

Pearl's recent view on causality is that it is a fundamental aspect of understanding the world around us, and that it can be inferred from observational data using the Do operator (Pearl, 2009). The Do operator is a mathematical tool that allows for the manipulation of counterfactual statements, which are statements about what could have happened under different circumstances. The Do operator allows for the manipulation of these statements in a way that allows for the identification of causal relationships. He argues that by manipulating counterfactual statements, we can identify the causes of certain events and that this understanding can help us to make better decisions and predictions.

In the following sections, some aspects of causation will be revisited. A deeper philosophical discussion about causality is not required for the pragmatic approach taken in this research.

8.4 Newtonian-Cartesian worldview

Classical mechanics as formulated by Newton (1643-1727) and followed by Laplace and others is based on the logic formulated by Descartes of analysis and reductionism (Heylighen et al., 2007). The logic to understand a phenomenon was to take it apart into components. When the components were still too complex, the analysis had to continue to take the components apart until the parts could be understood. This process of taking apart will end with the smallest possible particles, the atoms, which means the indivisibles (von Bertalanffy, 1968). Therefore, the Newtonian ontology is materialistic, assuming that all phenomena, physical, biological or social, ultimately consist of matter.

For Newton, the only difference between particles is their position and speed. This lead to his development of dynamics, which is now called classical mechanics (Mitchell, 2009). Newton’s laws are the foundation of dynamics and explain motion in terms of force and mass. These laws lead to the notion of a clockwork universe and Laplace’s demon. This is the idea that when the demon knows the position and speed of every particle in the universe, he could predict everything for all time since movement is governed by the Newtonian deterministic laws of cause and effect.

In a similar fashion, Ackoff describes as the first basic idea of reductionism, the belief that everything in the world and every experience of it can be reduced, decomposed or taken apart to simple elements. Reductionism has been the prevailing approach since Descartes in the 16th century (Klir, 2001) and was adopted by Newton. Ackoff gives the example of atoms in physics, monads, and basic instincts in psychology and psychological individuals in sociology. The application of reductionism can be seen across all sciences. This way of thinking gives rise to the analytical approach to finding explanations and gaining an understanding of events in the world. The analysis takes what is to be understood apart into independent and indivisible parts. Then the behaviour of the parts is explained and finally the aggregation of the explanations of the parts into an explanation for the whole. In this approach, when relationships and dynamics are disregarded, the whole was the sum of the independent parts. This way of thinking, also called the Newtonian-Cartesian view (Dekker, 2014a) leans on the ideas of reductionism and mechanism as shaping the nature of the world (Ackoff, 1973) and how we humans seek to understand it.

The second basic idea Ackoff describes is that of mechanism, the belief that all phenomena could be explained by the relation between cause and effect. This logic is based on Newton's third law of motion concerning action equals re-action. A cause was assumed to be required and sufficient, meaning no other environmental effects were required. He describes this view as a 'closed-system' view and attributes this to the development of laboratory studies to exclude environmental effects on the research topic. The notion that effects are completely determined by causes leads to the idea of a deterministic world an important topic for predictability in science and management. Additionally, the third law of Newton regarding equal and opposite forces supports the assumption of linearity and proportionality. The classical physics Newtonian-Cartesian worldview shapes an epistemology that has consequences for understanding behaviour, safety and management in organisations and these can be summarised as:

- Psychological behaviourism used the notion of stimulus and response as mechanistic, predictable relations between inputs and outputs, similar to the cause-effect notion of Newton (Dekker, 2019).
- An undesired situation as an effect must have a cause.
- The symmetry between cause and effect.

It should be noted that Newton was aware of and used non-linearity in his universal law of gravitation, but this is not considered in the social and safety scientists' explanation of the Newtonian worldview.

Scientific thinking has been equated with Newtonian thinking and the Newtonian methodology. The apparent simplicity, coherence, and common sense underpin this pervasive influence. Matter, space, time, and the forces that govern movement are all included in Newton's ontology. Life, mind, and purpose are all considered to be specific arrangements of particles in space and time. Knowledge, according to Newtonian epistemology, is an imperfect reflection of the world around us, and science's task is to improve the mapping between external and internal concepts. (Heylighen et al., 2007).

The deterministic view of prediction clashed with Heisenberg's discovery of the uncertainty principle in quantum mechanics in 1927, which showed that a particle's position and momentum cannot be precisely measured at the same time. In systems that exhibit chaotic behaviour and are known to be sensitive to initial conditions, inaccurate measurements can have huge consequences (Mitchell, 2009). The meteorologist Lorenz demonstrated this phenomenon in his computer model for weather forecasting. A small change in a variable like temperature can have a big impact on the weather forecast. This is the nonlinearity effect, which is discussed in the complex systems theory section.

Gershenson explains non-linear causality does not necessarily lead to non-linear system behaviour and linear causality does not necessarily lead to linear system behaviour (Gershenson, 2015). Non-linear causality refers to the idea that the effect of a cause is not proportional to the cause itself, meaning that small changes in the cause can result in large changes in the effect. Non-linear system behaviour refers to systems where small changes in the initial conditions can result in large changes in the final outcome. However, it is possible for a non-linear system to have linear causes, as well as for a linear system to have non-linear causes. On the other hand, linear causality refers to the idea that the effect of a cause is proportional to the cause itself, meaning that small changes in the cause will result in small changes in the effect. Linear system behaviour refers to systems where small changes in the initial conditions result in small changes in the final outcome. Gershenson (Gershenson, 2015) concludes, it is possible for a linear system to have non-linear causes, as well as for a non-linear system to have linear causes.

The above means we have to be careful when we analyse cause-and-effect relationships in safety and management science.

The mechanistic linear cause-effect assumptions can be found in safety science, in the Domino Model (Heinrich & others, 1941).

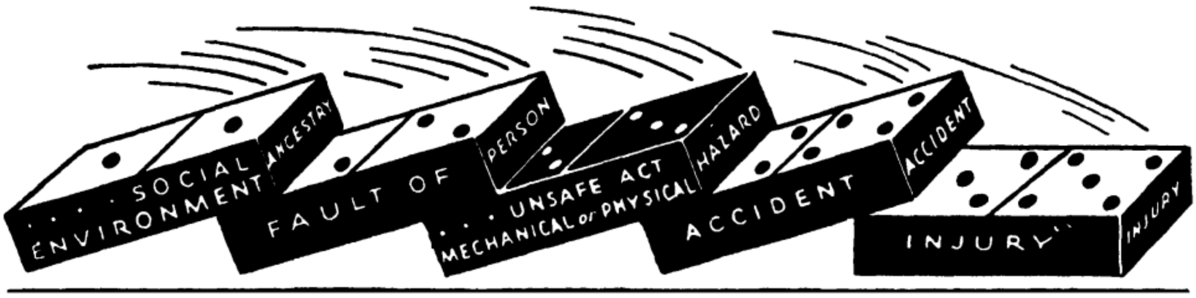


Figure 8-3 The injury is caused by the action of the preceding factors (Heinrich & others, 1941).

Heinrich explains (Heinrich & others, 1941): *"The occurrence of a preventable injury is the natural culmination of a series of events or circumstances, which invariably occur in a fixed and logical order. One is dependent on another and one follows because of another, thus constituting a chain that may be compared with a row of dominoes placed on end and in such alignment in relation to one another that the fall of the first domino precipitates the fall of the entire row…"*

Heinrich's seminal book was a huge step forward for the time and a source of inspiration for future research. The linear model, as it is known (Hollnagel, 2014b), is deeply ingrained in the way most people with a Western education view the world. The assumption that activities in a procedure have a fixed step-by-step order, such as the Waterfall method, in which one step is completed before the next is executed, is an example. Linearity is frequently associated with proportionality, which is the assumption that small causes have small consequences, or that the size of the cause and the size of the effect have a fixed relationship. The problem is that in complex systems, the amplification of effects by feedback is exponential rather than linear proportional and this amplification is crucial for understanding system behaviour.

However, the increasing complexity of work, organisations and society required more sophisticated approaches that could capture a higher variety of causal influences and interdependencies than those modelled by the linear cause-effect model (Hollnagel, 2014b). Limitations of the Newtonian approach were recognised in many branches of science (Capra, 1983) and also in safety science (Dekker, 2004).

Different scholars such as management scientist Ackoff (Gharajedaghi & Ackoff, 1984) and safety scientist Leveson (Leveson, 2011) (Dekker et al., 2011)(Hollnagel et al., 2007) describe the development of an alternative to the mechanistic way of thinking and understanding the world which is presented in the next section.

8.5 Systems theory; distinctions and differences that make a difference

The ancient Greek philosophers understood the order of the cosmos as a living organism rather than a mechanical system (Capra & Luisi, 2014). For them, part has an innate purpose to contribute to the whole. Leonardo da Vinci (1452-1519) exposed interest in nature and living systems in his studies, but this perspective on the world did not become mainstream. The mechanistic worldview became mainstream in the 16th and 17th centuries, the age of the Scientific Revolution or Newtonian science as described in the previous paragraph. Because the world became more diverse, more connected and interdependent, new ways of seeing the world were needed.

In this section, I provide a short high-level history of systems theory and systems thinking followed by some main systems concepts relevant to safety and management science.

8.5.1 Introduction

Organismic biologists began to use the remains of holistic thinking to develop new ideas about connectedness, relationships, and context in the early twentieth century. In perception, the concept of Systems thinking arose from natural ecology and Gestalt psychology. The first formulations of actual systems theories, known as classical systems theories, were developed in the 1940s. General Systems Theory, developed by biologist Ludwig von Bertallanffy, and cybernetics, developed by a multidisciplinary group of mathematicians, neuroscientists, social scientists, and engineers, were two of these theories. The influence of systems theory on engineering, social sciences, and management science has grown over time.

In the 1970s, an epistemological break, based on constructivism or phenomenology, occurred in systems thinking (Mingers, 2011). The break developed the notions of soft as opposed to hard systems thinking and in cybernetics second-order versus first-order cybernetics.

Hard systems thinking and first-order cybernetics were based on traditional empirical sciences (Metcalf & Deguchi, 2020) and presupposed that real-world problems can be tackled on the basis of the following assumptions (Jackson, 1994):

- There is a desired state of the system S1, which is known.
- There is a present state of the system S0.
- There are alternative ways of getting from S0 to S1.
- It is the role of the systems person to find the most efficient means of getting from S0 to S1.

The hard-systems approach assumes a well defined problem and thus (nearly) complete knowledge. Furthermore this approach assumes the world is a set of systems, i.e. is systemic and these can systematically engineered to achieve pre-defined objectives (Ellis et al., 2013). The soft-systems approach is more suitable for ill-defined, messy, or wicked problems. A further differentiation between the two is that the soft-systems approach sees the word as problematic and includes the process of inquiry as systemic. The Soft System Methodology by Checkland (Checkland, 2000) is an example of this approach.

The knowledge field of the systems sciences is much bigger than what is used for this research. A list of about 80 special knowledge topics (Troncale, 1988) about systems patterns of structure, mechanisms and processes which have similarities across many diverse systems includes topics such as: Autopoiesis, Couplings, Feedforward, Oscillations synergy. Troncale (Troncale, 1988) also compiled a list of about 80 systems methods such as Automata theory, Category theory, Constraint analysis, Multi-variant statistics.

The evolution of cybernetics will be discussed in the following section. I like to refer to the map of the complexity sciences from a few pages ago to remind the reader that there are many different versions of development, relationships, and influences between these fields of science. I won't try to be exhaustive or complete, but I will highlight some key concepts that are important for me to complete this research project.

8.5.2 Systems concepts

Systems thinking is a way of looking at the world (Weinberg, 2001). The Merriam-Webster dictionary description of a system is a regularly interacting or interdependent group of items forming a unified whole. It follows from this common-sense definition that system stands, in general, for a set of some things and relations among the things (Klir, 2001). A formal definition is: S = (T, R) where S stands for System, T stands for Thing (often called element or component), and R stands for the relations between the T. An object can be viewed as a system when it can be described in term of the formal definition. A pile of books is not a system but a set, a collection of things without relations between the things. When the books are written by a single author, then there we can speak of a relation and the set can now be treated as a system. Other relations between the books such as size, publication date etc. give rise to different systems with the same set. The same relations applied to other things give also rise to systems.

(Klir, 2001) further explains by restricting T to certain kinds of things leads, for example, to the classical classification of the sciences, physics, biology, economy etc. For this classification the type of relations is not specific, making this classification experimentally based.

By restricting R to certain type of relations gives rise to different classes of systems, each characterised by a special kind of relations without reference to the kind of things T. Systems with different types of relationships R require different theoretical treatments which is fundamental in systems science.

(Ackoff, 1991) provides three restricting properties for the T or elements of a system:

- The properties or behaviour of each part of the set influences the properties or behaviour of the set as a whole. For example, every organ in an animal's body affects the performance of the body.
- The properties and behaviour of each part and the way they affect the whole depend on the properties and behaviour of at least one other part in the set. Therefore, no part has an independent effect on the whole. For example, the effect that the heart has on the body depends on the behaviour of the lungs.
- Every possible subgroup of elements in the set has the first two properties. Each has an effect, and none can have an independent effect on the whole. Therefore, the elements cannot be organized into independent subgroups. For example, all the subsystems in an animal's body-such as the nervous, respiratory, digestive, and motor subsystems-interact, and each affects the performance of the whole.

Ackoff explains these properties ensure that the system has some characteristics that none of its elements has and elements of a system are affected by being part of the system.

(Skyttner, 1996) proposes two criteria to qualify for the name system:

- Continuity of identity, because something that cannot be distinguished over time cannot be recognised as a system.
- Goal directedness is viewed as the ability to execute a function.

(Backlund, 2000) argued most systems definitions, including some mentioned above, are not exclusive enough meaning things which are not systems could be regarded as system. He proposes a more exact definition to ensure that parts of the system are not isolated from other parts. For the systems descriptions in this thesis, the systems definitions given above are not problematic.

8.5.2.1 Constructivism versus realism

I think it is important to realise that different epistemological perspectives approach the system concepts differently. While most will accept a system description, the construction of a system depends on ontological and epistemological assumptions of the system constructor. In this section, I contrast two opposing perspectives.

Following the constructivist perspective, (Gaines, 1979) defines a system as what is distinguished as a system. This may seem like an empty statement, but he argues that for defining a system to distinguish a system is required and sufficient. As an example, he tests the same logic for defining a rabbit and shows that distinguishing an object as rabbit is required but not sufficient because more distinctions are needed to differentiate a rabbit from a dog. He suggests the generality of the concept makes General Systems Theory powerful. Gaines holds the position that we cannot find systems ready made for us but that we construct them by making distinctions that are appropriate for our purposes. The distinctions we can make are based on our perceptual and mental capabilities.

In similar lines (Goguen & Varela, 1979) maintain a distinction that splits the world in two parts, this and that. In systems theory, this is a fundamental act to distinguish a system from its environment They content to accept that the world does not cleanly divide itself into systems, subsystems, and surroundings for us to see. For our own convenience, we create these divisions. The chosen approaches and terminologies for defining systems in accordance with their aims have been created by scientific fields.

Realism thus assumes the existence of systems in the real world. This position introduces a question about resolution, or granularity of elements and how these can be independent of human introduced distinctions. Klir (Klir, 2001) describes that the realist position is that each system is got by applying correctly the principles and methods of science. Such as system represents some approximate aspects of the real world. The approximation or simplification is related to the limited resolution of our senses and measurement instruments. With higher resolution measurements, the real-world mapping becomes more refined.

8.5.2.2 Describing a system

The systems approach integrates the analytic and synthetic method, encompassing both holism and reductionism (Heylighen, 2009). In our human attempt to make sense and act on the world to make progress towards whatever our intentions are, we make distinctions that give rise to a system. By making these distinctions we are reducing the totality into topics of interest.

Scientists and non-scientists are often interested in change and how it arises from processes and actions. Since interactions among elements only exist in time, a process is brought alive. By selecting a process of interest, some interacting components are selected, which is the system that brings the process of interest alive (Mobus & Kalton, 2015).

To explain the dynamics of any system, we need to investigate the relations between the parts but also how these interact with the context in which the system operates (Maturana & Varela, 1987). This understanding requires us to take some distance from the observed to be able to observe the system and its environment. Under specification of systems and their environments leads to confusion or unjustified agreement or disagreement. Also, in scientific debate, the epistemological perspective of the system nominator should be clear to understand the logic of the distinctions made.

8.5.2.3 Systems classification

An agreed system classification scheme can facilitate the communication between scientific domains when employing systems concepts. A general systems ontology similar to the biological ontology describing all systems and classifying them unambiguously has not yet been established (Rousseau, Wilby, et al., 2018).

(Rousseau, Billingham, et al., 2018) developed a first proposal for a concept map of systemology concepts. As an inventory of possible systems, he proposed:

- Physical systems
- Living systems
- Sapient (wise) systems
- Technological systems
- Social systems
- Socio-technical systems
- Conceptual systems
- Systems of Systems

The systems used in this research are found in nearly every systems classification and probably most systems scientists agree on them:

- Social systems, e.g. people in the departments of the airline organisation discussing issues.
- Technical systems, e.g. aircraft systems such as autopilot or software tools.
- Socio-Technical systems, e.g. flight crew operating an aircraft or managers using a software tool and data for decision support.

The degree to which technology and people are mixed is determined by the system definition. This includes the granularity of the system elements as well as the system boundary. We can find people (e.g. flight crew) and teams (e.g. flight deck crew) at the lowest level of my value production system model, which justifies classifying the use of social systems concepts. As we move up the hierarchy, we can see system elements that are a mix of people and technology, such as a flight, which supports the concept of socio-technical systems. The research artefacts I created could be classified as technical systems, but most use-cases should include the user, making it a socio-technical system.

The behaviour of a system distinguishes it from a purely technical system and a social (technical) system. The social aspect makes a significant difference, which will be discussed in greater detail in the section on system behaviour.

8.5.2.4 System Boundary and Environment

The environment of a system consists of all variables which can affect the systems state (Ackoff, 1971) but are not part of the system. The system boundary separates a system from its surroundings. The surrounding system can be the environment of an inner system in a system of systems or nested systems. Because the observer has an objective in compiling a specific system description, the location of boundaries is observer dependent.

A closed system is one that does not have an external environment. There are no external variables that can influence any of the system's specific variables, and the system is self-contained. The system boundary in an open system can be crossed by energy, materials, or signals, for example. Open-ness and closed-ness are system properties that are important for comprehending, designing, managing, and operating systems.

Aviation systems are designed to minimise environmental influences on the system for safety reasons. Technical systems like the anti-ice system on the wings, for example, make an aircraft less sensitive to winter weather.

When signals from the environment cross the system boundary, the system is can be affected if the system can distinguish these signals. In living systems or systems with living elements or sub-systems, the system response is determined by the structure of the specific system and not by the signal (Maturana & Varela, 1987). The reaction to a goal in football triggers different responses for different people. Maturana explained that when we press on the play button of a tape recorder and nothing happens, we don’t investigate the finger but the structure of the tape recorder.

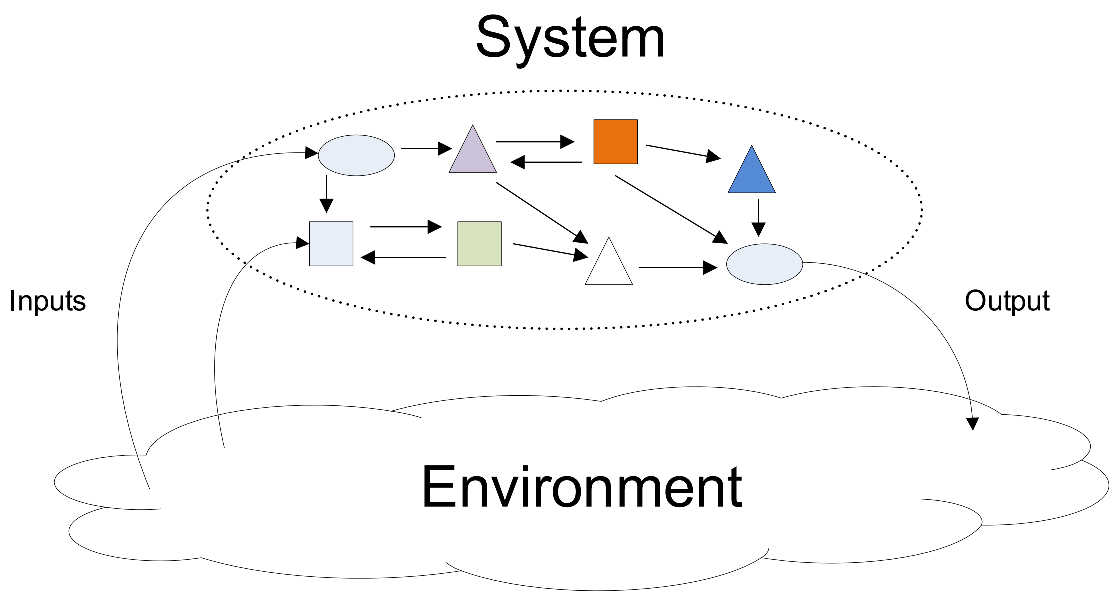


Figure 8-4 Interaction of a system with its environment

(Beer, 1979) explains each system has its own language and signals crossing a system boundary either from the environment or from another system have to be translated by what he calls a transducer. The capacity of the transducer in terms of distinguishing signals is very important and further explained in the section of cybernetics.

The observer seeks to define relevant system inputs and system outputs since these constitute the interactions between systems and their environments. The relationship between the inputs and outputs is important for an understanding of the system dynamics. A consistent relationship means the system is organised while a random relationship implies a lack of organisation (Mobus & Kalton, 2015). Patterns and pattern changes in the relationship between input and output can be informative for properties of the system, such as the adaptive capacity. System dynamics will be discussed in a next section.

8.5.2.5 Nested systems and hierarchical systems

A single reduction of the totality into a single system is often not sufficient to create a desired understanding. Therefore the reduction continues in sub-systems to increase granularity at a lower level or super-systems when higher levels are required to provide context. At the same level of analysis, sibling systems can be defined to increase an understanding of same-level interactions.

Nested systems and hierarchical systems are both ways of organizing systems into smaller parts that can be studied and understood individually, but they differ in the way that the smaller parts are related to each other (Gershenson, 2015).

The main difference between nested systems and hierarchical systems is in the way that the smaller parts are related to each other (. In a nested system, the smaller parts are embedded within each other, with the smaller parts being completely contained within the larger parts. For example, a forest ecosystem is composed of nested systems such as individual trees, which contain smaller systems such as branches and leaves.

In contrast, a hierarchical system is organized into a series of levels, with the smaller parts being a part of the larger parts, but not necessarily contained within them. For example, an organization is composed of a hierarchical system of departments, with each department being a part of the larger organization, but not necessarily contained within it (Gershenson, 2015).

A basic assumption regarding general systems theory related to hierarchy are that the Universe can be seen as a hierarchy of systems, which means simple systems are synthesized into more complex systems from elementary particles to civilisations. Novel characteristics appear when moving upward in the hierarchy. Higher-level systems are more and more open in their interaction with their environment (Skyttner, 2005).

A hierarchy is an arrangement of systems that are represented along a dimension, e.g., in the direction of power hierarchy. A system of systems description in terms of nested systems is also a type of hierarchy. In a hierarchical system, each level adds to the scale of the system description. A level or recursion (Beer, 1994) can be defined as a next step in a dimension. E.g., In the dimension of geography, a next step from country could be state and a next could be municipal depending on the purpose of the system description. Rios (Rios, 2012)describes this logic for the level as a recursion criterium.

Each level requires an effective system description. Depending on the system under analysis, the distinctions for this new effective system description can be made. When a system level can be defined by aggregations from the lower levels, many options for grouping are normally available. When a system level is defined based on new properties that were not present at lower levels, so-called emergence, often fewer options for defining levels are available. We should remember the requisite variety of the observer limits the distinctions the observer can make for defining more levels.

For this research, I have used the dimension of value production units as logic for unfolding the system in 4 hierarchical levels. Using the proposed definitions of independent and mutually exclusive scale, scope and resolution by (Febres, 2018) the example Value Production Unit (VPU) diagrams (below) the following can be said:

- Scale: The set of different symbols used in a description. The scale can be numerically expressed as the symbolic diversity of the system's description interpretation.
    - Scales are the levels of the hierarchy which is in this example 4
- Resolution: The density of symbols (alphabet symbols or encoded symbols) used to create the symbols used in a description.
    - The number of elements at a specific level
    - Network, the number of elements is 1
    - Regions, the number of elements is 4

- Routes, the number of elements is 8
- Flights, the number of elements is 24
- Scope: The total number of symbols used in a description.
  - The total number of elements in the model which is in this example 37

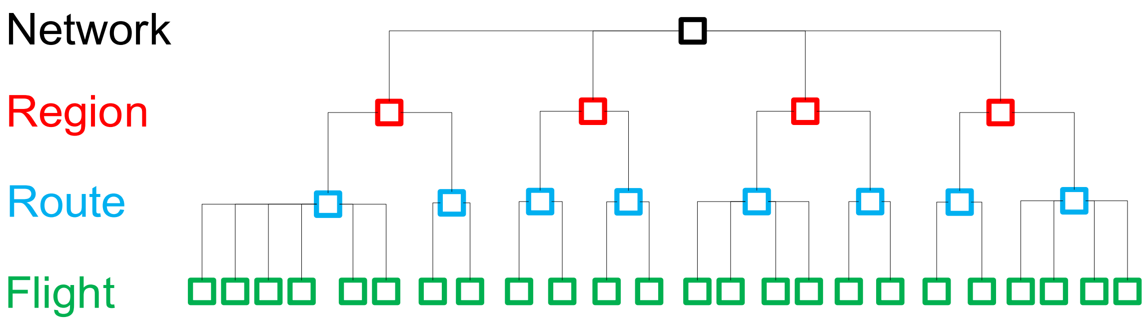


Figure 8-5 Diagram of hierarchical systems view of Airline Value Production System

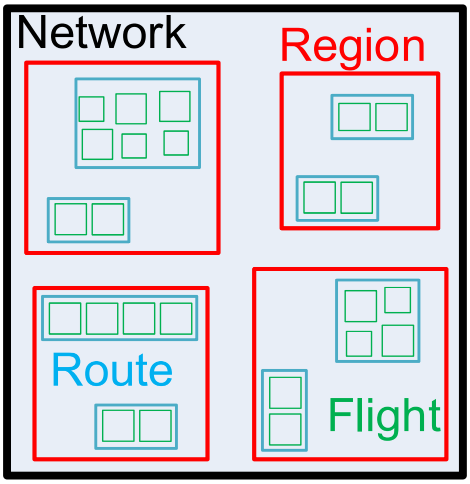


Figure 8-6 Diagram of nested systems view of Airline Value Production System

The purpose of the system description determines the stop rule for vertical or horizontal system definitions. In biological system the decision for different hierarchical level or nesting of systems has probably less degrees of freedom than in social systems. In general three levels are necessary to allow a sufficient understanding of the middle level system (Goguen & Varela, 1979) (Beer, 1979) because the level above and the level below have direct influences on the system in focus. Others (Klir, 2001) call for caution to be open to include interaction across levels in the system behaviour description.

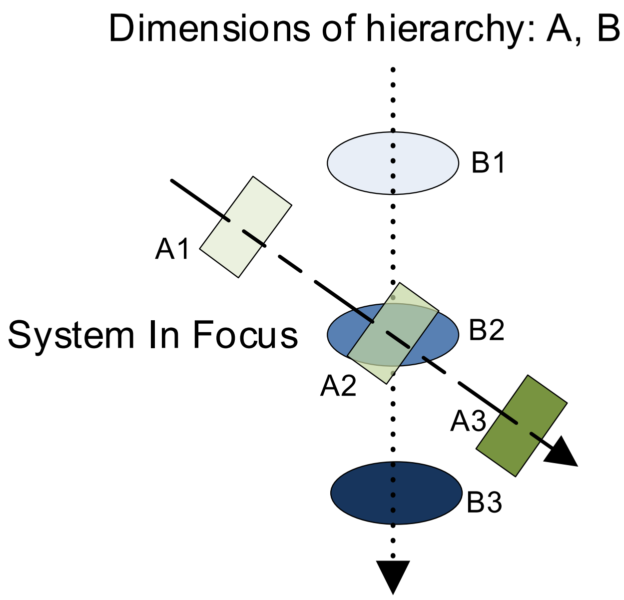


Figure 8-7 Two hierarchies unfolding from System in Focus

In heterarchical systems, no hierarchy exists, since the system unfolds on a single level. Trees in a forest can be modelled as a heterarchical system. In socio-technical systems that include organisations, there is a discourse about hierarchical versus heterarchical organised businesses. In this debate, the hierarchical dimension is always considered being the power dimension without the note that other hierarchical dimensions are also possible. The Value Production hierarchy in my model can be viewed as nearly orthogonal, meaning nearly independent, from the power hierarchy. Beer (Beer, 1981) argues that authority does not lie in the chain of command, but in the relevance of information.

8.5.2.6 Aspect system and Sub-system

Within system, several types of sub-systems can be distinguished. Two of these types are sub-system and aspect system (Veeke et al., 2008). A subsystem is a partial collection of the elements in the system whereby all the systems' relationship are considered. A national office of an international firm is an example of a sub-system. An aspect-system is a partial collection of the relationships but concerning all elements.

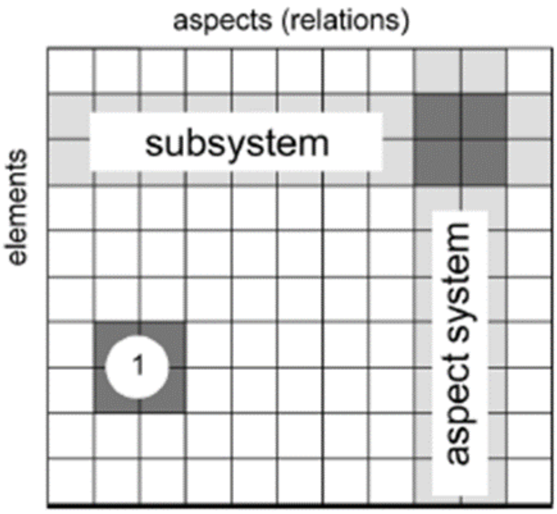


Figure 8-8 Sub-system versus aspect-system

All the aspects of the system are interdependent and combined in the total business system. Hale (Hale et al., 1997) proposes the SMS as an aspect system. Each aspect system is embedded in the environment of the other aspect system. This means all aspects are interdependent since a change in one results in changes in the others. SMS, as an aspect system, requires that safety must have a translation for each level in the entire organisation (element), from top to bottom. This perspective makes safety management an integral part of the overall organisational business management system. Examples of these translation are given in the AVPPM chapter above.

8.5.2.7 System behaviour and dynamics

The systems we define are mostly dynamic and show behaviour. Change is a constant which means systems change but they change in different ways and on different time scales. Mobus (Mobus & Kalton, 2015) describes four categories of system dynamics:

- Motion and Interactions. These are simple dynamics in systems that do not change structure or function and their elements have no (changing over time) interactions. These kinds of systems are typically studied by physics.
- Growth and Shrinkage. Understanding the limits of increase or decrease of a system variable over time is important in e.g., economy and biology while maintaining the system structure.
- Development and Decline. These dynamics involve the change of the system structure and can be studied in biological and human systems.
- Adaptivity. This dynamic is described as changing behaviour and is a response to and environmental change while using existing resources. Homeostasis, the process of maintaining balance, such as e.g., body temperature, is an example of this behaviour.

Based on different types of causal influences and effects (Gharajedaghi & Ackoff, 1984) distinguishes three types of system behaviour that occur when a system or environmental event occurs:

- A reaction R of a system is an event that is deterministically caused by another event i, which is sufficient for the reaction to occur; linear causality (R = f(i))
- A response R of a system is an event as a consequence of another event i that is necessary but not sufficient to explain the response. In a response, the system is a coproducer of the response. (R = f(i1, i2, i3 …))
- An act of a system R is an event that occurs without being triggered by the environment. Acts are self-determined events s, autonomous behaviour. (R = f(s1, s2, s3 …))

Systems described as mechanical systems can be expected to show reactive behaviour. This kind of behaviour correlates with maintaining a system state in reaction to environmental changes, e.g., a thermostat controlled room heating system.

A goal-seeking system is a system that can respond to changes in the environment by choosing voluntary a type of behaviour. When these systems have a memory, they can learn and strive for goal seeking efficiency.

A purposeful system is a system that can produce the same outcome in different ways in the same environment. It can also produce different outcomes in the same environment and in different environments, while it can also change its goals. Such systems cannot only learn, but can also create.

In a hierarchy of state-maintaining, goal-seeking and purposeful systems each higher has the properties of the lower. Socio-technical systems typically include all three types of systems and system behaviours. Gharajedaghi (Gharajedaghi & Ackoff, 1984) have summarised these behaviours in the following table:

Type of system	**Behaviour (Means and Structure)**	**Outcome (Ends and Functions)**
Passive (tools)	Fixed, one structure in all environments	Fixed, one function in all environments
Reactive (Self-maintaining system)	Variable but determined One structure in any environment Different structures in different environments	Variable but determined One function in any environment Different functions in different environments
Responsive (Goal-seeking)	Variable and chosen Different structures in same environment	Variable but determined One function in any environment Different functions in different environments
Active (Purposeful)	Variable and chosen	Variable and chosen

	Different structures in the same environment	Different functions in the same environment.

Figure 8-9 System type, behaviour and outcome (Gharajedaghi & Ackoff, 1984)

An airline company is an example of an Active or purposeful system. The organisational structure of each airline is different while the function of delivering safety, efficient and customer friendly transportation is the same. At the same time, the airline structure provides functions such as being employer and a training centre. In general, when people are part of the system description, the system will be purposeful. This type of behaviour is often also classified as complex and that topic is addressed in a next section.

8.5.2.8 System properties

Emergence is an important concept in management and safety science because it helps to explain how complex systems behave and how they can be controlled. In management, understanding emergence is important for understanding how organizations and other systems function and how decisions can be made to improve their performance. In safety science, understanding emergence is important for understanding how accidents and other safety incidents can occur and how they can be prevented.

The phrase 'the whole is more than the sum of its parts' has several variants and explanations and was already discussed by Aristotle. When the whole is more or different, it is often said the whole has emergent properties. These properties cannot be reduced to the properties of the parts but instead are the resultant of the interactions, interdependencies and adaptions of agents and parts in the system.

According to George Klir, there are three meanings of emergence that he describes: aggregate properties, collective properties, and emergent properties (Klir, 2001):

- Aggregate properties are properties that are a simple sum of the properties of the individual components. These properties can be predicted by studying the individual components alone, and are often linear in nature. For example, the total weight of a group of objects is an aggregate property, it's the sum of the weight of each individual object.
- Collective properties are properties that emerge from the interactions between the individual components. These properties cannot be predicted by studying the individual components alone, and are often non-linear in nature. For example, the behaviour of a group of animals in a flock is a collective property, it emerges from the interactions between the individual animals.
- Emergent properties are properties that cannot be fully predicted or understood by studying the individual components of a system alone, and are often qualitatively different from the properties of the individual components, as they arise from the interactions between the individual components. These properties

are often the most important and interesting properties of a system, and are often associated with complex systems. For example, the intelligence of a human brain is an emergent property, it cannot be predicted or understood by studying the individual neurons alone.

Among scientists from different domains, there is no agreed definition of emergence, thus differences of the nature of emergence will continue.

Ellis describes some notions that are associated with the concept of emergence (Ellis, 2016):

- Irreducibility. This means the emergent phenomena are autonomous from their more basic elements that give rise to them, even though the emergent phenomena depend on them.
- Unpredictability. A state or feature is emergent if it is impossible, either in principle or in practice, to be predicted.
- New variables are needed to describe the new emergent properties. These variables make not much sense at lower levels of the system.
- Holism. Some properties of emergent phenomena arise only out of wholes.
- The whole is more than the sum of the parts is what he describes as the macro level properties cannot be obtained by simple addition of the lower lever properties.

The degree to which emergent properties can be predicted from the underlying systems and element interactions results in the concepts of weak versus strong emergence. Walloth (Walloth, 2016) describes weak emergence as the formation of patterns that can be surprising but it does not require novelty to come into existence. Chalmers (Chalmers, 2006) describes weak emergence as a high-level phenomenon which arises from the lower level nevertheless the truths concerning that phenomenon are unexpected given the principles that govern the lower level, but in principle, the phenomenon is deducible from lower-level principles. Although there is no agreement about a single definition of emergence, weak emergence is what is often implied when emergence is discussed in, e.g., complex systems theory. In the case of strong emergence, the higher-level phenomenon cannot be deduced from lower-level truths, not even in principle. This type of emergence is often implied in philosophical discussions. The existence of strong emergence is debated and often consciousness is mentioned as an example of strong emergence (Healey, 2021). Bar-Yam (Bar-Yam, 2004a) argues for four types of emergence in a logical order of part-whole relationships:

- Type 0, considers parts in isolation without reference to the whole. This is not considered a type of emergence in most sciences.
- Type 1, weak emergence, parts are viewed at a macroscopic level for their collective behaviour, e.g., physical properties such as temperature and pressure.

- Type 2, strong emergence, occurs when the system at a particular level is constraint, e.g., a fixed budget constraint for a company requires all the departments to coordinate expenses. This illustrates that in this case higher level system organisation is necessary to understand the behaviour of the subsystem. This notion is relevant for the network, region, route, flight hierarchy of the AVPMM.
- Type 3, strong emergence, occurs when the system requires a specific relationship with the environment, such as a key matching a lock.

Safety is often describing as emergent property and an understanding of emergence theory provides opportunities for system intervention to improve safety performance. The topic of emergence will also appear in the section on safety science. I suggest the reader to be cautioned when in safety science literature safety is described as emergent and subsequently that emergent properties cannot be predicted. The existence of an ultra-safe aviation system suggests system behaviour prediction and control is at least to some extent possible. It suffices for this thesis to summarize that the whole can be qualitatively different from the sum of the parts depending of the system description.

8.5.3 Observers and the observed

Based on a constructivist epistemology, systems are defined by observers for some purpose, such as to understand or to manage. A perspective depends on the place of the observer relative to what it observes. We can consider the observer to be part of the system, a system element observing the system in which the observer operates, or an external observer having no influence on the system it observes other than defining it (de Haan, 2006).

