FACULTY OF TECHNOLOGY, POLICY AND MANAGEMENT

The Potential of Computer Vision Technologies for the Baggage Handling Ecosystem of Hub Airports

Insights into a value proposition design process by the identification of use cases for a data-driven technology that can lead to a digital transformation of the baggage handling process

Master Thesis
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Preface

As a kid, I was inspired by the stories my father used to tell me about his work at KLM. Schiphol Airport has, therefore, always interested me. It is not only a complex environment consisting of technologies I still find difficult to understand, but it also provides joy and the excitement of traveling to other places. So, I was delighted that I got the opportunity to do my graduation thesis at Royal Schiphol Group.

When I told people about my research subject, I noticed that everyone could talk about their experiences concerning this subject. All could imagine the feeling of arriving at their holiday spot without their suitcase. This gave me even more excitement, as I was investigating a technology that might solve or minimize the problem of mishandled bags experienced by many. This excitement was lacking at the start of my thesis when I was insecure and nervous about my capabilities to perform this research. Luckily, these negative feelings quickly disappeared due to the warm environment created by my supervisors, where I could discuss everything that I wanted.

First of all, Mark de Reuver. I would like to thank you for your supervision. You gave me the confidence and energy to work hard to achieve this result. You always made time for me if I wanted to discuss something, which I am highly grateful for. Mark de Bruijne, I want to thank you for your detailed feedback, the insights on including the multi-actor perspective more, and the enthusiastic discussions we have had. Our meetings always led to an increase in motivation to continue working on it. Wirawan Agahari, we met more than a year ago to discuss my thesis plans. Even though my thesis subject changed significantly, you stayed to help me. I would like to thank you for that, and for the valuable insights you provided during the meetings that helped me bring this thesis to the next level.

And last but not least, Larissa Plink. From the moment I walked inside the Schiphol office, you made sure I felt at ease. You always motivated me, helped me tackle issues, and ensured me that everything was going well. Because of you, I felt welcome within the Innovation Hub, which provided me with a great insight into the working life I have ahead of me.

I can say that these past six months were full of ups and downs, but thanks to the support of all people from the Innovation Hub, both Marks, and Aga, it has been a rewarding experience from which I learned a lot. I hope you will enjoy reading this thesis, as I have enjoyed working on it.

Evelien van Brakel
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Executive Summary

The amount of passengers in the aviation industry is likely to grow in the coming years. This results in an increasing number of bags that need to be handled at airports, making it harder to manage and keep track of all bags. Mishandled bags have already been one of the major challenges of the aviation industry over the years. Baggage handling systems have not significantly improved in decades due to a missing urgency to change combined with the complex dependencies between actors in the industry. However, to handle the increasing amount of bags in the future, baggage handling ecosystems need to implement innovative solutions. An example of such an innovative solution is Computer Vision Technology (CVT), which uses cameras to identify bags using data and artificial intelligence. This data-driven technology requires the design of a data-driven business model (DDBM) to achieve agreements on the investments for the technology. The value of CVT for the baggage handling ecosystem needs to be known to design a DDBM, which is currently unknown. Besides this practical knowledge gap, a scientific gap is found as well. The majority of the literature on digital transformations has an organizational viewpoint and does not incorporate established ecosystem perspectives. It is unknown how a value proposition needs to be designed for a data-driven technology to lead to a digital transformation of an established ecosystem.

Following the practical knowledge gap, a research question is formulated to close this gap and be able to achieve the research objective: "To design a value proposition for baggage handling ecosystems at hub airports by identifying use cases for computer vision baggage identification technologies to provide the aviation industry a building block to further develop the required data-driven business models." A Design Science Approach (DSR) is used to answer the main research question to meet this objective, which is formulated as follow:

"What use cases can be included in the data-driven business model to capture the value proposition of implementing computer vision baggage identification technologies for hub airports?"

The DSR approach is executed in a situated setting at Schiphol Airport. First, a literature review is conducted to gain a firm understanding of existing literature on the design of a value proposition for a digital transformation within established ecosystems. Next, field research is performed to analyze the current and desired situation of the baggage handling process at Schiphol Airport, which is used as input during the ideation process of CVT use cases. The results show that the implementation of CVT provides value for Schiphol Airport, the baggage handling system provider, airlines, handlers, passengers, and society. The value proposition of CVT is the automated identification of bags based on visual images that provides thirteen use cases applicable throughout the whole baggage handling process, which leads to more autonomous processes, process improvement, the generation of more (types of) valuable data compared to the current identification techniques and can contribute to the achievement of sustainable goals if it replaces the current identification techniques. However, a dependency on other airports to implement CVT and on other actors to share required data has been identified to gain optimal value out of the implementation of CVT.

The aviation industry can use this knowledge but future research is recommended on the establishment of a real-time data sharing environment within the baggage handling ecosystem, as this is identified as highly important to gain optimal benefits from CVT. In addition, further research is recommended on the quantification of the use cases. This is needed to make agreements for the required data-driven business models to ensure CVT implementation.

The results not only contribute to the aviation industry, but the insights gained during the research are also valuable for future digital transformations within other established ecosystems. During the research, a lack of ecosystems' support for the digital transformation was identified, caused by two factors. It was found that certain process choices had a positive influence on these two factors, which inspired the formulation of process guidelines (PG):

A missing shared urgency to change:

- **PG1: Identify the current challenges and needs of the ecosystem:**

It must be indicated how the digital transformation will influence current challenges and needs to make the impact and necessity of the transformation more tangible.

- **PG2: Identify the added value of the new technology per use case:**

The added value provides the possibility to design the value proposition, which is needed to illustrate how the technology could change the current situation.

A reluctance towards the feasibility of the change:

- **PG3: Focus on the holistic perspective on the ecosystem:**

Multi-disciplinary meetings ensure that the perception of the feasibility of a DT can be improved as complexities indicated by one actor can be solved directly by other actors present.

- **PG4: Ensure that the digital transformation is seen as realistic:**

It is found of high importance that the digital transformation is seen as a realistic option to achieve more support. This support stimulates the ideation process of use cases, which is required for the value proposition design process.

These guidelines contribute to the digital transformation knowledge base as they provide insights into how to enhance ecosystems support for digital transformations. In this way, it guides future digital transformation processes within established ecosystems. Furthermore, the research provides an approach to get a grip on a complex established ecosystem and a tool to specify data-driven use cases in combination with its implications for the established ecosystem. No tool existed to accommodate that. Therefore, a tool was constructed and used, which provided guidance on the use cases' specification and could be valuable within future ideation processes of data-driven use cases for established ecosystems.