In social and socio-technical systems, such notions as interaction, cooperation, and self-organisation are relevant for their understanding. The cognitive point of view of the observer, a perspective with presuppositions and attitudes, determines the system and its boundary definition. The observer can choose the focus of attention either on the internal parts of the system or the environment (Goguen & Varela, 1979). Each focus point has consequences for the system description. An observer may choose to focus on the internal structure while viewing the environment as background that can exert perturbations on the autonomy of the system. From this viewpoint, the properties of the system emerge from the interactions between the components. Another example of perspective can be found in hierarchical systems. At a particular level, the observer sees systems one level below from the outside and systems above from the inside. Workers in a system are part of that system as elements and change the system behaviour but also the system description by learning (Mobus & Kalton, 2015). In the following illustration by (Goguen & Varela, 1979), each perspectives shows and hides possible distinctions and different configurations of systems, subsystems and perspectives.

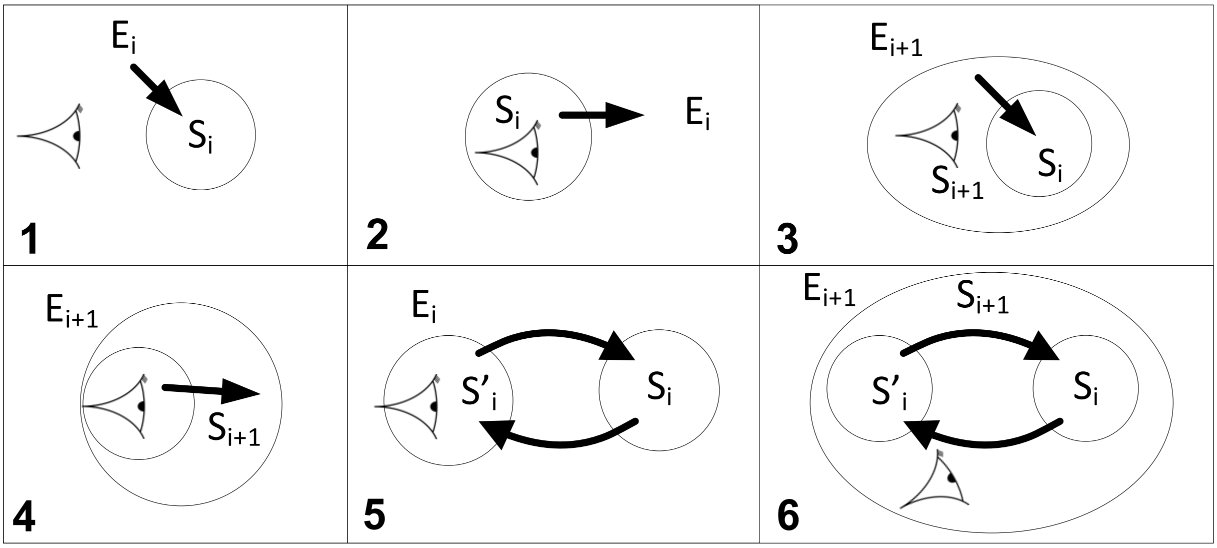


Figure 8-10 Cognitive viewpoint and system configurations (Goguen & Varela, 1979)

They propose various configurations of systems, subsystems and marks. Each configuration represents a cognitive viewpoint and the eye-mark indicates its centre. The arrows indicate the flow of signals and interactions.

- Control of a System Si by its Environment Ei.
- Autonomy of System Si in its Environment Ei
- Control of a Sub-system Si in System Si+1
- Autonomy of a Sub-system Si of System Si+1
- Feedback control of System Si by System S'i
- Communication between (coordination of) two sub-systems Si, S'i of System Si+1.

The realisation that perspective matters for the explanations of events and that perspectives can be added for a richer picture and understanding is used in this research. Both in the AVPMM experiments where the Safety, Economy and Passenger perspective are joined and in the recognition that the pilot's perspective in a FlightStory about flight operations is crucial, the notion of perspective is utilised.

8.6 System behaviour and Complexity theory

As described in the section on systems theory, we can use the concept of systems to make sense of our world and to achieve our purposes. Whether starting from a process of an element, a full system description includes some sort of description of the system behaviour. The choices made when selecting system elements and defining relationships between the elements must match the behaviour that is attributed to the system. Each system description is just one of the innumerate possible. The selected system description should provide the utility to achieve the intentions of the modelers.

Building a model of an organisation using atoms as elements and the atomic forces as relations would be nonsensical. The description of the motion of every water molecule in a cubic centimetre of water would already require more than 10 billion times the number of books in the Library of Congress of the USA of more than 100 million. However, the length of the microscopic description it is irrelevant to the macroscopic behaviour of a cup of water (2023b). Water serves as an effective macro description for the collection of molecules and their interactions for building a boat. Water density as a property of all the molecules of the water provides relevant information for designing and building my boat. This illustrates how a system description can be intractable at a small scale but tractable at a larger scale, this nuance is not always recognised in safety science publications.

(Siegenfeld & Bar-Yam, 2020) describe three types of behaviour applicable to physical, biological and social systems.

- Random system behaviour is the consequence the independence between the system elements, e.g., in a gas, independent microorganisms, and crowds of people.
- Coherent system behaviour occurs when all elements behave in the same way, e.g., the same direction of the same activity such as in e.g., a moving object, an infection and a roman army.
- Correlated system behaviour lies between the extremes of random and coherent and arises when elements are dependent, but not so strong that every element acts in the same way. E.g., a snowflake, a human body and an organisation.

The degree of complexity of behaviour can be described along a continuous scale from low to high and is based on the length of the description of the possible behaviour the system can show. The greater the number of possible behaviour descriptions, the greater the complexity. In a similar way (Pringle, 1951) proposed complexity as the number of parameter needed to fully define the system behaviour in space and time. Pringle continues by pointing out that the above depiction of complexity is epistemic rather than ontological in nature, since it relates to the complexity of the description, i.e., the assertions made about the system, rather than to the complexity of the system itself. He contends that ontological complexity has no empirically discoverable meaning since it is not workable to refer to a system's complexity regardless of how it is observed or characterised. Hollnagel and Woods (Hollnagel & Woods, 2005) explain this critical philosophical difference is often taken for granted or ignored.

A defining property of system behaviour is the type of relationships between the system elements. Miller and Page(Miller & Page, 2009) describe how four types of relationships between elements lead to different system behaviours. Moderate levels of four complexity aspects; connectedness, interdependency, diversity, adaptation will lead to complex system behaviour.

- Connectedness is a measure of the number of linkages between elements of a system.

- Interdependency is a measure of strength of the linkage between elements of a system.
- Diversity is a measure of the differences of types of the elements in a system, thus not so much variations of a particular type.
- Adaptation is a measure of the degree of learning, as a change of behaviour, as a result of the interactions between the elements of a system.

For complex system behaviours, all four aspects must be present, but not 'too much' or 'too little'.

Finally, Complex Adaptive Systems (CAS) is the concept of a system exposing complexity and goal-directed adaptive behaviour. A CAS can adapt to its environment by establishing new goals and modifying its model structure if the maintenance of the system's structure becomes challenging because of changes in the environment or the system. CAS are characterised by organisation refinement and development, system adaptability to environmental shocks and environmental variety, multi-finality with structure formation, positive feedback, and institutionalised deviations (Metcalf & Deguchi, 2020). By maintaining a balance between the variety of the environment and the variety of the system, CAS adjusts to environmental changes. Some examples are:

- Biological systems such as ecosystems, where organisms interact with each other and their environment to survive and reproduce.
- Economic systems, where individuals and organizations interact to produce and exchange goods and services.
- Social systems, such as societies, cultures, and organizations, where individuals and groups interact with each other to achieve goals and satisfy needs.

The Viable System by Beer is an example of a CAS and will be further discussed in a next section.

8.6.1 Complexity profile

The complexity profile expresses complexity as a function of scale and hence describes the system's behaviour Bar-Yam explains (Bar-Yam, 2008) that the complexity profile counts the number of independent behaviours that are visible on a particular scale. The term "complexity" refers to a quantitative theory that quantifies the difficulty of describing a system's behaviour. At its most basic level, this theory simply counts the number of distinct behaviours as a proxy for the complexity of a system. We're reviewing a system that's been described in various levels of depth, intuitively. The complexity profile indicates how much data is needed to explain a system at each level of detail. A camera's zoom lens appears to represent this concept, as zooming in shows greater amounts of data. The problem is that when we zoom in, we see a less and smaller fraction of the system. We must always explain the entire system to be consistent with what we're describing and to keep the same scope, no matter how detailed our explanation becomes. As a result, it is better to think about improving the camera's focus accuracy. The precision of observation is affected by scaling up or down, not the system being seen. This demonstrates that, as the level of clarity improves, so does the length of our explanation.

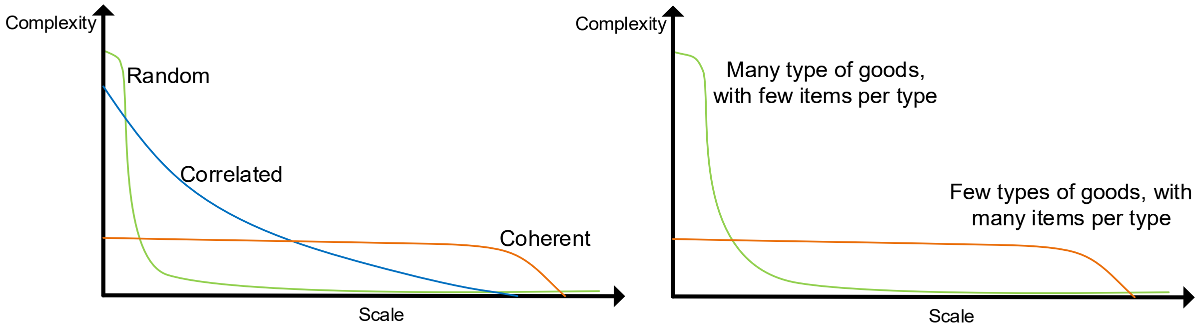


Figure 8-11 Complexity profile for random, coherent and correlated systems (Bar-Yam, 2008) and (Siegenfeld & Bar-Yam, 2020).

A system may contain elements of each at varying scales (Siegenfeld & Bar-Yam, 2020). The complexity profile of a factory that can produce a large number of identical copies of a small number of product types, as opposed to a factory that can produce a variety of goods but not in large quantities. Because mass production necessitates larger-scale coordinated action in the factory, the quantity of a good produced is a proxy for scale (e.g., an assembly line). The number of different types of commodities that can be manufactured at a given scale is a proxy for the number of possible factory behaviours and, consequently, its complexity at that scale.

(Siegenfeld & Bar-Yam, 2020) Explain how a comparable observed system can have different scales of aspects and behaviours. The volume of data connected to system behaviour, as well as the scale of system interventions that can be implemented, should be considered. Using the complexity profile as a guide, make the system description should be as short as feasible while keeping it as complicated as necessary. This entails progressing from a low to a higher scale and halting before the required variety of the system description for the specific purpose has been lost. Moving beyond this optimal point for the specific objective will cause the loss of differences that make a difference.

(Siegenfeld & Bar-Yam, 2020) discusses the complexity versus scale trade-offs. The idea that complex systems need order is justified: for complexity to exist at higher scales, there must be behaviours requiring the coordination of a vast number of smaller-scale elements. This coordination reduces the complexity of elements at smaller scales because their interdependencies now constrain their behaviours. The tension between small-scale and large-scale complexity can be quantified as follows: given a defined set of elements and a fixed number of possible individual behaviours, the area under the complexity profile will remain constant irrespective of element interdependencies (or lack thereof). The total complexity of a system at each scale (i.e., the area under its complexity profile) will equal the sum of the complexity of each component. As a result, there is a basic trade-off for every system between the quantity of behaviours it may have and the scale at which those behaviours can occur.

8.6.2 Complicated systems

The terms "complex" and "complicated" are often used interchangeably, but they have different meanings in the fields of systems and complexity theory. Complicated systems are those that have many parts and are difficult to understand or operate, but they are still deterministic and can be analysed and understood through the examination of their individual components.

Complicated systems can be analysed using a reductionist approach. They can have many parts, but their relationships are fixed. Such a system can be taken apart and put together again, e.g. an aircraft. Most aspects of the system are known, or at least knowable. Prediction is possible since the system should work tomorrow the same as today. However, the prediction of the system's environment which impacts on the system and thus might trigger system response, might be difficult and cause for uncertainty.

Adding people to a complicated system allows complex system descriptions of the joint system (Dekker et al., 2011). The chosen scale, scope, and coarse graining determine the degree of complexity of the joint system(Bar-Yam, 1997) e.g., individual flight crew aircraft control functions versus connecting flights at the network hub.

8.6.3 Characteristics of systems capable of complex behaviour

Systems capable of complex behaviour are often called complex systems. Since complexity is so very multi-faceted, no single definition exists or would be useful. Below is a list of characteristics generally applicable to complex systems. Based on (Cilliers, 2002), (Miller & Page, 2009), (Bar-Yam, 1997) complex systems generally have:

- Many elements and relationships between the elements that are dynamical, diverse and changing.
- Many types of relationships exist between the elements, such as physical, informational, psychological or cognitive (e.g. emotional, anticipation), sociological (e.g. cultural).
- High interdependency between the elements. The removal of an element (or sub-system) will have a strong effect on the remaining system and on the removed element.
- Non-linear interactions giving rise to non-linear system behaviour, so small changes or disturbances can have large effects.
- Element interactions involving positive and negative feedback loops. The first increases input while the latter is error reducing.

- Interactions with their environment. They act upon the environment and are acted upon by the environment. They are open systems. Closed systems are usually complicated.
- Elements act locally based on local data, with limited or no knowledge of the totality of the system. Actors input gets modulated and effects can be delayed and or unexpected.
- Continuous operations to respond to and adapt to perturbations from the environment to maintain acceptable performance for survival.
- A history of development and show path dependence. This means future actions are not only based on the current state of the system but also on its history.
- Emergent properties in which higher-level variables cannot be reduced to lower-level variables.
- System behaviour is difficult to predict and depends on the scale of the system description and the information about the system.

Complexity has consequence for talking and thinking about accidents. Dekker (Dekker et al., 2011) summarises this as follows. When accidents are seen as complex occurrences, it becomes difficult to establish a relationship between individual system component behaviour (or dysfunction, such as "human errors") and system-level outcomes. System-level behaviours, on the other hand, are the result of a large network of linkages and links that exist deeper inside the system and cannot be reduced to those components. Inquiries that embrace complexity, on the other hand, may forsake the hunt for "causes" of failure or success. Rather, they construct a number of narratives from diverse viewpoints inside the complex system, offering usually overlapping and frequently contradictory views on how emergent occurrences occur. The complexity viewpoint calls into question the applicability of simple solutions to complex system events.

8.6.4 Coping with complexity

Complexity challenges the design, operation, and analysis of systems in all industries.(Woods & Hollnagel, 2006) (Bar-Yam, 1997). Given our current scientific and practical knowledge, we have to accept the ontological complexity of the problem domain. It is by using epistemological methods we should cope with complexity to such an extent the aviation system can grow, airlines can play their role and safety can be maintained or even further improved.

Both research projects are based on methods to cope with the airline organisational and operational complexity. Some strategies to cope with complexity will be mentioned below.

Reduce undesired variety by agreeing on essential variables for value exchange with the environment:

- A design criterion for the AVPMM is the reduction of complexity by focusing and scoping on the value production management function of the airline. Value production as a decision context for decision-making about essential variables reduces guidance to people in the airline and thereby reduces variety.

Use effective system descriptions:

- The design for the AVPMM includes the concepts of fractal and scaling to structure complexity, which has already been discussed. But the design also includes coarse graining and fine graining, a combination of methods for making macro or micro descriptions of systems. A coarse-grained macro-description leaves out irrelevant micro-level data without losing information at the higher level. Better models and theories develop towards more coarse-grained views, removing irrelevant details step by step (Auyang, 1998).
- The scale of actions must match the model scale to avoid extra surprises (Bar-Yam, 2004b). Complex systems will have unintended consequences, so surprise is unavoidable but can be reduced when the model scale is adjusted for or fits the action scale. Depending on the scale, systems can exhibit behaviour from simple to complex. The complexity profile is a tool that can help to cope with complexity.
- The scale at which the system is described may have an effect on the applicability of various statistical models. When strong nonlinearities are absent and a sufficiently large dataset is analysed, the central limit theorem may allow the use of simplified statistical models, such as normal distributions. When strong nonlinearities or scaling effects, such as power laws are present, suitable probability distributions, such as fat-tailed or skewed distributions are required to avoid the risk of drastically underestimating the likelihood of tail events (Taleb,2007).

Improve the management system by using and managing models through which the airline is managed:

- Managers and operators manage their activities in different dynamics under different conditions. Whatever the actions are, they are based on a model. This model is often an implicit and buggy mental model. The AVPMM has at least a high level explicit model that is designed for value production and delivery using a functional model of management activities to distribute and coordinate activities to maintain requisite variety for the organisational systems. Complexity is reduced by using effective system descriptions by using a hierarchy of value production units.

Use multiple perspectives:

- For the sensemaking of complex issues, the Soft Systems Methodology (Jackson, 2000) and CYNEFIN (Snowden et al., 2020) can be used within the context of the overarching AVPMM. Both approaches employ conversations for shared model building to arrive at agreed system level descriptions and use them for effective problem solving and decision making. FlightStory is a very good example of using the perspectives (Dekker et al., 2011) and expertise from flight crew to improve the management of the complexity of flight operations.

Although aviation and airline organisations are often coined as complex systems, principles and methods are available to cope with complexity. Illustrative is the fact that, although many aspects are complex, network airlines can operate a network at high reliability. Also, aviation has been able to develop flight execution as an ultra-safe system even though it has many complex aspects (Amalberti, 2002).

8.6.5 Summary

Using a combination of synthesis and analysis, building on systems theory and reductionistic theory the management of complex systems can be achieved.

The model below shows the concepts in a hierarchical model diagram that designers, analysts and managers can use for their specific purposes.

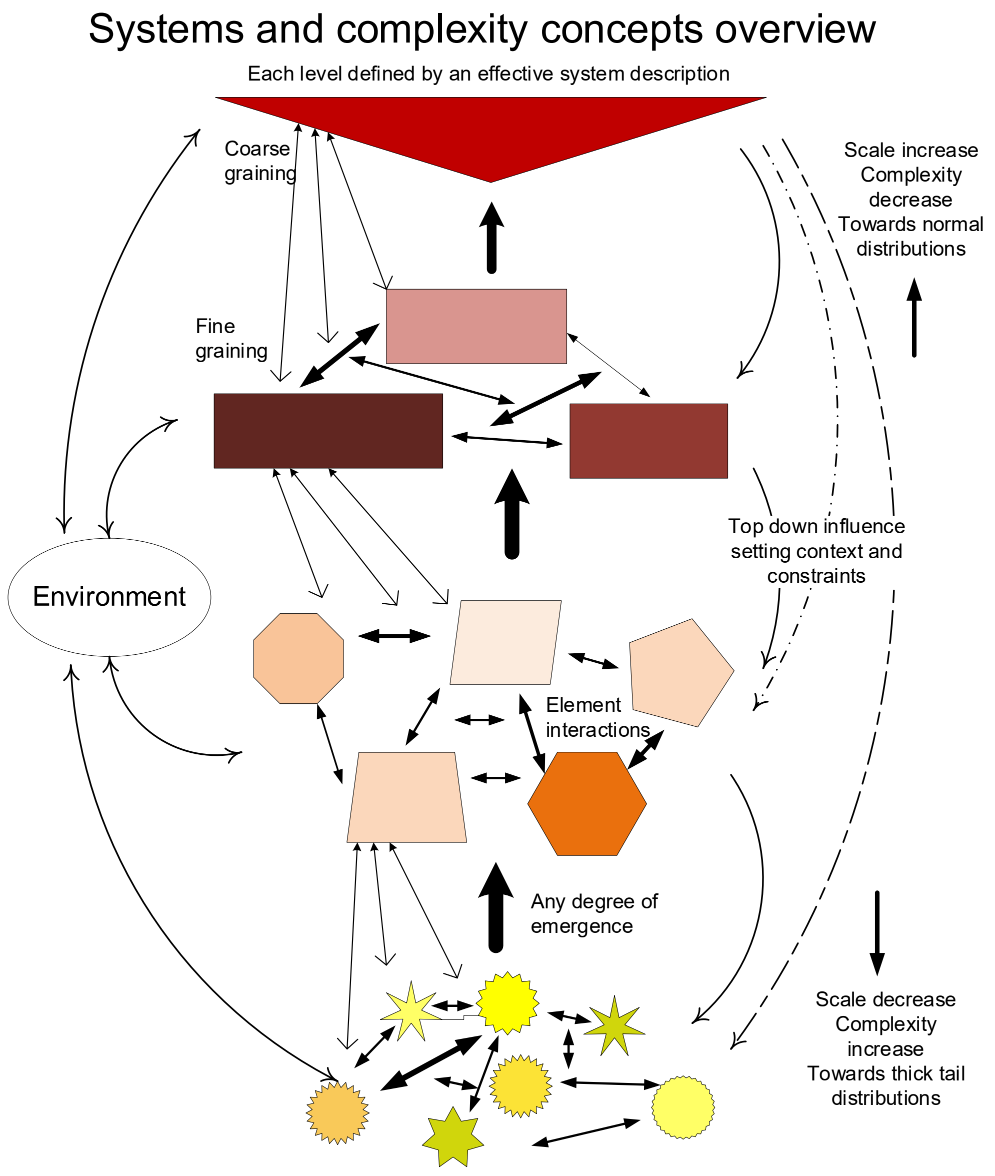


Figure 8-12 Systems and complexity concepts

8.7 Cybernetics

Cybernetics, derived from the Greek kybernetes meaning steersman, was initially used by Plato and later Ampère in the 19th century as a science of successful administration. One of the most influential books on the subject was Norbert Wiener's Cybernetics, or the study of control and communication in animals and machines (Wiener, 1948). Wiener set out to establish a universal theory of organisational and control linkages in systems, inspired by Claude Shannon's concurrent mathematical theory of communication. It currently stands apart from information and control theory. Different from artificial intelligence, cybernetics focuses on control and communication in natural systems like organisms and communities. From 1944 through 1953, a series of interdisciplinary meetings established the field of cybernetics as we know it today. The Josiah Macy Jr. Foundation sponsored the Macy Cybernetics Conferences. Psychosocial systems (e.g., Bateson and Ashby) were added to the list of cybernetics' applications to recover Plato's original focus on social control relations. To establish a cohesive science, cybernetic philosophers started to cohere with Ludwig von Bertalanffy's General Systems Theory (GST). Cybernetics focuses more specifically on goal-directed, functional systems which have some form of control relation (Heylighen & Joslyn, 2001).

By explaining goal-directed behaviour in terms of control and information, cybernetics has made a significant contribution to understanding mind and life. Environmental factors or internal dynamical processes do not absolutely define the behaviour of organisms. Negative feedback control loops are regarded as essential models for organism autonomy because they attempt to attain and uphold goal states(Heylighen & Joslyn, 2001). Although intentional, their behaviour is not rigidly determined by either ambient inputs or internal dynamical processes. (Clemson, 1991). Cybernetics predicted much of today's work on robots and car self-driving.

Cybernetics has always been concerned with error signals in intricate control and communication systems. The discipline emphasizes the close interconnection between control and communication. Information concerning function and control is not only exchanged between the various components of a system but also with the system's environment. This is done with the objective of achieving balance, which refers to the preservation of order. This maintenance of physiological variables within predetermined boundaries in living systems is known as homeostasis. Therefore, cybernetics is concerned with stabilising all types of systems (Skyttner, 2005).

8.7.1 First-order versus second-order cybernetics

First-order cybernetics is the study of observed systems, while second-order cybernetics is the study of observation. The concept of second-order cybernetics is based on the difference between an object that is observed and the processes within a subject that observes. Second-order cybernetics thus implies that the observer is always a participant, interacting with the system(Skyttner, 2005).

The idea behind second-order cybernetics is that cybernetics should engage in self-reflection and apply its own methodologies to itself. This is logical, as cybernetics has long noted the circularity inherent in feedback systems, and thus should extend its study of circularity to the link between the observing system and the observed system (Jackson, 2019). The term "second-order cybernetics" was first coined by Von Foerster in 1974.

The concept of "hard systems" includes first-order cybernetics, classical system dynamics, and certain applied general systems theory, such as contingency theory. Based on a mathematical model that purports to describe the logical linkages governing the behaviour of the system, hard systems thinking typically assumes that experts are positioned outside the system under investigation, advising managers on how to proceed. First-order cybernetics places goal setting outside the system and aims to implement negative feedback mechanisms to assure goal achievement (Jackson, 2019). This strategy is consistent with a positivist viewpoint and in safety science literature coined by (Dekker, 2011b) as Systems Thinking 1.0.

On the other hand, the concept of “soft systems” includes second-order cybernetics and is compatible with a constructivist viewpoint, the main view of this research. Soft systems thinking made a paradigm break with hard systems thinking and created systems methodologies for problem-solving based on the interpretive paradigm. By employing metaphors and paradigms, a soft system approach enables individuals to creatively tackle problem situations. This approach also allows them to respond to such situations by attempting to solve, resolve, or dissolve them through holistic interventions constructed from various metaphors and paradigms. (Jackson, 2004). This approach has a larger overlap with the Systems Thinking 2.0 approach as described by (Dekker, 2011b).

8.7.2 Organizational cybernetics or Management cybernetics

Jackson in (Jackson, 2000) describes that in 1959, Beer made a pioneering contribution to the field of management by applying cybernetics in a comprehensive manner. His work included a new definition of cybernetics as the "science of effective organization," (Beer, 1979) and he defined management as the science and profession of control. Beer continued to be an influential figure throughout the 1960s and early 1970s, producing a large body of work as both a writer and practitioner. During this period, he developed the Viable System Model (VSM), which could be applied to identify and address weaknesses in existing organizational systems or to design new systems that adhered to well-founded cybernetic principles.

Beer (Beer, 1959) was the first to apply cybernetics to management in any comprehensive fashion, defining management as the science and profession of control. He also offered a new definition of cybernetics as the “science of effective organization” (Beer, 1979). Throughout the 1960s and early 1970s Beer was a prolific writer and an influential practitioner. It was during this period that his model of any viable system, the

VSM, was developed. This could be used to diagnose the faults in any existing organizational system or to design new systems along sound cybernetic lines.

Beer (1981) suggested that cybernetic principles such as black box, negative feedback, and variety are effective in understanding and enhancing complex systems, including organizations that exhibit high complexity, self-regulation, and uncertainty. Rather than breaking systems down into individual components for understanding, the black box approach emphasizes the importance of monitoring system outputs and adjusting inputs accordingly. Negative feedback can then be utilized to regulate systems and achieve desired outcomes. All healthy organisations must be able to manage negative feedback processes in order to regulate and halt abrupt market forces of positive feedback.

8.7.3 Basic principles and concepts

In this section, some basics will be introduced to a degree to sufficiently understand the application of cybernetics in the research. More detailed descriptions and applications can be found in the work of authors such as Ashby, Beer, von Foerster, Espejo, Heylighen, Malik, Harnden and many more.

8.7.3.1 Distinctions and relations

Cybernetics is a field that is concerned with the properties of systems that are independent of their material or constituents. This property enables cybernetics to explain physically diverse systems, such as electronic circuits, brains, and organisations, using the same concepts and to search for isomorphisms between them. Fundamental to all of these relational concepts is the notion of difference or distinction. Cyberneticians are mainly interested in the difference between a phenomenon's existence and absence and how it relates to other differences related to other phenomena. This idea has its roots in the philosophy of Leibniz and is encapsulated by Bateson's famous definition of information as "a difference that makes a difference."

When investigating a system, any observer must start by conceptually isolating the system, the object of research, from the rest of the universe, the environment. A more thorough investigation will distinguish between the existence and absence of specific properties or dimensions of the system, such as colour, weight, position, or momentum. Each of these properties can be expressed as a binary, Boolean variable with two possible values: "yes" if the system possesses the property, or "no" if it does not.

The only way to abstract a system's physical characteristics or components while maintaining its core structure and functions is to investigate relationships: how do the components differ or connect? Cyberneticians explore how high-level ideas such as order, organization, complexity, hierarchy, structure, information, and control materialize in various sorts of systems in order to address these questions. These ideas are relational in nature since they enable us to examine and formally represent different abstract aspects of systems and their dynamics, allowing us to investigate whether complexity tends to increase over time.

Heylighen and Joslyn (2001) suggest that the cybernetic approach has the potential to provide a common language and methodology for studying systems across different fields, from biology to social science. In this sense, cybernetics is an interdisciplinary field that has the potential to offer insights into the workings of complex systems in a wide range of domains.

8.7.3.2 Variety

Ashby (Ashby, 1956) introduced the notion of variety as a measure for the number of distinguishable states a system can have. Variety is important for all change, options, and data. Selection is the process of reducing the variety available. If actual variety is less than potential variety, then there is constraint.

Essential is the way variety or in other words the number of distinctions that can be made (Ashby, 1958). This introduces the observer, the model builder, and the manager since these people are making their distinctions. The properties of the observer such as his or her background determine the number of distinctions he or she can make. Without the capability to make distinctions all is equal and management is impossible. A (normal functioning) Dutch traffic light has a variety of three; red, amber and green. For complex systems, such as aviation and airline organizations, the variety is extremely high. The absolute count of variety is often not important but the balance between that what is to be regulated and the regulating system is critical.

8.7.3.3 Essential Variables

A system state can be indicated by variety. Essential variables are variables in a system that must be kept within (physiological) constraints in order for the system to exist in its surroundings (Ashby, 1960). As a result, the variety of essential variables should be limited. In the human body, blood sugar levels and body temperature are essential variables. These variables must be kept within limits by the 'body management system,' or we will become sick when they approach the limits, and we will die if they exceed the limits. The concept of essential variables can be useful for businesses (Malik, 2016). In this research safety, economy and customer experience have been nominated as essential for airline value production.

8.7.3.4 Requisite Variety

The variety of the control system must be large enough to counteract the variety of the disturbances and maintain the variety of the essential variables within limits. Ashby (Ashby, 1956) termed this notion the law of requisite variety: "only variety can destroy variety" in the context of active regulation. This requires that the regulator, controller, or manager have sufficient variety to deal with undesirable variety. The solution must be sufficiently diverse to address the problem, and the model must be sufficiently diverse to accommodate the diversity of the essential characteristics of the system of interest.

According to cybernetics, a regulator must possess a broad range of actions to ensure a narrow range of outcomes for essential variables. This seemingly paradoxical idea has important implications for real-world scenarios. Since a system can face an infinite number of potential perturbations, it is crucial to increase its internal variety or diversity to be prepared for any foreseen or unforeseen contingency. Thus, it is necessary to constantly strive for maximum internal variety to enhance the system's adaptability and stability (Beer, 1984).

Bar-Yam considers variety in the context of complex systems through his concept of complexity profile as discussed above. Bar-Yam (Bar-Yam, 2004b) suggests a nuanced generalised Law of Requisite Variety expresses both the scale and variety required, and specifically states that the variety required to meet the tasks at each scale must be greater than the task requirements, which can be defined as necessary variety at each scale.

In today's world, systems are highly complex and subject to rapid change, resulting in a significant level of variety. To effectively control such systems, managers must focus on reducing the system's variety or increasing their own variety. This process, known as variety engineering, involves balancing the varieties to achieve optimal results. Beer (Beer, 1972) emphasized the importance of Ashby's Law of Requisite Variety to managers, equating it to the significance of Einstein's Law of Relativity to physicists. The AVPMM is a variety engineering tool to support the organisation in maintaining requisite variety over the essential variable safety, economy and customer experience.

8.7.3.5 Control

Control in cybernetics is the act of influencing, regulating the variety in a system. The regulator acts to limit the outcome to a particular subset, or to keep some variables within certain limits, or even to hold some variables constant or in balance.

Control, often viewed as a conservative force, may paradoxically lead to dynamic or progressive outcomes, depending on the complexity of the goal (Heylighen & Joslyn, 2001). For instance, if the goal is defined in terms of the distance relative to a moving target or the rate of increase of a quantity, suppressing deviation from the goal requires constant change. Consider an autopilot system in an airplane that maintains a selected altitude. In a broader context, the goal can be seen as a fitness function or gradient that assigns importance or preference to different states in the state space. Consequently, the problem of control becomes one of continuous optimization or maximization of fitness.

8.7.3.6 Mechanisms of control

Two principles of control that can be distinguished are passive and active control. Buffering is an passive type of control while feedforward and feedback are active types of control.

While the perturbations in a control relation can come from within the system (e.g. functioning variability) or outside the system (e.g. market changes or weather changes), we can treat them all as if they came from the same external source functionally (Heylighen & Joslyn, 2001). The system must be able to block the effect of such perturbations on its essential variables to achieve its goal despite them. Buffering, feed-back, and feed-forward are the three basic methods for achieving such regulation.

8.7.3.7 Buffering

Buffering refers to the passive absorption or damping of perturbations, such as the thicker or better insulated wall of a thermostatically regulated room or a car's shock absorbers, which dissipate uncoordinated fluctuations without active action (Heylighen & Joslyn, 2001). However, while buffering can stabilize a system around an equilibrium state, it cannot systematically force or maintain it in a non-equilibrium state, and in the long run, it cannot maintain desired values. Therefore, although buffering is useful in mitigating the impact of perturbations, it has its limitations and cannot guarantee optimal system performance. For example, a well-insulated wall can't keep a room warmer than the average outside temperature.

8.7.3.8 Feedforward

A disturbance will be suppressed by feedforward control before it has a chance of affecting the system's essential variables. Ashby (Ashby, 1956) refers to feedforward control as cause-control regulation because it reduces the effect of a disturbance as a cause for system deviation. To effectively compensate for perturbations and avoid damage to the system, control systems must be able to predict the impact of external fluctuations on the system's goal. This necessitates the acquisition of early data on these fluctuations (Heylighen & Joslyn, 2001). One example of this is the use of feedforward control in a thermostatically controlled room, where a temperature sensor outside the room alerts the thermostat to a drop in outside temperature, allowing it to adjust heating before the inside temperature is affected. However, such forewarning can be difficult to implement or unreliable, and errors will accumulate over time, eventually leading to system failure. Despite its limitations, feedforward control is a crucial aspect of effective control system design.

In most businesses, strategic control is required, which is based on feedforward information and attempts to predict disruptions before they affect the organisation. External control, or intervening directly in the environment to make it more conducive to the organisation, may also be useful.

Feedforward requires a model of the operation in order the predict the effect of the disturbance. The accuracy of the model is critical in the performance of the feedforward function.

A feedforward example in aviation is the pilot's decision to take extra fuel based on the weather forecast. Weather may disrupt the flight path and cause delays at the destination airport, increasing flight time and thus the required fuel for a flight. The ability of the flight crew to make these judgement calls can mean the difference between arriving at the destination and diverting to an alternate airport.

8.7.3.9 Feedback

Feedback is the information returned to a system that causes a change in the system's subsequent actions, such that those actions become the means by which the system achieves its goal. Feedback is a circular process that moves from intention to action, sensing the outcome of the action, comparing the outcome to the intention, and adjusting future action. This circularity is at the heart of all cybernetic systems, or goal-seeking systems.

To prevent the accumulation of errors in feedforward control, feedback control is necessary. Feedback control, also known as error-controlled regulation (Ashby, 1956), uses the error between the actual and desired state to determine the control action. For example, a thermostat samples the temperature inside a room and turns on the heating whenever the temperature falls below a certain reference point from the goal temperature. While feedback control is imperfect since it allows for a deviation or error to occur before acting, it can be very effective because deviations from the goal usually increase gradually, giving the controller the chance to intervene early when the deviation is still small. A sensitive thermostat, for instance, may begin heating as soon as the temperature falls even slightly below the desired temperature, and when the temperature reaches the goal again, it turns off the heating, keeping the temperature within a narrow range. In contrast, feedforward control cannot be made error-free in practice due to the infinite variety of possible perturbations.

FlightStory is a great example of improving the feedback from flight operations to the airline management system. Another example is the customer survey to get data from the customer experience for the management system to adjust to and improve customer service.

8.7.3.10 System dynamics

There are inputs and outputs in a system that transforms. The inputs are the result of the environment influencing the system, and the outputs are the system influencing the environment. Time separates input and output, as in before and after, or past and present (Heylighen & Joslyn, 2002).

As the name implies, feedback loops send information about the outcome of a transformation or action back to the system's input. These new data are positive feedback if they help and accelerate the transformation in the same direction as the previous results. Negative feedback occurs when new data produce results opposite to previous results, stabilising the system. The initial value does not matter in a negative feedback loop the principle will reduce the error. In the first case, exponential growth or decline occurs; in the second, equilibrium is maintained.

Positive feedback causes divergent behaviour: indefinite expansion (running away to infinity) or total blocking of activities (a running away toward zero). There is a snowball effect with each plus. Many examples: chain reaction, population explosion, industrial expansion, compound interest, inflation, cancer cell proliferation.

In either case, a positive feedback loop left unchecked will destroy the system, either by explosion or by blocking all functions. Negative loops must control positive loops' wild behaviour. This control is essential for a system's longevity.

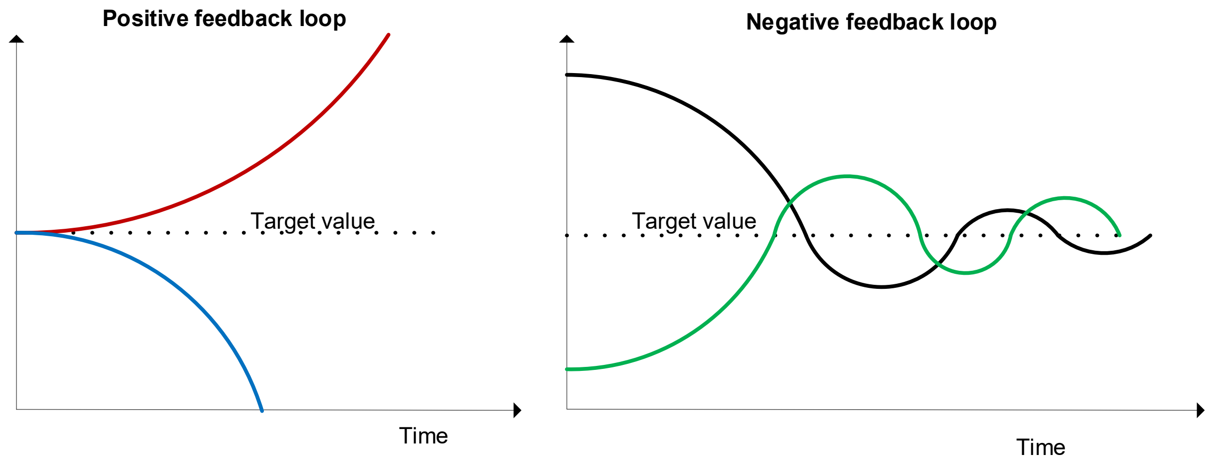


Figure 8-13 Positive and negative feedback

In systems combinations of positive and negative feedback loops as well as feedforward loops explain the existence of non-linear and complex behaviour.

8.7.3.11 Components of a control system

Generally, four types of system elements can be distinguished (Türke, 2008) in a control system. The Actors are those who are involved in implementing the purpose of the system. They execute Actions which are the time, timing and duration of activities. Instruments which are utilities means and skills are used to reach what the Actors want to reach. Instruments create the link between Images and Actions to achieve the purpose of the system.

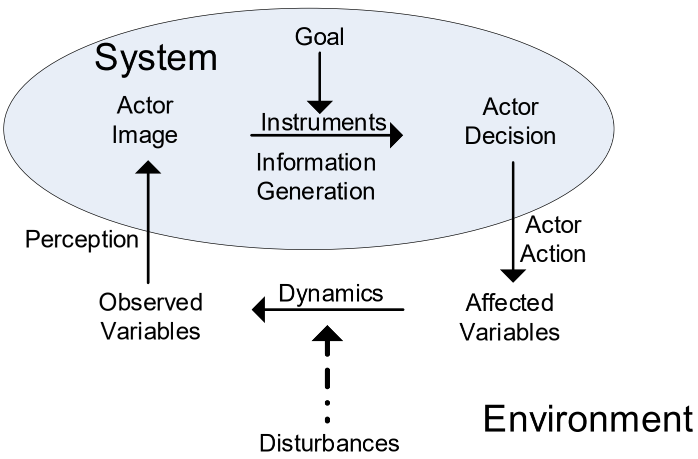


Figure 8-14 Component of a control system based on (Heylighen & Joslyn, 2001)

This feedback loop control system has two types of inputs: the target value for the essential variables and the disturbances in the environment that affect the essential variables. The system starts by observing or sensing the variables in the environment that affect the essential variables. This step of perception is updating the internal image of the outside situation. The data in the image or representation in generating information to determine in what way the goal may be affected and what should be the best response action to maintain the essential variables with limits. Actors using instruments to affect parts in the environment execute the action. The dynamics in the environment are expected based on the knowledge the system has. The disturbances are undesired side effects and other unknown variables that results in a difference between the affected variables and the observed variables. The loop continues as long as the system is active in achieving its purpose.

Similar description of this control loop are provide by Neisser and Hollnagel (Hollnagel & Woods, 2005) in the theory of Joint Cognitive Systems.

8.7.3.12 Hierarchical control systems

Control models can be nested or hierarchical. A fractal-like unfolding of control systems is possible and is limited in practice by the purpose of the modelling and the capacity of the model builder.

For a requisite system description often several hierarchical layers are needed to absorb the complexity of the modelled system. A simplified model of a control system is depicted below.

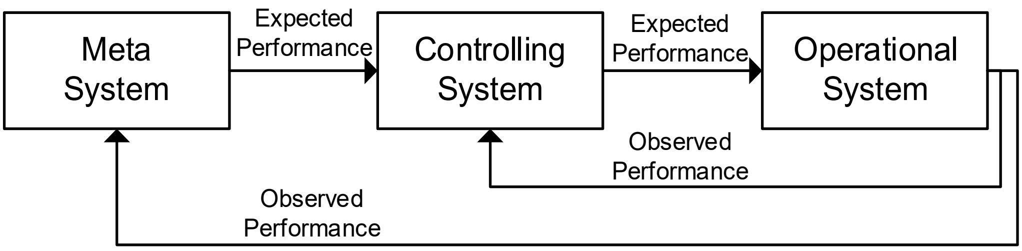


Figure 8-15 Simplified single control level based on (Kingston-Howlett, 1996)

The system's output is controlled by the system controller. The controller uses a goal setting for the systems output but how does the controller determine the goal setting? Kingston uses the concept of a meta-controller which provides the values for the goals. The structure has two feedback loops. The first is between the system controller and the operating system. The observed operational performance is compared with the goals and results in new desired or expected performance instructions. The second feedback loop carries the observed performance data to the meta controller which evaluates this performance against the current goal setting and might consequently change the desired goal value setting.

Using the hierarchical or recursive principle we can build a higher level to include control to the meta controller.

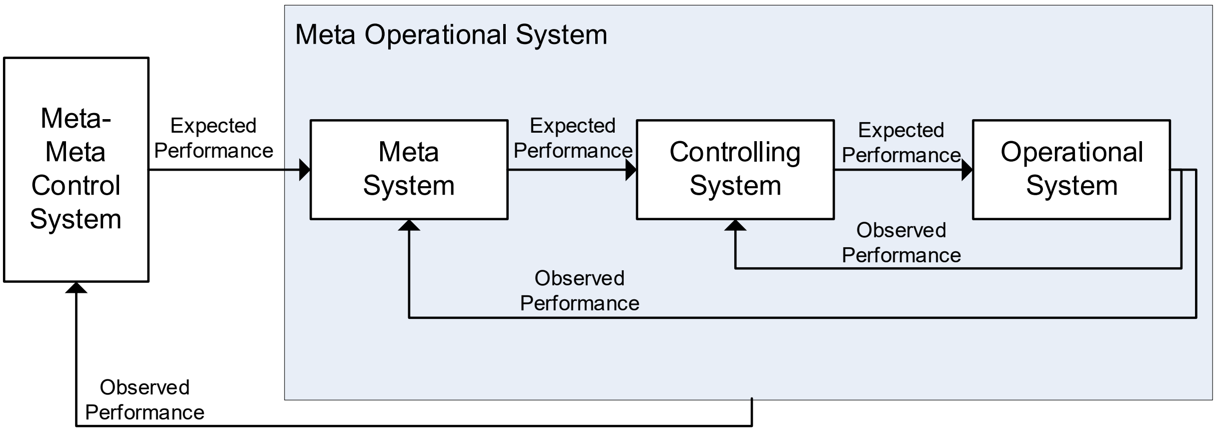


Figure 8-16 Meta system level control based on (Kingston-Howlett, 1996)

The meta-meta control function provides the lower level meta control with performance goals. The communication between the meta-meta and meta control functions is in a higher level 'language' than the lowest level communication. Where at the lower level the value of variables matters and the higher level the type of variable matters. This is analogues to double loop learning by (2023a). For example, the first loop is concerned with the performance of a particular task while at the second level the task is considered.

Another way of combining control systems is integration of control systems at the same level. The horizontal integration is depicted below and instantiated by the essential variables of the AVPMM, safety, economy and customer experience.

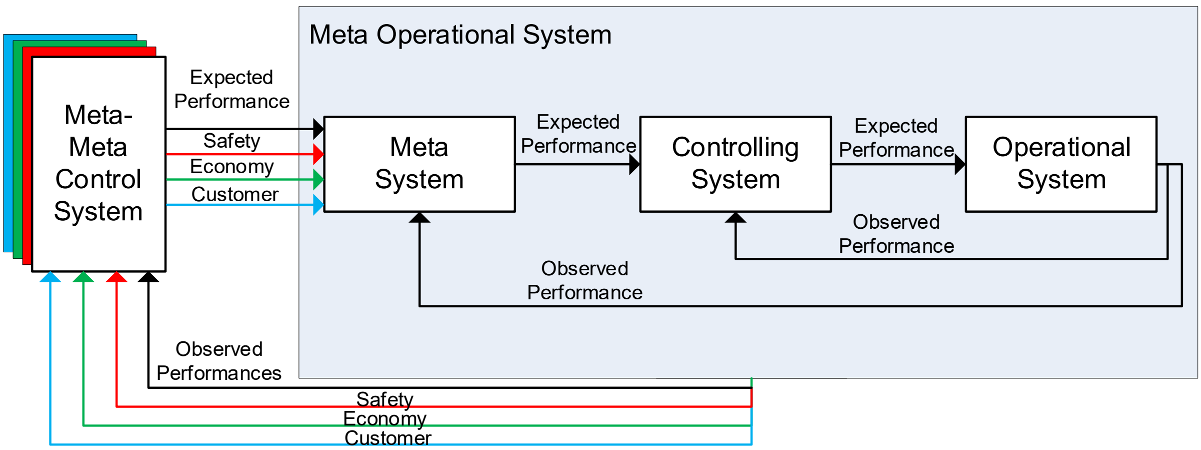


Figure 8-17 Integrative meta control based on (Kingston-Howlett, 1996)

Based on the AVPMM a next higher level of control could be added to represent value as the highest meta control system variable. Value provides then the closure for optimisation discussions in the middle meta-meta controller. This logic is further explained in the section of the Viable System Model.

8.7.3.13 The Black Box technique

When a system can only be described as a complex system or for convenience cyberneticians use the concept of a 'black box' as a place holder for a system description (Jackson, 2007). A transparent or white box, on the other hand, is one in which all possible states are observable and understandable. Organizations and their environments are essentially treated as black boxes. To deal with black boxes, managers and their advisers must gain some understanding of system behaviour, even if they will never fully understand what causes the behaviour.

According to Ashby (Ashby, 1956), analysis is not the way to approach an extremely complex system, a black box. A reductionist analysis of each component of the system will never allow for the understanding of the entire system's interactions. We find that we cannot reassemble a complex system in the same way that it produced the same pattern of behaviour when we disassemble it for analysis. The black box technique of input manipulation and output classification should be applied instead of analysis. Using this approach, an experimenter may find some patterns that make the system more predictable. Managers cannot possibly anticipate every interaction that might occur within the systems they are in charge of. They should instead employ the black box technique, which involves manipulating inputs and observing outputs, rather than attempting to proceed analytically.

When confronted with a black box, a manager does not need to enter it to learn more about it. Instead, the system is investigated through the collection of a long protocol that is drawn out in time and shows the sequence of input and output states. Snowden (Snowden, 2020) proposes fail-safe micro experiments. This means they may fail, but they should be designed in such a way that the organisation suffers no consequences. It is also critical not to draw conclusions about a system's behaviour without first observing it for a sufficient period of time (Beer, 1979). Nonetheless, it is an important tool that can be used at all times because only by working with black boxes the overwhelming by confusing detail and losing required variety, can be avoided.

8.7.3.14 Good regulator

According to the Law of Requisite Variety, the variety of outcomes of a system can only be reduced by increasing the variety in the system's controller. The regulator's purpose is to keep the system's output variety within certain limits. This reduction in the variety of outcomes is only possible if the regulator's variety is at least equal to the system's variety. Effective control is therefore impossible if the controller has less variety than the system. This implies that the regulator must be a model of the system in that the regulator's behaviours must be identical to those of the system.

The design of a complex regulator often includes the making of a model of the system to be regulated. The making of such a model has often been regarded as optional, as merely one of many possible ways. The Conant Ashby theorem (Conant & Ashby, 1970) claims, that under very broad conditions, any regulator that is maximally both successful and simple must be isomorphic with the system being regulated. Making a model is thus necessary. The AVPMM is an example of a model to support achieving requisite variety over value production.

The operation of the regulator can be exercised with some defined measures of performance(Skyttner, 2005). Three often used measures are the following:

- Effectiveness. This is a measure of the extent to which a system achieves its intended goals.
- Efficiency. The measure of the extent to which the system achieves its intended goals with the minimum use of resources.
- Efficacy. A measure of the extent to which the system contributes to the purposes of a higher-level system of which it may be a subsystem.

The various cybernetic concepts can be used to improve system performance of the regulator.

8.7.3.15 Variety engineering

For an organisation to be viable, it must be capable of navigating its environment's complexity. Organizations cannot create the same amount of complexity internally as their environment exposes: only variety absorbs variety (Beer, 1979). In order to deal with complexity, the variety the organisation can produce must be amplified towards the environment at the lowest cost possible, while the variety that the environment exposes must be attenuated towards the organisation.

The most essential feature of variety engineering is not counting the possible states of a system, but rather matching them. The proliferation of variety in complex systems makes management difficult or practically impossible, therefore successful control involves the capacity to establish a level of variety through regulatory action that corresponds to the variety of the complex system to be managed.

We can imagine an operation in an environment. In a social technical system, there will be many interactions between the environment and the operational unit. The operations will have interactions with its management function depicted by the square box. Clemson (Clemson, 1991) extended this model by adding the available models of the management function, depicted by the tri-angle. When we for modelling convenience separate the four elements, we get the diagram below of a basic operational unit. As in the essence of cybernetics, each element is a function and we are not concerned with the actual implementation of these functions in either a human, a machine or any combination. This is a scale invariant diagram which means it can be applied on an individual managing his own operation or a large company.

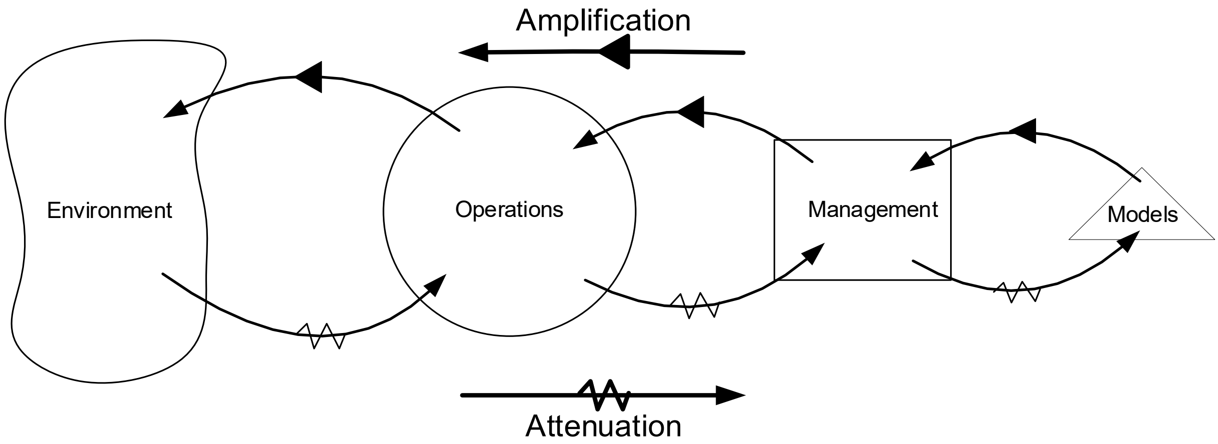


Figure 8-18 Basic operational unit based on (Clemson, 1991)

If we took the number of people in each element as representative for the possible variety, then we could say the environment has more variety than the operation, which has more variety than the management unit, which has more variety than the model in use for this unit. Examples of unbalances in variety are very common such as people in a waiting queue, managers have no time for an operational issue and the management usage of out of date models resulting in simplistic intervention falling short in solving the issue.

For a balance in variety, the variety flowing (cascading) from left to the right must be attenuated (absorbed) and the variety from the right to the left must be amplified (increased) to achieve a balance. In this document management is a function and not a particular group of people. In my view everybody manages his own work and is therefore both manager and operator. Operations can be seen as ‘the doing’; management can be seen as ‘the thinking about’.

Since only variety can absorb variety, variety generators must be used to absorb (counteract) the incoming variety and to amplify the outgoing variety. Below are some examples to illustrated the concepts of variety generators for a flight operational unit (single or multiple flights) and its environment.

Environment	Operations	Management	Models
Weather (e.g., wind thunderstorms, snow) Passengers Number of surrounding aircraft ATC (Air Traffic Control) Etc.	Number of procedures Equipment Number of flight crew (3 or 4 people crew) Experience of flight crew Etc.	Captain Purser Company operational support Etc.	Experience and knowledge of captain and purser Etc.

Figure 8-19 Examples variety generators

Safety management interventions can be classified as variety attenuator or as variety amplifier. An intervention on the wrong side of the variety balance will increase variety unbalance with possible tragic consequences. Below are some examples of variety balancing interventions that are used in the flight operational unit for a single or multiple flight.

Amplification		
Operations >> Environment	Management >> Operations	Management >> Models
Advanced auto-flight systems (to balance ATC requests and increase the number of type of approaches that can be flown) Weather radar (to balance weather variety) Etc.	Crew Resource Management training Operational philosophy (to provide a compass for crew decision making) Flight crew training (to increase the number of situations (e.g. technical failures) a flight crew can deal with) Etc.	Company identity interpreted for flight operations Business plan Safety models Etc.
Attenuation		
Environment >> Operations	Operations >> Management	Management >> Models
Aircraft anti-icing systems (to make the aircraft less sensitive to weather variety) Data-link communication with Air Traffic Control (to reduce communication variety) Etc.	Operational (safety) reports Business pilot Safety (kind of safety issue front office relative to the departmental managers) Etc.	Management dashboards Etc.

Figure 8-20 Examples of variety balancing interventions

8.7.3.16 Signal to Noise

The signal to noise ratio is a measure of the strength of a signal relative to the amount of background noise. In the context of the law of requisite variety, the signal represents the desired response of a system, while the noise represents the unwanted or irrelevant inputs that the system must filter out to respond correctly (Ashby, 1956). A high signal to noise ratio indicates that the system is able to distinguish the desired response from the background noise, while a low signal to noise ratio indicates that the system is overwhelmed by noise and unable to respond correctly (Wiener, 1948).

To adapt to its environment, a system must be able to respond to a wide variety of inputs, which means that it must have a high signal to noise ratio. This is because the more noise that a system can filter out, the more signals it can respond to. In other words, the more variety of response a system has the more adaptable it is.

In practice, the signal to noise ratio is an important consideration in many fields, such as telecommunications, signal processing, and control systems, where the ability to distinguish a signal from noise is critical to the functioning of the system.

This concludes an introduction to cybernetics for the purpose of providing a background for the applied methods and concepts in the research. The sufficiency of this chapter depends on the knowledge of the reader. Many references are provided might a reader desire to find more information and explanation of these topics.

8.8 The Viable System Model

The AVPMM is an instantiation of the Viable System Model (Beer, 1979). The VSM is based on systems theory and is inspired by the brain's ability to coordinate muscles and organs. Its theoretical foundations are Ashby's work, specifically the Law of Requisite Variety, Wiener's research of cybernetics, recursive systems mathematics, and McCulloch's ideas of neural networks.

The VSM is a model of the organisational structure of any self-producing autonomous system. Any system constructed in such a way as to satisfy the needs of survival in a changing environment is a viable system. Adaptability is one of the most important characteristics of systems that survive. The VSM is an abstracted Management Cybernetic (regulatory theory) definition of a viable system that may apply to any organisation that is a viable system and capable of autonomy.

The VSM is a valuable tool for analysing organisational structure (Hoverstadt, 2011). It focuses on the resources and connections required to maintain an organization's viability rather than the formal structure, thus avoiding the traditional emphasis on hierarchical relationships. Its core premise is that viable organisations arise when people create and keep group identities despite environmental disturbances such as an airline that survives for over 100 years. These capabilities require developing organisational mechanisms such as coordination and delegation for the creation, re-invention, development, and maintenance of the organisation across time in one form or another. These systems are made up of individuals who are supported by a range of resources which help the organisation formulate policies and offer intelligence, cohesion, coordination, and execution capability. The design problem is establishing the conditions for individuals to interact in such a way that the organization's changes for long term viability improve.

According to (Espejo et al., 1999), the VSM is significant because it helps managers to design and manage these mechanisms in a way that allows people to contribute to the success of the organisation to the best of their abilities.

VSM addresses this complexity in two ways (Hoverstadt, 2011): by assessing the balance of complexity among various system aspects, and by unfolding in a fractal structure, in which systems are made up of sub-systems with the same basic organisational qualities. In other words, viable systems are made up of viable systems that are made up of viable systems. At every fractal level, the same systemic concepts should apply. This means that the same management functions may be used to any structured system, ranging from a team to a country's socio-economic system or a specific industry sector.

When linking viability with complexity, we can see that viable organizations exist in a world that is indefinitely more complex than they can ever be (Achterbergh & Vriens, 2010). The success of a regulator in maintaining essential variables within boundaries is determined by the relationship between the variety of disturbances and the variety of regulatory operations, according to Ashby's law. If essential variables for viability are to be kept within bounds, viable organisations must cope with the vast variety of the world in which they operate. The VSM provides a set of rules (explained later) for diagnosing and planning organisational viability by describing the essential and sufficient functions for organisational viability.

Everywhere, the same organisational processes, the same viability requirements, apply. The mechanisms are unaffected by the nature of the interaction; the same checks and balances, as well as the same controls, apply at all levels of the organisation and across all organisations.

Hoverstadt (Hoverstadt, 2011) explains how the VSM depicts the organization's structures and interactions. Important procedures, communications, and data movement are all included in this category. The concept of complexity, as well as how an organisation and its management deal with the complexity of their environment and their own actions, is a major topic. Big systems have the same systemic characteristics as small systems, and they function and collapse in the same ways. This means that anyone can understand any company of any size in any industry if they understand how to apply the fundamental model. In this study, I used the VSM to model a network airline's Airline Value Production Management system.

Viability, (Beer, 1979) according to him, is the ability to survive or maintain one's identity in a changing environment. The variety balancing act between the environment and the organisation must function adequately in a viable system. The diagram below depicts three elements of a viable system. A basic VSM diagram depicts the embedded environment and operation with a management function. Every type of operation requires management, and thinking and doing should not be separated. Acting without first thinking is doomed to fail, and thinking without first acting has no effect. A person who combines thinking and acting, or in VSM terms, a person who manages his own operation. The VSM is a functional model that is unconcerned with physical implementation in a real-world environment.

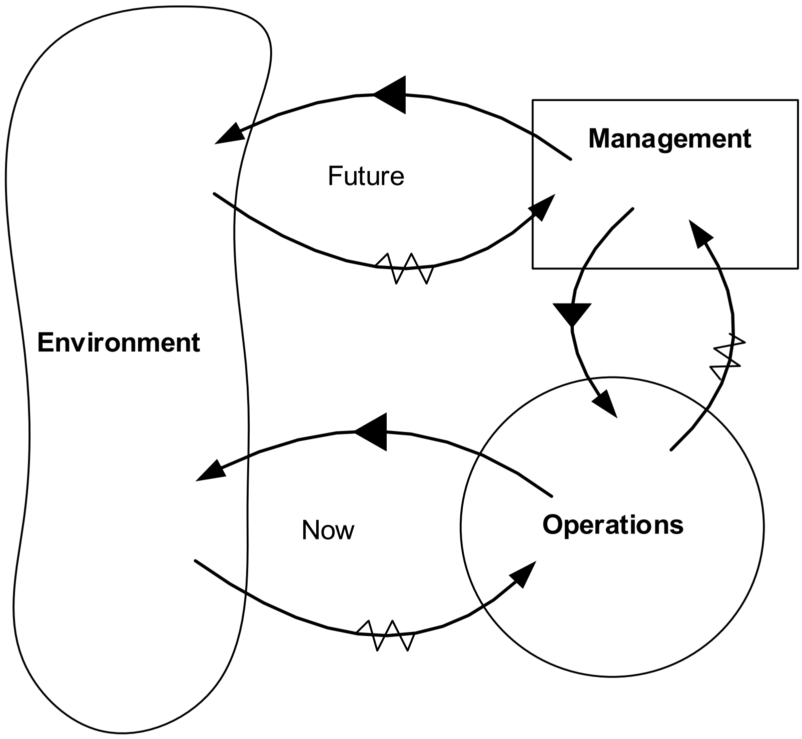


Figure 8-21 Baisc diagram of the VSM

8.8.1 Recursion

An organisation, such as an airline company, has complex system aspects. To enable successful management, it is necessary to reduce complexity in a methodical manner while preserving the variety required. To maintain work in progress, tasks must be separated across people, time, and geography. The distribution of labour produces an organisational structure. Numerous designs and implementations are based on the management and organisational concepts employed by senior management. Every design will incorporate some type of hierarchy. As Simon (Simon, 1977) says, hierarchies can be detected in complex systems since these systems have the time to grow due to their stability. In a hierarchy, the top and bottom handle events differently. What defines the top, and the bottom is an essential question. Frequently, the organisational map illustrates the development of the hierarchical organisation where the hierarchy is based on decision scope and power.

Similarities exist between the VSM's idea of recursion and the layers of a hierarchy. In the VSM, every recursion must be viable, hence nominations for recursion are restricted to situations where viable systems can be proposed. A middle management layer, as frequently observed in organisational hierarchies, is not a VSM-viable structure. This layer cannot exist independently since it has no value exchange with its surroundings. Selectable dimensions for layer selection can vary. Organizational structure, functional groups, and geography are examples. In my primary explanation of airline organisation, I employ the dimension of value. This implies that the recursions chosen (as a need to minimise variety) must contribute to the generation of value. I chose value because a (commercial) organization's viability is contingent on its ability to sustain a value exchange with its surroundings. Each recursion must provide value to the client, the investor, and the employee. The VSM is not an organisational chart, but rather a model of the structural communication channels and interactions among the various organisational roles.

8.8.2 VSM System functions

The management function regulates the operations, or those activities that produce the organization's identity (e.g. flights for an airline), in a viable system (e.g. scheduling, accounting). To provide the requisite variety, organisational design (structure and processes) must include both attenuation and amplification of variety. For effective regulation, communication channels (reports, instructions, discussions, etc.) must be diverse (e.g., a few lines in an air safety report provides insufficient variety for an effective intervention). The VSM identifies five organisational functions that, when taken together, are sufficient to support viability and maintain the required variety. These are enumerated as systems 1 to 5:

- System 1: Operations, primary activities, implementation of the activities that define the nature of the business.
- System 2: Conflict resolution, co-ordination, stability.
- System 3 Internal regulation, monitoring, synergy, agreeing on autonomy and cohesion of system 1 at the lower level.
- System 3*: Audit operations of system 1 based on an agreement (visit and look for unnecessary variety) between system 3 and its system 1s.
- System 4: Intelligence, adaptation, scanning the outside for forward planning and strategy development.
- System 5: Policy, ultimate authority, identity the norms and values that define the organization.

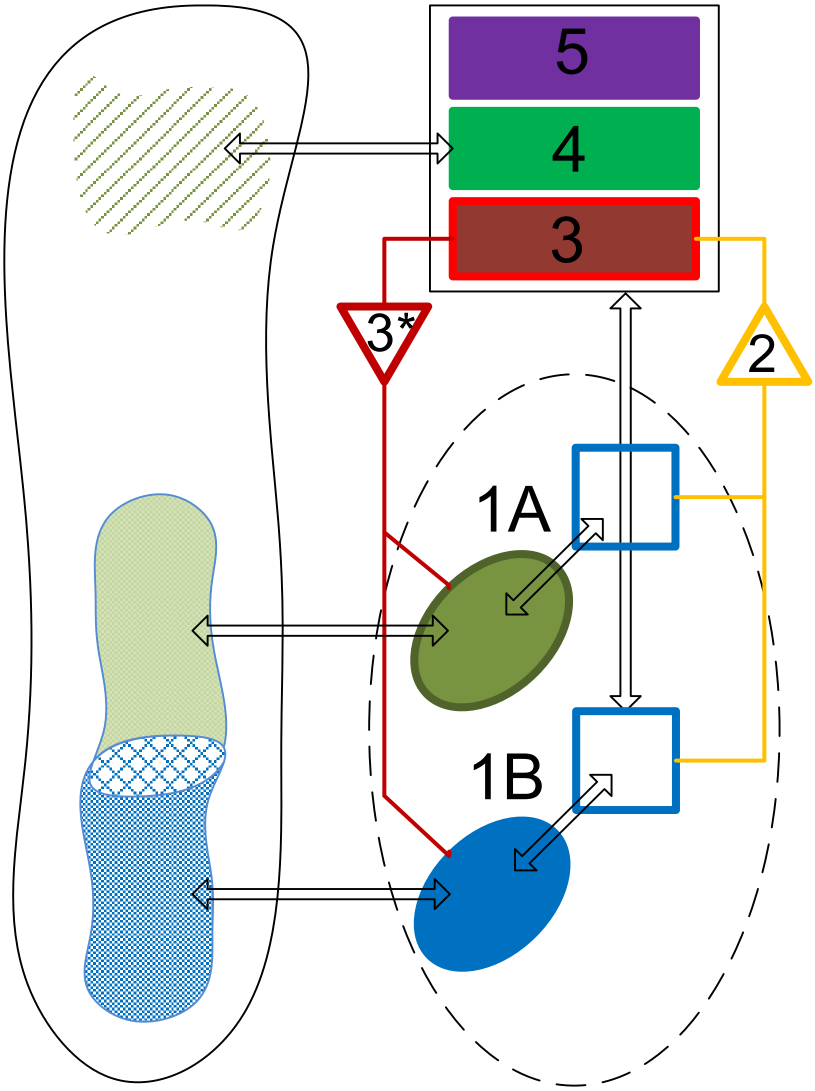


Figure 8-22 The Systems in the Viable System Model

Systems 1, 2, 3, concern themselves with what is happening ‘inside and now’. System 4 concerns itself with what might happen in the future, ‘outside and then’. The rules of interaction between the two are determined by System 5.

8.8.2.1 System 1

The model starts with unfolding the operations — the ‘primary activities’ of the organization. These are the activities that deliver the product or service that the organization exists to provide.

System 1 is responsible for delivering the organization's goods or services to the relevant market or environment. This system comprises operational organizational units, which are complete viable systems and responsible for specific lines of activity or products. It is these units that produce what the organization is meant to deliver. (Rios, 2012).

For a hospital, different types of clinical care would be primary activities. Medical care provided by first aid providers at an Aircraft Maintenance Organisation would not be primary, since the organisation exists to produce maintenance services.

8.8.2.2 System 2

The purpose of System 2 is to prevent the collection of organizational units in System 1 from interfering with one another. Within System 1, units may either be interdependent or compete for the organization's common resources, suppliers, and other resources, which may lead to conflict as each unit strives to accomplish its own objectives, namely delivering the assigned products or services. System 2, on the other hand, supports System 3, which is responsible for absorbing significant amounts of variation (complexity) generated by the day-to-day operations of the elementary operational units. (Rios, 2012).

Mechanisms for ensuring that different primary activities do not interfere with one another are referred to as coordination. We frequently take coordination mechanisms for granted since they are basic yet highly effective (Hoverstadt, 2011). Common standards, protocols, and airline time table are examples of typical coordinating systems. In the realm of safety science, effective communication and mutual understanding among operational units can be just as vital as following formal processes. Common language and shared cultures are key factors that enable effective communication, foster mutual agreement, and promote overall safety within organizations. All of them are intended to smooth out difficulties between operating units and avoid one's actions from interfering with another's.

System 2 topics concerning coordination involve the interdependency of sub-system interests and how they can be coordinated (Türke, 2008):

- What are the actual and interdependent activities of the sub-systems?
- Where do activities of sub-systems clash and how can they be harmonised?
- What is the status of the ongoing attenuation of sub-system interdependency?

Hoverstadt describes (Hoverstadt, 2011). when coordination mechanisms fail, we find issues such as process bottlenecks, failed production planning, resource conflicts across departments, and the need for a higher management level to handle the conflict.

8.8.2.3 System 3

The organization's "Operational Management" is represented by System 3. It is dealing with day-to-day activities. It is focused on the "here and now" of the organisation’s operations. The primary objective of the system is to ensure that the operational units comprising System 1 are effectively producing and delivering the products or services assigned by the organization (and each of its elementary operational units) to the market or its clients. In doing so, the system aims to optimize the use of resources, achieving the highest possible levels of efficiency and effectiveness. System3 is tasked with optimising the operation of System 1's diverse operating components. This system has the ability to establish synergy overall System 1s since it has a perspective of the whole system that no other system has (Rios, 2012)

Three topics, including the description of "sub-system" conceptions, their interdependence, the resources to be allocated, and the actual capability and effectiveness of the overall system, focus on the "inside and now" of the "systems" under consideration. (Türke, 2008):

- What are necessary and reasonable requirements and constraints for °sub-systems°?
- How should Two issues be resolved?
- What is currently being done for sub-system implementation and how?

System 3 should not generally interfere with the operation of the primary components (Rios, 2012). System 3's lack of direct involvement in concerns pertaining to these units indicates the organization's well-designed structure and efficient operation. Their activities should be handled with a great deal of independence by their own "management." Each of these subunits is, in and of itself, a fully functional, viable system.

8.8.2.4 System 3*

System 3* serves as a support system for System 3, with its primary function being to gather information about how System 1 is operating. This information cannot be obtained through the communication channels linking System 1 with System 3 directly or through the connection between System 2 and System 3 (Rios, 2012). Like all other systems that comprise the VSM, System 3* is vital and should aim to minimize unnecessary variety.

Even though information about the performance of System 1 is expected to flow through the regular information channels, such as System 2 and accountability, some of it may get filtered out and not reach System 3. To address this issue, System 3* needs to be designed. The main objective of System 3* is to guarantee that the information exchange between System 1 and System 3 is comprehensive. This is accomplished through various methods, including auditing (such as quality audits, opinion surveys, compliance with accounting procedures), work studies (industrial engineering), operations research, surveys, and special studies. (Rios, 2012).

8.8.2.5 System 4

System 3 is primarily in charge of ensuring that the organisation functions today, whereas System 4 is primarily in charge of the organization's future and (external) environment (Rios, 2012). It is a critical component of the adaptive structure of the organisation. Viability is the ability of an organisation to expand beyond simply doing what it does effectively and efficiently. It indicates the ability to modify oneself, one's activities, one's form, one's identity, and one's environment. Organizations must be adaptable in order to remain viable, and adaptation mechanisms must exist at all levels of the organisation (Hoverstadt, 2011). To ensure that the organisation can always achieve its mission and maintain its identity in the face of environmental changes (in economic, technological, social, political, educational, ecological, commercial, or legislative areas, for example), it must be capable of identifying these changes and implementing the necessary internal adjustments in a timely manner.

System 4 topics – for strategic governing apply to anticipations of future developments of the system (Türke, 2008):

- What external factors are to be considered relevant for sustaining the system notion?
- How do they affect the outcome?
- How can the actual situation be understood, interpreted, modelled?
- What could and should be done to prepare for future threats and problems?

8.8.2.6 System 5

The purpose of System 5 is to balance the organization's present and future, considering both internal and external factors (Rios, 2012). It is to determine the organization's "identity," or identifying what it is or wants to be, as well as what it "is not or does not want to be." Such distinctions are especially significant for defining the organization's boundaries, or defining the boundaries between what belongs in the environment and what belongs in the organisation. The establishment of the values, standards, and rules of conduct that should prevail and infect the organisation at all levels of recursion its "ethos," is implicit in this. These will aid in the overall set's coherence. System 5's typical responsibilities include determining the organization's vision, mission, and strategic goals. The type of management it must supply is "Normative Management," as opposed to System 4's "Strategic Management" (with the help of System 3) and System 3's "Operative Management."

System 5 not only oversees the organization's stability, internal equilibrium, and adaptation to the external environment, as described by Beer in (Beer, 1984), but it also has the responsibility of preserving the organization's identity. System 5 topics address the boundary judgements adopted by the actors involved and the norms deriving from them (Türke, 2008):

- What is and what should be the purpose of the system?
- Who is and who should be the client?
- What is and what should be the measure of improvement?
- How shall present and future, as well as internal and external perspectives, be accommodated?
- What criteria shall be applied for interpreting the environment?
- What supreme values, norms, and rules do actors have to comply with to legitimise their engagement in implementing the system notion?

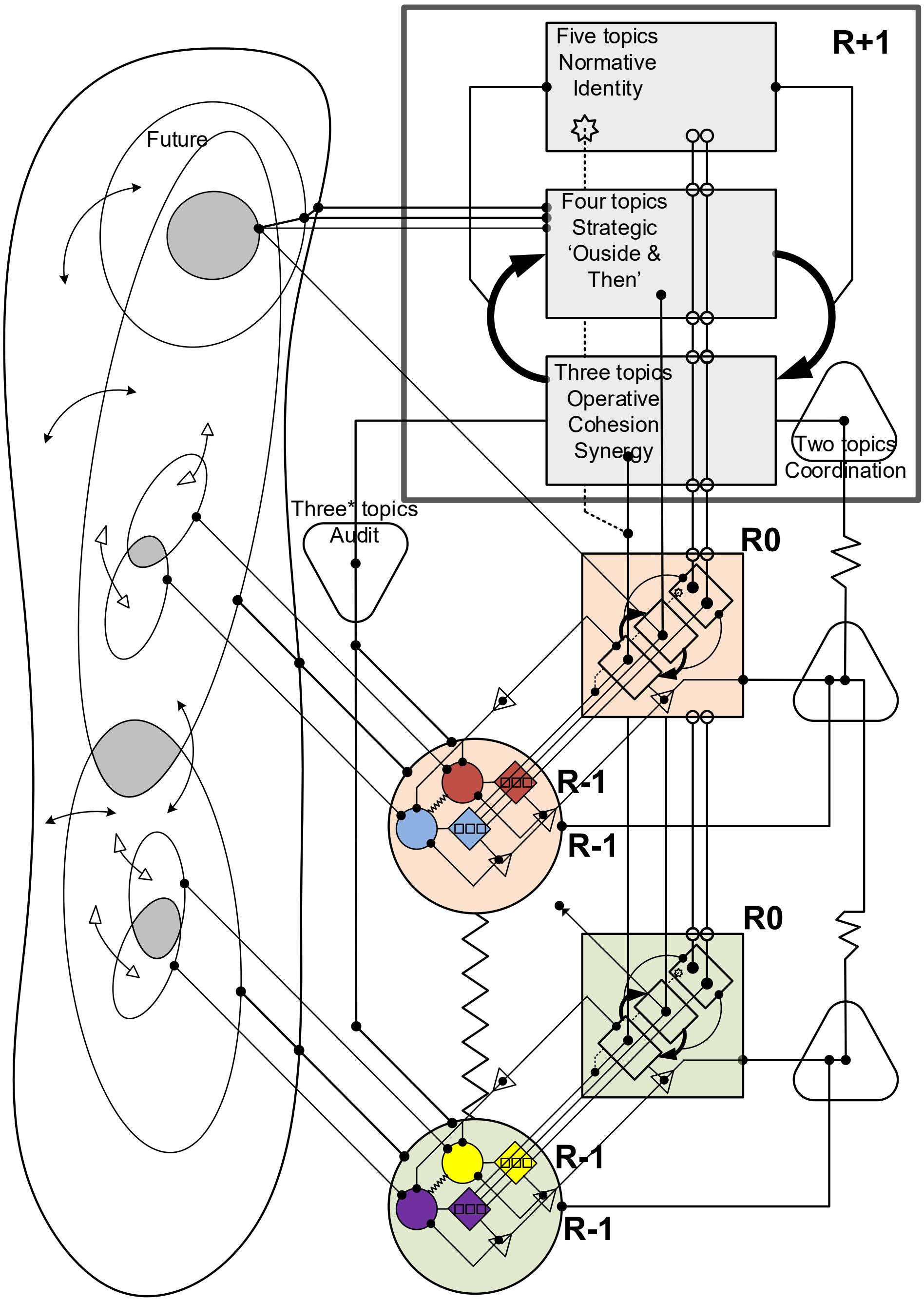


Figure 8-23 The Viable System Model based on (Beer, 1994)

8.8.2.7 Invariant systemic topics

Türke (Türke, 2008) complied a table of all systemic topics specific for each communication loop between the five different systems. Each systemic topic applies for each recursion and should be instantiated at each recursion in the appropriate language for that recursion. All systems issues should in principle be relatable to the systemic topics.