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Abbreviations

AAS: Amsterdam Airport Schiphol
API: Application Programming Interface
ASM: Asset Management
BHS: Baggage Handling System
BSM: Baggage Source Message
CI: Check-in
CISS: Central Information System Schiphol
CoSEM: Complex Systems Engineering and Management
CVT: Computer Vision Technology
DDBM: Data-Driven Business Model
DnA: Data & Analytics
DSR: Design Science Research
DT: Digital Transformation
EU: European Union
GDPR: General Data Protection Regulation
GH: Ground Handler
IATA: International Air Transport Association
IT: Information Technology
KPI: Key Performance Indicator
LPN: License Plate Number
LU: Loading Unit
MHB: Mishandled Bag
MIS: Management Information System
OSS: One-Stop Security
PG: Process Guideline
RFID: Radio-Frequency Identification
RSG: Royal Sch iphol Group
SHOCON: Short Connection
SITA: Société Internationale de Télécommunications Aéronautiques
TNO: Toegepast Natuurwetenschappelijk Onderzoek (Organization for Applied Scientific Research)
TRF: Transfer
TTT: Tail-to-Tail

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Chapter 1. Introduction

The aviation industry is expected to grow in the coming years (IATA, 2018). This growth will increase passenger volume, which results in a high amount of baggage that needs to be handled. More than 4.5 billion bags are currently handled every year by baggage handling systems at airports worldwide, and this number is expected to nearly double to 7.8 billion by 2036 (Sorrells, 2018). This expected growth will make it harder for airports to manage and keep track of all baggage (Joshi, 2018). The way that baggage is being handled at airports has not substantially improved in decades as it relies on the same basic legacy systems that have been in place since the 1960s and 70s (Marcellin, 2018). Innovative improvement of baggage handling systems is a holistic task that requires a firm understanding of the business, organizational, technical, and political aspects of baggage handling, and communication between involved actors is crucial for process improvement success (Koldkjær, 2017).

An example of such an innovative improvement can be found in computer vision technology (CVT), which can visually identify baggage without the need for physical attributes such as barcode labels attached to bags. CVT works with cameras that recognize bags by their unique characteristics using a technology that combines deep learning and computer vision (Bagsid, n.d.). A possible use case of CVT is to steer baggage flows optimally based on real-time, action-oriented insights by using data and AI. Prioritizing baggage flows on a 'hot-cold' base instead of 'first-in-first-out' could solve the capacity problems airports are currently facing, as the capacity of current baggage handling systems could be used more efficiently (Sorrels, 2018; Marcellin, 2018). Not only the efficiency of the baggage handling system could be improved by implementing this technology. It could also result in more convenience for travelers and lower costs for airports, as losses in the aviation industry could decrease by 10%, which includes mislaid, lost, and damaged baggage (Singh et al., 2016).

Baggage handling systems face a multi-actor environment since airports depend on other airports, airlines, customs, baggage handlers, and passengers, making the entire coordination and management process complex (Dou, 2020). Therefore, implementing new technologies in such an ecosystem remains a challenge. Rencher (2019) states that rapidly evolving technologies such as Blockchain, IoT, and AI ask for a more integrated aviation industry, where actors in the ecosystem will collaborate to achieve the optimal benefits of these technologies. For this collaboration, it is required that it is known for whom these technologies are valuable to reach agreements on investments for the technology. Creating a business model for implementing this technology could be helpful, as this describes how an organization creates value (Timmers, 1998; Alt & Zimmermann, 2001). However, given the complex dependencies within the aviation industry, the interests of all involved actors need to be taken into account to realize the implementation of such a new technology (Bouwman et al., 2008a; Bahari, Maniak & Fernandez, 2015). A two-layered dependency is seen, as airports are not only dependent on actors operating within the airport itself, but also on other airports due to the need for backward compatibility (Marcellin, 2019). Therefore, it is of high importance to take these dependencies into account when designing business models to capture the value of new technologies (Bouwman et al., 2008b).

The value of implementing CVT in the baggage handling process is currently unknown for hub airports. Knowledge is lacking on possible use cases for this technology and its corresponding value for the baggage handling ecosystem. This MSc thesis investigates the value of implementing CVT in the baggage handling process for Hub Airports by identifying use cases supported by this technology.

1.1 Linkage with the CoSEM Program

A CoSEM master thesis is focused on designing solutions for large and complex socio-technical problems. This research designs and assesses the impact of a new technical solution for hub airports and considers airports' interconnectedness, including the complex multi-actor environment the aviation industry faces. This is required to deal with the technological complexity and the diverging interests of the involved actors. In addition, this research focuses on the technical aspect of implementing technologies and includes the relevant societal and institutional elements, which fits perfectly with the Master program Complex Systems Engineering and Management.

1.2 Scientific Relevance

Implementing a data-driven technology into a complex multi-actor environment such as the aviation industry to achieve innovation and efficiency is a challenge. This chapter provides an introduction to the research that has been performed in this field to analyze the scientific relevance of this research.

Digital Transformation

The aviation industry is at a turning point, as digitalization will change operation processes and positively impact the industry (Sikander, 2019). The shift from identifying baggage based on printed barcode labels towards digital identification via CVT leads to the increasing use of digital technologies. Therefore, this shift can be linked to the theory of digital transformations (DT). Digital transformations have become a focal theme in research (Hönigsberg, Dias & Dinter, 2021). Given the complex ecosystem characteristics of the industry, where airports are dependent on other airports, airlines, customs, baggage handlers, and passengers, a collaboration between actors is required to achieve a DT (Dou, 2020). Nevertheless, most literature on DT's has a single organizational viewpoint, which can be divided into two research streams. The first stream focuses on the different impacts of a DT, where Kayser, Mueller and Kronsbein (2019) write about the impact of a DT on an organizations' performance. In addition, Schallmo and Williams (2017) illustrate that DT's can influence business models and processes to fundamentally improve the performance or scale of an organization. However, a DT is not always successful (Andriole, 2017; Kanadakis & Linturn, 2021). Kanadakis and Linturn (2021), therefore, emphasize the importance of studying the contrast between hyped technologies and organizational reality, as this currently lacks knowledge.