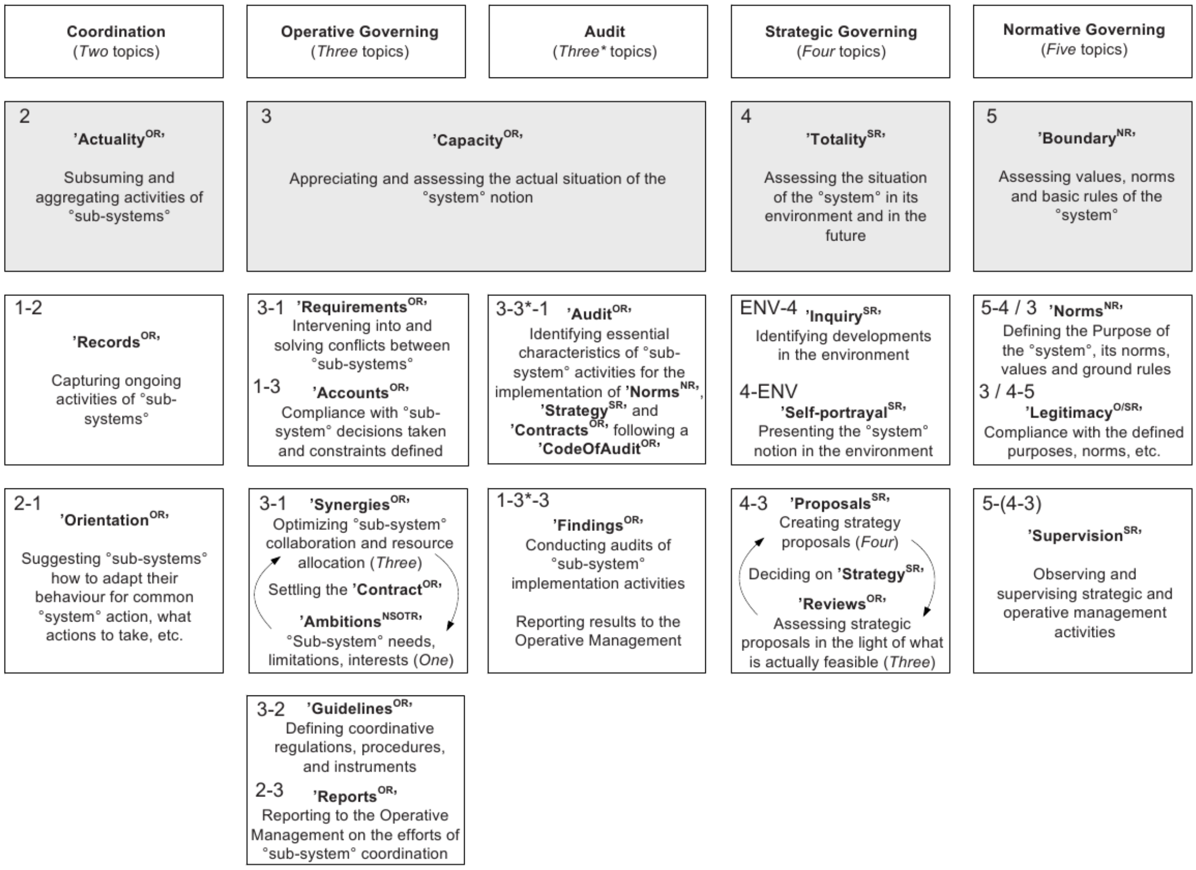


Figure 8-24 Invariant systemic topics (Türke, 2008)

A system can only stay viable if the interactions done for its implementation address these four invariant topic domains for Systems 2, 3, 4, and 5 (Türke, 2008). Each of these topic domains requires distinct interactions to resolve its challenges. It is necessary for each interaction to develop sufficient representations, specific channels, methods, and transducers. To address specific domain concerns, it must be ensured that all interactions address the topic's properties. The four issue domains are resolved in any system implementation, such as that of an airline company. In fact, whether this is done sustainably depends on the strength of the defining linkages (and their structures) to persistently address problems that arise across all issue domains.

8.8.3 FlightStory in the VSM

The management team of the Flight Operations (MTFO) department executes their role as a System 3 relative to an individual flight which is managed by a captain. The MTFO provides the captain of a flight with the required resources and requests a flight execution according to requirements which include regulatory and operational requirements. The flight should be conducted in a manner that fulfils the promises made to the passengers. MTFO delivers all Operational Performance Conditions such as training, technical status of the aircraft, procedures, a flight plan and more. The passenger service delivery may encounter particular circumstances which may include delays, bad weather and other flight disturbances and the reference values of safety, economy and customer provide guidance for operational decision making. As an example, the captain may request more fuel to the specific flight because e.g., delay is expected at the destination airport. This negotiation dialogue between System 3 and System 1 is called the "Resource Bargain" in the VSM language.

The Resource Bargain is the 'deal' by which some degree of autonomy is agreed between the Senior Management and its junior counterpart, which are operating as systems 1 (Beer, 1994).

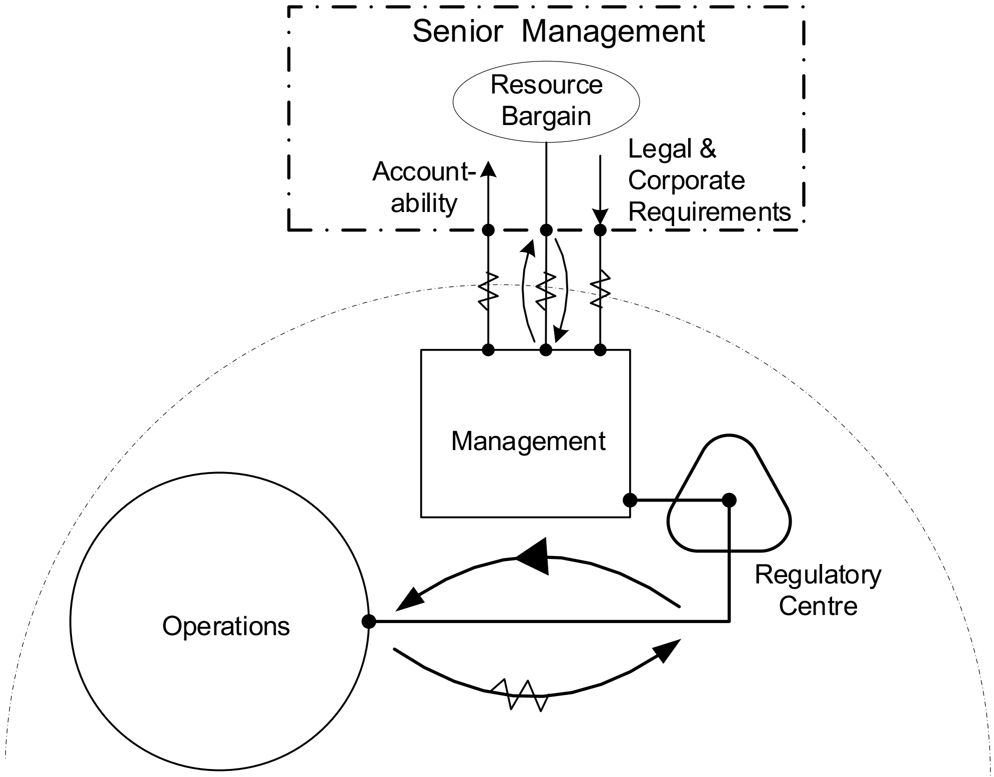


Figure 8-25 System 3-1 interaction based on (Beer, 1994)

Both cockpit and cabin crew have their reporting systems to feedback to MTFO about the adequacy of the resources and are accountable for their performance. The way this accountability is handled by senior managers is an aspect of just culture. Accountability, as Dekker (Dekker, 2007) explains, is a trust issue that is fundamental to human relationships. A decent, open, and functioning society requires people to be able to explain why they did what they did. Safety (learning and improvement) and accountability must be balanced in a just culture. Just Culture encourages people to share information about what needs to be improved with groups or individuals who can help, and to focus their efforts and resources on making safety improvements rather than diverting resources to legal protection and liability limits.

FlightStory is a specific report written from the pilot's perspective and based on the actual experience, the flight crew provide feedback about aspects of the Resource

Bargain. This provides useful information for the MTFO for managing the Operational Performance Conditions of flight operations.

This example shows that the VSM can capture the relationship between flight operations and MTFO in a useful way.

8.8.4 AVPMM as VSM

An airline can be considered a flight producer. Origin destination pairs, or OD pairs, are a specific approach for a network airline to maximise market offerings. In a network hub and spoke system, the hub is used to transfer passengers and create a large number of O-D pairs. The purchase of an O-D pair ticket serves as the foundation for the value exchange between the airline and the customer. This is true for both passengers and cargo shippers. To evaluate the two research interventions in this study, the OD transfer on the hub was not required to be included in the model.

The features of the model used for modelling should correspond to the modelling requirements. To achieve the required variety in the airline model, the model must be capable of capturing the complexity of the airline. In systems theory, the principle of hierarchy allows for as many levels of effective system descriptions as are required. The VSM, thanks to its fractal-like unfolding principle, supports as many recursions (hierarchical levels) as the modeller requires. A network airline's network is defined as the highest recursion, while the flight that transports the person or cargo involved in the value transaction is defined as the lowest. In the AVPMM, I propose network, which is composed of regions, which are composed of regions, which are composed of routes, which are composed of flights as effective hierarchical system descriptions. When the value exchange with a single customer on a seat, for example, is of interest, the unfolding could be scaled down to a lower level. The four recursions of the AVPMM made sense to the experts involved in the interventions and kept in touch to the company's organisational structures.

In this regard, the model requirements matched the model features. There are more features in the VSM than were explicitly used and evaluated in this study. Furthermore, the software model of the AVPMM instantiates all VSM functions and homeostats. Türke's invariant system topics all have a tab that serves as a placeholder for the specific data, which was only a few in the study.

For flight operational decisions, the key performance variables for safety, economy, and customer experience are used as a reference. These three variables have been designated as essential variables in the flight operations Basis Operating Philosophy. The integrated management of these three variables makes sense at each recursion of the AVPMM model. As discussed in the AVPMM chapter, we can find discussions about these variables at each recursion throughout the organisation. Because value optimisation outperforms local single variable optimisation, the VSM connects these discussions and promotes an integrated approach to optimal resource allocation for value creation. Each System 3 and System 1 homeostat in the AVPMM requires an integrated evaluation of the three key variables to address network value production performance.

It is a challenge to make the organisational processes in the current organisational structure match the required meeting and topic structured as proposed by the VSM. The AVPMM intervention participants confirmed the need for the integrated approach but also explained some of the challenges to overcome. The required breakdown of silo's is a often discussed topic in safety (Hajek, 2013)and management (Ackoff, 1999) (Metcalf & Deguchi, 2020) science.

8.8.5 VSM Software model

Despite the fact that the VSM is about 50 years old and has grown in popularity over the last decade, no commercial VSM building software is available. Some businesses have created their own VSM model software, while others rely on proprietary software to support their work. Under the supervision of Professor Pérez Ros, the university of Valladolid in Spain developed the free VSM tool VSMod between 2003 and 2007. This tool can help you explain the VSM model. Although you can create a VSM structure with this software, you cannot add web-based business data. Furthermore, it is built with old technology software and operates independently.

To use the VSM model in this research, I had to create a software tool. With the assistance of Steve Brewis and Richard Dijkstra, the required VSM functionality was created in Python and web technology. The tool can support a variety of unfolding logics, as many recursions as needed, and as many sub-systems as needed at each recursion. Moreover, at each system in focus, the relevant systems above and below, as well as placeholders for each communication channel depicted in the VSM diagram, are also available. Using web-based software, dashboards for specific business topics can be added as needed. The software has more features than are required for this study.

Cybernetics, as the science of information and control in machines and animals, provides concepts, principles, and models that can be used to support both the AVPMM and FlightStory interventions. Only the most basic requirements for evaluating this research have been introduced.

8.9 Safety science

Safety science is the interdisciplinary study of accidents and accident prevention (Dekker, 2019). It contains theories inspired by engineering, physical sciences, epidemiology, sociology, psychology, anthropology, and more. Since the 1980s systems and control, theory became more main stream while since the 2000s complexity theory became an explicit field of reference.

Safety Science is multidisciplinary (Aven, 2014). The Safety Science journal contributors and its audience range from psychologists to chemical engineers. The journal covers the physics and engineering of safety; its social, policy and organisational aspects; the management of risks; the effectiveness of control techniques for safety; standardization, legislation, inspection, insurance, costing aspects, human behaviour and safety. The field does not have a precise date of origin, but dedicated journals began to be published in the 1970s.

8.9.1 Some history

Since the early twentieth century, the study of safety has been an important aspect of making the world a better place. Most, if not all, sectors have had to address the human component in order to achieve progress in terms of safety. The way safety is developed, ensured, constructed, and planned is influenced by people. Our scientific knowledge of the human factor underwent a significant development over the twentieth century.

In the first half of the 20th century, the human factor was mostly seen as the cause of safety trouble (Dekker, 2011b). Human-centred safety interventions included aptitude testing, selection, training, reminders, sanctions, and incentives. Technologies and tasks were viewed as fixed: humans had to be selected and trained to fit the technology and work. Matching the correct human to the task is dependent upon their individual differences. Controlling the human was used to address safety issues (Dekker, 2014a).

Authors in safety science (Dekker, 2019) have dubbed this period's thinking about cause and effect as Newtonian. This reductionist, mechanistic methodology and worldview are supported by classical mechanics. This means that the world is viewed as a collection of interconnected machines that can break, and the search for the cause is a search for the broken component, which is frequently a human. Heinrich's domino model (Heinrich & others, 1941) shows how one cause fully explains an effect, which then becomes the cause for the next effect. The mechanistic, Newtonian paradigm appeals to people's intuition and common sense because of its simplicity, coherence, and apparent completeness.

In the second half of the 20th century, the human was seen as the *recipient* of safety trouble—trouble that was created upstream and then handed down by imperfect tools, technologies, or tasks (Dekker, 2014a). With better design and organisation, safety interventions targeted the system. Technology was viewed as adaptable, allowing it to be tailored to human strengths and limitations, instead of the other way around. Individual differences were less important than developing technologies and systems that could resist or tolerate individual actions regardless of differences. Controlling technology was used to solve safety issues.

In this period, we saw the introduction of system thinking and safety management systems. Still, often from a positivist perspective, 'the system' was used as a useful concept, as if 'the system' was the same for everybody as a rock that one could trip over. Attention shifted from the sharp end of the operators to the blunt end of management and the regulator. Reason (Reason, 1997) introduced the term 'organisational accident' and more and more accident investigations did not accept Human Error as the final or main cause of the accident. However, when operator error is replaced with manager error, not much progress has been made. The concept of Joint Cognitive Systems and Cognitive Systems Engineering shifted the focus from the components to the larger system and system properties in an attempt to design, build and operate with increased safety performance.

Since the beginning of the 21st century, complexity theory became more applied in safety science. Analytical reduction cannot explain how several different people, things and processes act together when exposed to several different influences at the same time (Dekker et al., 2011). The interaction between the components of a system causes complex behaviour which can be difficult to predict or control. It requires focusing on relationships rather than individual components. These interactions produce the system's properties, which are not contained within individual components. Complex adaptive systems must adjust some of their internal structure in response to changing environmental conditions. The system's behaviour cannot be reduced to the behaviour of its constituent parts. To study such systems, we must look at them as wholes, taking into account the non-linear dynamics caused by feedback and feedforward loops between the components and choose appropriate scopes, scales and resolution for effective system descriptions. See the section about complexity above in this Chapter.

I think that modern complexity scientist such as Bar-Yam (2023b)(Bar-Yam, 2004b)(Siegenfeld & Bar-Yam, 2020) Anthro-complexity specialists (human complexity) like Snowden (Snowden et al., 2020)(van der Merwe et al., 2019) and mathematicians such as Taleb (Taleb, 2009)(Taleb et al., 2014) and Pearl (Glymour et al., 2016)(Pearl & Mackenzie, 2018) to name but a few, will see their theories and concepts used in the further development of safety science.

8.9.2 Definitions of Safety

The foundation of safety concerns has always been the presence, possibility, or occurrence of negative consequences, regardless of whether they are classified as risks, hazards, near misses, incidents, or accidents, throughout history (Hollnagel, 2013).

Since about the 2000s, two safety definitions have been used. One, the more classical definition, refers to safety as a condition where nothing goes wrong, with no undesired outcomes (injuries, accidents/incidents/near misses) or more cautiously as a condition where the number of things that go wrong is acceptably small (Hollnagel, 2014a) which he coins as Safety I. Hollnagel explains that when an accident occurs, then there was an absence of safety and therefore the above definition of safety is problematic because the lack of safety becomes the subject as opposed to safety as such.

A second newer definition takes a different approach. Weick suggested that reliability can be seen as a ‘dynamic non- event’ (Weick, 1987). Hollnagel (Hollnagel, 2014a) argues that Weick’s reliability can be replaced by safety, making safety a dynamic non-event. Weick describes reliability requiring the dynamics of ongoing efforts from the controllers to maintain requisite variety over the problems and disturbances. The meaning of a 'non-event' is that safety is present when there are no adverse events, i.e., when nothing goes wrong. The balancing act for requisite variety matches the notion of safety as a control problem, as noted by Leveson (Leveson, 2011) and Rasmussen and Svedung (Rasmussen, 1997).

Hollnagel argues (Hollnagel, 2014b) that instead of focusing on why things go wrong occasionally, proactive safety management should try to increase the number of things that go well. For this perspective he proposes the name Safety-II. Safety-II assumes systems work because people can adapt their behaviour to the conditions of their jobs (Hollnagel, 2013a). Hollnagel has argued that in Safety-II, outcomes of events should not be used as the starting point for safety management, but as a means of learning how success is achieved in everyday work. Rather than focusing solely on negative outcomes, Safety-II aims to understand how people and systems succeed in the face of risk and uncertainty. Hollnagel has emphasized that safety management must be proactive and focused on identifying and improving the factors that lead to success, not just the factors that cause failure (Hollnagel, 2014). People are able to enhance their capacity to recognize and address design flaws and functional glitches by identifying the precise demands of a given situation and subsequently adjusting their performance accordingly. Such abilities are reinforced by their capacity to interpret and apply relevant procedures that are tailored to align with the prevailing conditions. As per Norman's (1988) concept of affordances, people who are actively engaged in a task can easily detect and rectify errors before they become critical. This proactive intervention helps in maintaining positive performance variability, which is viewed as an essential aspect for ensuring safety and productivity. Rather than being seen as a deviation from established norms or standards, performance variability represents necessary adjustments required for achieving optimum output. This approach emphasizes the significance of designing systems that encourage human participation and adaptive behaviour. (Hollnagel, 2017).

This description is coherent with a definition of safety as a capability such as, safety is the ability to perform work in a varying and unpredictable workplace environment (Conklin, 2012).

Dekker, (Dekker, 2014a) proposed the concept of Safety Differently, which is a new way of looking at safety management that focuses on how work is actually done, rather than how it is supposed to be done. This approach recognizes that people are not the problem, but are instead the solution to safety issues. Safety Differently emphasizes the importance of understanding and managing the complexity of work systems, as well as the need for continuous learning and improvement.

The re-introduced notion of safety as a capacity aligns well with the system control and management cybernetics approach and illustrates again the multidisciplinary character of safety science. Safety as a control problem relates Ashby from the 1950s via the Law of Requisite Variety with the modern complexity theory of Bar-Yam (Siegenfeld & Bar-

Yam, 2020) describing multi-scale variety and Resilience Engineering concepts (Hollnagel & Nemeth, 2022). I agree with Levenson's caution to not only focus on the human operator on the sharp end but to build the required capabilities at each level in the organisation (Leveson, 2021). This was also the position of reason in the 1990s (Reason, 1997)

I see some of the scientific discussions about definitions of safety as linguistic arm wrestling (Cooper, 2022). However, introducing Safety-II, Resilience Engineering and Safety Differently opened new avenues for safety research and when combined with proven Safety-I methods from fields such as safety engineering (Leveson, 2021) might break the safety improvement asymptote (Dekker, 2019).

8.9.3 Safety Management Systems

The conventional approaches of aviation safety management were reactive in nature and primarily relied on incident investigation to identify hazards and risks. However, this approach was limited because it was only after an incident or accident occurred that an investigation was conducted to identify and manage the hazards. Moreover, the reactive approach did not provide a comprehensive understanding of hazards and their associated risks (Ghobbar et. al. 2015).

To address the limitations of the traditional approach, SMS was developed. SMS is a systematic approach to managing safety that integrates all aspects of aviation operations to manage risks and hazards. The International Civil Aviation Organization (ICAO) and the Federal Aviation Administration (FAA) have recognized SMS as the cornerstone of their safety management framework for the aviation industry (ICAO, 2018b).

The main objective of SMS is to ensure that risks and hazards are proactively identified, assessed, managed, and continuously monitored (FAA, 2006). SMS involves the implementation of a range of processes and procedures that help in the identification, assessment, and management of hazards, including risk assessment, safety reporting, safety analysis, and safety audits (ICAO, 2018b).

A SMS is an organisational instrument for developing, planning, measuring, analysing, and controlling an organisation's total safety performance, as well as guiding decision-making for choosing safety assurance tasks (Hale, 1997). Various industrial sectors, such as the process, construction, and transportation industries, have used SMS as a vehicle to improve occupational safety and reduce catastrophic accident risk. On the one hand, an SMS must comply with applicable safety laws for compliance and certification purposes, while on the other hand, it must also take into account the organization's unique danger profile and accident causation patterns. SMSs occur in a variety of shapes and sizes, thanks to differences in industry-specific regulatory requirements, adherence to diverse safety philosophies and theories of accident causation, and the variety of tools and techniques used (Goerlandt et al., 2022).

Hollnagel (Hollnagel, 2008b) presents a basic management structure that includes feedback and feedforward control i.e., feedback controls attempts to eliminate discrepancies between an actual state and a desired or planned one (setpoint). The fundamental concepts are that a defect or discrepancy is recognised and that remedial action is implemented. Whereas feedback control can be entirely data driven, feedforward control must be guided by a model that defines both the process and any environmental disruptions. A feedback signal is not model-independent since the feedback signal must make sense for the controller which is model-based. Feedback control looks back because it must wait for a disruption to occur and have an impact. Feedforward can be quicker and more efficient since it anticipates rather than reacts to disruptions and deviations. A feedforward controller alone may not be able to maintain stability in a system because it does not account for changes in the system or disturbances that may not have been predicted. By adding a feedback loop, the controller can continuously adjust its predictions based on the actual system response, resulting in more accurate and stable control (Krstic et. al., 1995).

One key feature of feedforward control is that it can never outperform the underlying model because of the Conant-Ashby theorem (Conant & Ashby, 1970) that every good regulator must be a model of the system. The model outlines the risks that the safety manager should be prepared to accept. However, because the reality is non-deterministic and complex, even the best models will include residual risk or uncertainty that cannot be eliminated.

An SMS should, in principle, have both feedback and feedforward features and a SMS can be audited on the effectiveness of these basic control theoretical properties.

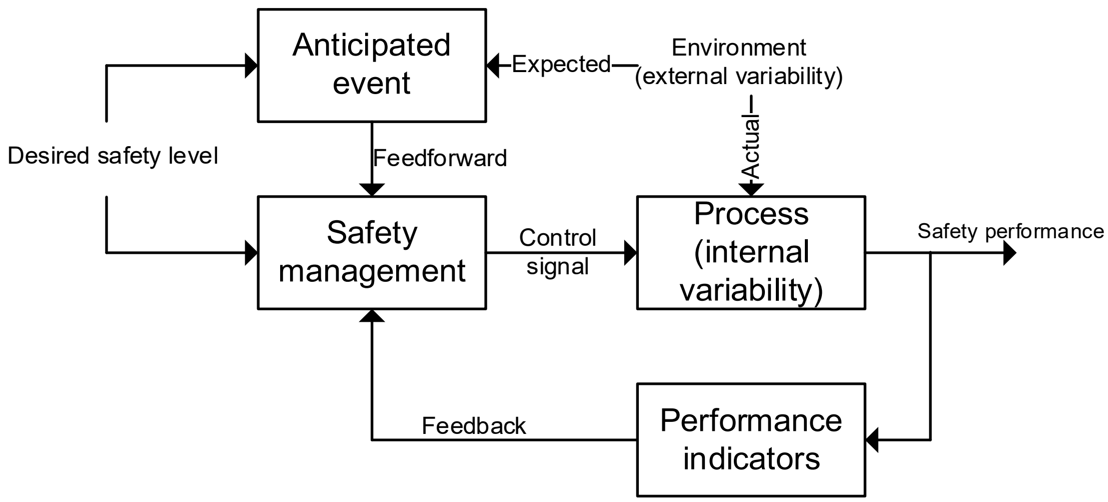


Figure 8-26 Safety management as combined feedback and feedforward control (Hollnagel, 2008b)

Safety management systems have been claimed to be an important part of bringing safety to the foreground in executive decision making (Maurino, 2017). However, the increased bureaucratization that their execution involves may have negative repercussions, such as lowering the marginal yield of safety measures and suffocating organisational freedom and innovation (Dekker, 2014). A detailed examination of the role of uncertainty in balancing stability, flexibility, accountability, and control could thus help to improve safety management. Furthermore, while there is some evidence that SMS deployment improves organisational safety performance, there are many hurdles and barriers to their application in practice (Goerlandt et al., 2022).

Within the context of aviation, safety is "the state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level" (ICAO, 2018a).

The ICAO SMS manual states aviation safety is dynamic. New safety hazards and risks continuously emerge and must be mitigated. As long as safety risks are kept under an appropriate level of control, a system as open and dynamic as aviation can still be kept safe. It is important to note that acceptable safety performance is often defined and influenced by domestic and international norms and culture.

Progress in aviation safety can be described by four approaches, which roughly align with eras of activity (Groeneweg, 1992) (ICAO, 2018a). The approaches are listed the figure below.

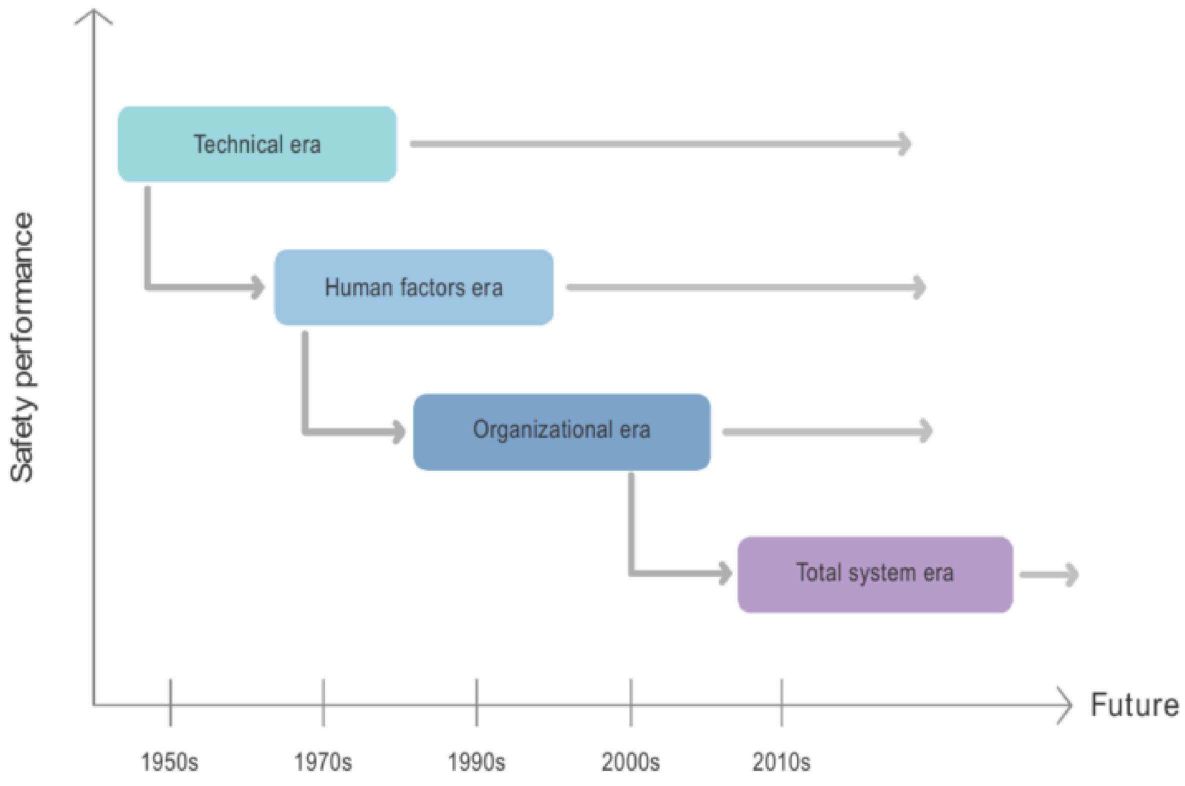


Figure 8-27 Developments in Safety Management (ICAO, 2018b)

a) Technical —Aviation arose as a mode of mass transportation from the early 1900s until the late 1960s, with reported safety flaws first attributed to technical issues and technological failures. As a result, the research and improvement of technical problems became the focus of safety efforts (e.g. aircraft engines). By the 1950s, technological advancements had resulted in a progressive decrease in the frequency of accidents, and safety systems had been expanded to include regulatory compliance and oversight (ICAO, 2018a).

b) Human factors — By the early 1970s, the frequency of aviation accidents had dramatically dropped due to huge technological advancements and improvements in safety regulations. The emphasis of safety initiatives was widened to include human components such as the "man/machine interaction," making aviation a safer mode of transportation. Human factors are still identified as a recurring aspect in accidents, despite efforts in error reduction. Human factors emphasised the person without taking into account the operational and organisational context. It wasn't until the early 1990s that people realised they were operating in a complicated environment with a variety of factors that might impact their behaviour (ICAO, 2018a).

c) Organizational — By the late 1980s, there was universal consensus that both local working conditions and upstream organisational factors impact human performance at the cutting edge. Theoretically, Swiss cheese is comparable to safety management systems. These programmes and regulations are directed at the administrative level of an organisation, where assurance of safety is sought through management systems, accountability, processes, and data (Dekker, 2019). Safety began to be evaluated from a systemic perspective in the mid-1990s, encompassing organisational, human, and technological challenges. The notion of an "organisational accident" was introduced. The impact of organisational culture and policies on the effectiveness of safety risk measures was investigated from this perspective. Furthermore, by frequent safety data collection and analysis employing reactive and proactive methodologies, firms were able to monitor existing safety risks and detect developing safety trends. These enhancements provided the foundation for the current safety management methods (ICAO, 2018a).

d) Total system — Since the beginning of the twenty-first century, many states and service providers have adopted traditional safety techniques and advanced to a higher level of safety maturity. They have begun to adopt SMSs and are experiencing the benefits of increased safety. To date, however, safety systems have been primarily concerned with individual safety performance and local control, with little attention for the larger context of the overall aviation safety system. This has resulted in a rising appreciation of the aviation system's complexity and the several entities that all play a role in aviation safety. There are numerous examples of mishaps and situations in which organisational interfaces have contributed to undesirable consequences (ICAO, 2018a).

What ICAO means by the total system is not a company-wide total system approach. They seem to mean a silo all the way up from the company safety office to worldwide safety management guided by ICAO where the business aspect is not in focus. The AVPMM can be viewed as a company total system approach. It takes safety out of the silo and puts it in the business context of economy and customer experience and network development.

Because of the constant, compounding growth of safety, states and service providers are now paying close attention to the interactions and interfaces between the system's components: people, processes, and technology. This has led to a greater appreciation for the positive role people play in the system. Collaboration between service providers, as well as between service providers and states, enhances safety. This viewpoint has spawned a slew of collaborative projects among service providers, as well as an understanding of the advantages of working together to solve safety concerns. A good example is the ICAO Runway Safety Program (ICAO, 2015).

The interfaces and interactions between organisations (including States) must be properly understood and controlled for the collaborative whole-system approach to succeed. States are also beginning to appreciate the need of a comprehensive aviation system approach in the establishment of their state safety programmes. For example, it helps to manage safety risks which cut across multiple aviation activities (ICAO, 2018a). However, a more business-integrated approach inside an organisation is not really addressed by the ICAO SMS manual.

The ICAO (ICAO, 2016) recommended SMS comprises four components and twelve elements as the minimum requirements for SMS implementation:

1. Safety policy and objectives
   1.1. Management commitment
   1.2. Safety accountability and responsibilities
   1.3. Appointment of key safety personnel
   1.4. Coordination of emergency response planning
   1.5. SMS documentation
2. Safety risk management
   2.1. Hazard identification
   2.2. Safety risk assessment and mitigation
3. Safety assurance
   3.1. Safety performance monitoring and measurement
   3.2. The management of change
   3.3. Continuous improvement of the SMS
4. Safety promotion
   4.1. Training and education
   4.2. Safety communication

In my research, the AVPMM case discussions address both safety risk management components and safety risk assessment and mitigation elements. Because the ICAO SMS is not a business-integrated approach, the ICAO manual does not mention or recommend business decisions as risk mitigations, such as a timetable change. The extent to which the perceived benefits of mitigation outweigh the costs of mitigation in a cost-benefit analysis. The extra solution space for risk mitigation presented in this thesis is not yet recommended in the ICAO manual. However, with minor wording changes, this could be included in a future version of the SMS.

Dekker (Dekker, 2014) cautions against safety bureaucratization, which is based on hierarchy, specialisation, labour division, and written regulations. Standardization, transparency, control, predictability, and a decrease in partiality, as well as a reduction in harm, have all been achieved by safety bureaucratization, as envisioned by modernism. Bureaucratization has been aided by legislation and regulation, changes in liability and insurance arrangements, a wholesale move to outsourcing and contracting, and increased technological capabilities for surveillance, monitoring, storage, and analysis of data. Bureaucratization, on the other hand, produces unforeseen consequences such as process management issues that are incompatible with its original goals. The bureaucratization of safety, involving different incentives for different stakeholders, has been shown to result in (Dekker, 2014):

- Lower output of bureaucratic safety initiatives: Bureaucratization can lead to a decrease in the effectiveness of safety initiatives, as bureaucratic processes may slow down decision-making and implementation. For example, a bureaucratic safety management system may require multiple layers of approval before implementing a new safety initiative, which can lead to delays and a decrease in the initiative's overall impact.
- Structural secrecy: Bureaucratization can also lead to an increase in secrecy within the organization, as bureaucratic processes may lead to a lack of transparency and communication among different parts of the organization. Experts may lose oversight when data is contained in process steps.
- A focus on bureaucratic accountability: Bureaucratization can also shift the focus from safety outcomes to bureaucratic accountability, as there may be more emphasis on compliance with bureaucratic procedures than on actual safety outcomes. For example, a bureaucratic safety management system may require employees to fill out extensive paperwork to document their compliance with safety procedures, even if the procedures themselves are not effective in improving safety outcomes.
- Quantification and "numbers games": Bureaucratization can lead to a focus on quantifying safety performance, such as counting the number of safety reports and assigned risks. This can result in organizations manipulating the data to meet targets or make the numbers look better, rather than focusing on actual safety improvements that might be hard to measure in an ultra-safe system.
- Creation of new safety problems: Bureaucratization can lead to a focus on compliance with regulations and procedures that may create new hazards or

unintended consequences, rather than identifying and addressing underlying safety issues.

- Suppression of innovation: Bureaucratization can lead to a focus on following established procedures and regulations, rather than encouraging new ideas and approaches to improve safety. This can result in the suppression of innovation and new ideas that could lead to safer systems and processes. An example of this would be an organization rejecting a new technology or approach to safety management because it does not align with existing processes.

The evolution of the aviation regulatory framework and the SMS guidelines demonstrates how an SMS within an airline is simultaneously embedded, constrained, and supported. The ICAO SMS proposals have been adopted by the FAA in the USA and the EASA in Europe. The airline should comply with ICAO regulations and must comply with FAA and EASA regulations. ICAO-based regulations express the what of that *what* should be done in the SMS. The airline has the freedom to determine the *how*, as long as the regulator agrees, that requirement for compliance has been met.

8.9.4 Risk management in a dynamic society

One of the few academic publications that address the integration of safety with the product delivery of an organisation illustrates a diagram of the adaptive control systems that connect control of production, costs and safety (Rasmussen et al., 2000). They explain Risk management is essentially a matter of controlling potential hazards. Industrial accidents occur when there is a lack of control over a physical production process, leading to harm to individuals, financial losses, or environmental damage. To achieve this, it is necessary to continuously monitor the actual level of safety and maintain an adequate margin between current conditions and safe operating standards through a closed-loop feedback control strategy. The control model demonstrates how various closely linked closed loops work together to align product specifications and quality with market demands (quality management), optimize the cost-effectiveness of the production process (resource management), and maintain safe operation (risk management). Quality management and risk management set the limits for how much cost-cutting can be done in response to market competition while still remaining within acceptable bounds.

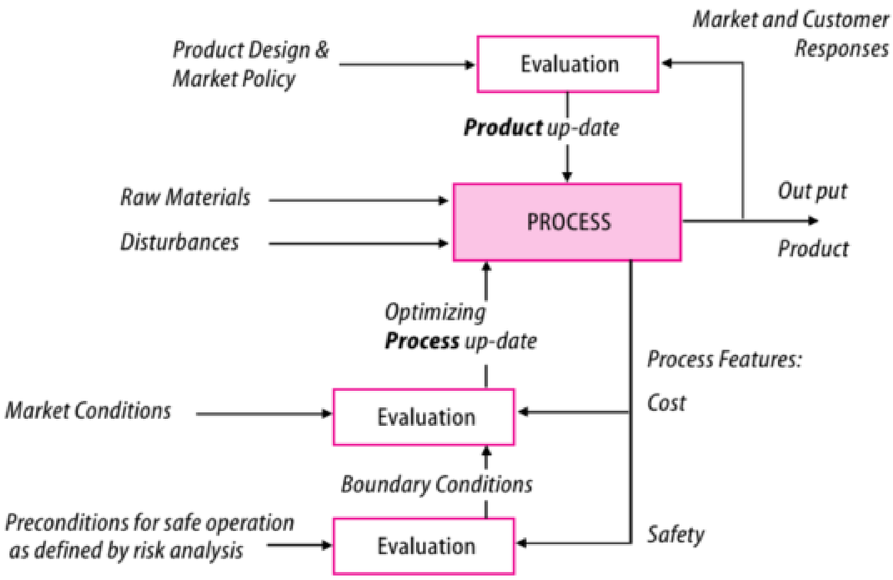


Figure 8-28 The adaptive control systems connecting control of production, cost, and safety (Rasmussen et al., 2000).