The second stream covers the DT process, in which Westermann, Bonnet, and McAfee (2014) state that organizational performance can be improved due to the fundamental change in an organization's processes. The work of Hrustek, Tomičić Furjan, and Pihir (2019) covers drivers behind organizational' DT's. The increase in technical applications pressures organizations to reflect on how it could improve processes (Euchner, 2016; Schüritz & Satzger, 2016), leading to a technology-driven DT process (Hrustek et al., 2019; Kanadakis & Linturn, 2021). During such a process, identifying use cases on how the technology could be applied is required

(Kanadakis & Linturn, 2021). The identified use cases could help design the value proposition of the technology for the organization, which is highly important based on Andriole's (2017) work. The majority of the research performed on DT's focuses on organizational implications (Kraus et al., 2021), as can be seen in the work mentioned above.

Established Ecosystem

Despite the focus in the literature on an organizational level, DT's can also span beyond the boundaries of one organization (Chesbrough & Teece, 1996) within a so-called ecosystem. An ecosystem can be defined as a set of interrelated components (actors, technological artefacts, and institutions) working towards a common objective (Hekkert et al., 2007). This context is seen within the aviation industry, as the baggage handling ecosystem needs to collaborate in order to achieve innovation of the baggage handling process. The collaborative effort of actors to achieve innovation is not unfamiliar, as it gained growing interest from practitioners and scholars (Dedehayir, Mäkinen & Ortt, 2018). However, this collaborative effort is mostly linked in the literature to the creation or birth of innovation ecosystems (Carlsson et al. 2002; Dedehayir et al., 2018) rather than the innovative transformation of already established ecosystems. Established ecosystems face different characteristics, as they are often bound by legacy systems built over time (Hartmann et al., 2016). The aspect of an established situation is mentioned within the literature on an organizational level, referred to as organizational inertia, path-dependency constraints, or habits (Criscuolo et al., 2012; Hunke et al., 2017; Kayser et al., 2019).

Existing research provides some insights into the collaborative effort of established ecosystems to achieve innovation but is limitedly focused on the transformative process. Carlsson et al. (2002) talk about the analysis of innovation systems but do not cover the transformative aspect of the ecosystem caused by innovations. This transformative aspect also lacks in the work of Dedehayir et al. (2018) who investigate the collaborative effort by actors to achieve innovation, but focus on the creation of those ecosystems. The research results of Anke et al. (2020) indicated that it takes multiple actors with diverse roles to actualize the potential of technology of smart service systems. However, this work is limited to the identification of the different roles of the actors within the ecosystem, and future research was recommended on inter-organizational collaboration to achieve innovation.

Value Proposition

Each actor in the ecosystem must know its role in the system and its value streams to achieve innovation (Bahari et al., 2015; Bettencourt et al., 2014). The process of identifying value from technological innovation is often contributed by a business model (Chesbrough & Rosenbloom, 2002). Business models can explain how an organization creates and captures value (Chesbrough, 2007; Jensen, 2014). Although business models are widely mentioned in the literature, there is no commonly accepted definition and understanding (Zott et al., 2011). This research follows the definition of Bouwman et al. (2008a): *"A business model is a blueprint for a service to be delivered, describing the service definition and the intended value for the target group, the sources of revenue, and providing an architecture for the service delivery, including a description of the resources required, and the organizational and financial arrangements between the involved business actors, including a description of their roles and the division of costs and revenues over the business actors".* A business model will present the concrete operational implementation of a new technology (Bouwman et al., 2008a). Business models that support data-driven processes are called data-driven business models (DDBM)

(Hartmann et al., 2016). A characteristic of data-driven business models is that data is necessarily required for the value proposition (Engelbrecht et al. 2016). To design DDBM's, use cases need to be identified to design a value proposition of a technology (Oosterwalder & Pigneur, 2010). It is often unclear how organizations need to implement new technologies to optimize the value (Schüritz & Satzger, 2016). This unclarity will even be strengthened in an ecosystem setting, where actors are dependent on each other to realize an implementation (Chesbrough & Teece, 1996; Anke, Poeppelbuss & Alt, 2020). Literature provides insights into the creation of DDBM's. Still, there is a lack of understanding of how organizations should transform their existing business models into data-driven business and how the added value of this transformation can be monetized (Schüritz & Satzger, 2016).

1.3 Knowledge Gap

Two knowledge gaps have been identified based on the capacity problem the aviation industry is facing and the existing literature on DT's. These gaps can be divided into two layers. First, a practical gap is seen in the aviation industry, as knowledge lacks on the value of CVT for the baggage handling ecosystem. A promising data-driven technology has been identified for the baggage handling process of hub airports. This can be seen as a technology-driven digital transformation, which requires the design of a value proposition (Kanadakis & Linturn, 2021) to achieve agreements on the investments. Nevertheless, it is currently unknown what use cases this technology could provide and what kind of value it would bring to the baggage handling ecosystem to design the value proposition. This is needed to make agreements to develop the required data-driven business model to ensure a digital transformation of the baggage handling process.

Second, a scientific gap is identified in the literature, as knowledge lacks on the digital transformative process within an established ecosystem. The DT process is mentioned within the literature (Bonnet and McAfee 2014; Hrustek et al., 2019; Kanadakis & Linturn, 2021), but this literature remains limited, as the majority focuses on organizational implications (Kraus et al., 2021). Thus, the transformative process of established ecosystems towards digitalization lacks knowledge. There is a need for new theories in the context of innovation and digital transformation (Kraus et al., 2021). Technology-driven DT´s require a value proposition design (Kanadakis & Linturn, 2021). The outcome of the designed value proposition is determined by design choices made during the design process, which may be influenced by the interests of actors in the ecosystem. Knowledge lacks on the DT process occurring in ecosystems and the contrast between hyped technologies and reality (Kanadakis & Linturn, 2021). It is, therefore, valuable to contribute to this scientific knowledge gap by gaining insights from a real-world situation to guide future digital transformations within ecosystems.

1.4 Research Approach

The research will follow the design science research (DSR) approach to contribute to the identified practical and scientific knowledge gaps. This approach studies and creates artifacts that people will use to solve practical problems of general interest (Johannesson & Perjons, 2014), which allows the creation of an artifact to find a solution for the gap within the literature and practice (Kuechler & Vaishnavi, 2012; Athanasopoulou, Haaker, & de Reuver, 2018).

The design of a DDBM could be helpful to capture the value of CVT and to conclude on operational and financial aspects. Nevertheless, the process of designing a DDBM involves intensive engagement with the involved actors and making agreements and negotiations, which is out of scope for this research. This research will focus on the exploratory task of designing the value proposition of CVT for the baggage handling ecosystem of hub airports, as this is the fundament of the DDBM (Richardson, 2005; Teng & Lu, 2016; Hrustek, Tomicic Furjan, & Pihir, 2019; Rachinger et al., 2019). This will be done by the identification of use cases that could be implemented in the baggage handling process. The designed value proposition provides the aviation industry a building block to further develop the required DDBM. A business model is needed to implement CVT and to achieve a digital transformation of the baggage handling process. The objective of this research is the following:

"To design a value proposition for baggage handling ecosystems at hub airports by identifying use cases for computer vision baggage identification technologies to provide the aviation industry a building block to further develop the required data-driven business models."

As knowledge lacks on the design process of a value proposition for a data-driven technology that will be implemented in an established ecosystem, this research will provide insights into this process. In this way, the design will not only contribute to a global practice but also to a scientific body of knowledge (Johannesson & Perjons, 2014). For this research, a design science approach is selected over an action design science approach since the latter requires on-organizational-site artifact implementation and evaluation (Kuechler & Vaishnavi, 2012). This approach is out of scope for this research as CVT is not yet ready to be implemented. Another possible research approach is to set up a case study and analyze another process of identifying use cases for a data-driven technology so that lessons from previous DT's could be applied to the aviation industry. However, this approach will not be applied, as the aviation industry has specific and crucial layered ecosystem dependency characteristics that need to be considered (Dou, 2020). These characteristics influence the DT, making it less suitable to copy best practices of DT's from other industries.

It is important to take the ecosystems' environment into account. Therefore, the design science approach will be performed in a situated setting at Schiphol Airport, where the current situation will be analyzed to design a well-suited value proposition. This situated setting will open many opportunities, as it provides access to information and people needed to generate the required data to answer the research question. Using data from this situated setting will make the research more concrete. This concreteness can ensure a more realistic answer to what extent CVT can bring value to the baggage handling ecosystem of hub airports. In addition, insights and evidence from a real-world situation can be gained to contribute to the digital transformation knowledge base.

1.5 Design Science Cycle

For this research, it is chosen to adopt the design science cycle approach of Vaishnavi and Kuechler (2004). This approach highlights the importance of starting with the awareness of the problem and the context. This suits the scope of this research, as it is important to analyze the current and desired situation to identify use cases for the CVT. Another reason why this approach is chosen is that one of its fundamental principles is to specialize a general theory to a more tightly scoped domain (Vaishnavi & Kuechler, 2012). Thus, the design cycle emphasizes the importance of considering the domain in which something will be designed. This aligns with the scope of this research, as it focuses on designing for the aviation industry, in which this context is critical. As described in section 1.4, the actual DDBM will not be developed as this is out of scope given the time limits, but the focus will lie on the design of the value proposition of CVT. The design science cycle can be found below, in which steps 1-4 will be performed within this research *(see figure 1.1)*. The outcome of this research can be used for the remaining steps to develop, evaluate and conclude on a DDBM for CVT at hub airports.

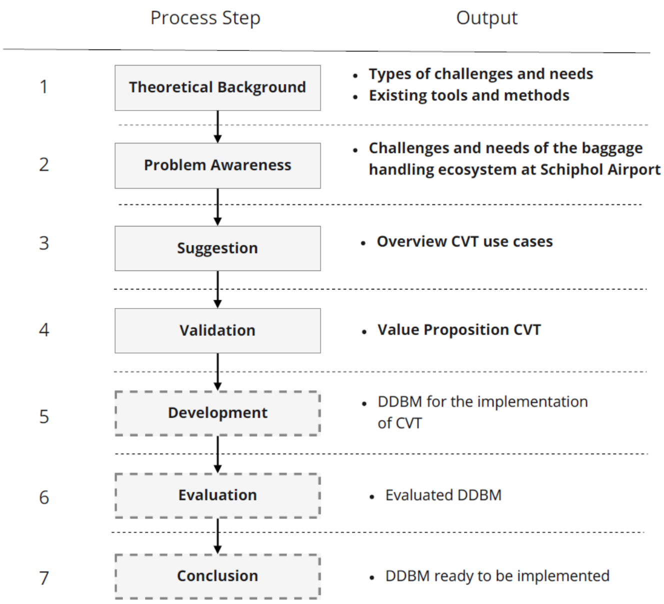

Figure 1.1. The Design Cycle, inspired by the design cycle of Vaishanvi & Kuechler (2004).

1.6 Research Questions

Based on the research objective, the main research question is framed as follows:

"What use cases can be included in the data-driven business model to capture the value proposition of implementing computer vision baggage identification technologies for hub airports?"

The knowledge necessary to answer the main research question will be gained by answering several sub-questions derived from the main research question. The sub-questions are divided into four process steps of the design cycle of this research: the theoretical background step, the awareness of the problem step, the suggestion step, and the validation step.

- Step 1. Theoretical Background

The research starts with a literature review to gain background knowledge and theories necessary before beginning the design cycle. It is crucial to build and relate research to existing knowledge (Snyder, 2019). As found in the knowledge gap, it is unknown what the value of implementing CVT is for the baggage handling ecosystem of hub airports. Therefore, a value proposition needs to be designed to overcome this knowledge gap. The design cycle applied in this research focuses on the current challenges and needs of Schiphol Airport's baggage handling ecosystem to guide the design process of the value proposition (Vaishnavi, Kuechler & Petter, 2004/19). It is interesting to see if these challenges and needs are related to the types of challenges and needs that exist in DT processes within ecosystems. Therefore, literature will be reviewed to identify key concepts of challenges and needs during a DT process on an ecosystem-wide level. These concepts will be used to classify the identified current challenges and needs at identified at Schiphol Airport. The first sub-question is as follow:

SQ1: What types of challenges and needs exist in a digital transformation process within an ecosystem, and how do they relate to the key concepts of a digital transformation?