FlightStory Rasmussen and Svedung also stress the importance of a closed-loop feedback function that feeds back the actual state of affairs (Rasmussen et al., 2000). The FlightStory project can be viewed as an important aspect of the total feedback system from flight activities related to the management systems of these activities. They also consider the interpretation of data and objectives which is also considered in my research.

8.9.5 Aviation Safety as Ultra-Safe system

Amalberti (Amalberti, 2001) argues in an often-referenced paper, that the traditional common sense approaches to safety is becoming outdated because it has the following implicit assumptions; systems are safe, humans generate unsafety with a misleading reference to the 80 percent of accidents being caused by human error, and third, safety reporting is critical. This common sense approach was beneficial for decades, but it is now losing relevance for optimising the safety of systems on the asymptote to total safety. This is especially true for today's ultra-safe macro-technical systems, such as nuclear power, civil aviation, and the European railroad system. These systems' safety becomes asymptotic approaching a mythological frontier, which is located somewhere about $5x10^{-7}$ chance of catastrophic accident per safety unit in the system.

Amalberti describes three classes of systems based on their safety performance. These systems have different characteristics in how safety is achieved(Amalberti, 2001):

Dangerous systems, when the probability of an accident exceeds one every 1000 occurrences (e.g., bungee jumping, or mountain climbing). These systems are amateurish and fall outside the scope of his article. They match people's desire for thrills and peril. These systems' safety regulations take an especially individualised approach.

Regulated systems, where the likelihood of an accident ranges from one per 10,000 events to one per 1000 events. Examples falling into the upper safety range of this category include driving, the chemical industry, or chartered flights. Professionals are responsible for ensuring safety in these regulated systems. Common safety approaches include:

- Regulations and procedures increasingly go hand in hand with safety performance.
- Accidents or near-accidents are almost a repetition of stories of past accidents and near-accidents.
- Error-resistant design (cutting down on the number of errors), and a reporting policy are dominant and efficient safety strategies.
- Safety managers usually get results for newly implemented measures within a couple of years (in a 10^{-5} system), which means they normally get credit for their work.

Ultra-safe systems, where the chance of disaster is below one accident per 10^{-5} or even 10^{-6} safety units. Scheduled civilian flights, railroads (in Europe) and the nuclear industry are examples of industries have reached this level. None of these systems has managed to achieve a global safety performance beyond one accident per 10^{-7} safety units. These systems have specific features:

- They tend to be ageing, are over-regulated, rigid and highly non-adaptive
- Accidents are different from those that occur in safe systems because they usually happen without any significant breakdown or serious error. Rather, they result from a combination of various factors, each of which alone cannot cause an accident or even a serious incident. As a result, it becomes difficult to detect and recover from these combinations using traditional safety analysis logic (Amalberti, 2001).
- Because of this, traditional, compliance-based reporting becomes less relevant in predicting major disasters. This is especially true in systems with very low overall accident risk, where the predictive value of incidents is very small (Amalberti, 2001).
- For their successors, system managers are employed (over 8 years of inertia before being able to correctly assess the results of any new safety measure in the case of 5x10-7 systems). So, rather than being a scientific issue, the safety of these ultra-safe systems often turns into a political one, with short-term solutions being preferred to long-term ones. (Amalberti, 2001).

Risk Management and Safety Management data methods should fit aviation as an ultra-safe industry with many complex aspects, rare events and often a high degree of uncertainty and nevertheless a rarity of events. Simple measurements involving mean and standard deviation can be highly problematic because of the limited number of observations of the total possible data set and the fact that single extreme events determine the statistical properties of the complete set (Taleb, 2020). Unfortunately, the ICAO Safety Manual(ICAO, 2018b), SMS collaboration group (Group, 2018) and (Stolzer et al., 2008) are not very explicit about the requirement for statistical methods. The risk data used in the AVPMM experiment in my research considered the risk matrix issues and also did not include this type of data because of the caveats in that method.

Amalberti (Amalberti, 2001) suggests as one way forward is not to over-optimise current safety management methods. These solutions cannot help improve safety beyond 10^{-7}, because over-optimised risk measures prove to be counterproductive, by over-rigidifying the system through the elimination of adaptive flexibility. FlightStory and the AVPMM, by being disruptive innovations, are not over-optimisations of current methods but bring new possibilities for safety management.

8.9.6 Safety-II

Having laid the basis and having sketched the developments of safety thinking and safety management, this section will address current actual themes of safety science and safety methods development. FlightStory as a method contains elements of new developments that relate to Safety-II and Resilience in flight safety. The AVPMM is also related to these concepts but at an organisational business level where success or failures can be found in the value production viability.

For this aviation safety research project, I adopt the notion of Safety-II to understand system performance over the whole operating range. But at the same time, not every performance outcome has the same information potential for learning about system performance. Not every flight can teach us new things. A flight from and to a modern airport in a low traffic period with nice weather; well-rested flight crew with an aircraft with no technical issues, no time pressure, just a few passengers going for a holiday or business and a happy cabin crew will reveal no new insights but only confirm the current understanding. I have had hundreds of these kinds of flights and in my, after landing debriefing procedure we concluded we had learned nothing and we enjoyed it. Also, the safety department or the Management Team of Flight Operations would not get any new insights from this kind of flights other than confirmation that we can operate flawlessly under favourable conditions. Therefore, in flight safety, I am more nuanced than Hollnagel who states that Safety-II looks at all events regardless of their outcomes, but in particular at the events that occur frequently that lead to the expected outcomes and which therefore are seen as 'normal' (Hollnagel, 2014b). A more efficient Safety-II approach would be to look more at flights that have a higher information potential.

Stafford Beer stated that to better understand a system, it had to be perturbed (Beer, 1979). An explanation for this claim is that when a system is perturbed or disturbed, the control capabilities have to be engaged to keep the system in a desirable state. The realisations of these interdependent control functions have the potential to give new insights. Therefore I propose, for aviation safety, to replace the model with the normal distribution of outcomes with a model which has on the x-axis an increase of perturbations and on the vertical y-axis the degree for potential insights.

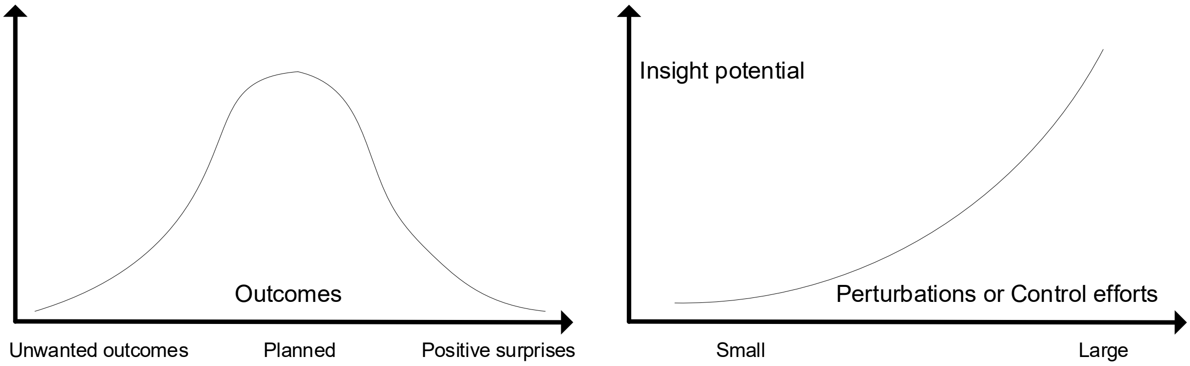


Figure 8-29 Where can we find learning opportunities.

Woods (Woods, 2019) characterises the idea of an adaptive universe by three properties: resources are finite, surprise is fundamental and change never stops. In flight operations, these properties will occur more towards the right side of the right diagram. This matches my experiences in 35 year of flight operations in flights where the people involved, ranging from dispatchers, ground handling, passenger handling, maintenance, cabin crew and flight crew had to adapt and respond to perturbations. This is also why I invited the flight crew that had experienced such conditions to tell their story and provide answers to questions about the strategies that were used and the quality of the Operational Performance Conditions for managing the flight to deliver an optimal outcome in terms of safety, cost and customer experience. All the questions in FlightStory can be found in the specific chapter.

8.9.7 Resilience

Holling (Holling, 1973)(Holling, 1973) defined an ecosystem's resilience as its ability to absorb changes while remaining viable. He compared resilience with stability, which he defined as a system's ability to recover to its equilibrium condition following a transient perturbation, and claimed that resilience and stability were both significant qualities of ecological systems (Hollnagel et al., 2007). Engineering resilience assumes that natural systems live near a stable steady-state. The capacity to recover to a new steady-state after a disruption is referred to as resilience. In the early 2000s, when resilience engineering was proposed as an alternative (or as a complement) to the conventional view of safety (Hollnagel et al., 2007). According to Hollnagel, Woods proposed the actual term as early as 2000. I happened to be at the right place at the right time to be present at a think-tank session as practitioner-participant of what could be called the birth of Resilience Engineering in Söderköping Sweden in 2004.

The definition of resilience has changed over the years, showing the developments in the field.

In the first book (Hollnagel et al., 2007) the following definition was given. "The essence of resilience is therefore the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress."

In 2008, Hollnagel (Hollnagel, 2008a) argues that in the modern dynamic operating environment, performance variability is unavoidable and required but should be managed. Safety management aimed at performance variability is consistent with resilience engineering, which is based on the following principles (Hollnagel et al., 2007):

- Individuals and organisations must adapt their performance to the present conditions, since performance conditions are always under specified. Because resources and time are limited, such modifications must be approximate.
- Most adverse occurrences in tractable systems can be traced to component failure or malfunctioning and normal system processes. However, most unfavourable events in intractable systems cannot be linked to components. Instead, they are best understood as the result of unanticipated combinations of typical performance variability, or as the inverse of the adaptations required to deal with real-world complexity.
- Effective safety management cannot solely be based on hindsight, nor can it be based on error tabulation and failure probability calculations. Safety management must be proactive as well as reactive. Resilience Engineering seeks ways to improve organisations' ability to develop robust yet flexible processes, monitor and adjust risk models, and employ resources proactively in the face of interruptions or ongoing production and economic challenges.

In 2008 a resilient system was defined by its ability to adjust its functioning prior to, during, or following changes and disturbances so that it can go on working even after a major mishap or in the presence of continuous stress. Hollnagel(Hollnagel, 2008a) listed 4 essential qualities of resilience which he later called the cornerstones of resilience (Hollnagel, 2013b).

- Respond: knowing what to do, how to respond to regular and irregular disruptions and disturbances either by implementing a prepared set of responses or by adjusting normal functioning. this is the ability to address the actual.
- Monitor: knowing what to look for, how to monitor that which is or can become a threat in the near term. the monitoring must cover both that which happens in the environment and that which happens in the system itself, its own performance. this is the ability to address the critical.
- Anticipate: knowing what to expect, how to anticipate developments, threats, and opportunities further into the future, such as potential changes, disruptions, pressures, and their consequences. this is the ability to address the potential.

- Learn: knowing what has happened, how to learn from experience, in particular how to learn the right lessons from the right experience, successes as well as failures. This is the ability to address the factual.

In the fourth book (Nemeth & Hollnagel, 2014) the definition had changed to: "The intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions."

Hollnagel renamed 'cornerstones' to 'potentials' in his 2017 book Safety-II in Practice (Hollnagel, 2017) to emphasise their role as functions. Each potential's description remained mostly unchanged. He claims that these four potentials are both necessary and sufficient, as well as interrelated, which are crucial factors to consider when determining a model's required variety. For the sake of argument, he claims that the explanation for the four possibilities is pragmatic rather than logical or deductive. Many descriptions and analyses of occurrences identify the four potentials outlined here, and the four combined appear to be sufficient without being redundant. He argues that it is evident that none of the four potentials can be ignored when it comes to the notion of resilient performance, which is defined as an organization's ability to function as necessary in both expected and unexpected events.

Hollnagel (Hollnagel, 2017) continues that by accepting that the four potentials are necessary, one is justified to ask whether also they are sufficient or whether a fifth or a sixth potential may be required. He suggests, what he calls, three obvious candidates which are the potential to plan, the potential to communicate and the potential to adapt.

- Planning is necessary for an organization's survival, not for resilient performance.
- Communication is fundamentally vital for any organisation or system. However, the ability to communicate does not immediately contribute to resilient performance in the same way that, for example, reacting does. Explicit communication is important for an organisation to coordinate how its diverse elements work, but communication, like planning, is required for an organization's survival rather than resilient performance.
- Adaptation is a third contender. However, adaptation is a composite rather than a fundamental ability. Based on experience, an adaptive system can update or modify itself, or rather the way it performs. Adaptation might thus be viewed as a combination of the ability to learn, the ability to respond, and possibly the ability to monitor. As a result, adaptation is not a fundamental ability.

In 2021 Hollnagel (Hollnagel & Nemeth, 2022) updated his resilience definition to "resilience as the ability to succeed under varying conditions, so that the number of intended and acceptable outcomes (everyday activities) is as high as possible and to respond appropriately to both disturbances and opportunities." With this generalisation, he proposes a move towards general system performance and not just to remain safe. Additionally, he generalises towards threats and opportunities which are both required for sustained survival in a competitive environment. In my view, this development of what is called resilience resembles much of what Beer (Beer, 1984) proposes as viability, namely the capability to maintain a separate existence by maintaining essential variables within limits in a changing world (Achterbergh & Vriens, 2010). More about these analogies will follow in a next section.

Woods has a compatible but different framing of Resilience. He explains that today's systems are interdependent due to new technology and pressures to be faster, better, and cheaper (Woods, 2015). Interdependent networks create unanticipated side effects and sudden dramatic failures. Many people from different fields have noticed that some systems are more resilient than others due to unintended consequences. In the last decade, the idea that systems have 'resilience' has become popular. Research questions that drive resilience research include:

- how adaptive systems fail in general and across scales;
- how systems can be prepared for inevitable surprise while still meeting pressures to improve on efficiency of resource utilization;
- what mechanisms allow a system to manage the risk of brittleness at the boundaries of normal function;
- what architectures allow systems to sustain adaptability over long times and multiple cycles of change.

Related to these questions Woods discusses four interdisciplinary concepts of resilience (Woods, 2015) which could be labelled as resilient performance characteristics.

Rebounce: The term resilience refers to how a system recovers from disruptive or traumatic events and returns to prior or typical activities.

Robustness: People use the term resilience to refer to the concept of system robustness as an increased ability to absorb perturbations.

Graceful extensibility: When surprise events strain a system's bounds, a third use of the term resilience is the idea of graceful extensibility, which is how a system increases performance or brings more adaptive capacity to bear to mitigate the danger of brittleness. Recent studies have revealed how specific systems prevent the risk of brittleness, which is the likelihood of abrupt failure when events exceed the system's capability to manage varying disturbances and fluctuations.

Sustained adaptability: This research led to the development of a fourth use of the word resilience, concentrating on the topic of what architectural properties of layered networks enable persistent adaptability, or the capacity to react to future surprises as conditions change. This study looks at how networks can deal with the basic trade-offs that all systems face. It aims to find governance rules that operate across layered networks in biological, social, and technological systems in order to establish which governance policies maintain the network's capacity to function properly and avoid slipping into trade space traps as conditions change over time.

In the initial phases of analysing how systems cope with increasing complexity, the concepts of the first two notions have been frequently referenced in resilience studies. These ideas seem to offer a means of generating explanations for how certain systems handle heightened complexity, stressors, and challenges.

Control systems fail when their capacity to respond saturates, which occurs when they run out of capacity to respond as disruptions rise (Woods, 2019). This is usually a horrible condition if you want to control a physical process or vehicle. All physical and biological control mechanisms have limits. Brittleness occurs when events push these systems to their limits and no other mechanism exists to increase performance. These new strategies contribute to the possibility of graceful extensibility. As a result, all control systems must be capable of detecting when the risk of saturation is growing and then deploying and mobilising new reaction capabilities. In scenarios such as emergency care, military operations, and space mission operations, these processes of anticipation and preparedness for reaction can be observed.

Sustained adaptation in socio-technical systems addresses a system's dynamics throughout several life cycles or change cycles (Woods, 2019). Earlier phases of the system's design must include the ability to adjust or be flexible as the system encounters anticipated changes and impediments during its life cycle. It's critical for resilience to figure out what key architectural principles provide the essential flexibility to continue to evolve across extended scales. The system in issue will need to adapt during its life cycle in order to take advantage of opportunities and respond to challenges by readjusting itself and its interactions in the layered network.

Resilience engineering's task is to discover how a governance structure, such as a layered network architecture, balances the expression of initiative as the danger of surprise changes (Woods, 2019). Stresses experienced by other interdependent units can either energise or drain initiative, and therefore the ability to respond. These influences also change how initiative is coordinated across adaptive units, depending on their perspective, work, and relationships. When trade conflicts arise, the constraints limit and control how initiative manifests itself, prioritising certain goals while sacrificing others, such as in the reports of NASA failures that led one line of research into robust systems. When expectations and risks grow, the pressure on the operation decides which objectives are sacrificed. It is both a scientific and a practical concern to understand these systems.

In my view, both the works on resilience from both Hollnagel and Woods develop towards more general notions for managing an organisation in a dynamic complex competitive environment with unexpected events. My research fits that development because I have taken safety out of the silo by using the VSM and make it an aspect of value production which drives the airline business viability.

8.9.7.1 Resilience versus Viability (Woods, 2015)

Hollnagel, a prominent figure in resilience engineering, argues for a comprehensive understanding of resilient performance across various aspects, such as quality and productivity (Hollnagel & Nemeth, 2022). The Systemic Potential Management, introduced as a successor to the Resilience Assessment Grid, evaluates four systemic potentials—respond, monitor, anticipate, and learn—and their changes over time, providing organizations with insight into their capacity to absorb disturbances (Hollnagel et al., 2021). Meanwhile, Woods (2015) underlines the importance of governance policies within hierarchical networks in biological, social, and technological systems, focusing on the identification of policies that support the network's capacity to operate effectively and avoid falling into traps in trade spaces.

The Viable System Model (VSM), developed by Stafford Beer, potentially satisfies both Hollnagel's four potentials for resilience and Woods' notion of poly-centric control or governance. VSM is a model for organizing systems in a way that ensures their survival in a changing environment. Its fractal-like hierarchical and horizontal unfolding supports variety absorption and requisite variety, and its properties make it applicable to model any desired level of an organization. The VSM and the four potentials can be viewed as complementary models for resilience management (Dijkstra, 2007).

The VSM's capabilities as described in (Beer, 1994)(Beer, 1979)(Türke, 2008)(Hoverstadt, 2011) in relation to the four potentials (Hollnagel et al., 2021) are as follows:

To respond: System 1 operational units in the VSM ensure coherent responses to disturbances, striking a balance between autonomy, synergy, and coherence. These units have agreed upon resources and performance with higher management and select actions as a result of conversations between future and current situation perspectives. Their actions are coherent with the system's purposes at both higher and lower levels of the organization.

To monitor: The VSM includes multiple specific monitoring capabilities for both external and internal factors. External monitoring is carried out by Operational System 1 units, which scan the environment for opportunities and threats to ongoing operations. System 4 identifies developments in the environment that may have positive or negative impacts in the future. Internal monitoring involves assessing the system's performance relative to agreed-upon goals, coordinating activities among operational units, and auditing operations. System 5, a supervision function, monitors the conversation between strategic development (System 4) and current operation management (System 3).

To learn: First loop learning, based on the effects of current actions, is embedded in System 3, which manages the inside and current view of the operations. Failed actions are discussed with System 4, which extracts knowledge from the environment. The VSM's main interaction occurs between System 3 (operative governing) and System 4 (strategic governing). Current models and understanding are reviewed and updated as needed through double loop learning (Argyris & Schön, 1978).

To anticipate: System 4 in the VSM scans the environment for opportunities and threats, presenting itself to the environment to influence and increase awareness. System 4 presents proposals to System 3, which reviews these proposals considering their feasibility. The interaction between Systems 3 and 4 ensures that the organization remains aware of and prepared for potential environmental threats and opportunities while maintaining requisite variety.

The VSM's fractal-like unfolding and communication channels offer extra capabilities, extending the four resilience potentials. Every layer or recursion is connected by required communication channels to manage a coherent functioning system that avoids issues due to layers pursuing incompatible goals or resource mismanagement. In addition, the VSM models all required and sufficient communication channels between the functions, while its cornerstones do not provide such channels.

In conclusion, the Airline Value Production Model (AVPMM), as an instantiation of the VSM, can be considered an Airline Resilience Management system.

Chapter 9: Discussion

In this chapter, I will reflect on the answers to the research questions and relate them to the literature reviews. Depending on the research method and structure, the discussion chapter of a thesis is often about interpreting and explaining the results. In the DSR structure used for this research project, the answers to the research questions have been given near the end of the specific project chapter. Also, some lessons for practice, design and science have been mentioned at the end of each specific project chapter.

In this chapter, I will summarise and synthesise the findings and relate them to the literature review findings. Next, I will describe some limitations of this research and some unique opportunities I had as a researcher inside a company. Finally, the story of my research inside the company will explain the opportunities and limitations of the research.

9.1 FlightStory research findings

The FlightStory research questions were composed to investigate how and to what extent flight operational feedback from flight crew can help several learning loops related to value delivery. For an airline, the execution of a flight is the central part of the value delivery to a customer, and delivering a memorable customer experience requires flexible and resilient flight operational support. The research questions address the different feedback loops that are part of the learning loops. The continuous dynamics of the flight operational environment require effective learning loops and FlightStory is designed to provide essential data for these learning loops.

For the FlightStory survey 20 participated, of which 13 experts and 7 managers. 159 flight crew answered the online survey.

The following research questions have been evaluated in the FlightStory chapter 6.10:

RQ 1.1 How can flight crew flight operational experiences feedback:

- Support flight crew performance, self-reflection and learning?
- Support flight crew to flight crew learning?
- Support flight crew training?
- Support the management of flight operations?
- Support Safety Management?
- Provide insights for Safety-II and resilient performance?

The survey answers given by experts, managers and flight crew show high agreement in most answers about an increase in each learning loop performance compared to the current situation.

- Support flight crew performance, self-reflection and learning?

18 of the 20 respondents agreed that by filling out the questions (such as the story, the critical events, the lessons learned, the operational strategies (tri-arcs), the Performance Conditions) in a FlightStory, the submitting flight crew(s) are supported in taking a reflective view on their own performance, enhancing their own learning process more effectively than ASR 1.0, TR and FDM. FlightStory is therefore an improvement of the current reporting practices.

- Support flight crew to flight crew learning?

FlightStory supports learning by providing a more effective method of sharing stories and lessons learned from operational events with other flight crew, compared to ASR 1.0, TR, and FDM. While the managers were somewhat less in agreement than the experts and flight crew themselves, the overall consensus was that FlightStory can effectively provide learning opportunities for other flight crew through the sharing of experiences and lessons learned.

- Support flight crew training?

The managers and experts agree that the different question themes of FlightStory provide the training experts with more relevant topics such as conflicting goals, for flight crew training programs than the current ASR 1.0, TR and FDM.

- Support the management of flight operations?

The answer to this sub-question was composed of 5 questions in the experts' and managers' survey. The experts agree more than the managers on the claim that FlightStory data supports the management of flight operations. Some managers entered their concern about the lack of integration during the trial of the FlightStory data sharing process and the SMS process. However, they mostly agree the rating of the OPC and tri-arc strategy indications are useful data.

- Support Safety Management?

The answer to this sub-question was composed of 4 questions in the experts' and managers' survey. The experts agree somewhat more than the managers that the FlightStory data supports Safety Management better than current ASR1.0, TR and FDM. They mostly agree that the rating of the OPC and tri-arc strategy indications are useful data.

- Provide insights for Safety-II and resilient performance?

The FlightStory data contains the stories of the flight crew and which strategies they used, indicated via the tri-arc responses, to manage the disturbances. In addition, flight crew rate the performance conditions and make a judgement of the safety performance potentiality, capability and actuality. The survey responses also show an agreement that FlightStory data provides insights for a Safety-II and resilience perspective because

FlightStory is not focused on failures or an undesired outcome but on the manner overall performance in context was achieved.

RQ 1.2 How can flight crew flight operational experiences feedback:

The second research question evaluates the use of FlightStory data in support of the AVPMM.

- Support Airline Value Production management?

The experts in the AVPMM were largely in agreement that FlightStory data supports the approach to integrated management, as it maintains the rich context of the often competing goal conflicts and trade-offs between safety, cost, and passengers. This highlights the importance of FlightStory in enabling effective decision-making within aviation management, by providing a comprehensive understanding of the complex factors at play in operational events.

9.1.1 FlightStory findings in relation to the literature review

The literature review revealed that many modern safety publications advocate a system safety approach. However, this asserted approach is then not fully expanded to a system of systems approach where safety is an aspect system of the business system. Furthermore, no research advises collecting 'warm data' composing of stories and opinions of flight crew. Storytelling in other settings has been researched in other settings, but not for flight crew. Also, some researchers (Dekker, Hollnagel and Kingston) report some shortfalls related to providing insights into Safety-II and resilience through safety reporting and incidents reports. They have only proposed some new elements for reporting. These proposals have not been evaluated in actual settings. In the FlightStory research project, some proposals are operationalised, tested and evaluated and confirmed their utility.

The FlightStory findings show a beyond-compliance combination of question topics that support different learning loops, take safety out of the silo and provide new insights into the execution of challenging flights. In this way FlightStory research fills a significant gap, as revealed by the literature review and provides many aspects for further research.

9.1.2 Limitations

The FlightStory app was not part of each pilot's standard software suite on the iPad, which probably resulted in fewer participants.

The evaluation of FlightStory took place during the initial phase of the COVID pandemic, which led to various organizational challenges. As a result, the availability of managers from the Flight Operations department was limited, and a review of the actual data in a focus group setting could not be conducted. Instead, a video demonstrating FlightStory's data analysis features was provided to the testers. However, an actual conversation among Flight Operations managers about real FlightStory data would have strengthened the claim about the data's actionability and offered valuable insights into their ability to work with the concepts that form the basis for the categories of questions used in FlightStory.

9.2 AVPMM research findings

The AVPMM research questions were composed to investigate an approach of Value Management for the integrated management of safety, economy, and customer satisfaction. This approach was chosen from the point of view that an airline company, just like any commercial organisation, can be seen as a decision factory. Therefore, value as a combination of the three nominated essential variables, safety, economy and customer experience, is used as a context for decision-making about value production topics such as network design and schedule planning.

7 senior experts participated in the group session and completed the survey.

The main research question is:

RQ 2: How can we develop and use a Value Production Management model for the integrated management of Safety, Economy and Passenger experience for a Network Airline?

To develop and implement a Value Production Management model for the integrated management of Safety, Economy, and Passenger experience for a Network Airline, it is necessary to first create a Value Production model that takes into account the airline's activities. This model should consider the various aspects of the airline's operations, including the execution of flights or combinations of flights, as well as the different regions and routes that the airline serves. By scaling up the airline's main activities from a flight, via a route, then the regions and finally to the network level, the airline can encompass all the different value production clusters.

To ensure that the integrated management of essential variables is effective, the airline can use the Viable System Model. This model provides a framework for organizing the airline's activities and implementing the necessary management functions. With the Viable System Model, the airline can manage the different functions of the organization, from strategic planning to operational management, while maintaining a focus on essential variables.

Different properties of the resulting Airline Value Production Management Model are then compared and evaluated for adequacy by answering the following research questions.

RQ 2.1 How can the AVPMM improve on the management of production-protection?

The focus group of experts, which included senior experts and director experts representing flight operation, network management and customer experience, answered predominantly that the three variables of safety, economy and customer experience of the AVPMM are better supportive for airline value management than the two variable production-protection ICAO model because the experts could relate their work more to the AVPMM than to the ICAO model. In addition, the operationalisation of the AVPMM variables matches more with the experts' current practices than the ICAO model does. Furthermore, the experts agreed the AVPMM goes beyond the ICAO safety space toward a richer optimisation challenge.

The AVPMM is considered to be more effective in managing airline value in practice due to its three variables that are easier to operationalize. On the other hand, the ICAO model is likely more effective as a conceptual model to raise awareness of safety risks to senior and executive management, given that the concept of operational pressure has been adopted within managers language.

RQ 2.2 How can the AVPMM improve Network Performance Management?

An important change from the current practice of network performance management to the AVPMM's proposed practice is to include explicitly safety as a network performance aspect. Two topics were discussed with the focus expert group.

The first topic addresses the current practice of safety, mainly a sub-system, as seen from the perspective of network management. A sub-system topic means that it is not elaborated upon in other parts of the system such as network management. The consequence is that safety performance is treated as binary, either sufficient (safe) or not sufficient (not safe). The AVPMM approach makes safety an aspect of the system and thus more part of the decision making in network management.

The second topic addresses the increase the number of network management decision criteria as part of the AVPMM approach. This means that particular distinctions become visible when adding safety performance for a particular route or flight and allowing new network management decisions.

The consensus was that the use of the AVPMM implies an increase in the variety of network decision making. When using the AVPMM, safety performance becomes available as a criterion to decide, e.g., which airport or route to close for equally poor performing routes or stations or which schedule changes can reduce not only economical, but also safety risk.

RQ 2.3 How can the AVPMM improve 'optimal resource allocation'?

Using the AVPMM, airline management can decide on value production issues using a larger solution space to optimise value production. The interdependencies can have an effect, e.g., safety risk reduction can be very effectively reduced by implementing flight or route network changes. E.g., a case that was discussed in the group meeting, a high yield route allows for more investment in risk reduction measures, such as intermediate stops and extra crew to reduce crew fatigue risk. The consequences of the safety risk mitigations should be evaluated for the effect on passenger experience as part of the value equation. This feature of the AVPMM has been recognised and is now part of the airline's new risk management strategies. The new risk process requires evaluating risk mitigation for the impact on the network, economy and passenger experience domains.

All answers combined provide arguments to claim that the AVPMM can support the organisation to optimise value production with the available resources.

The experts are knowledgeable of actual flight operations. I could have supported them more by providing them with the thematic analysis of the safety, economy and customer aspects based on FlightStory data.

9.2.1 AVPMM findings in relation to the literature review

To evaluate the knowledge gaps in safety science publications, we can compare the research questions' answers with the search results of the literature review. First, I will address the literature related to value production, and after that, I will do the same with the literature regarding safety as a business aspect.

In the section on value production, I concluded that none of the literature search results is explicit about an airline value production structure. Wittmer (Wittmer, Bieger, & Müller, 2011) comes close by referring to levels (global, national and local) of the aviation system. The AVPMM can be seen in this light as a logical extension of the increase of lower specific levels into network, region, route and flight. The Cybernetic Business Model by Brewis (Brewis et al., 2011) was very inspirational for the AVPMM. This is shown by the required ability of the AVPMM to support answering questions of flight or route viability in terms of Value Production as the aggregation of safety, economy or customer experience.

Eight results are presented in the section Safety as Business Aspect literature review. Five of the eight publications discuss the importance of integration, but only three discuss the *how* of the integration to some extent. Except for the ICAO Safety management manual (ICAO, 2018b) and (Ulfvengren & Corrigan, 2015b), none of the literature search results explicitly mentions flight safety or emphasises process safety versus occupational safety. These two publications are also the only two explicitly addressing an airline context.

The first publication discusses Safety Management and Lean Airline Management. Ulfvengren (Ulfvengren & Corrigan, 2015b) argue for integrating the Lean process-oriented approach with a Human Factor human-oriented approach to balance production and protection. The discussion section describes how a joined-up organisation is difficult to develop. However, the research also explains that Lean is not sufficiently comprehensive for SMS and system safety. In the discussion section, the researchers state that Safety Science struggles with developing new safety management approaches that include organisational change. However, their research does not suggest nominating safety as an airline business aspect, nor does it provide a business integrated safety management model.

The second publication(Vogt et al., 2010) discusses using a Balance Score Card (BSC) approach to provide a Human Factors perspective on organisational strategy and performance. They provided a BSC proposal, but it has not been tested nor evaluated. Their conclusion aligns with the AVPMM approach because they state that their basic finding is that the safety management approach should be top-down and part of the organisation's overall BSC. They have not tested this claim, but the AVPMM research results confirm their conclusion.

The third publication, (Turek & Bajdor, 2019) shows the opportunity to integrate enterprise processes with Occupational Health and Safety (OHS) processes when using Enterprise Resource Planning (ERP) software. ERP finds its origin in Business Process Re-engineering (BPR). The process approach binds together information, knowledge, and quality management. Then they show an example of an integration in ERP software but do not discuss the actual activities that bring the integration alive. While ERP can be a beginning of an integrated approach, it is not sufficient. It requires a functional structure such as the AVPMM to bring the actual integration alive.

(Barbosa et al., 2018) conclude in a cross-industry research project that integrating management systems towards an Integrated Management System (IMS), including Quality Management and Environmental Health and Safety, is an organisation's attempt to optimise resources and efforts. The same arguments for efficiency by integrating management processes are made in the ICAO Safety Management Manual (ICAO, 2018b). The advice for integration may initially seem validity, but it underestimates airline management. A reasonable caution against integration is the fear of increased complexity, which is not explicitly addressed in the ICAO publication. The AVPMM explicitly addresses the complexity of integration by providing the requisite management control system structure of the VSM and the unfolding into four recursions to structure the complexity absorption capacity of the management system.

The shortlist of influential safety science writers argues and explains the 'why' for an integrated approach, but they stop short of the 'how' of the actual integration. The AVPMM shows a 'how' of the integration.

Considering the above, I claim that the lack of publications related to value production in an airline and safety as a business aspect showed the gap in scientific knowledge about these two concepts. The AVPMM design, implementation, research questions, and answers fit into this gap and provide anchor points for new research and implementation experiments.

9.2.2 Limitations

The evaluation was executed during the second half COVID pandemic, which caused a lot of organisational issues. Therefore the limited time availability of the required experts and managers was limiting the scope of the experiment. There was insufficient time to explain the AVPMM software model to demonstrate value issue identification and contemplation; therefore, the software model itself was not completely evaluated.

In the experiment, we did not test an actual case in an actual setting. Although the people in the experiment have experience in issue resolution between the Flight Operations department and the network scheduling department, an actual case setting was not part of the experiment.

Because of the circumstances, I could not do a review of the AVPMM with the COO of the company. However, we had a casual conversation, and he helped me by advising heads of departments to cooperate with the project. He also agreed to adopt the new risk analysis and risk management strategies, which extend a safety risk analysis to consider economy, network and passenger effects. These are positive signs, but unfortunately, I could not do a complete evaluation.

9.3 What did working in an airline context mean for the research content?

During the research projects I had three roles that changed every week from one to another and sometimes two simultaneously. In my primary role as a captain on a flight, I was responsible for a safe, economical and customer-friendly flight. As a captain I led a team of competent professionals in managing the operational disturbances that interfered with our flight. I could fill a book with stories about operational challenges with weather, Air Traffic Delay, unruly passengers, fatigue and more.

In my role in the safety department, I was human and organisational factor advisor in incident investigations, safety consultant and safety management innovator. My safety consultancy was built on the theoretical concepts I learned about for my role as a researcher. As a researcher, I have been in touch with the developments in safety science for the last 15 years, and I was also studying the foundations of safety theories.

The combination of the roles as an airline captain, safety consultant and safety science researcher was very exciting. The combination enriched each separate role. This is also why the roles of flight crew and risk analyst are often combined in the safety office. Each role provides the opportunity to reflect on the importance and relevance of the work I did in the other roles.

My Master's education from Sidney Dekker provided insights I could share with colleagues in the Safety department and during regular flights. During long intercontinental flights, ample time is available to discuss flight safety and safety management topics. Many of my flight crew colleagues liked to talk about my second job in the safety department and my research. These conversations, in the cockpit and in the office, were a good practice to formulate my perspectives and ideas in plain language. Operational line flying allowed me to test the relevance of safety management concepts. I had to write ASRs myself and while filling out the ASR form, I realised which data and insights I had available during the flight that I could not make available via the ASR to the safety investigators in the office. An example would be the quality of the Operational Performance Conditions during the handling of an event. The lack of this kind of data makes sensemaking of events by the Event and Risk Analysts in the office difficult since they did not have the full access to the operational context of the event. These experiences together with my theoretical knowledge of human factors and safety management and my reflective nature allowed me to verify, falsify, improve and invent concepts.

Access to data and people when you work in an airline is a dream for a researcher. However, the windows of opportunity for achieving change in a high workload operational department are small and far apart. Although I had a good relationship with most of the relevant managers in Safety department and Flight Operations department, I had to create opportunities mostly by myself. I compensated for the lack of a sponsor and an ambassador by informing the managers about my research projects to the extent that they knew what was coming when they met me.

As a safety consultant I was often involved in risk analysis processes. With my research background, I could pinpoint the missing parts in safety management, such as Operational Performance Conditions and network changes for risk mitigation. Many parts that I found missing are part of the AVPMM and FlightStory. The airline context of the research helped me to verify the relevance of these concepts.

The main concept of FlightStory was relatively easy to explain, and most stakeholders understood the relevance. The big challenge was to get the project agreed upon in the management processes. The whole process took several years but had nothing to do with the project's relevance for flight operations. Roles and responsibilities based on compliance and the way SMS was implemented made it difficult to develop innovations that crossed organisational boundaries.

My understanding of the airline context gave me the impression that the innovations of my research could actually be put to practice by the current organisation. I might have been too optimistic. The organisational complexity makes it sometimes difficult to introduce changes that cross departmental boundaries. The concepts behind FlightStory were much more comprehensive than managers realised. Because of the lack of safety management theoretical knowledge, they did not recognise the full potential and, because of lack of time and opportunity, I could not explain. My logic was that if you understood all the benefits of FlightStory, you would embrace it no matter the politics. Although the safety and flight operations departments work on continuous improvement, larger cross boundary innovations can be hampered by politics about role and responsibility issues.