A conceptual model is needed to answer this question that can help classify different types of challenges and needs. This model will be made via conceptual analysis, a technique to provide a comprehensive understanding of a phenomenon (Jabareen, 2009). The technique aims to generate and identify a phenomenon's key concepts, which together constitute its theoretical framework. This will be done by reviewing the literature on the concept of digital transformations, whereafter relevant key concepts mentioned in the literature will be reviewed next to create a firm understanding of the existing theory that is needed for this research. The conceptual analysis focuses on the interplay of making inductions, deriving concepts from the literature, and making deductions by identifying relationships between concepts (Patton, 2002, p. 454). The analysis conducted in this research is divided into four phases:
Phase 1: Review literature on DT´s and identify concepts mentioned in literature.
Phase 2: Review literature of concepts mentioned in the literature.
Phase 3: Synthetization of concepts with similar meanings and themes.
Phase 4: Conceptualizing a model of theory on digital transformations and describing the relationships between the derived concepts.

The output of this literature review will form the structure of this research, as it determines the key aspects that need to be considered during this research. It will guide as a structure for the rest of the research, as it will guide the process of clustering the found challenges and needs in reality based on the conceptual model.

The second sub-question related to the theoretical background step refers to the state of art, methods and tools necessary to design a value proposition for a digital transformation within an ecosystem:

SQ2: What state of art methods and tools can be used to explore and identify use cases and design the corresponding value proposition of data-driven technologies in an ecosystem setting?

A literature review will be performed to provide an overview of the available theory, methods, and tools that can be used. The answer to this sub-question will help specify the methodologies used to answer the following sub-questions, which are illustrated in chapter three. The methodology is determined based on knowledge and insights generated during the execution of the literature review.

- Step 2. Problem Awareness

An important aspect of the design cycle is that it starts with identifying the problem. Part of this step is to become aware of the current problem as well as the desired situation to guide the design process of the value proposition (Vaishnavi, Kuechler & Petter, 2004/19). It is chosen to focus on needs instead of requirements as it represents desires of where the ecosystem wants to be instead of hard requirements that the ecosystem needs to meet. A thorough understanding of the problem enables the design of solutions according to the primary user needs (Islam, Weir & del Fiol, 2014). The third and fourth sub-question, therefore, gather information on the current challenges and needs of the baggage handling ecosystem of Schiphol Airport:

SQ3: What are the current challenges occurring in the baggage handling ecosystem of Schiphol Airport?

SQ4: What are the current needs of the baggage handling ecosystem of Schiphol Airport?

- Steps 3 and 4. Suggestion & Validation

The third step of the design cycle focuses on identifying CVT use cases for the baggage handling process at Schiphol Airport. These use cases will be analyzed and validated by stakeholder during the validation step, which will result in the design of the value proposition of CVT for the baggage handling ecosystem of Schiphol Airport. The fifth sub-question gathers knowledge on what kinds of use cases can be implemented and what corresponding added value they provide:

SQ5: What use cases for computer vision baggage identification technologies could be implemented in the baggage handling process at Schiphol Airport, and to what extent do they provide value for the baggage handling ecosystem of Schiphol Airport?

1.7 Research Design

A research flow framework has been constructed to structure the research and visualize how the study will be conducted *(see figure 1.2)*. First, a literature review on digital transformations will be executed, illustrated in chapter two, and applied to the situated setting at Schiphol Airport. This helps to define the methodology used for this research, which can be found in chapter 3. The current and desired situation of the baggage handling ecosystem at Schiphol Airport will be identified and illustrated in chapters 4 and 5, based on workshop results, informal interviews, field and desk research. The challenges and needs resulting from the defined current and desired situation will be clustered to provide an overview of the ecosystems' current challenges and needs, which will be used as input during the use case workshop. The outcome of the use case workshop will be a list of use cases, which can be found in chapter 6. This chapter also illustrates the added value of the use cases for the ecosystem, based on stakeholder validations. The move toward discussing, generalizing, and concluding on the research results will be made and presented in chapter 7.