I conclude that not all understood the full concept, otherwise, the alternative is a very pessimistic view of some managers.

My research, initiated, designed and executed by myself, would provide lessons for the organisation, but I could not rely on organisational resources to execute parts of the research project. I could talk to all kinds of people, but I had to develop all AVPMM and FlightStory software myself. Without my skills as a programmer and time available during the stopovers of my operational flights, the software to operationalise the AVPMM and FlightStory would not be available.

Research in the context of an airline can increase the relevance of the research results, and I would suggest that airline companies support this kind of research. Both safety science and organisational learning would benefit from more cooperation. The DSR relevance cycle is served by work in an airline company, and the DSR rigour cycle is not desired in a company because it takes time and is not required.

A benefit is that other researchers get an idea of how things work in an airline and calibrate their assumptions about the inner workings of an airline. I see airline safety management that goes beyond compliance as a kind of top sport. It requires well-educated professionals supported and enabled by managers. I was lucky to have some of both in my working environment.

9.3.1 Related SMS innovation projects

Two projects for the innovation of the SMS for which I was one of the main drivers have provided some introduction for the concepts in FlightStory and the AVPMM. In these projects, I could introduce some concepts as the next steps for the organisation in safety management. Both projects were executed very synergistically with my aerospace-engineer-turned pilot colleague, Thomas Bos. He represented a more mathematical engineering approach, and I represented the human factors and cybernetics approach.

The first project was the development of a next-generation bowtie model, which we called BowTie 2.0 or BT2. The first-generation bowtie or BT1 is the well-known threat, barrier and consequence model used by the UK CAA to develop flight safety risk models. The introduction of the SMS resulted in the development of risk management. The bowtie model was selected for risk modelling. At the time, no other alternative sufficient developed models were available and the model seemed easy to understand. Inspired by the FRAM by Hollnagel (Hollnagel, 2012a) I started the concept of barriers as functions and supervised an intern student to further develop the concept (Fakkert, 2014). Together with Thomas Bos, we developed the idea is that barrier elements and their interactions deliver the barrier function. The failure of one element can reduce the barrier performance of other barriers that use that element. The organisation delivers the potential quality of the elements and their interactions in the flight operational barriers. The failure to deliver adequate functioning barrier elements can also be modelled with this bowtie concept in which the consequences of the organisational bowtie are barrier elements that reduce performance capability. The link with FlightStory is that the OPC can be mapped on the organisational bowtie, making them relevant for a systemic perspective of the flight operational bowties. By relating the OPC to the bowties, I wanted to introduce this concept to a wider audience in the safety and flight operations departments.

In another project, also executed with Thomas Bos, we developed a new approach to risk analysis and risk management packed under the name of Risk Analysis Framework and Risk Management Strategies (RAF/RMS). We did not use a risk matrix anymore because of the many problematic issues we had encountered using a matrix within KLM. Instead, we developed different types of risk expression based on the knowledge, available data and resources and risk characteristics. The OPC were defined as proxies for risk assessment. Simply said, low-quality OPC increase risk. The other notion introduced was to 'take safety out of the silo' and consider the risk impact and relationship with the network, economy, passengers and environment domains.

Both projects are part of what is called ISMS2.0 and are KLM-initiated and developed safety management innovations. Safety scientist scholars have reviewed the methods, and at the highest level of responsibility, that of the COO, the methods are agreed to be implemented in 2022. This SMS development exemplifies the desire for the company to be an industry leader in safety management.

FlightStory data matches the bowtie2.0, and the RAF/RMS need for data. The AVPMM extends the notion of safety in the context of other business domains. Compatibility between methods and concepts is vital for an effective SMS. I hope the concepts will contribute to the enhancement of safety and business performance of the company.

9.4 Discussion conclusion

Through my research projects, I have been able to uncover significant insights into how safety management can be improved in an actual airline setting. The results of my study have shed light on crucial gaps that exist in the current scientific literature and have provided valuable information on how these gaps can be filled. Despite limited resources in terms of time and personnel, I was able to successfully complete this research and demonstrate improvements beyond the current compliance-focused practices. Through increased engagement with the organization, the relevance of this research to the organization has been heightened. This research presents a model and method that can support maintaining current safety levels in a rapidly evolving world and potentially break the plateau in safety performance, as identified by Dekker (Dekker & Pitzer, 2016).

The ultimate acceptance of the results in the organisation depends on many factors including the perceived need, and gap between current practices and the innovation, and very importantly the support from executive management.

Chapter 10: Conclusions and Further Research

This chapter will finalise the study by summarising the key research findings in relation to the research aims and questions. In addition, I'll discuss the research's contributions to science and some of the projects' innovative aspects. The research was conducted inside an airline by an employee but as external PhD student relative to the university. I elaborate on some effects this had on the research and the challenges I encountered. The transferability of the concepts to other settings or industries will be discussed, and some propositions for future research will be made. Finally, I will conclude with a description of how the events in the war stories from the first chapter could play out in an idealised future where the concepts of the AVPMM and FlightStory have been fully embraced and have become the dominant logic for decision-making.

10.1 Introduction

This thesis containing two research interconnected design projects. During the process, I did not want to split the controller and the feedback system since the thesis is based on underlying systems and control theory. So instead, I've kept the system as a whole and focussed on two different but related parts and how they can support each other.

10.2 Research findings

For both projects, evaluations have been executed. Managers and experts working in the specific domains have cooperated in conducting a focus group session about the AVPMM and answering surveys for both projects. In total, 10 managers, 16 experts and 150 flight crew have contributed to the survey data used for compiling the research question answers. The number of participants was sufficient for each type of evaluation method and this supports the validity of my claims.

10.2.1 FlightStory research question answers

The FlightStory research topics are designed to study how and to what extent flight operational input from flight crew might aid many value delivery learning loops. For an airline the execution of a flight is the most important component of providing value to a customer, and providing a memorable customer experience requires flexible and adequate flight operational support. The research questions focus on the various feedback loops that comprise learning loops of critical operational support systems and peer-to-peer learning. FlightStory is designed to give critical data and flight crew expertise for these learning loops because of the continual dynamics of the operational flight environment that the organisation must cope with. The FlightStory data covers the pilots' stories and the strategies they used to manage the disturbances to their flight. In addition, they rate the performance conditions and offer a judgement of the safety performance potentiality, capacity and actuality of themselves and the company.

FlightStory, based on the cybernetic logic of a variety amplifier provides data that can be used to support several learning loops. Without FlightStory most of this data is not available for the organisation and it cannot be replaced by big data.

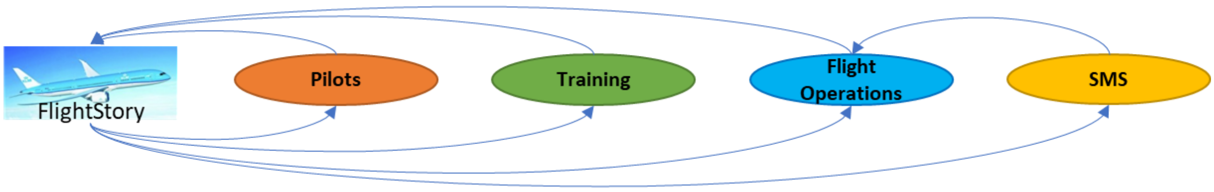


Figure 10-1 FlightStory feedback and learning loops

The research questions address each learning loop depicted above and also ask whether FlightStory provides insights for Safety-II and resilient performance. The survey answers given by experts, managers and flight crew show high agreement in most answers about an increase in each learning loop learning performance compared to the current situation. The survey responses also show an agreement that FlightStory data provides insights for a Safety-II and resilience perspective by revealing lessons learned and operational strategies.

A second main research question addresses the contribution of FlightStory data to the AVPMM. The experts for the AVPMM answered, largely in agreement, that FlightStory data, which maintains the rich context of the often competing goal conflicts and trade-offs between safety; cost and passengers, support the AVPMM approach to integrated management.

All answers have at least descriptive, theoretical, and indicative levels of evidence. Some causal level of strength has been shown, and for more specific topics where causal evidence is likely, more research on application and further evaluation of FlightStory should be executed.

I conclude that this was a very successful research project because flight crew provide, by using FlightStory, data on their story, lesson, operational strategy and the quality of the OPC, new topics that are currently not collected. These topics contribute to the effectiveness of the learning loops. The data usability is more extensive than with current methods without the need for extra resources in the offices for analysis. In principle, FlightStory data should be available for everybody who can learn from it and can use that learning to improve the network, region, route or flight operation. The dissemination of FlightStory data across multiple departments will require decisions to change the data flow structures. The high agreement of the respondents that the lessons from FlightStory should be used for improvements confirms my conclusion.

10.2.2 AVPMM research question answers

In the AVPMM research project, a model for an integrated approach to value production is designed and tested with some use cases. Value comprises safety, economy and customer experience variables and represents a shared context and goal for organisational decision making related to flight, route, region and network activities. These variables are nominated by airline management as the key performance variables for the execution of a flight and can be operationalised at each recursion of the value model. The consequence of this logic of structuring and managing complexity is that none of the domains of safety, economy or customer satisfaction should be managed in a silo. Many topics and problems are linked, and making decisions in silos would lead to sub-optimisation and sometimes create risks in other domains. In the AVPMM evaluation, existing network and flight issues have been discussed to discover how the larger solution space involving the three variables can provide new risk mitigations that otherwise might not be so obvious and reachable.

First, compared to the less specific and more general two-variable ICAO model of production versus protection, the experts see advantages in the AVPMM for meaningful operationalisations.

Second, the experts agree that when safety is added as a network performance variable, new distinctions can be made, and thus new decisions regarding resource allocation become possible. During the group session some network and customer experience experts agreed that the current safety assumption, in network management of either safe or unsafe is too simplistic. They recognise that an operation is never unconditionally safe, and they have no idea under what conditions safety might be at risk. That could be conditions that come into existence by network decisions while they are unaware of the increase of safety risk. This problematic situation is mainly due to the safety as sub-system approach and could be overcome by safety as aspect system approach. An expert warns that safety should not be traded for economy or customer satisfaction. A new performance view based on the AVPMM makes it for example possible to evaluate the flight safety risk and performance of poor economic performing routes. This may lead e.g., to discontinuing a route (or changing the time table) and using the resources of airplanes and people for higher value-producing routes with less risk. Ultimately the network design with time table sets the base risk for the company.

In issues with value production, the safety experts contribute to the issue solution by presenting expert judgements supported by available data which may include FlightStory data. Reducing such a complex topic of safety into a single or few variables would be an oversimplification and lead to losing requisite variety. The flight operational risk is also very adequately managed by a competent flight crew, which illustrates a topic does not need to be reduced to a few variables to be manageable by competent experts. Therefore, risk management as an aspect of operational route, region and network decision making can be executed similarly with safety data compiled in a way suitable for the type of decision-making at each recursion. The range of possible solutions for problems is expanded by an integrated approach. A prominent example is a network schedule change as a very effective mitigation for reducing safety risk. The cultural aspects of integrated management should be considered but out of scope for my research.

The unexpected application of the AVPMM as a model to describe all relevant topics for a corporate risk analysis of the impact of COVID on the airline as a whole can serve as a kind of validation for its completeness and usability.

10.3 Contributions to science

Both projects contribute to the scientific knowledge base in several ways. This research provides stepping stones for other researchers to further develop the scientific knowledge base.

- Both projects address gaps in the scientific literature. The review shows a lack of research bridging the gap between safety and the business activities of an airline. Business researchers stay in their domain with an occasional reference to safety, and safety research focuses on safety with probably more references to the business side than vice versa. My two research projects focus on value production management, encompassing an integrated approach to safety and the business.
- Both projects show developments for safety management that go beyond compliance. As such, it may serve as an incentive to elevate the lowest common denominator in safety management systems on which regulations are based.
- Both projects show the adequacy of management cybernetics as an approach to managerial challenges. However, the full potential of the Viable System Model has yet to be discovered, and the related concepts demonstrated in this research can help improve business needs.
- The AVPMM shows the massive coverage it provides for value production management decisions. It greatly surpasses the data dashboard developments that currently are scattered throughout the organisation. These dashboards generally do not include the management system behind the infographics on the dashboard, as opposed to the VSM with all required and jointly sufficient regulatory functions and conversations.
- The integrated AVPMM approach to network design provides a new decision context of value production. In addition, the integrated approach increases the solution space for conflict resolution.
- FlightStory and the AVPMM are a combination of feedback and control systems. Therefore, research should consider the compatibility between these two system elements, as exemplified in this research.
- An unexpected finding is the confusion or reluctance of managers, both from safety management and Flight Operations management, towards the non-conformity with standard established safety management data distribution processes. The direct sharing of the stories and lessons outside of the process of analysis and risk evaluation raised concerns by some managers. This process orientation and role and responsibilities discussions might be related to the drive and perceived urgency for compliance as well as to the traditional view held by

many managers that there can only be one correct version of the event description.

- The research provides a basis for making better use of the front-end operator as an intelligent feedback generator, not just a factual data reporter. Initial reactions to FlightStory suggested a problem with the reporter's subjectivity, even though this subjectivity is crucial in storytelling research. FlightStory is the first application of storytelling in safety reporting in aviation.
- FlightStory data topics include unique data as part of a reporting tool available to all flight crew that has not been researched before. The quality of the OPC for the conditions in which the flight crew found themselves are very useful as feedback for a systematic and systemic management of operational working conditions. The operational strategies, as explained by the flight crew using the tri-arcs, provide a unique way to discover patterns in the way disturbances have been managed. For the first time, Viable System Model concepts have been used as descriptors for pilots' flight management activities. The stories are elicited from the flight crew by providing pointers towards topics such as becoming aware of the situation, critical decisions and their reasons, and how to prevent worse and create success. These three innovative data topics together provide new ways to understand actual operations and the gap between Work-As-Imagined and Work-As-Done.

A significant driver for me to continue and complete this research after all these years is my conviction the projects will add to the scientific knowledge base and provide other researchers with connections for further research.

10.3.1 Disruptive innovations

While the two research projects might not be disruptive in the sense that they disrupt an economic market, they can be viewed as disruptive because they provide innovations that are not just improvements of existing methods.

- They show that compliance falls short of more effective feedback methods for the airline it, e.g., ASR versus FlightStory.
- Flight crews as active, intelligent feedback providers using a reporting system are a source of information that big data and Artificial Intelligence cannot deliver.
- An integrated approach provides a larger solution space for decision-making. The research projects also show the limitations of a single perspective. Outside the business context, a safety perspective is both limiting and insufficiently capable of capturing goal conflicts and the consequences of resource constraints. Furthermore, a business perspective with safety as a sub-system may not find the best value solutions.

10.4 The influence of the airline context on the research

Since the research was conducted within the airline and in cooperation with the airline, I had to coordinate activities and get some agreements for parts of the project. Research in the company has no high priority in my company, and since I had no inside formal promoter or ambassador, I needed to get attention for my research mostly by myself. I had to find opportunities and time to speak to managers to inform them and get the trial projects accepted. During the projects, some manager positions changed, and I had to start over. It was my strategy to work as much as possible by myself and to be as independent as possible because dependencies on others could negatively affect the research project's progress.

The DSR research method as applied gave me a lot of independence. My programming skills and the help I got from friends kept me independent of the company's IT department. This allowed me to make my own designs for the research tools. I was granted a developer account on my company laptop that allowed me to program and store the data according to company protocol.

The independence also allowed me to design my own selection and format of questions for FlightStory. I did not need to get an agreement on the type, format or number of questions. Only the fatigue questions were formulated in agreement with the fatigue specialist from the safety department.

Also, for the AVPMM, I had minimal dependence on the organisation for the design and development of the model. I used experts to discuss the content presented in the AVPMM, and I did not need any agreement from others.

The freedom for design and development would probably have been different in a full action-research setup for the projects.

My role in the airline as a safety consultant allowed me access to experts and relevant managers. This familiarity in and with the organisation allowed me to do a focus group session which was not hindered by confidentiality about topics. Since I was an insider with insider knowledge, I could discuss actual relevant cases. The participants did not hold back in their answers and their explanations. This contributed to the research results in the sense that N=7 participants for the AVPMM and N=20 for FlightStory were sufficient to get valid results.

10.5 Transferability

The research was conducted in a full-service network airline, and based on the results, I can make statements about the AVPMM and FlightStory for this specific context. However, the specific solutions are based on generic problem-solving concepts using cybernetics as a generic language. Therefore, we can expect the concept of value production and value production management to be more general and maybe even valid for every commercial organisation. The inspirational work by Brewis (Brewis et al., 2011) developing a value delivery function was conducted in a large telephone provider and is currently applied to a large chain of over a hundred hairdressers. This application is not exactly the same as the nomination of essential variables but is comparable. The AVPMM is based on the VSM and this model is used in many different contexts, from government to cooperatives and from federations to banks and factories. These applications provide a basis to expect the AVPMM approach is transferable beyond network airlines to other businesses while I recognise that a model is required but not sufficient.

FlightStory as a reporting and storytelling tool is based on the intention to increase the variety of a feedback channel and is also based on and explained by generic cybernetics principles. The importance of operational feedback by professionals at the sharp end can be found in other industries such as shipping, oil, and healthcare. I expect some FlightStory questions would need to be adapted to the specific operational environment, but many questions can be similar because of the general nature, such as OPC and several of the operational strategies.

The wide range of possible applications of both the AVPMM and FlightStory makes this research relevant and a useful contribution to science because it fills gaps and others can apply the concepts in other settings and make improvements. The research results might be instrumental to break the safety performance asymptote as indicated by (Dekker & Pitzer, 2016).

10.6 My reflections on research and the research projects

I started as a novice interested in human factors for flight crew. It took me years to get an idea about the different schools of thought about human factors until I realised the importance of the fundamental difference in ontological and epistemological assumptions between scientists and schools of safety science. Most scientists are not explicit about their assumptions or even convictions and the reader must analyse the author's claims to understand the author's background of assumptions about, e.g. situational awareness, information processing, safety culture and complexity.

Safety related research is very wide-ranging and multidisciplinary. It is hard to be knowledgeable in all aspects of safety science. Developments in supporting sciences, e.g. complexity science take some time to become adopted in mainstream safety science. The treatment of complexity in safety science has been rather simplistic compared to the complexity science notions as explained by e.g. Bar-Yam (2023b). While certain safety authors and experts occasionally appear to exploit complexity as a justification for their inability to understand or act, the last 15 years of complexity science discoveries by, for example, Snowden and Bar-Yam, present new insights and methods forward. Also, the mathematical developments relevant for extreme low probabilities and high impact as in aviation safety by Taleb provide clues for new developments. Furthermore, the traditional arguments that safety management has many properties of quality management are problematic in aviation because the normal distribution and linearity are not the norm but rather the exception. Instead, non-linearity and fat-tails are the norms.

In my view quite a few authors and safety experts are unfortunately not sufficiently acquainted with cybernetics, systems and control theory which are fundamental. For example, the sloppiness of system definition and the lack of reference to the law of requisite variety are arguments for my point of view. Many of the concepts on which my research is built are more than 40 years old, and still these ideas can support new developments, as this research shows.

10.6.1 Research method

With the assumption that research requires resources and that these resources are provided by the community and businesses directly or via taxes, the results should benefit at least some resource providers. Safety science is a science that should find its application in actual settings to reduce harm, injury, damage and loss and to increase success. Therefore, the relevance of the research is an important aspect.

Most safety science publications and books relevant for aviation require experts in an airline to operationalise the theory, and the experts must convince managers to get resources for experimentation and implementation. This is not an easy task and is very dependent on the managers and company culture. The gap between theory and theory-informed practice can be hard to bridge in an airline context.

The applied research method influences the size of the gap. Action Research and the related Design Science Research approaches have the potential to deliver relevant research results and give guidance for the operationalisation and implementation of the research. The encounter with the actual practices, organisational complexities, and trade-offs will provide useful lessons for the researchers. The benefit of the DSR structure is that it includes both rigour for scientific requirements and relevance for societal aspects.

10.6.2 Research in a company as an external PhD

Large organisations probably often have interns and students doing a BSC or MSc project or thesis. I have been supporting students myself for these kinds of projects. PhD research would also benefit from this kind of support but the problem is that there are few people available that have the desired background for effective conversations. Flight operations as a kind of production department is not very populated with academics. I have asked a few managers to become sponsor or ambassador for my research, but nobody was willing. However, some managers were cooperative and provided critical opportunities to move the project forward. I was lucky to have a few colleagues with an MSc and PhD potential willing to discuss topics and methods. Still, as a PhD researcher, I was an outsider in the company for most people. As an external PhD, I was an outsider in the university as a researcher. I have had a few encounters with fellow PhD researchers. I should add that I started the PhD programme before the university became very active in supporting and connecting PhD students. I am thankful for my promotors being available to guide and redirect me when I asked for it.

10.6.3 Challenges I had to overcome

The blue colour of KLM and its reputation have remained very stable over the years but the organisation itself, the back offices, the organisational structure and managers have been very dynamic. Restructuring plans and programs have been going on since I joined the airline in 1985. The consequence was that I did not have a stable research context. Managers came and went, and windows of opportunity opened and closed. A big challenge was to keep some managers in my network informed about my research, and I invited them to keep an open eye for opportunities. I had to overcome some separation between the subject matter experts and most of the managers. A manager's personal interest in the research topics very much determined the degree I could get connected with them. The main problem was getting time to speak to them. Since there was no formal agreement after 2010 that the organisation was supporting my research, I had to convince managers of the relevance of the topics so they would make time available for me to explain my projects. I have had at least ten meetings planned with higher managers that were shortened or cancelled at the last moment because of acute issues. These were frustrating experiences because I needed time to bridge knowledge gaps between the manager's knowledge of safety management theory. It takes time to explain the concepts in the research and to convey the benefits of the projects for them and for the organisation.

A requirement requested by safety managers was to complete the process for a Safety Issue Risk Analysis to ensure the FlightStory project would not create unexpected risks. The result was that I added to the main screen of FlightStory that it did not replace the requirements for the regular Air Safety Report.

Another challenge was negotiating an agreement between the pilot union, the airline Flight Operations department, and the Safety department about data security and usage of the data. Because the project was safety science research, all parties were willing to come to an agreement.

Another hurdle I had to overcome was to make my data collecting, storage and analysis processes compliant with personal data protection regulations. With help from the headquarters privacy officer and the safety department IT manager, I could make the project compliant.

With the help of some of my direct colleagues who served as a network to find opportunities and threats, I could navigate all obstacles and complete the projects.

10.7 Further research recommendations

Both the AVPMM and FlightStory have been argued to fill gaps in the scientific knowledge base. In addition, the projects provide many interesting aspects that can serve as an inspiration for further research.

- More DSR or action research. Involve safety managers and airline (network) managers.

- Multidisciplinary research:
- Economics and safety scientists working together bridging the gap between safety and the business.
- Complexity scientists, mathematicians, data scientists and safety scientists

Further AVPMM related research suggestions:

- An AVPMM based innovation in the airline is taking economy, customer satisfaction, and network effects into consideration in risk management. This has been dubbed as 'taking safety out of the silo'. The breakdown of silos towards integrated management requires more research.
- Add to safety as a unit of analysis also business as a unit of analysis.
- Integrate safety risk management with business management.
- Research the pros and cons of joining all the company's different types of risk management activities. To name a few, financial risk management, safety risk management, network operational risk management and more types of risk management can share concepts or provide inspiration for new developments.
- In this research, three essential variables have been chosen. The importance of sustainability has grown to such an extent that it might be nominated as fourth essential variable. This would create a new dimension to the value function, create new trade-offs, goal conflicts and richer solution space for issues.
- The VSM logic has provided an argument for the design of a functional integration of safety, economy and customer experience. The VSM concepts can provide more guidance for designing, building and evaluating other business topics.

Further FlightStory related research suggestions:

- The stories that are collected using the FlightStory method can be analysed and presented on dashboards in many different ways, both qualitative and quantitative.
- Data topics such as OPC and tri-arc can be developed to a next version to develop a language for Safety-II and resilience.
- Analyse the data to identify different types of lessons for each learning loop.
- The different data topics can be related to relationships such as operational strategies, operational performance conditions, and safety performance capacity judgements.
- The ease of reporting or the requirement that reporting is 'hassle-free' is an important precondition for flight crew to report. Research may find acceptable trade-offs between the time required to complete a FlightStory report versus the desired content of the report. For example, fewer topics in the report demand less time, and emerging techniques like spoken reports can help make reporting easier while maintaining the required substance.

- The research has shown that FlightStory supports flight crew in self-reflection. This capability can be tested for its support in, e.g., career development, crew management training and performance evaluation.

10.8 Declared future for AVPMM integrated with FlightStory

The thesis starts with three stories of events I had experienced as a flight crew and as safety investigator. These stories were an entry into the descriptions of problematic situations in the organisation, which inspired this research. How would the organisation respond to similar events if they happened in the future, when my research had been fully embraced and integrated into the company's decision-making processes?

The three events were the organisational responses to the bird hit in Entebbe, the engine oil loss over western Russia and the delayed departure during severe winter operations.

I envision a kind of value production operations and value productions management setting as a next step in developing the Operations Control Centre (OCC). This might even become a virtual OCC achieving the control function more by well-informed people at the sharp end. The functional framework for the Value Production Centre (VPC) is based on the AVPMM in a similar fashion as Stafford Beer envisioned the management of Chile (Beer, 1972). Decision making processes have implemented the functional structure of the AVPMM, and the organisational structure in terms of roles, authority, responsibilities and personal capabilities such as knowledge level has been aligned with the functional structure. The organisation's governance is constantly working on maintaining a structure capable of requisite variety without overstressing people. The organisation maintains an understanding of itself and the operation because WorkStory, as a sequel to FlightStory, provides the organisation with a lot of information about itself.

A value production issue would have been recognised at Entebbe because the management of value production is carried out in an operational context with the AVPMM as the view on the execution of the existing and planned airline operating plans. The Entebbe operation would have led to a value production issue because bird strikes have caused flights to return to the departing airport, delays for maintenance to conduct engine inspection, additional maintenance costs, network disruptions due to delays, passengers complaining about missed connections, and flight crew reports. The flight crew would have been instructed by stories of other flight crew who had previously suffered consequences from a bird strike. The integrated approach would rapidly understand a network modification is the best solution for the value production issue. Experts representing the key variables will hold frequent value production issue meetings. To address the value production issue, the arrival and departure schedules can be altered to lower the possibility of a bird strike and the associated safety risk, maintenance costs, network disruptions, and passenger inconvenience.

For a flight experiencing an abnormal engine behaviour such as oil quantity loss, the organisation would have active monitoring systems and people to respond to triggered alerts. The crew would be directly informed, and at the Value Production Centre, response scenarios for the digital twin of the flight would be evaluated. When the aircraft is always online the digital twin might be in the device of the flight crew. The crew would benefit from insights learned from prior relevant engine oil problem situations and would have access to efficient tactics that were in use at the time.

For severe winter operations, the Value Production Centre will advise extra flight plan fuel based on comparable experiences. The economics of extra fuel has been far costly than the disturbances on the network and the passenger connecting flights as was learned from the winter in 2017 when only 4 aircraft departed and many had to return to the gate for refuelling. The flight crew will have unambiguous performance calculation procedures because previous FlightStories have shown the old procedures' possible traps. Then flight crew will be advised about possible strategies to serve the customer needs in these situations.

The organisation will be able to create memorable experiences for the customer and use the available resources for optimum value production by monitoring for opportunities and threats, by being innovative in matching actual conditions and future demands, coordinating activities, delegating and agreeing on tasks and verifying ongoing activities and by learning from operational experiences at all recursions of the value production organisation in a way that does minimal harm to the environment and support the wellbeing of people.

Chapter 11: Appendix

11.1 Mapping Design Research and Thesis

The thesis consists of two DSR research projects. Below I provide the mapping of the DSR steps and the thesis chapters.

Design Science Research steps	**Thesis chapter**
Agenda of problem owner: Description of challenges in integration of Business and Safety management.	1 2
Theory: Selection of ontological, epistemological and methodological perspectives providing concepts, models and methods.	5
Research Agenda: Safety science and safety management literature review regarding the three thesis research topics.	3 Research questions 4 Literature review 6,7,8, Problem description for each research project
Design of solution: Generic theory based model that should be operationalised for the specific 'real world' problem situation.	For each research project: 6. FlightStory 7. Value Production Model
Diagnosis: Description of current problem of improvement opportunity with involvement of business topic owner.	For each research project: 7. FlightStory 8. Value Production Model
Intervention planning: Describe specific project setup and objectives with business stakeholders. Execute focus group before the intervention interview.	For each research project: 7. FlightStory 8. Value Production Model
Implementation: Execution of project interventions.	For each research project: 7. FlightStory 8. Value Production Model
Evaluation: Evaluation of project interventions.	For each research project: 7. FlightStory 8. Value Production Model
Lessons learned: Description of lessons learned. Execute focus group after the intervention interview.	For each research project: 7. FlightStory 8. Value Production Model
Reflection: Analysis of intervention project effects on the business and possible lessons for practice and for the science knowledge base.	9.Discussion For each research project
Knowledge development:	10. Conclusion and further research

11.2 Literature reviews

11.2.1 Literature collection search process

The literature search was completed 1-sep-2020 using WoS (https://webofknowledge.com), and GS (https://scholar.google.nl).

The WoS search was executed using a Chrome browser with authentication via a VPN with TU Delft. The GS search was executed using the research tool Publish or Perish version 7.14.2619.7235 (Harzing, 2007).

All retrieved literature was stored in Qiqqa (www.qiqqa.com), which is a research assistant software application. This software allows to tag documents and parts of a text to support the review.

Literature Review results Web of Science				
Nr	**Search elements**	**Web of Science search term query of the 154,496,851 in the selected data limits**	**Search hits**	**Remaining after abstract review**
1	Air Safety Report	TOPIC: ("Air Safety Report") Databases= WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years Search language=Auto	1	1
2	Flight Safety Report	TOPIC: ("Flight Safety Report") Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	1	0
3	Pilot Safety Report	TOPIC: ("Pilot Safety Report") Databases= WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years Search language=Auto	0	0
4	Pilot Report Aviation	TOPIC: ("Pilot Report") *AND* TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	6	0
5	Flight Report Aviation	TOPIC: ("Flight Report") *AND* TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	4	1
6	Pilot feedback Aviation	TOPIC: ("Pilot Feedback") *AND* TOPIC: (Aviation) Databases= WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years Search language=Auto	3	0
7	Safety Report Aviation	TOPIC: ("Safety report") *AND* TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	9	3
8	Occurrence Report Aviation	TOPIC: (Occurrence Report) *AND* TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	1	0
9	Incident report Aviation	TOPIC: ("Incident Report") *AND* TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	14	0
10	EASA 376	TOPIC: (EASA 376) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	1	0
11	Storytelling	TOPIC: ("Storytelling") *AND* TOPIC: (Aviation)	6	1

		Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto		
12	"Near Miss" Aviation	TOPIC: ("Near Miss") *AND* TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	34	2
13	ECCAIRS	TOPIC: (ECCAIRS) AND TOPIC: (Aviation) Timespan: All years. Databases: WOS, BCI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC. Search language=Auto	6	0

The figure below is a screenshot of search terms and the number of hits when using the Publish or Perish literature software search tool.

Search terms	Source	Papers	Cites	Cites/year	h	g	hI,...	hI,ann...	acc10	Search date
✓ "Event report" [title], Aviation Safety	Google Scholar	4	207	8.63	2	4	2	0.08	1	23-08-2020
✓ Story learning [title], Aviation Safety	Google Scholar	5	79	2.63	3	5	3	0.10	0	23-08-2020
✓ "Air Safety Report" [title]	Google Scholar	4	1	0.05	1	1	1	0.05	0	23-08-2020
✓ Story pilot [title], Aviation Safety	Google Scholar	19	180	3.60	7	13	7	0.14	0	23-08-2020
✓ Pilot Report [title], Story Aviation	Google Scholar	13	133	2.56	5	11	3	0.06	1	23-08-2020
✓ Pilot Safety [title], Story Aviation	Google Scholar	12	70	1.94	3	8	2	0.06	0	23-08-2020
✓ "Near miss" [title], Aviation Safety	Google Scholar	106	2698	107.92	20	51	13	0.52	4	23-08-2020
✓ "Storytelling" [title], Aviation Safety	Google Scholar	42	387	17.59	8	19	7	0.32	3	23-08-2020
✓ "Safety Report" [title], Aviation	Google Scholar	49	102	1.62	5	8	4	0.06	0	23-08-2020
✓ ECCAIRS [title], Aviation	Google Scholar	12	19	1.00	3	4	2	0.11	0	23-08-2020
✓ learning incident reporting [title], airline aviation	Google Scholar	6	103	3.55	4	6	4	0.14	1	23-08-2020

The literature search strategy yielded: 8 relevant search results based on WoS search terms and 11 relevant search results based on GS search terms.

Due to the low number of search results using the strict systematic search strategy procedure, I continued to search using expert judgement which yielded another 37 relevant GS search results:

- GS to search in search results, this can be achieved by limiting a search only to the search in results of a previous search.
- Topics discussed in the shortlist of relevant safety science literature.
- Relevant references found during the literature review and relevant aviation regulations.
- Other work domains where relevant safety science research is conducted.

Review of literature collection The search result publications were reviewed regarding the three identified safety reporting problems. Most publications were relevant for one to two of the identified problems. Nearly none applied to each of the three issues.

The table in the appendix shows authors, types of publications and assigned review tags in the left column. The tags include relevant research domains and relevant safety research topics all of which will be explained in the specific review section. Mostly (peer) reviewed publications are shown while some non-peer-reviewed publications have been studied and referenced in the review. Some publications are relevant for more than one of the defined problem areas and are therefore referred to more than once.

11.2.2 FlightStory literature collection publications

The search result publications were reviewed regarding the three identified safety reporting problems. Most publications were relevant for one to two of the identified problems. Nearly none applied to each of the three issues.

The following table shows authors, types of publications and assigned review tags in the left column. The tags include relevant research domains and relevant safety research topics all of which will be explained in the specific review section. Mostly (peer) reviewed publications are shown while some non-peer-reviewed publications have been studied and referenced in the review. Some publications are relevant for more than one of the defined problem areas and are therefore referred to more than once.

Collection of reviewed publications.				
Tag \ Type	**Search hits**	**Book**	**Journal**	**PhD thesis**
"Silo No" Safety not in Silo	[3]	(Hollnagel, 2017) (Dekker, 2011a)	(Amalberti, 2001) (Sujan et al., 2017) (Rae et al., 2020) (Stone, 2006) (Wiegmann & von Thaden, 2003)	(Bramfitt-Reid et al., 2017) (Kingston-Howlett, 1996)
Safety silo	[20]	(Sánchez-Alarcos Ballesteros, 2007) (McKinnon, 2012) (Davies et al., 2003) (Van der Schaaf et al., 2013)	(Rae, 2016) (Madsen et al., 2016) (Roelen et al., 2011) (Stemn et al., 2018) (Lindberg et al., 2010)	
S1 Safety-I	[32]	(Sánchez-Alarcos Ballesteros, 2007) (Van der Schaaf et al., 2013) (Macrae, 2014)	(Cabon et al., 2012) (Drupsteen & Hasle, 2014) (Fitts & Jones, 1947) (Barach & Small, 2000) (Rae, 2016) (Davies et al., 2003) (Dekker, 2011a) (McKinnon, 2012) (Leva et al., 2010) (Drupsteen et al., 2013) (Drupsteen & Guldenmund, 2014) (Madsen et al., 2016) (Roelen et al., 2011) (Sanne, 2008) (Hovden et al., 2011) (Amalberti, 2001) (Wiegmann & von Thaden, 2003) (Valdés & Comendador, 2011)	
S1+S2 Safety 1 and Safety 2	[7]	(Dekker, 2011a) (Hollnagel, 2014b) (Hollnagel, 2017)	(Kelly et al., 2016) (Thoroman et al., 2019) (Rollenhagen et al., 2017) (Sujan et al., 2017) (Rae et al., 2020) (Stone, 2006)	(Kingston-Howlett, 1996)
Positivistic	[5]		(Cabon et al., 2012) (Rae, 2016)	

Interpretative	[7]	(Dekker, 2011a) (Hollnagel, 2017)	(Fitts & Jones, 1947) (Davies et al., 2003) (Sanne, 2008) (Gherardi & Nicolini, 2000) (Stone, 2006)	(Kingston-Howlett, 1996)
Domain: Generic	[14]	(Van der Schaaf et al., 2013) (Hollnagel, 2017)	(Drupsteen & Hasle, 2014) (Rae, 2016) (McKinnon, 2012) (Drupsteen et al., 2013) (Drupsteen & Guldenmund, 2014) (Amalberti, 2001) (Margaryan et al., 2017) (Stemn et al., 2018) (Lindberg et al., 2010) (Gherardi & Nicolini, 2000)	(Kingston-Howlett, 1996)
Domain: Aviation	[16]	(Sánchez-Alarcos Ballesteros, 2007)	(Cabon et al., 2012) (Fitts & Jones, 1947) (Leva et al., 2010) (Thoroman et al., 2019) (Madsen et al., 2016) (Roelen et al., 2011) (Hovden et al., 2011) (Wiegmann & von Thaden, 2003) (Valdés & Comendador, 2011)	
Domain: Healthcare	[3]		(Dekker, 2011a) (Sujan et al., 2017) (Stone, 2006)	
Domain: Rail	[5]		(Davies et al., 2003) (Sanne, 2008) (Hovden et al., 2011) (McHugh & Klockner, 2020)	
Domain: Shipping	[1]		(Hovden et al., 2011)	
Storytelling	[3]		(Dekker, 2011a) (Sanne, 2008) (McHugh & Klockner, 2020)	
WAD-WAI	[1]	(Hollnagel, 2017)	(Sujan et al., 2017)	
Learning double loop	[1]		(Drupsteen & Guldenmund, 2014)	
Learning: Individual	[3]	(Hollnagel, 2017) (Dekker, 2011a)	(Kelly et al., 2016) (Gherardi & Nicolini, 2000)	
Learning: Organisation	[9]	(Hollnagel, 2017)	(Cabon et al., 2012) (Leva et al., 2010) (Drupsteen et al., 2013) (Drupsteen & Guldenmund, 2014) (Margaryan et al., 2017) (Rajala, 2010) (Wiegmann & von Thaden, 2003)	
performance shaping factors	[1]		(Davies et al., 2003)	
Learning from successes	[1]		(Kelly et al., 2016)	

11.2.3 Literature collection Airline Value Production Management Model

Literature was collected on 31-Oct-2019 using WoS (https://apps.webofknowledge.com), and GS (https://scholar.google.nl).