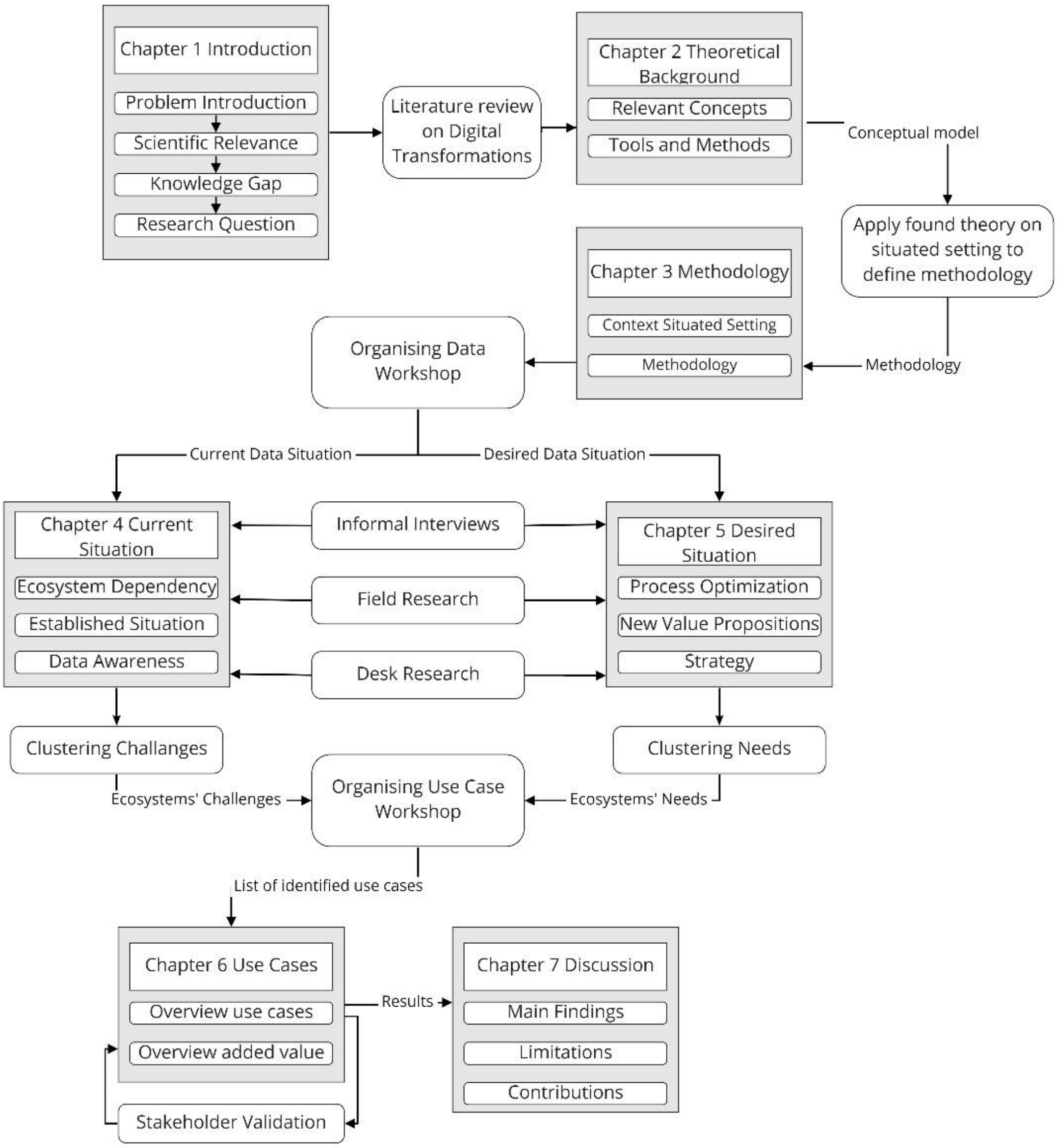

Figure 1.2: Research Flow Framework

Chapter 2. Theoretical Background

This chapter will first define and discuss relevant core concepts in section 2.1 to provide more insights into the scientific context of this research. Section 2.2 will go into depth on the current state of art, methods, and tools necessary to identify use cases and design a value proposition.

2.1 Types of Challenges and Needs

The research focuses on the identification process of use cases for a data-driven technology for hub airports. Implementing the technology will lead to a digital transformation (DT) of the baggage handling process. A conceptual analysis is performed for which literature on the concept of DT's is first reviewed. This provided a concept definition and its relation to other relevant concepts, which were reviewed after that. Thus, relevant concepts and references have been identified during the literature review process. After reviewing relevant literature, the relations between the concepts were determined and captured in a theoretical conceptual model *(see figure 2.1)*. Based on the literature, key types of challenges and needs of a DT process within an ecosystem are highlighted. The model forms the basis for the research, as it provides key types of challenges and needs that need to be considered during the rest of the research steps. By performing the literature review and capturing the relations between relevant concepts of a DT, an answer to the first sub-question of the research is provided:

"What types of challenges and needs exist in a digital transformation process within an ecosystem, and how do they relate to the key concepts of a digital transformation?"

2.1.1 Digital Transformation

Two important concepts are part of the theory on DT's: digitization and digitalization. Digitization differs from the concept of digitalization, in which digitization is defined as the technical conversion of analog information into a digital form (Autio, 2017), while the latter is viewed as the use of digital technologies to change a business model to provide new value opportunities (Gartner IT glossary, 2017). New value opportunities can lead to a transformation of business models and the creation of economic growth (Gölzer & Fritzsche, 2017), which can result in major impacts on many aspects of our civilization (van Veldhoven & Vanthienen, 2019). Due to the possibility of significant impact, DT's have become a focal theme in research (Hönigsberg et al., 2021). Literature on DT's can be divided into two research streams, where the first stream focuses on the different impacts of DT's. The impact can be identified and recognized on an organizational level, as well on an ecosystem level. However, most literature still focuses on the impact for an organization, as Kayser, Mueller & Kronsbein (2019) write about the impact of data generation and leveraging the capabilities and potentials of this generated data on an organization's performance. This performance can be improved due to the fundamental change in an organization's processes by either optimizing processes or creating new value propositions, according to Westermann, Bonnet & McAfee (2014). The organizational viewpoint is also seen in the research of Schallmo (2016), who states that DT's can influence organizations, business models, processes, and stakeholder relations to fundamentally improve the performance or scale of the organization.

The other focus of the literature on DT's lies in the presentation of guidelines, models and lessons for organizations on how to deal with digital transformations (van Veldhoven & Vanthienen, 2019) and covers, therefore, more the process of a DT. This vision can be seen in the work of Goerzig and Bauernhansl (2018). They define DT as a fundamental change process initiated through the evolution of IT into an essential part of value creation. In this way, the increasing use of technologies is seen as a transformative value creation process and not only as a technological tool to improve process efficiencies. This research stream focuses more on the process to get results rather than on the specific impact the process will have. It is seen that this research stream also mainly focuses on the DT process within an organization, rather than having a more broad view towards other organizations and actors.

Despite the focus in the literature on an organizational level, digital transformations can also span beyond the boundaries of one organization (Chesbrough & Teece, 1996). This can be seen when transformations require coordination among actors and significant adjustments to the ecosystem. A system can be defined as interrelated components working towards a common objective. The components of the system can be actors, technological artefacts, and institutions and are linked with certain relationships (Hekkert et al., 2007). The behavior of each component can influence the behavior of the whole system, and due to this interdependence, components cannot be divided, but the system has to be analyzed as a whole (Carlsson et al., 2002). Hekkert et al. (2007) state that it is a challenge to find all involved components of an ecosystem and primarily to determine if you have found all components. When investigating a DT occurring in an ecosystem, it is of high importance to determine the appropriate level of analysis, i.e. delineate the system and identify involved actors and components (Carlsson et al., 2002).

The concept of ecosystems was initially presented by Moore (1993). His vision was that organizations could not grow individually and were dependent on different resources such as partners, capital, and customers. Moore combined this vision into the definition of a business ecosystem, wherein organizations co-evolve their capabilities around innovation, both working cooperatively and competitively. Anke, Poepelbuss & Alt (2020) acknowledge this and state that innovation often occurs in ecosystems of collaborating actors since single parties often do not possess all required competencies or resources. Ecosystems are characterized by cooperative and competitive interactions between actors (Peltoniemi, 2004) working towards a common objective and are also characterized by a system-level goal (Appleyard & Chesbrough, 2017). It is essential to have a clear understanding of the system-level goal, to guide the digital transformation process. However, in reality, it is often seen that actors' objectives and interests are contradictory or conflicting, despite the existence of a common high-level system goal (Bouwman et al., 2008a). Thus, such a clear understanding is not always possible, which makes the process of understanding the system-level goal in reality not as clear and straightforward as it seems in the literature.

The systemic point of view on innovations is also proposed by Dedehayir, Mäkinen, and Ortt (2018), as they define it as the collaborative effort of a set of actors towards innovation. A characteristic of such a systemic view is the emphasis on recognizing the holistic value embedded in products and services. According to Bocken et al. (2013), such a holistic view is required, where the involved costs and benefits of innovations should be investigated not only from within one organization but should include a broader range of actors from the ecosystem. This highlights the importance of delineating the system and finding the challenges and objectives for all involved actors to recognize the holistic value of the DT for the ecosystem. A pitfall of this systemic view is that it slows the process of technological change due to the complex interdependencies of involved components (Hekkert et al., 2007). These complex interdependencies highlight the importance of balancing the involved actors' requirements and interests in the ecosystem. This can be complex due to conflicting needs or strategic interests and a lack of resources to provide perfect solutions for all involved actors (Bouwman et al., 2008a). Balancing the requirements and interests means that some actors need to give in on some parts to receive a more significant outcome on other parts of technical, operational, and financial decisions during the digital transformation process. The intended value arising from these decisions can be defined as the ecosystem's value proposition (Appleyard & Chesbrough, 2017). This has a link with the definition of ecosystems by Adner (2016): *"The ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize."* In this definition, actors in the ecosystem require interactions to realize a value proposition. A DT can lead to a new value proposition (Rachinger et al., 2019). Thus, a DT occurring in an ecosystem requires interactions between actors to realize a new value proposition. Therefore, literature on value propositions and their design will be reviewed and discussed in subsection 2.1.2.

Combining the results found in both research streams, it can be stated that a digital transformation is a process initiated by the increasing use of digital technologies and its corresponding generated data to influence value creation, which can result in a new value proposition. DT's can either occur inside an organization or an ecosystem of cooperative and competitive actors. Therefore, the link between existing theory and its applicability to an ecosystem setting will be discussed during the literature review. Literature on the transformation process will be reviewed next, whereafter literature on the value proposition of a DT will be addressed at subsection 2.1.2, followed by theory on the characteristics and opportunities of leveraging data to create value in subsection 2.1.3.

2.1.1.1 Digital Transformation Process

DT's differ in their scale, impact, and the setting in which the transformation occurs. Hrustek, Tomičić Furjan, and Pihir (2019) indicate that it is important to identify the drivers behind DT's to successfully steer the transformation process. These drivers are indicated for organizational' DT's and can be divided into three categories:

- A customer-driven drive, as a wish exists by the organization to adapt to new customer needs,
- A technology-driven drive, as emerging technologies give new possibilities for implementing within an organization,
- An organizational drive, as a goal of improving the current way of working within an organization exists.

As stated in the introduction, the DT investigated in this research is technology-driven. Many DT's are technology-driven, as a driving force behind changes in business models is the increase in technical applications. This pressures organizations to reflect on how it could improve processes and thereby change their business models (Euchner, 2016; Schüritz & Satzger, 2016). Due to the emerging technological applications, organizations are urged to identify and use technical potentials (Kayser et al., 2019). As stated above, a technology-driven DT is mainly linked to an organizational viewpoint, where technologies provide opportunities for organizations. Andriole (2017) states that such a technology-driven transformation is not always successful, since not all transformed business models are likely to be as profitable as the original one. This emphasizes the importance of identifying the value of the transformation carefully. Kanadakis and Linturn (2021) support this vision and highlight the importance of studying the contrast between hyped technologies and organizational reality. The expected benefits of hyped technologies are often not seen in reality within the organization after the implementation. Since the contrast between hyped technologies and organizational reality is already lacking in knowledge (Kanadakis & Linturn, 2021), this contrast is also unknown on an ecosystem-wide scale. The situation should be prevented where technologies with hyped expectations will be implemented that cannot live up to these expectations later. This is of high importance on an organizational level for organizational performance. However, such a situation could even have more impact in an ecosystem-wide setting, where DT's can influence stakeholder relations (Schallmo, 2016). Thus, relations and trust levels between actors in the ecosystem could be damaged due to hyped expectations of technologies that cannot be met, which is a situation that must be prevented.

Even though such an ecosystem viewpoint on the DT process is interesting to consider, the literature covers mainly the organizational process level. This is seen in the work of Heavin and Power (2018). They state that while technology is a crucial aspect of a DT, the role of humans, organizational culture, and the need for a strategy also needs to be taken into account during a DT. A strategy can be defined as formal strategic planning, in which decisions will be made on how to achieve the goal of the DT (Heavin & Power, 2018). Thus, the focus of a DT process should not lie solely on the technology, but there are needs for excellent leadership, a supportive organizational culture, and new business processes (Heavin & Power, 2018). A supportive organizational culture can be defined as a culture where values such as openness and willingness to change are embedded, which is essential for the success of a DT (Osmundsen et al., 2018; Kraus et al., 2021). This culture can be stimulated by actively and interactively involving actors during the DT process (Geissdoerfer et al., 2016). In these papers, the link is being made with the organizational culture and involving actors within an organization. However, an ecosystem-wide supportive culture is not mentioned in these papers. This supportive culture is needed, as although having a strategy is defined in the literature as a necessary condition for a successful DT, this strategy must also be supported by the organization as a whole (Osmundsen, Iden & Bygstad, 2018). Thus, when facing an ecosystem-wide approach, the strategy must be supported by the ecosystem as a whole, making the process more complex, as the interests of actors in the ecosystem can be contradictory (Bouwman et al., 2008a).

The organization's actions must be aligned with the strategy to accomplish a successful DT. Operationally, this means that the organizational culture should be closely aligned with the adoption of technologies (McKendrick, 2017). Although research primarily focuses on the DT process on an organizational level, the study of Hönigsberg, Dias, and Dinter (2021) bridges the link of the importance of having a strategy during the DT process with theory on an ecosystem-wide level. They state that the strategy should have an ecosystem-wide vision instead of focusing on the organization itself. An ecosystem-wide vision would result in including the objectives of all involved actors into the strategy, as this can support the transformation and the achievement of objectives of involved actors. This can govern and guide the process to achieve the desired future state for the ecosystem as a whole.

2.1.1.2 Digital Transformations in Established Ecosystems

DT's are unique as they are influenced by the characteristics of the setting in which the transformation occurs. New technologies and innovation through data usage are often commercialized through start-up companies (Criscuolo et al., 2012) since they are not bound by legacy systems built over some time (Hartmann et al., 2016). Therefore, the theory on data-driven service creation mainly focuses on start-ups and business models but lacks in theory on business model innovation in established industries. Abrell et al. (2016) highlight that large established organizations who face the challenge of being stuck in legacy systems often require structural changes to their business models when implementing digital technologies for smart innovation. Structural changes are defined as changes that need managerial attention or replace the core activities of an organization (Bock et al., 2011). Such structural changes in business models present a unique context of collaboration. This unique context is especially seen when performing ecosystem-wide structural changes, where actors in the ecosystem are dependent on each other to execute these changes. The combination of the required managerial attention with the existing actor dependence and required collaboration between actors in the ecosystem makes the coordination process of executing structural changes to a business model within an ecosystem complex (Bock et al., 2011).