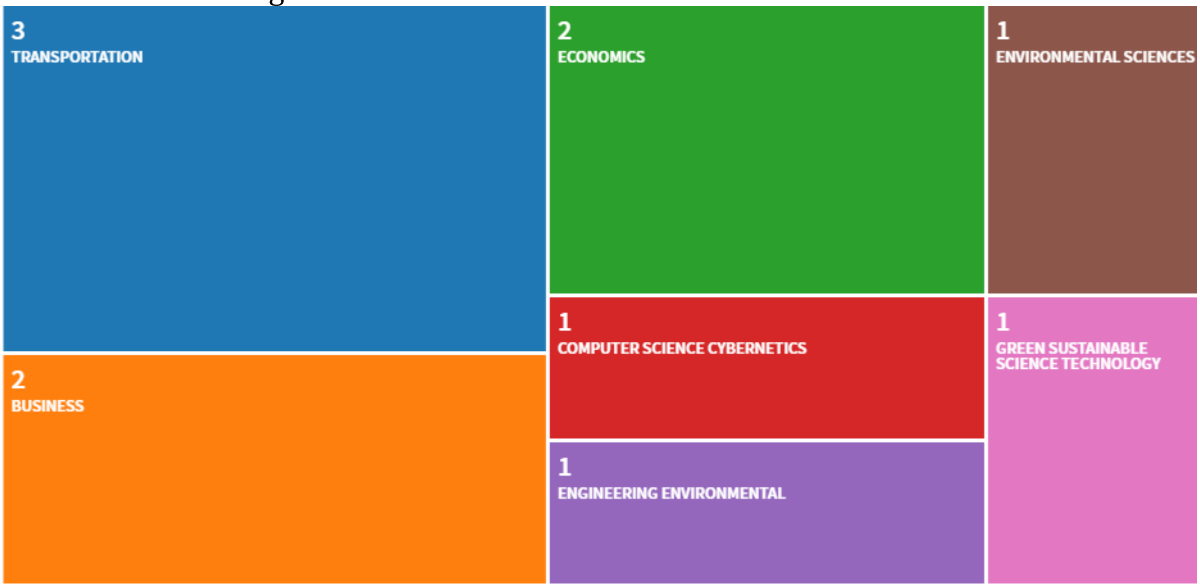
The WoS search was executed using a Chrome browser with authentication via a VPN with TU Delft. The GS search was executed using the research tool 'Publish or Perish' version 7.14.2619.7235 (Harzing, 2007).

All retrieved literature was stored in Qiqqa (www.qiqqa.com), which is a research assistant software application. This software allows to tag documents and parts of a text to support the review.

1.1.1.1

WoS AVPMM				
Nr	**Search elements**	**Web of Science search term**	**Search hits**	**After abstract review**
1	Value creation Value exchange Value production Value formation Value chain Creating value Creation of value Value based Value-based Business model	all=(("value production" OR "value exchange" OR "value chain" OR "value formation" OR "creating value" OR "creation of value" OR "value based" OR " value-based") AND airline AND aviation AND model) Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.	8 records matched the query of the 75,872,555 in the data limits selected.	2 excluded based on relatedness to airline business and value production. 6 included.
2	As search 1 and added: Safety	all=(("value production" OR "value exchange" OR "value chain" OR "value formation" OR "creating value" OR "creation of value" OR "value based" OR " value-based") AND airline AND aviation AND model AND safety) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	1 record matched the query of the 75,872,555 in the data limits selected.	1 excluded based on relatedness to airline business and value production. 0 included.
2	As search #1 and added: "Safety Management"	all=(("value production" OR "value exchange" OR "value chain" OR "value formation" OR "creating value" OR "creation of value" OR "value based" OR " value-based") AND airline AND aviation AND model AND "safety management") Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	0 records matched the query of the 75,872,555 in the data limits selected.	0

Web of science categories:



Google Scholar search (GS AVPMM):

Search terms	Source	Papers	Cites	Cites/ye...	h	g	hI,norm	hI,annual	acc10	Search date	Cache date
✓ airline "value creation" [title]	Google Sch...	14	100	7.14	3	10	3	0.21	1	31-10-2019	31-10-2019
✓ value production [title], airline model	Google Sch...	26	1788	52.59	9	26	8	0.24	3	31-10-2019	31-10-2019
✓ airline "value exchange" [title]	Google Sch...	1	2	0.00	1	1	1	0.00	0	31-10-2019	31-10-2019
✓ airline "value chain" [title], aviation	Google Sch...	2	0	0.00	0	0	0	0.00	0	31-10-2019	31-10-2019
✓ airline "value formation" [title]	Google Sch...	1	0	0.00	0	0	0	0.00	0	31-10-2019	31-10-2019
✓ airline "creation of value" [title]	Google Sch...	5	87	10.88	2	5	2	0.25	1	31-10-2019	31-10-2019
✗ airline "creating value" [title], aviation	Google Sch...	0	0	0.00	0	0	0	0.00	0	31-10-2019	31-10-2019
✗ airline "value based" [title], aviation	Google Sch...	0	0	0.00	0	0	0	0.00	0	31-10-2019	n/a
✗ airline "value-based" [title], aviation	Google Sch...	0	0	0.00	0	0	0	0.00	0	31-10-2019	n/a
✓ airline "value proposition" [title], aviation	Google Sch...	1	1	0.33	1	1	1	0.33	0	31-10-2019	31-10-2019

GS AVPMM				
Nr	**Google Scholar search term**	**Keyword**	**Search hits**	**After review**
	Allintitle: airline "value creation"		14	**2**
1	allintitle: Value Production	airline model	26	0
2	Allintitle: airline "value exchange"		1	0
3	allintitle: Airline “Value chain”	aviation	2	1
4	Allintitle: "value formation"		1	0
5	Allintitle: "creation of value"		5	3
6	allintitle: Airline "Value Proposition"		2	0
Total				6

After an initial review, the exclusion of publications was based on a document review from the perspective of relatedness to value production modelling in an aviation or airline environment.

11.2.3.1 Safety as Business Aspect (Search tags: WoS SABA, GS SABA)

Web of Science (WoS SABA) Search:

WoS SABA				
Nr	**Search elements**	**Web of Science search term**	**Search hits**	**After abstract review**

1	Business model Business structure Airline Organisational structure Organisational model Safety management Aviation Integrated Integration	all=(("Business model" OR "Business structure" OR "Airline" OR "Organisational structure" OR "Organisational model") AND "Safety Management" AND Aviation AND (Integrated OR Integration)) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	10 records matched the query of the 75,872,555 in the data limits selected.	1 included based on relatedness to search elements.
2	Production Protection Airline Transportation	ts=((production NEAR/3 protection) AND (airline OR transportation)) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	11 records matched the query of the 75,872,555 in the data limits selected.	0 included based on relatedness to search elements.

Google Scholar (GS SABA) search:

Search terms	Source	Papers	Cites	Cites/year	h	g	hI,no...	hI,ann...	acc10	Search date
✗ Safety integrated Business [title], aviation	Google Scholar	0	0	0.00	0	0	0	0.00	0	15-Oct-19
✓ Safety integrated Business [title], transportation	Google Scholar	3	9	0.60	2	3	2	0.13	0	15-Oct-19
✓ Safety integrated Business [title]	Google Scholar	10	21	1.24	3	4	2	0.12	0	15-Oct-19
✗ Safety integration Management Business [title], aviation	Google Scholar	0	0	0.00	0	0	0	0.00	0	15-Oct-19
✓ Safety integrated Management Business [title]	Google Scholar	4	10	1.25	2	3	1	0.13	0	15-Oct-19
✓ Safety Management Business [title], Transportation	Google Scholar	29	198	6.83	6	14	6	0.21	0	15-Oct-19
✓ Safety Management Business [title], Aviation	Google Scholar	13	43	1.87	3	6	3	0.13	0	15-Oct-19
✓ Safety Management Business [title]	Google Scholar	84	350	10.94	8	18	7	0.22	1	15-Oct-19
✓ Safety Business Integration [title]	Google Scholar	5	13	0.57	1	3	1	0.04	0	15-Oct-19
✓ Safety Business Integrated [title]	Google Scholar	10	21	1.24	3	4	2	0.12	0	15-Oct-19
✓ Safety Business Aspect [title]	Google Scholar	0	0	0.00	0	0	0	0.00	0	15-Oct-19

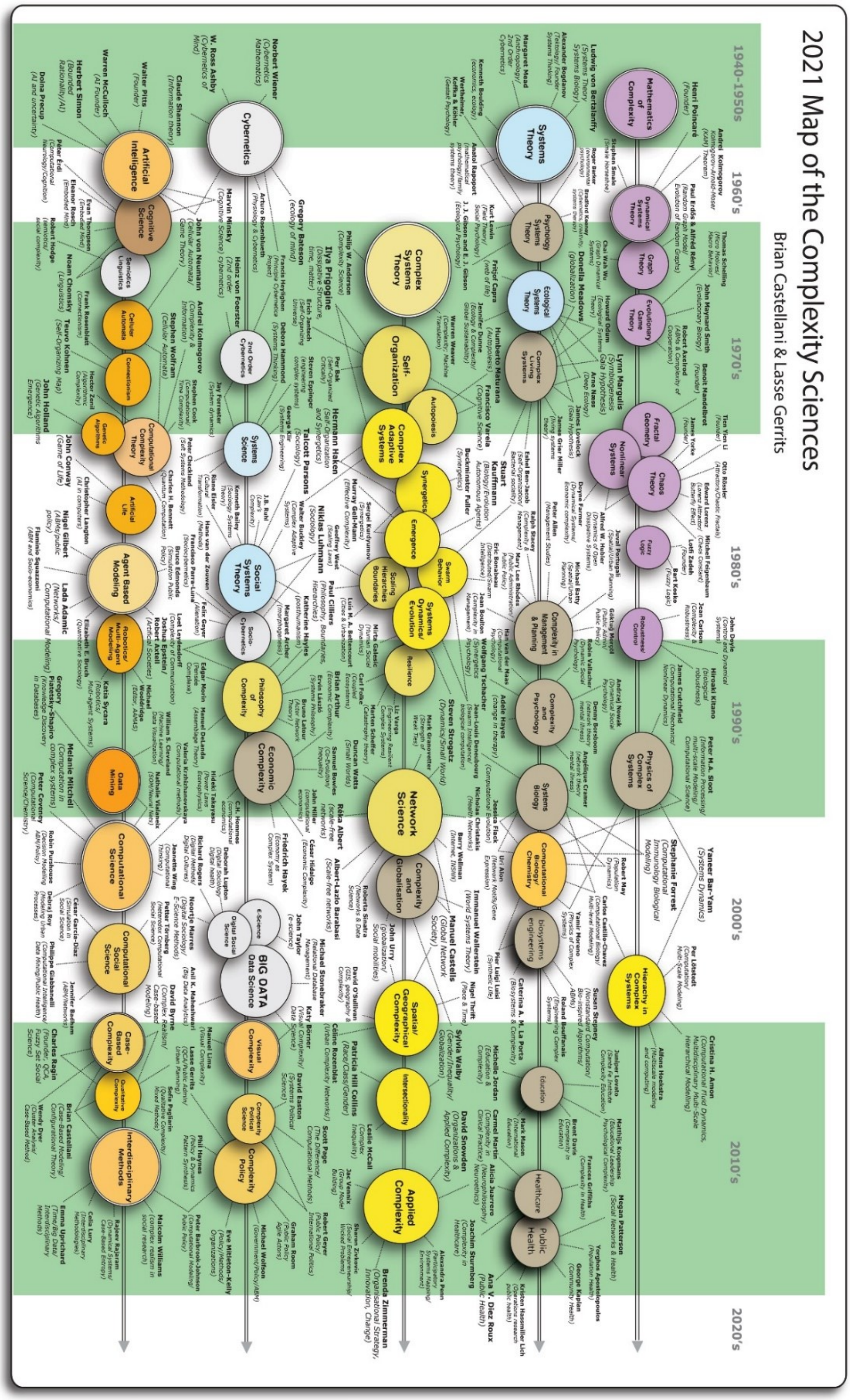
Hits are not of the type “citation”. A citation is a search result from Google that is only a reference to the publication but not the publication itself—total 159 publications of which 91 unique.

GS SABA				
Nr	**Google Scholar search term**	**Keyword**	**Search hits**	**After review**
1	allintitle: Safety Integrated Business		9	1
2	allintitle: Safety Integrated Business	With "Transportation"	3	0
3	allintitle: Safety Integrated Management Business		4	1
4	allintitle: "Safety Management" Business	With "Transportation" or "Aviation" or no keyword	126	2
5	allintitle: Safety Business Integrated		10	1
6	allintitle: Safety Business Integration		5	1
7	allintitle: Protection Production Safety	With “Transportation” or “Aviation”	12	0
Total				6

The after review exclusion was based on a document review from the perspective of relatedness to business management and safety management integration. Also, when the domain of interest in the particular publication was not generic or not transportation or not aviation or only occupational safety, it was excluded.

11.3 Map of complexity science

https://www.art-sciencefactory.com/MAP2021Sharing.jpg



11.4 FlightStory evaluation

Three evaluations have been executed:

1. Flight crew survey
2. Expert flight crew in the field of safety, flight operations and training
3. Manager flight crew in the field of safety, flight operations and training

11.4.1 Flight crew survey

FlightStory evaluation invitation and questions:

Dear colleague,

Thank you for taking the time to answer the following questions. After each rating question you see a question with the option to provide a free text explanation and or remark.

Your email address can only be seen by me and will not be part of the evaluation report. On Yammer I will announce when the report is available for the people that are interested. Thank you for providing this feedback for my research project!

Arthur Dijkstra

1. How familiar are you with FlightStory?

   A. Sorry, I never heard about it.
   B. I heard about it but that is all.
   C. I looked at the App page but did not install it.
   D. Sorry, I've the App but it is too much work.
   E. 0 I have the App but I've not submitted a FlightStory yet.
   F. I've submitted a FlightStory

2. I heard about FlightStory for the first time via

   A. article in the NewsApp
   B. a message on Yammer
   C. a poster in the simulator briefing room
   D. an instructor told me during a simulator briefing O a colleague told me
   E. the information display in the BMC briefing room O other

3. I know what the purpose is of FlightStory.

   Strongly agree / Agree /Neutral / Disagree / Strongly disagree

4. Remark: I know what the purpose is of FlightStory:

   Strongly agree / Agree /Neutral / Disagree / Strongly disagree

5. I could complete the install of the FlightStory app on my iPad

   Strongly agree / Agree /Neutral / Disagree / Strongly disagree

6. Remark: I could complete the install of the FlightStory app on my iPad

   Strongly agree / Agree /Neutral / Disagree / Strongly disagree

7. I am willing to submit a FlightStory when I experience an interesting operational event:

   Strongly agree / Agree /Neutral / Disagree / Strongly disagree

8. Remark: I am willing to submit a FlightStory when I experience an interesting operational event:

   Strongly agree / Agree /Neutral / Disagree / Strongly disagree

9. I've seen the app and I think it is easy to use:

Strongly agree / Agree /Neutral / Disagree / Strongly disagree

10. Remark: I've seen the app and I think it is easy to use:

Strongly agree / Agree /Neutral / Disagree / Strongly disagree

11. I've seen the app and I think the FlightStory form requests useful information:

Strongly agree / Agree /Neutral / Disagree / Strongly disagree

12. Remark: I've seen the app and I think the FlightStory form requests useful information:

Strongly agree / Agree /Neutral / Disagree / Strongly disagree

13. Please check the FlightStoryBook in mPilot under Other Manuals.

Suppose that many FlightStories have been submitted. Then consider the next statement:

“I think the stories we share can provide useful lessons.”

Strongly agree / Agree /Neutral / Disagree / Strongly disagree

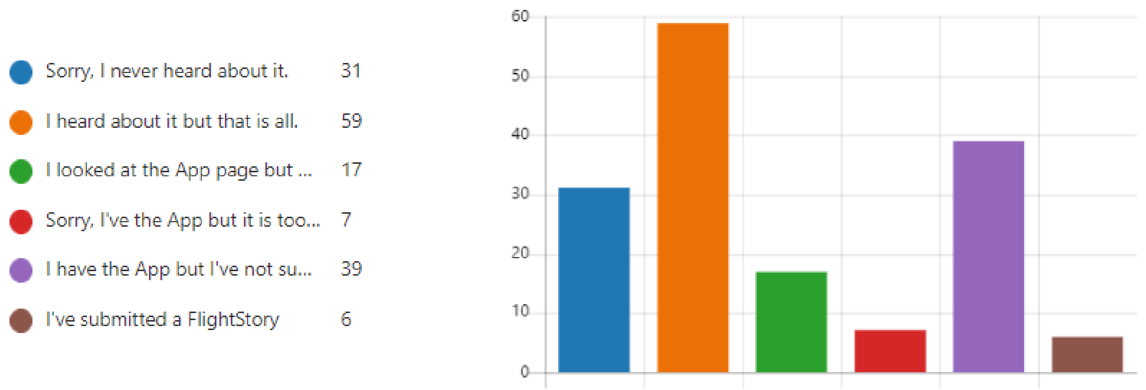
15. Do you have suggestions to improve peer to peer learning; to learn from other flight crew experiences?

159
Antwoorden

04:09
Gemiddelde tijd om te voltooien

1. How familiar are you with FlightStory?

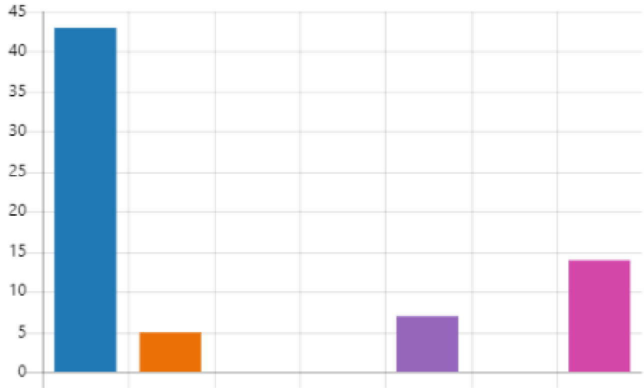
Meer details



2. I heard about FlightStory for the first time via

Meer details

article in the NewsApp	43
a message on Yammer	5
a poster in the simulator briefi...	0
an instructor told me during a...	0
a colleague told me	7
the information display in the ...	0
other	14



3. I know what the purpose is of FlightStory.

Meer details

Strongly agree	14
Agree	42
Neutral	12
Disagree	1
Strongly disagree	0

5. I could complete the install of the FlightStory app on my iPad

Meer details

Strongly agree	21
Agree	30
Neutral	13
Disagree	1
Strongly disagree	4

7. I am willing to submit a FlightStory when I experience an interesting operational event:

Meer details

Strongly agree	12
Agree	28
Neutral	18
Disagree	9
Strongly disagree	2

9. I've seen the app and I think it is easy to use:

Meer details

- Strongly agree 6
- Agree 19
- Neutral 30
- Disagree 8
- Strongly disagree 6

11. I've seen the app and I think the FlightStory form requests useful information:

Meer details

- Strongly agree 5
- Agree 19
- Neutral 38
- Disagree 5
- Strongly disagree 2

13. Please check the FlightStoryBook in mPilot under Other Manuals.
Suppose that many FlightStories have been submitted. Then consider the next statement:
I think the stories we share can provide useful lessons.

Meer details

- Strongly agree 20
- Agree 36
- Neutral 10
- Disagree 1
- Strongly disagree 2

11.4.2 Part 1: Experts FlightStory question by question evaluation

The experts received screenshots of every question in the FlightStory app. They were asked to provide an answer on a 5 point Likert scale which ranges from “Strongly Agree” to “Strongly Disagree” and to provide an explanation for their answer. The first part of the text below is the invitation and explanation of the survey, thereafter I provide an example of question.

<u>FlightStory expert evaluation</u>

The FlightStory project aims to support learning from operational events. FlightStory should support learning processes for the following four stakeholders; flight crew, flight crew training, Organisational KLM (Flight Operations) Management Team, and SCO for SMS. At the closure of the project, the learning potential of FlightStory data for all feedback channels will be evaluated.

This questionnaire is designed for three groups of experts in the project. Each group can access and evaluate FlightStory data and can use the FlightStory analysis dashboard to extract new insights and test current mental models. The reviewers are experts in their domain and are voluntary cooperating to execute this evaluation.

The three groups are:

- Risk Analysts / Safety Experts working in the safety department: RA1: RA2 RA3 …
- Business pilots Safety working in Flight Operations department and the point of contact for the Risk Analysts: BPS1: BPS2: BPS3:
- Flight crew training experts, working for the flight crew training department. TE1: TE2: TE3:

The names of the experts will not be used. Instead, each participant receives a code number such as RA2 or PT3. All names are known by the researcher.

Some guidelines to complete this survey:

- Please tick the box for each statement that represents your degree of (dis)agreement with the statement.
- An evaluation of the FlightStory project will indicate relevant data elements that could be added to the current ASR 1.0 to develop ASR 2.0.
- In the questions, we consider the potential of the FlightStory questions to collect data and generate information.
- Assume that based on this evaluation FlightStory and the current ASR will be integrated into ASR 2.0. Please indicate how strongly you advise that the specific FlightStory question should be part of ASR 2.0. This answer also informs about the relevance of the question. The more you disagree with adding the specific question to ASR 2.0, the less relevant the specific data item is in your view.
- In the remark section, you can explain your rating and or provide other relevant information related to the statement or to the depicted FlightStory item.
- The survey questions are focused on the data that can be collected with FlightStory. The considerations regarding the installation and usage of the FlightStory app are out of scope for the questions below. These issues are evaluated somewhere else.
- The particulars of the jQuery mobile interface is out of scope here except for a question about the tri-arcs. If you have very strong opinions about a particular aspect of the interface or widgets used in a question, you can mention this in the explanation part of the question.
- When 'his' is written it should be read as his or her.
- When desired for an answer to a question, you can view actual data by contacting Arthur.
- This video which shows the operation of the dashboard and how it assists in finding issues. A video with explanation be found here if you wish here is a somewhat more elaborate video.

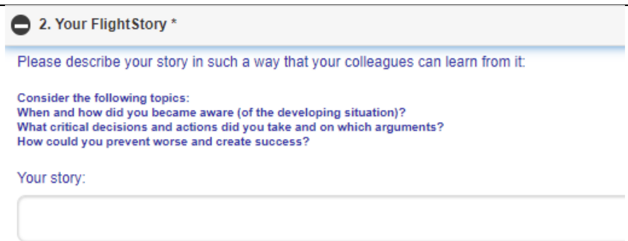
Your answers will provide essential information to develop ASR 2.0 based on the FlightStory project and are critical for my thesis.

Please provide your name and the date of submitting the evaluation at the end of this document.

Thank you very much for your cooperation!

Example question:

2



Statement:
The question to solicit the story from the pilot gives effective guidance to the pilot to tell a story that others can learn from.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☐	☐		☐		☐	☐
This question should be in ASR 2.0						
☐	☐		☐		☐	☐

Remark:

11.4.3 Part 2: Experts and managers FlightStory learning loops support survey

All 13 experts and 7 managers were invited to complete the survey questions in this section, shown below. The invitation started with an explanation and some screen shots of the FlightStory analysis dashboard. The respondents provided their consent. One manager explicitly stated he was not satisfactorily informed about the purpose of this research. I was unable to inform him because of lack of time.

In each table with a question, I provided the answers and the comments as given by the respondents.

Introduction survey information

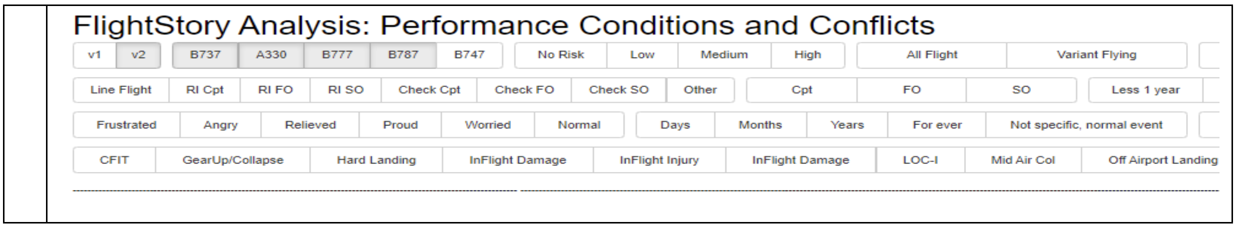
The questions which have been (or will be) evaluated in part 1 are the basis for the pilots' answers. These answers are the data that can be displayed in an analysis tool. Please look at the screenshots below to understand how an interactive analysis dashboard can help the analysts extract critical data from a collection of FlightStories.

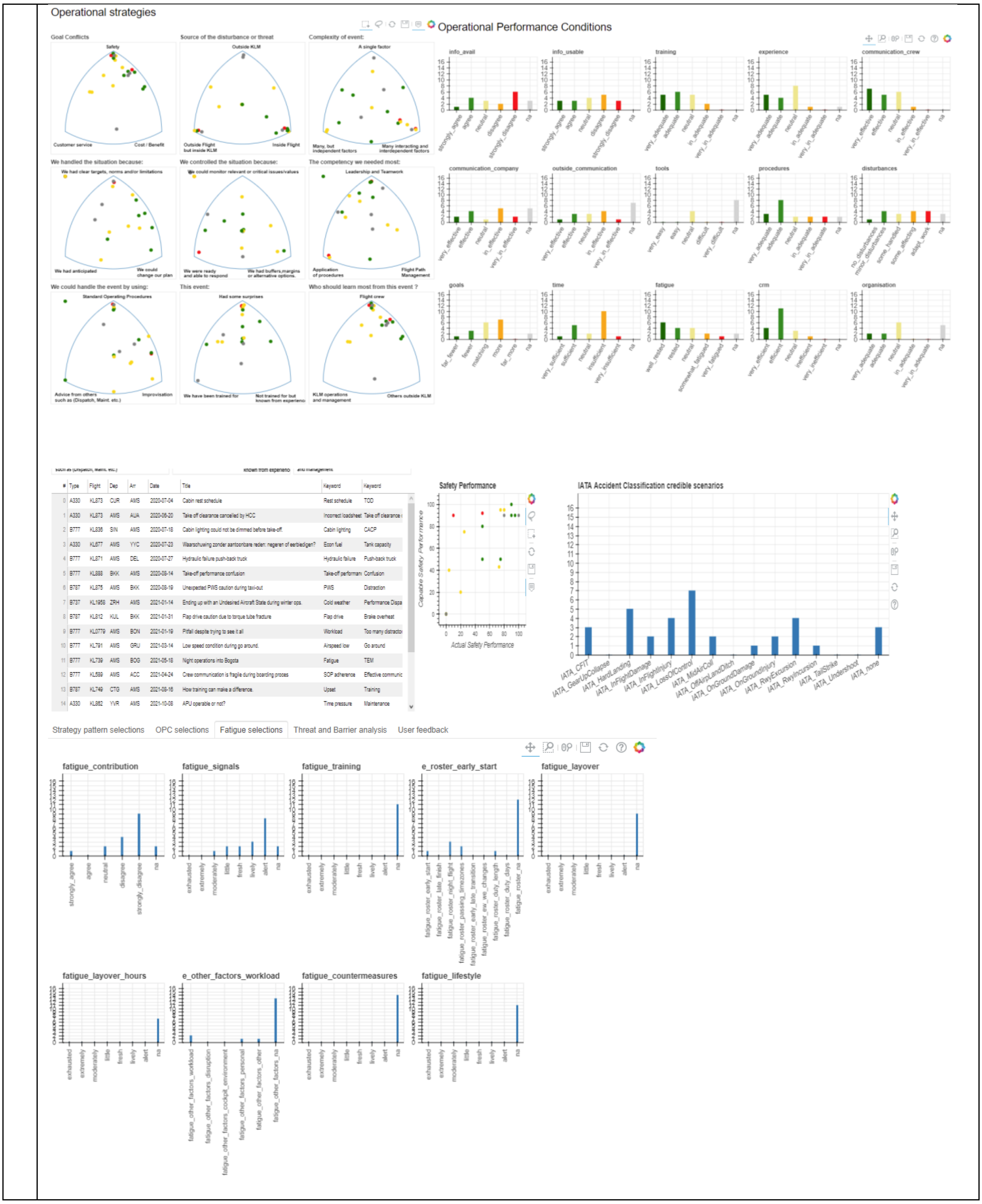
A more advanced dashboard can be built. The design of an analysis tool, the analysis processes, and the analysts will determine the extent to which insights can be gained from the available data. This example is illustrative of the information potential of FlightStory.

The FlightStory project aims to test and evaluate how operational feedback can improve some different learning processes. FlightStory supports learning processes for four stakeholders; flight crew, flight crew training, Organisational KLM (Flight Operations) Management Team, and Safety Management System. The current operational feedback channels are ASR 1.0, Trip Report (TR) and Flight Data Monitoring (FDM). These reports are sent to different parts of the organisation and are not connected. A flight crew filing an ASR is sometimes requested and willing to share a 'Share your Experience' article in the NewsApp. Unlike FlightStory, no guidelines are provided to the flight crew to include specific elements in the Share Your Experience story. Trip reports are never shared and only read by the receiving department.

An evaluation of the FlightStory project will indicate relevant data elements that could be added to the current ASR 1.0 to develop ASR 2.0.

Your answers will help identify the relevant distinctions between current (automatic system) reporting (ASR 1.0, TR, FDM) and FlightStory.




Operational strategies
Operational Performance Conditions
Goal Conflicts
Source of the disturbance or threat
Complexity of event:
We handled the situation because:
We controlled the situation because:
The competency we needed most:
We could handle the event by using:
This event:
Who should learn most from this event ?
Safety Performance
IATA Accident Classification credible scenarios
Strategy pattern selections
OPC selections
Fatigue selections
Threat and Barrier analysis
User feedback
fatigue_contribution
fatigue_signals
fatigue_training
e_roster_early_start
fatigue_layover
fatigue_layover_hours
e_other_factors_workload
fatigue_countermeasures
fatigue_lifestyle

#	Flight	Dep	Arr	Date	Title	Story	CFIT	GearUp	HardLand	IFltDam	IFltInjur	ILOC	MidAir	OffAirp	GndDam	GndInjur	RwyExc	RwyInc	TailStr	UnderSht	None
0	KL873	CUR	AMS	2020-07-04	Cabin rest schedule	Onze SP heeft bijgevoegde	0	0	0	0	on	0	0	0	0	0	0	0	0	0	0
1	KL873	AMS	AUA	2020-06-20	Take off clearance	The flight crew was on board,	on	0	0	0	0	on	on	0	0	0	0	on	0	0	0
2	KL836	SIN	AMS	2020-07-18	Cabin lighting could not be	Description: During taxi SP	0	0	0	0	0	0	0	0	0	on	0	0	0	0	0
3	KL677	AMS	YYC	2020-07-23	Waarschuwing zonder	Lekker naar YYC, in m'n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	on
4	KL871	AMS	DEL	2020-07-27	Hydraulic failure push-	Just before completing the	0	0	0	0	0	0	0	0	on	0	0	0	0	0	0
5	KL888	BKK	AMS	2020-08-14	Take-off performance	Technical stop for crew	0	0	0	0	0	0	0	0	0	0	on	0	0	0	0
6	KL875	AMS	BKK	2020-08-19	Unexpected PWS caution	Tijdens taxi-out op twy A	0	0	0	0	0	on	0	0	0	0	0	0	0	0	0
7	KL1958	ZRH	AMS	2021-01-14	Ending up with an Undesired	Today was day 3 and it	0	0	0	0	0	0	0	0	0	0	on	0	0	0	0
8	KL812	KUL	BKK	2021-01-31	Flap drive caution due to	This day we were bound for	0	0	on	0	0	0	0	0	0	0	on	0	0	0	0
9	KL0779	AMS	BON	2021-01-19	Pitfall despite trying to see it	When we arrived in the	0	0	0	0	0	0	0	0	0	0	0	0	0	0	on
10	KL791	AMS	GRU	2021-03-14	Low speed condition	Observed from the jumpseat	on	0	0	0	0	on	0	0	0	0	0	0	0	0	0
11	KL739	AMS	BOG	2021-05-18	Night operations into	When approaching	on	0	on	on	on	on	on	0	0	0	0	0	0	0	0
12	KL589	AMS	ACC	2021-04-24	Crew communication	During boarding	0	0	0	0	0	0	0	0	0	on	0	0	0	0	0
13	KL749	CTG	AMS	2021-08-16	How training can make a	Just before leaving	0	0	0	0	on	on	0	0	0	0	0	0	0	0	0
14	KL862	YVR	AMS	2021-10-08	APU operable or not?	During pushback and	0	0	0	0	0	0	0	0	0	0	0	0	0	0	on
15	KL1776	HAM	AMS	2021-10-13	Dispatch de-icing limitation	Aircraft was dispatched to	0	0	on	0	0	on	0	0	0	0	0	0	0	0	0
16	KL791	AMS	GRU	2021-10-12	Unpredictable GRU	Approaching São Paulo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	KL1511	AMS	VLC	2021-10-17	Suboptimal follow-up of	During flight encountered	0	0	on	0	on	on	0	0	0	0	on	0	0	0	0
18	KL1131	AMS	CPH	2021-10-28	Air turn back to AMS due to	Flight to CPH was the 3rd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	KL0677	AMS	YYC	2021-10-15	Oven smoke in cabin	Share your experience,	0	0	on	on	0	0	0	0	0	0	0	0	0	0	0

Threat 1: Barriers, barrier performance and remarks

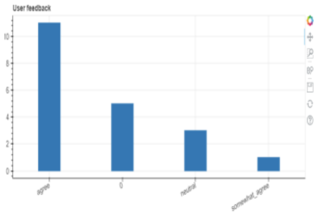
#	Threat 1	Barrier 1	Bar 1 perf	Bar 1 remark	Barrier 2	Bar 2 perf	Bar 2 remark	Barrier 3	Bar 3 perf	Bar 3 remark
0	Cabin crew being mer	SOP	not_available	No SOP describes unt	Cockpit crew	not_effective	We have no guideline:			
1	Incorrect fuel distribu	SOP: adjusted Loadsh	not_effective	Incorrect adherence tc	SOP Fueling by maint	not_effective	No entry in AML			
2	More time needed dur	Make CA aware and g	effective		P and SP with effectiv	effective		Hardly any passenger	effective	
3	Fuel spillage?	Ready knowledge	not_available	Bij geen van de drie vl	Dispatch	reduced	Kon in eerste instantie	Fuel operator	effective	Kwam in de cockpit ne
4	Engine shut down afte	Normal operation durir	effective		Crew cooperation	effective	Discussing all steps ta			

Threat 2: Barriers, barrier performance and remarks

#	Threat 2	Barrier 1	Bar 1 perf	Bar 1 remark	Barrier 2	Bar 2 perf	Bar 2 remark	Barrier 3	Bar 3 perf	Bar 3 remark
0	Not enough Cabin sta	SOP	not_available	There is an ABC proce	Cockpit crew	not_effective	There are no guideline			
1	Extra input during high	Crew	effective		HCC	not_effective	Should not have interv	ATC	not_effective	Should not have put o
2										
3										
4	Taxi through hydraulic	Push-back driver infor	reduced	Ground operations ser						

Threat 3: Barriers, barrier performance and remarks'

#	Threat 3	Barrier 1	Bar 1 perf	Bar 1 remark	Barrier 2	Bar 2 perf	Bar 2 remark	Barrier 3	Bar 3 perf	Bar 3 remark
0	Unawareness of geog	SOP (cruise briefing, a	not_available		Cockpit crew	not_available	This is not a part of ou			
1										
2										
3										
4										



#	Learning	form_ver	Flight	Keyword	Learning	Remark Learning	Not like form	Like form
6	Als er in de nabije toekomst een groot aantal	8	KL875	PWS	agree	Over safety kunnen we het niet genoeg hebben.	Het is uitgebreid	Het is uitgebreid
7		8	KL1958	Cold weather	neutral	I haven't read the other events yet.		
8		8	KL812	Flap drive	0		Too long. Very extensive	
9	Succes met dit project!	8	KL0779	Workload	agree	I always learn from other incidents. Even the ones I see on aircrash-investigation.	Takes quite some time	
10	made this on PC. couldn't send it. Had to copy/paste	8	KL791	Airspeed low	0		It's so comprehensive and thorough from a safety department point of view, that for a operator's (pilot) perspective it's not obvious and time consuming to fill out.	It's very comprehensive
11	Super Arthur. De naam van de ISSO staat nog op	8	KL739	Fatigue	agree	I have not read any flightstories, as i was unaware that i could find them in mplist	It is very long, takes a lot of time to fill out properly. motivation to be accurate suffers. Shortening form could lead to more accurate answers.	
12	None	8	KL589	SOP adherence	0	None	None	None
13	0	7	KL749	Upset	agree	0	0	0
14	0	7	KL862	Time pressure	agree	0	It takes a lot of time to write and fill in.	Think it may help the system become more productive
15	0	7	KL1776	Conflicting Goals	agree	0	0	0
16	0	7	KL791	Fuel	0	0	0	0
17	0	7	KL1511	weather radar	agree	Crew perspective on out-of-the-ordinary situations helps increasing own knowledge and improving future response to comparable situations.	0	0
18	0	7	KL1131	Pressurization	agree	It's interesting to read and learn from mistakes made by colleagues.	Too many ways for reporting and ideally there should only 1 form/app. I understand this is a trial but I think that the current way for ASR reporting should be amended and we don't need an entire new reporting form. This Flightstory is a bit too extensive/takes too much time and therefor, in my opinion,	So others can maybe benefit of our lessons learned.
19	NaN	7	KL0677	Smoke	agree	NaN	NaN	NaN

	Please make sure you have read the introduction at the top of the document.
1	Statement: **FlightStory collects 'warm' (human) rich data that provides insight into the sensemaking of the pilots and how they viewed and understood the interdependencies between event facts to provide a systems view of the event** **more effective than ASR 1.0, TR and FDM.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

2

Statement:

FlightStory offers suggestions, free text keywords and personal lessons learned, supporting the pilot to tell his story in such a way that others can learn from it,
more effective than ASR 1.0, TR and FDM.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

3

Statement:

FlightStory supports the pilot to give his judgement about Operational Performance Conditions more effective than ASR 1.0, TR and FDM.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

4

Statement:

The feedback about the quality of the Operational Performance Conditions is very relevant for my role in Flight Operations.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

5

Statement:

The feedback about the Operational Strategies (TriArcs) is very relevant for my role in Flight Operations.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

6

Statement:

By sharing (via mPilot) the stories and lessons learned, FlightStory provides *<u>learning opportunities</u>* for other PILOTS from operational events
more effective than ASR 1.0, TR and FDM.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

7

Statement:

By filling out the questions (such as the story, the critical events, the lessons learned, the operational strategies (TriArcs), the Performance Conditions) in a FlightStory, the submitting pilot(s) are supported *<u>in taking a reflective view on their own performance, enhancing their own learning process</u>*
more effectively than ASR 1.0, TR and FDM.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

8

Statement: If you are not a training expert, please give your opinion based on your knowledge of the work of training experts.

FlightStory provides the data for training experts to *<u>find learning opportunities</u>* for PILOT TRAINING
more effective than ASR 1.0, TR and FDM.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

9

Statement:

FlightStory provides the data for Business Pilots Safety and supports Flight Operations Management *<u>in improving flight operations</u>*
more effective than ASR 1.0, TR and FDM.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

10 Statement: If you are not a RA or SC, please give your opinion based on your knowledge of the work of safety experts.
FlightStory provides data for risk analysts, safety consultants, and Safety Management System processes *to learn more from operational events*
than can be learned from ASR 1.0, TR and FDM data.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

11 Statement:
FlightStory provides the data items for Flight Operations Managers as well as for other Managers of operational departments *to learn from operational events*
more than ASR 1.0, TR and FDM data.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

12 Statement:
FlightStory provides more *actionable* data, for Flight Operations Managers as well as for other Managers of operational departments
than ASR 1.0, TR and FDM data. Actionable data provides immediate and specific insight and guides decision making and can be acted upon.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

13 Statement:
We should implement the lessons from the FlightStory project in e.g. ASR 2.0.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Explanation:

Please provide any remark you find relevant for this project:

- I like…

-I don't like…

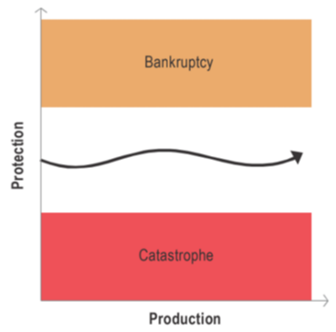
-Other:

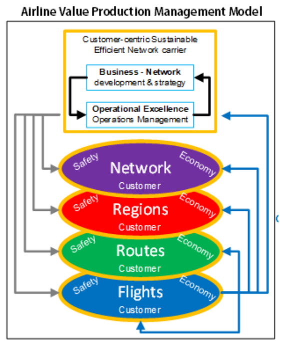
11.5 AVPMM Focus group survey results

11.5.1 1. ICAO versus AVPMM

Please provide your judgement on the following statement:

The three variables, safety economy and customer as in the Value Production Model provide us as an airline more guidance in managing our activities than the ICAO two variables Production-Protection model.





Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
7	1,2,6,4,5	3		

Please explain your answer:

1: In the context of making Network decisions I regard the customer as part of economy. The interests of customers have been translated into financial measures. An example is the calculation of the expected market share based on the attractiveness and amount of connections between 2 stations taking the Networks of competitors into account. Another example is loss of value due to a lowered repurchasing intention when a customer has a delay or cancellation.

The customer experience is highly driven by the booking process, airport process and the flight itself. Also important is how customers are being helped when they have questions, demands or disturbances in any of the processes.

So the “agree” is a combination of “disagree” in the Network context and “strongly agree” in the FlightStory” context.

2: I think the purpose of the two models differ. As stated above the ICAO model expresses the concept that production and protection should be in balance and that leaning too much towards one side, will cause problems.

The AVPMM model also shows that both production and safety add value and do not have to be contradictory. I am not sure if the extra variable, customer, makes a big difference. The customer perspective can also be expressed in the Economy value.

The AVPMM does give more guidance, because the value parameters are always shown as integrated values that do not have to be contradicting to each other.

The AVPMM model also gives the possibility to zoom into a more detailed level.

A point that I still find difficult is in what metric the value is expressed as the value of Safety and Economy are aggregated. It does give the impression that the model could steer to more value loss due to safety, if the Economy gain is large enough. This is not the way we should make a flight schedule.

In relation to the statement: safety is seen as TRUE or FALSE: I think that to the Network department it is clear that safety is a risk with a distribution. However, the safety experts should make the call if the risk is acceptable, and if accepted, it is possible to plan the flight.

3: Of course I am very positive and much in favor of adding CX as a separate element, but for simplicity you could also argue that CX is part of the Revenue/Economy side (versus Safety as a 'cost' on the other side of the trade-offs). The customer experience is (or otherwise should be) taken into account in network planning and day-to-day operations (such as is the case taking into account the loss of loyalty and future value in the case of delays – any operational/flight disruption leading to a loss of CX thus also leads to a loss of revenue/economy. In that sense, it would make sense to combine CX into Economy. However, while as a company we luckily have so much emphasis on CX (through NPS), it also does make sense to keep it as a separate element. For sure in the FightStory feedback tool, I am very much in favor of adding a standrad element on the impact the disruption/issue had on the customer, as a mandatory part of the feedback, to create maximum awareness of the fact that all that we do has an impact on the customer experience and therefor (future) revenue.

As mentioned during the meeting, I think that the ICAO model is a bit of a conceptual macro model, while the AVPPM-model is more of a micro model to manage incidents on individual case level.

PS also in the new model, safety should of course always be paramount, while the customer and economy are needed to remain in business in the longer run. And they surely go hand-in-hand, as also the customer will be very happy and more be inclined to book more with KLM, knowing that we are the safest airline in Europe and the number 2 globally, according to this recent study I am sure you're aware of.

4: To identify the customer as a separate key variable makes the model more complete.

5: In theory you would have more ability for manoeuvrable with a three variables in a model (economy, safety and customer) vs. two variable in the ICAO model Catastrophe (safety) and Bankruptcy (economy). But in practice it is extremely difficult to design value which is able to multiple KPI's. Even within one domain it is already extremely difficult (e.g. within economy on how to treat tensions between long en short term benefits). The model is more complete but more cumbersome in practice.

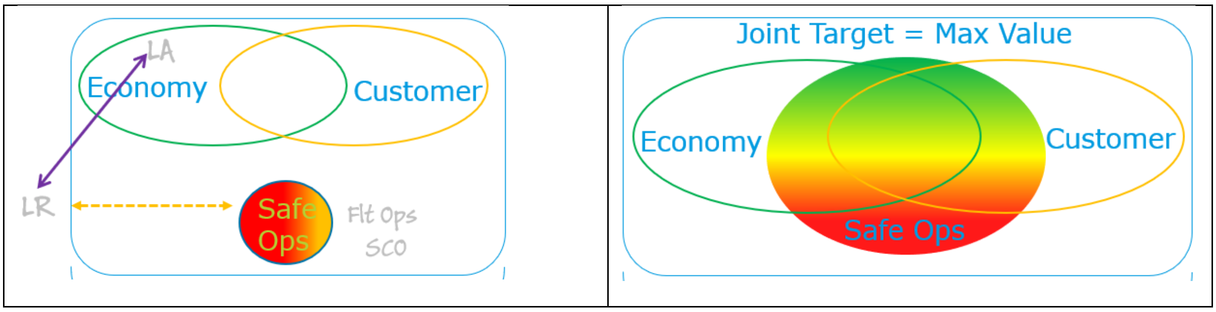
6: The AVPMM provides the industry with more tangible controls to judge their product. The industry agrees one of the key components is safety. Despite this position, up to now, safety has not really been an integrated parameter in the day to day decision making but was merely experienced and handled as a burden that could not be neglected. In this model is made readily available and easy to use to run the business.

7: It is relatively easy to come up with examples where production – protection provides insufficient resolution for decision making. Within the protection container and within production container effects may be present that need balancing as well. By lumping it all together these differences that matter for decision making get out-of-focus. As an example, production includes the effects on economy and the effects on customer experience, however these interests are not necessarily aligned. The safety, economy, customer variables seem an excellent high level categorisation where each variable can easily be refined further, when deemed necessary, to provide more context.

11.5.2 2. Safety as sub-system versus safety as aspect system

Please provide your judgement on the following statements:

The current practices resemble more safety as sub-system approach (left picture) where safety is treated as binary (safe or not-safe) than safety as an aspect where safety is more nuanced and completely integrated (right picture).



Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1,3,6,7	2,4, 5		5	

Please explain your answer:

1: Network Planners and Schedule Development Planners have well organised direct contacts with fellow workers from many other departments to shape KLM's Network. Safety experts are not amongst these direct contacts, 2 or 3 "middlemen" are common. As a result the knowledge of the background of safety restrictions is limited.

The known safety restrictions at the moment are simple rules with little background or nuances.

I would like to add from personal experience an observation of attitudes that I believe results from separating the column safety and Network.

The attitude towards more in dept investigation of potential gains has been “let the other party put in the work first”. An example is the route UIO-GYE which has a daylight restriction in order for flight crew to spot any volcanic activity along the route. Ecuador has significantly improved it’s monitoring system of volcanic activity and discontinuing the daylight restriction might be possible. This would allow the UIO-GYE operation to move to a later bank and thus increase the amount of European connections. The commercial department has been pushing to lift the restriction first before an in dept investigation of the financial gain would be conducted, the safety department has been pushing to calculate the financial gain first before lifting the daylight restriction would be investigated. It took quite some time of negotiating to brake the grid lock and get both sides moving in parallel. (outcome: daylight restriction can be lifted but that is not being actively managed because commercial in depth calculations showed no additional value)

2: In the current situation, a schedule is proposed and is tested on feasibility (“maakbaarheid”). In general this is a closed question: YES or NO. In case of not feasible, it is investigated what the issues are and what possible solutions are available.

To what the commercial interest is of a flight, is in general not expressed in the request for feasibility. I am also not sure if this is needed. There should also be trust that the request for feasibility is based on a valid business case.

I do believe that more communication and mutual understanding can help to reach a better outcome.

3: Fully agree to the fact that safety is apparently treated as a binary variable today, based on the discussions I heard in the meeting (I cannot judge from my own experience, so have to limit myself to the examples discussed and practices explained in the meeting).

Bottom-line my conclusion was that the key tension is between Commercial (revenue, economy) versus Operation (operational feasibility and safety). Within Network, this tension seems to be known and seems to be addressed by having LA (commercial/economy side) in the same Network department as LR (feasibility / ‘maakbaarheid’ of the schedule). Being under the same department and discussing/negotiating between these fields of tension, seems to give room for nuanced views and shades of grey at both sides (the probabilities and risk distributions mentioned in the meeting), leading to a common outcome that is acceptable to both ‘parties’/sides. Basically, they seem to come to an ALARP solution. To me, this seems a great way to manage the (good and healthy) tension between the 2 sides of the coin (commercial interest versus operational and safety feasibility).

However, there seems not to be such a dialogue between Network (LA + LR combined outcome) with Safety. Moreover, it seems that the outcome of the LA-LR discussion is given to Safety with the question whether the proposal is considered 'safe' or not. Which is a binary question, resulting in a binary answer. Instead, if the same structure and process would be in place between Network and Safety as it is between LA and LR, the discussion would be far more fruitful. It would create more reciprocal understanding and a culture of collectively looking for an optimal solution, taking into account all elements concerned (which is the basic idea of the AVPPM-model, in my understanding).

So the solution seems to be not so much in applying a new model, but rather in applying new processes and better collaboration between the commercial & planning side with the operational & safety side.

(As an example, we discussed that during day-of-operations, you do normally not experience the problems we discussed during the group discussion. I then made the link to the OCC where all disciplines are under 1 roof and discussing in real-time the various trade-offs when decisions have to be made about the flight in the last 24 hours before and during operations – including the TFM model taking into account the (cost of) negative customer experience & loyalty. A similar structure and collaboration seems to be valuable also when making the longer-term flight schedule and network plan).

4: Based on the exchange in the meeting, it seems as a company we have room to improve the interaction between departments and move from left pic to right pic.

5: I see the added value of having safety measured as a risk distribution (but with a minimal level) instead of a binary system. Incorporating it in network decisions could also create extra benefits. I would not integrate it fully within economical based KPI's. For me the safety performance should be as transparent as possible in order to improve the safety standards also as much as possible. Safety could be valued in my opinion the best against risk distribution of other events. I would not try to trade off a risk distribution of an event vs. a more "grey" economical valuations of the same event (e.g. future sales because of NPS and or strategic positioning). At last, the economical value would be more confidential than the risk distribution of the event in my opinion and this will result in less transparency within the risk distribution. It be positive but also but the integration or trade-off should be limited, therefor two answers.

6: The AVPMM provides the industry with more tangible controls to judge their product. The industry agrees one of the key components is safety. Despite this position, up to now, safety has not really been an integrated parameter in the day to day decision making but was merely experienced and handled as a burden that could not be neglected. In this model is made readily available and easy to use to run the business.

7: Joint sessions are rarely taking place. Mitigation Action Plans (MAP) are typically provided by the process owner, with follow-on judgment by the Safety Department and/or final decision by Safety Action Groups. The current situation is a direct consequence of enforcing an independent role as Safety Department and avoiding any responsibility for decisions taken. The result is less involvement of the Safety Department in developing a MAP, but the same might be said for other business concerns, not directly under control of the process owner. As any mathematician knowns, all sub-optimizations are at best equal to the total optimization, but this is rarely the case. There is no contradiction between taking no responsibility for the final decision while at the same time contributing to an optimal solution and therefore participating in brainstorming on possible mitigations, etc. After all, the outcome will be judged by the Safety Department and exchanging information from a safety or risk perspective, will most likely result in better tuned solutions.

11.5.3 3. Safety as aspect of Network Performance Management

Please provide your judgement on the following statement:

When safety is added as a criterium to Network Performance some network decisions become more informed.

E.g., opening and closure of stations, routes and schedule changes.

See the video showing a proposal for a value production view on network management.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No judgement
6,7	1,4,5	2			3

Please explain your answer:

1: If there are relatively high safety risks these can be factored into the discussion.

In recent months we have seen that this also works the other way around. “When economy is added as a criterium to Safety considerations some safety decisions become more informed.”

This applies to the closing of Afghan airspace after the Taliban took over the country. Routes over Afghanistan, Iran and Iraq have been thoroughly investigated to see if they could be re-opened to boost the value of routes to India and the far east.

2: I think that safety is part of the Network Performance. The background of the network decisions and the safety risks could be shared more.

3: Hard to judge from my expertise. Moreover, this question asks about adding safety to network considerations only, and not vice versa. As explained with the previous question, I do see the solution in better mutual understanding and collaboration, with the exchange of the benefits and costs of the various options, to come to the best overall solution, taking into account all 3 elements (S, E, C).

As an illustration: during the meeting a specific case was discussed, where the answer from safety was that if they knew better what the revenue benefits were of a certain proposal, they could maybe re-assess their safety answer and be a bit more lenient towards the commercial side. (I don't recall exactly the specific case, but I found it an extremely insightful short discussion, highlighting where the real problem is and how (relatively easily) this could be solved by asking better questions and providing more nuanced answers, ideally by exchanging and communicating with each other in a better way).

4: In some cases, like Entebbe bird issues, thorough analysis would have brought a better decision. Balance is important however to prevent overanalysing and unnecessary delays in execution / competitive developments.

5: Yes, I agree in case risk distribution is more integrated in network decisions it would create a more complete picture. As an example, hot & high stations. Here operational performance (not directly risk distribution but at least link to safety measures) is directly linked to economic performance of a flight. E.g. The time of day operation on MEX has a consequence for the maximum allowable payload.

6: What is important though that the presentation, meeting and movie focus merely on the Safety component. Understandable regarding the background of the composer of the model. Still I feel it should be very helpful to create support for the model, also examples are presented where eg safety is not an issue but economy or customer satisfaction are an issue. The way it is now presented to the future users might fuel the opinion of key players active in Network or Customer satisfaction the model is merely there to 'push in' safety. I suggest you provide three cases with which you prove by using the tool a useful collaboration and process evolves resulting in an optimum result regarding the Value Production.

7: Safety is not a constant or a dichotomous outcome. Changes in network, e.g. number of flights, time of arrival, aircraft type, etc. all have an effect on safety. When safety becomes an integral part of decision making and not a true/false statement, decision making on network level will inevitably be affected as well. The ultimo outcome could be the closure of operations where the balance between safety, customer and economy is gone, e.g., when low profitability is combined with high risks. But many variants are possible, safety could be the driver for choosing between competing, but equally profitable routes, etc.

11.5.4 4. Effective handling of two cases: bird hit and fatigue

Considering:

the discussed cases EBB with a network change after 6 months.

ICN-PVG-AMS fatigue solution was not found in time.

Please provide your judgement on the following statement:

The integrated and interactive approach suggested by the Value Production Model provides a more effective and efficient method for finding conflicting issues and risk reduction options than current practices.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1,7	2,3,6,4,5	2,	5	

Please explain your answer:

1: When working closer together (safety & Network) mutual understanding and finding creative solutions will be improved and lead times will be reduced. EBB is difficult to judge as I was not involved, it seems that 6 months is a long time to come to the best solution.

For ICN-PVG-AMS there have been 2 to 3 parties in between Network and the safety organisation making it more complex for both to come to a good understanding of each other. The parties in between, such as Chef Pilots, have spent time explaining positions back and forth whilst dealing with assessing the risk themselves and coping with the workers council. An integrated meeting might have reduced the communicating and explaining and increased effective and efficient solution searching.

2: I do not know the background of the EBB network change and why it took so long. I do know that an aircraft was AOG for a long time at EBB. I am not sure if another schedule would have been taken if more information was shared beforehand.

I think the risk of Bird strikes was known, and the trade-off was made that the risk was acceptable.

After an actual bird strike, the risk for another was seen as too high. A solution was found in delaying the departure time

For the fatigue issue for the ICN-PVG-AMS, the crew working time was within the WRR limits. However, in the operation it did create fatigue issues. The schedules in China are very complex because of slots in China. I think many scenarios have been investigated. The investigation of the scenarios could be more in an integrated approach.

3: I do agree, as to the extent that the model highlights the importance of bringing the 3 elements of S, E, C more together. It should however be a two-way information exchange, bringing understanding of the ‘other’ side to all concerned. A regular (steering) meeting to discuss and decide on the planned network, where both LA, LR, Ops and Safety are participating seems to be a good way forward. In this meeting, also the feedback loop from FlightStory could be discussed to have both the longer term planning perspective in the right balance between economy, customer, feasibility and safety, as well as the day-to-day (or monthly / quarterly?) operations and experiences in practice (which will provide more robustness to the probability distribution for safety anticipated upfront, such as the birds issue in EBB).

4: Bringing Economics, Safety and Customer together, helps finding better solutions and mitigate potential risks.

5: For me the risk distribution of valuing the safety provides perfect insight of the cases. Here you can clearly see that the two example are outliers compare to all other events (flights). The value proposition model actually mitigated the two events because the economics and customer value were positive in that particular case. This is something what is not desired and beside that, it is extremely difficult to value to each other. So, there is a positive and negative side. (Note both an Agree and Disagree are indicated in the answer)

The network change on EBB, to change arrival and departure time is easier to implement than the fatigue example.

Pvd: See comments above. Both used examples result in adjustments improving safety. It is important to also demonstrate the model can highlight issues arising in the other two domains (Economy and Customer Satisfaction) and help in resolving these.

7: Only the big picture may provide adequate information on the constraints of the different variables, safety, economy and customer. Without the big picture, mitigating actions may fall outside of the constraints or may not be balanced. Many suboptimal outcomes are possible: closure of profitable operations, because the mitigations were not explored satisfactorily, or suboptimal operations from any perspective because the different interests were not properly taken into account.

11.5.5 5. Suggestion for next step in development

Please provide your judgement on the following statement:

I advise to higher management to develop a trial for a more interactive cooperation between the three aspects and network based on the Value Production Model concept.

> The purpose is to find ALARP solutions for flight, route, region or network safety issues by scanning the total 'solution space' for solutions.
> Safety issues could be indicated by being in the top of several risk ratios for a particular airport. E.g Fatigue and Diversion.
> Other benefits would be to find safety risk solutions more efficiently for commercially important flights and routes.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1,3,6,7	2,4		5	

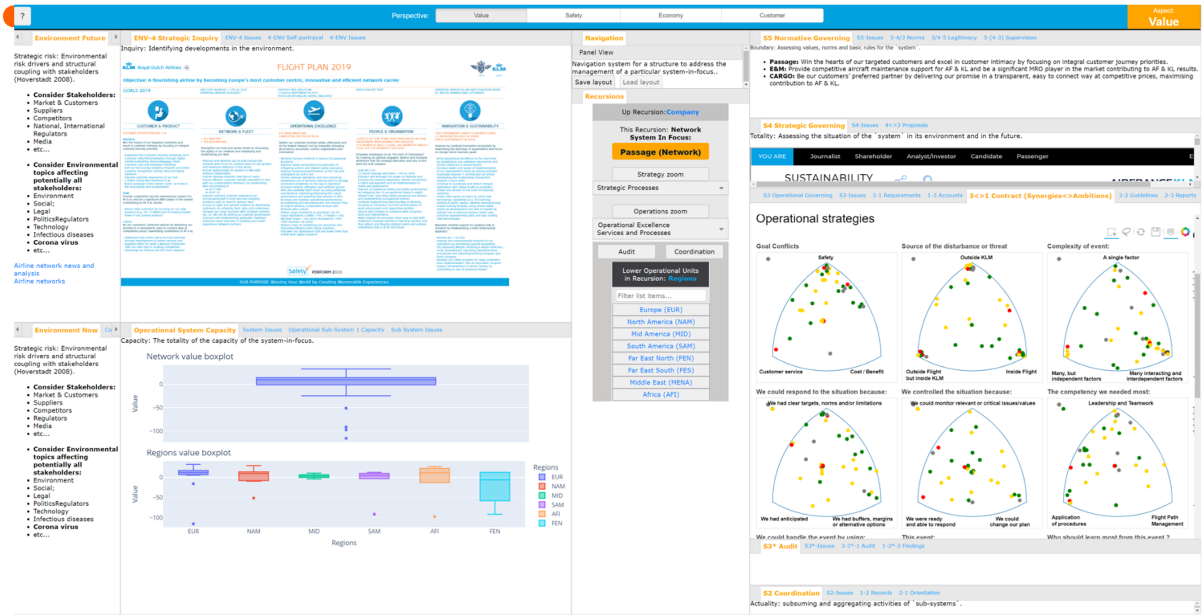
Please explain your answer:
1: For the majority of Network decisions this is probably not required. In cases where there is an increased safety risk it seems best to pro-actively organise a meeting with all stakeholders to find a solution. Representation from safety and network would be required as the model prescribes.
Depending on the nature of the safety risk and it's potential consequences representation of one or more of the following parties might be required: customer, cockpit crew, cabin crew, Schiphol, outstations, route development, dispatch, catering, operations control, cargo, Engineering and Maintenance, security services.
The benefit would be to pro-actively find better (economic, safety, customer) solutions.
2: I think there is benefit in a better cooperation and integral decision making.
3: Fully in line with my remarks so far. Mainly LA, LR and Safety (apart from planning and maybe also other operational departments which are concerned, but I am not aware of as that is not my expertise) seem to possibly gain a lot by more open and transparent exchange of each others' considerations, so that we move away from binary black-and-white questions, answers and decisions, but rather approach the network planning and execution as a whole, in an integral way.
4: Good to further explore effectiveness of this model.
5: I would not advise to trade off risk distribution directly to customer and/or economical decisions. I would advise to value safety with a risk distribution and incorporate the risk distribution within customer of economical decision as one of the elements to be weighted.
Remark: Always een win when you combine other parameters with network decisions.
6: Again, it has to be proven that all three parameters will be benefitting in increasing value (quality). The only way to finetune the model and creating support to use the model is by starting a test environment with key players from the relevant domains and let them use the model hands-on. If the result from this laboratory provides a better result than the present way of managing our network than it has reason to exist and will be embraced by management.
7: In addition to the importance of total optimization, an additional consideration here is the importance of relative indicators. For optimal decision making it is not always necessary to provide a complete assessment for all aspects involved. As an example, routes where detailed information is available on customer experience or economy and no apparent benefit of one over the other is present but that cannot be operated simultaneously, may be decided upon by providing relative information from the safety domain. Proxy indicators are particularly useful for supporting such decision making.

11.5.6 6. FlightStory synergy with AVPMM

Considering;

> The opportunity for a FlightStory is triggered when the value exchange (a safe, efficient and positive customer experience flight) is under threat from internal or external sources.
> Other flight crew reports do not include CX as a topic or trigger for reporting.
> Flight crew reporting data is not sufficient but should be complemented with other data sources and possibly new CabinStory and GroundStory data.

FlightStory data integrated with the AVPMM



Please provide your judgement on the following statement:

FlightStory supports Value Production Management by enhancing the feedback channel from actual flight operations to management.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
3,7	1,2,6,4,5			

Please explain your answer:

1: I am not familiar with the current feedback process. It seems only logical that flight crew, cabin crew and ground crew start using the same kind of feedback loop that provides at least categories for occurrences having a negative effect on economics, safety and customer experience.

Ultimately the feedback from customers themselves would be integrated as well.

2: I do agree that a good feedback loop can create better opportunities for continuous improvement.

I do find it hard to see how the Flight stories give feedback to the network design.

Incidents happen, can have negative impact on the Customer Experience or the Safety. However, the solution or mitigating action does not have to affect the schedule of the flight.

In the examples given, I see more procedures that can be adjusted and improved.

Introducing the AVPMM is maybe more an organizational change. Bringing departments closer together, enabling more transparent communications.

3: As a (CX) researcher, I am always in favour of collecting (customer) feedback, provided it is being used. A mandatory paragraph about the effect the disruption/incident had on passengers, is a great step to further enhance customer-centricity within the company.

Note: my suggestion is that the report contains qualitative feedback and remarks about the effect of the incident on the customers and their experience. Although I am in favour of providing more quantitative feedback about CX to the cockpit and/or cabin staff after each flight, we have to be careful in interpreting these results, as they are depending on many external factors that cannot be influenced but should be taken into consideration when interpreting (e.g. cultural differences leading to very different scores for exactly the same flight/experience between various nationalities; same for other factors like travel motives, etc. Secondly, be aware that NPS-scores per flight are based on a very small sample of people who are invited and answer the survey (by design, to avoid an overload of survey invitations, e.g. in case of a return flight with a connection within a few days – in that case, a customer will only be invited for 1 singe stretch only and not about the others, to avoid an overload of invitations).

4: Feedback loops are very relevant to improve (safety) processes, customer experience and increase our company value.

5: A flight story report would in opinion increase the transparency and the feedback between the different stakeholder. I would only remove the economical part from the model to be able to distribute it widely between all stakeholders.

6: Still it shall be user-friendly and minimum time consuming and if possible fun for the employees providing data into flight story. Paramount is also that the contributor receive preferably instant feedback on the effects or follow-up on his input.

7: When taking the importance of optimization over the three variables, safety, economy and customer as a given. It makes sense to provide a feedback mechanism that reports on the conflicts between the three from an operational perspective. Any back-office decision making (work-as-imagined) should be challenged by feedback from the real world (work-as-done). Current reporting mechanism are barely capable of addressing organizational issues that drive the various business concerns and are at best capturing superficial effects at the outcome level. In any complex system, feedback on operational performance conditions is essential and in my personal opinion significantly more important than long-term aggregated data, where the current focus lies and exemplified by airline rankings, high level safety reviews on accident categories, etc. The main opportunity for management to make a difference, is at optimizing the operational performance conditions, yet no effective feedback system exists today.

Respondent	Aspect	Department	Years in KLM	Years in relevant departments
1	Netw	Network Schedule	20	4
2	Netw	Network Schedule	22	6
3	CX	Customer & Market Insight	23	12
4	CX	Customer & Market Insight	20	3
5	E	Network commercial	11	7
6	S	Flight Operations and Safety	31	7
7	S	Safety	25	10

Chapter 12: Bibliography

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12.2 Relevant abbreviations

ASR	Air Safety Reports
ATC	Air Traffic Control
AVPMM	Airline Value Production Management Model
CAA	Civil Aviation Authorities
CRM	Crew Resource Management
CSR	Corporate Social Responsibility
EASA	European Aviation Safety Agency
ETOPS	Extended-range Twin-engine Operational Performance Standards
FAA	Federal Aviation Authority
FDM	Flight Data Monitoring
GPDR	European Data Protection Regulation
IATA	International Aviation Transport Association
ICAO	International Civil Aviation Organisation
IOSA	IATA Operational Safety Audit
JAA	Joint Aviation Authority
KLM	Koninklijke Luchtvaart Maatschappij
LOSA	Line Oriented Safety Audit
MCC	Maintenance Control Center
NAA	National Aviation Authorities
OCC	Operations Control Center
OPC	Operational Performance Conditions
OSH	Occupational Safety and Health
QMS	Quality Management System
SMM	Safety Management Manual
SMS	Safety Management System
TEM	Threat and Error Management
TR	Trip Report
WAD	Work As Done
WAI	Work As Imagined
WoS	Web of Science

12.3 List of figures

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Curriculum Vitae

Personalia:

Name:	Arthur Dijkstra
Title	MSc Master Human Factors
Address	Kooikerboog 7 1394 ND Nederhorst den Berg
Date of birth:	December 12th 1962
Civil status:	Married, 2 children
Retired:	KLM Captain B777 / B787
Active:	Human Factors and (Safety) Management system consultant
Contact:	arthur@admc.pro
LinkedIn:	https://www.linkedin.com/in/arthur-dijkstra-0ab1224/

Education:

- High school:
- VWO (Pre-university education) Pilot education:
- 1982-1984 Dutch Civil Aviation Flying School (former KLM Flight academy)
- Bachelor degree: Linkoping University Sweden 2003 – 2004 Högskole examen Ergonomics
- Master degree: Linkoping University Sweden 2003 – 2005 Human Factors

Professional education and functions:

- Pilot type rating training at KLM: DC9, B747-300, B747-400, A310, B767, B777, B787
  - Captain at A310, B767, B777, B787. 15000 Flight hours.
- Crew Management Courses (CRM) initial and advanced (1990)
  - CRM training consists of theoretical education on human and group behaviour and workshop exercises to apply this theory.
- Basic Instructor Training and Advanced Instructor Training (1992)
  - Instructor training: learning process, people personalities and attitudes, communication techniques for e.g. feedback and coaching as well as rating non-technical behaviour.
- Train The Trainer (1999)
  - This is about instructor training and coaching other instructors. Course content is extending the other instructor courses and going deeper and wider in theories for communication, human behaviour and teaching methods.
- (Senior) Type Rating Instructor (1999-2005)
  - Based on experience and skill I trained and checked other instructors and replaced the Training Manager on training issues.
- Senior Type Rating Examiner (1999-2005)
  - Checking pilots and instructors on their performance as required by the JAR regulations.
- KLM Flight Safety Investigator (2005 - 2016)
  - Training for incident investigator.
  - Working at flight safety department as an investigator.
  - Advisor on human factors and risk assessment.
- KLM Senior Safety Consultant (2016 – present)
  - Development of Safety Management System.
- Member Executive Committee Resilience Engineering Association (2010-2017)
- Flight safety researcher (2005 – present)
  - Developing a new Safety Management Systems Representing KLM in safety-related projects.
- Owner of Dijkstra Management Consultancy (2010-present)
  - Human Factors and (safety) management systems

My KLM research journey

I started flying for KLM in 1985. I flew DC-9, B747-300, B747-400, A310, B767, B777 and B787. In total, I flew 15.000 hours. Furthermore, I also was flight instructor and examiner for 16 years after which I worked in the safety department for 18 years.

In 2005, just after I finished my Master's study with Sidney Dekker, I started as a Human Factor expert and incident investigator in the safety department of the Flight Operations department. Shortly thereafter, I was privileged to be introduced to the KLM CEO, Peter Hartman. Dries Blommers, an advisor to the CEO, had agreed with him to discuss a possible PhD research supported by KLM by an active operational flight crew with an academic background. I just happened to be part of the first Resilience Engineering meeting in Söderköping and therefore I proposed to the CEO a topic which included Resilience. In consultation with my possible promoter, Andrew Hale, I had framed my research proposal as 'connecting pro-active and re-active safety management using Resilience Engineering concepts'. He agreed and asked how much time the project would take. Based on the advice from Professor Hale, I proposed to start with 5 years and a third of my time for research. With this proposal, he referred me to the Executive Vice President of the Flight Operations department who I had to convince myself and to discuss a possible working agreement. We quickly came to an agreement and I could register myself with Andrew Hale as a promoter at the TU Delft. Sidney Dekker and Erik Hollnagel were willing to be my co-promotors. I was very lucky to have such an esteemed academic dream team. Inside the KLM, I had no direct sponsors, ambassadors or research supporters. luckily, a few managers at key positions had a positive attitude to me and my research.

The former CEO Hartman once said to me you should work in the strategy and innovation department because your research is outgrowing your position in the safety management of flight operations. He was correct, but my attempt to reach out to that department got an organisational politics aspect and was blocked. After the CEO delegated my research support one level down, the research support was cancelled and the project was declared failed.

My ambition and drive could not be stopped. Since 2010, I didn't get research time from the company and I spent most of my time en route during layover working on my research projects. I could exercise my research hobby next to my role as a flight crew and safety consultant. The development and programming of the AVPMM model and FlightStory took me years and were huge learning processes, but I was fortunate to get help from some friends. During all those years, I enjoyed the synergy between the three roles of captain, safety consultant and researcher.

I was loosely connected to the implementation of the regulatory-required SMS. The mapping between the SMS and organisational roles and responsibilities of the SMS has been a constant challenge. Much emphasis was put on these processes and less attention was paid to the development of safety management knowledge and theory. It was often difficult to connect with safety and flight operations managers because my topics were very theory loaded and many managers had very minimal theoretical safety management knowledge. Also, they had always very little time for meetings to discuss topics not directly related to actual operational issues. Additionally, I have always been very reluctant to dumb things down or to over-simplify. The 60 seconds elevator pitch summary is what I have been practising but was difficult for me. It took years to be able to make it very simple. One reason was that I was alone in the company working on my projects and only a few colleagues were interested and took the time to engage with me and the developing ideas. Also, I had few academic encounters. The few times I was at the University talking about my research the academics respected my domain knowledge and were probably therefore reluctant to challenge the safety scientific concepts.

KLM's safety ambition provided opportunities for SMS developments. Because of my research activities and growing safety and management science knowledge, I have been a driving force in two projects. One is the development of the bowtie model and the other is the development of a risk management and strategy framework. Both are developments beyond compliance, approved by the COO, and provide a compatible basis for the next steps forward. A short description of the projects is provided in Chapter 9.

It took me 5 years to get FlightStory operational and available for flight crew. In that period, I had to navigate requirements and constraints from the safety management and flight operations department and the flight crew union. In this period, managers changed positions, opinions changed, and the organisation got restructured. With the support of a few managers that have been supportive all the years, I could get the project live.

With the support of the VP Safety and compliance, the KLM COO got involved and he wrote a supportive email to heads of the network and customer experience departments to support my AVPMM research project.

I was thrilled to conduct the experiments inside KLM with the cooperation of other KLM employees, both as participants and survey respondents. I am grateful for the time and energy all the respondents have put into the projects.

This project lasted about 18 years and has taught me a lot besides the academic aspects. It was an adventure to develop new concepts and try them in a real word setting. My KLM career from flight crew instructor to safety consultant, from co-pilot to captain and from novice to PhD was fantastic, and this thesis is my last deliverable in this respect.

Acknowledgements

A lengthy and comprehensive research project like this one could never have been accomplished without the help of others. I have received the necessary support in various aspects and am deeply grateful to many people. I would like to extend special thanks to some of them below.

First and foremost, I would like to express my sincere gratitude to the enthusiastic and visionary Dries Blommers. His proposal for my promotion and initiating contact with KLM CEO Peter Hartman allowed this project to start. They recognised the importance of connecting operational, organisational, and scientific knowledge and they opened doors for me to begin this journey.

I am grateful to Andrew Hale and Erik Hollnagel for their support in setting up the promotion process. My supervisors Sidney Dekker and John Stoop have been invaluable in helping me persevere through this long voyage. They both have a very broad view of what a supervisor does. Their acknowledgement that this research took place in different worlds has kept me going in each one. The importance of the primary world of family life was endorsed by both, and then I was supported in understanding the scientific world of research and writing. From the beginning, their encouragement and confidence have greatly supported and touched me.

My colleagues in the safety department have continually assisted me by sharing their insights, for which I am wholeheartedly thankful. I would also like to extend my gratitude to flight operations' managers Eimerd Bult and Paul van de Ven, who helped me navigate organisational politics and created opportunities for me to present my subject to stakeholders.

Steve Brewis and Richard Dijkstra, two friends and cyberneticians, have been instrumental in the development of ideas and software. Conversations with them have strengthened my intuition and helped me to make critical distinctions. Steve, thank you for the many Skype calls that have helped me to structure the complexity of the topics.

Thomas Bos, a highly valued colleague from the safety department, has made significant contributions to operationalising concepts into a form that is relevant to KLM. Our conversations about complexity, emergence, and so forth have been extraordinarily helpful in deepening and articulating my insights. Together with Andreas Torres, he has provided essential support for the development and maintenance of the FlightStory app.

I am very appreciative of the safety and training experts for the time they have taken to answer my numerous survey questions. Your contributions were critical to research the potential of FlightStory. The KLM department experts in network development, commerce, and passenger satisfaction have my utmost gratitude for making time for my project during the busy COVID period.

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I would like to thank my father and mother for giving me the space to develop my talents and dare to dream big. I dedicate this project to my father, who, unfortunately, cannot witness the successful completion of this project. His curiosity and thirst for knowledge, which I inherited from him, have helped me reach the finish line.

Finally, I would like to thank my wonderful wife and children, the most important supporters of my life and work. All three have vivid memories of situations where my body was present, but my mind was elsewhere. Liselotte and Niels, thank you for your patience. The immeasurable support and tolerance of my fantastic wife, Nicolette, have made this project possible. I am extremely grateful to her for her support during periods of setbacks when the project threatened to stall. Nicolette, thank you very much, I love you and let us now move on.

Arthur Dijkstra **Nederhorst den Berg May 2nd 2023**

This thesis proposes the of integrating safety, economics, and passenger experience and draws on the author's research and experience in aviation to develop a more comprehensive approach to airline business management. The research closes the gap between business and Safety Management Systems in airlines by introducing two novel and complementary concepts: the Airline Value Production Management Model and FlightStory as a tool to enable pilots as intelligent feedback providers.

"Our destiny is not limited by the stars above us, for the sky is not the limit - it's just a view. Instead, it's our own determination, perseverance and friendships that allow us to soar to new heights and achieve our dreams."

TU Delft Delft University of Technology

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