Another characteristic of the complexity of executing structural changes to business models of established organizations is the existence of organizational inertia or path-dependency constraints (Hunke et al., 2017). This means that the required structural changes need to be feasible as they must be compatible with the current situation. The existing path-dependency constraints highlight the importance of having an overview of the current situation before starting the DT process. It needs to be known what challenges occur, what kinds of opportunities exist, and what data and technologies are currently used (Kayser et al., 2019). In addition, the institutional field needs to be analyzed as digital innovations need to comply with the current institutions. Where institutions can be a driver for innovation, they can also hold back innovations (Rasiah, 2011). An overview of the current situation is needed to gain optimal benefits out of the digital transformation, as the transformation could then also be a solution to occurring challenges rather than only finding newly created benefits. Benefits could still be achieved if a DT would not solve the current challenges, but solving current bottlenecks and issues will optimize the result. Therefore, a fundamental step within the DT process is data awareness, which includes identifying and understanding the current data assets of the organization (Kayser et al., 2019). In the research of Kayser et al. (2019), the concept of data awareness has an organizational viewpoint, but data awareness can also be applied on an ecosystem-wide level. Nevertheless, the data awareness process on an ecosystem-wide level will be more complex. It will be hard to achieve full awareness since parties are often reluctant to share their data (Richter & Slowinski, 2019). So, the process of creating a complete overview of the collected, managed, and available data inside an ecosystem is more complicated to execute than within an organization. As creating data awareness is emphasized above, literature on the process and characteristics of creating data awareness is therefore illustrated in subsection 2.1.3.1

2.1.2 Value Proposition

The concept value proposition was first linked to theory on business and business innovation, as it was often referred to in terms of the offered value of a product or service (Wormald, 2015). Nowadays, the concept of value proposition is also adopted in the design world, whereas it is referred to as the value of a conceptual idea in its products' physical realization. To define this value, it should start with the product or service enrichment combined with a definition of how technology will be used to achieve this enrichment (Hrustek et al., 2019). Oosterwalder and Pigneur (2010) put the value proposition at the center of new business opportunities and define it as follows:

"The Value Proposition is the reason why customers turn to one company over another. It solves a customer problem or satisfies a customer's need. Each Value Proposition consists of a selected bundle of products and/or services that caters to the requirements of a specific consumer segment. In this sense, the Value Proposition is an aggregation, or bundle, of benefits that a company offers customers." (p.22)

In this view, the value proposition is focused on the value of a product or service for a specific customer segment. It is linked to the theory on customer value, which is considered a significant factor in an organization's success, as it is strategically used to attract and retain customers (Sánchez-Fernández & Ángeles Iniesta-Bonillo, 2006). However, when facing the characteristics of a DT occurring in an ecosystem, literature on collaborative or so-called value co-creation is relevant (Galvagno & Dalli, 2004). This is acknowledged by Hönigsberg, Dias, and Dinter (2021), who state that use cases need to be measured by means of all involved actors within established industries. The outcome needs a multidimensional view, rather than focusing on a single organization's business goals. Baldasarre et al. (2017) bridge this customer value proposition view towards a co-creation view. They emphasize the importance of designing a value proposition that allows value creation for multiple actors. Value co-creation will enable customers and actors to create value through interactions (Galvago & Dalli, 2004). This highlights the importance of understanding the interactions and relations between actors in the ecosystem during the design process of an ecosystem-wide value proposition. To achieve a value proposition design in an ecosystem setting, the involved actors need to rely on each other in their innovation ecosystem. This means that there exists a certain dependence between the actors, which can also be defined as ecosystem dependency (Talmar et al., 2020).

In this ecosystem approach, the value proposition can be divided into the value created and delivered by the ecosystem to the customer and value for individual actors of the ecosystem, as each actor embedded in the ecosystem seeks benefits for itself. The latter can also be referred to as captured value, as this represents how, what kind, and how much value created by the ecosystem is captured by a particular actor (Talmar et al., 2020). This distinction between value creation and value capture is important to identify when facing a value co-creation process. A DT can result in the creation of value. However, this value should also be identified and captured by involved actors to optimize the value proposition. One actor can create value, whereas another actor can eventually capture this value (Chesbrough et al., 2018). Thus, a characteristic of a value proposition design in an ecosystem setting is that it focuses both on the value for the customer and the involved actors. The latter needs to be known, as this can contribute to achieving agreements on investments for a new technology that will be implemented inside an ecosystem.

2.1.2.1 Data-Driven Business Model

The value proposition is a central part of many business model ontologies (Osterwalder & Pigneur 2010; Johnson, Christensen & Kagermann, 2008). The concrete operational implementation of new technologies will be represented in a business model (Bouwman et al., 2008), whereas the value proposition can be seen as a central building block for the development of business models. A result of digital transformations is the rise of DDBM's, business models that support data-driven processes (Hartmann et al., 2016). A characteristic of DDBM is that data is necessarily required for the value proposition (Engelbrecht et al., 2016). When facing a technology-driven DT the value proposition is the first thing that needs to be designed during the design process of a business model for that technology (Richardson, 2005; Teng & Lu, 2016; Hrustek, Tomicic Furjan, & Pihir, 2019; Rachinger et al., 2019), as this is viewed as a central building block for the development of business models for an identified technology.

As illustrated in subsection 2.1.1, DT's could have significantly impact on the organizations' value proposition. However, to improve the current way of working, technologies need to be applied correctly (Hrustek et al., 2019). The output of a DT will be defined by how technology is applied. This output is referred to as the added value and can include elements like efficiency, trust, speed, personalization and performance (Bouwman et al., 2008b). The added value of technology needs to be understood when defining a business model (Bouwman et al., 2008). This understanding can be created via a structured value proposition design (Kayser, Nehrke & Zubovic, 2018). This design is essential, as this can be used to study how and to what extent this technology would influence value creation and capturing (Breitfuss et al., 2008). Linked to the theory of ecosystems, the added value should be explored and identified for all actors, to optimize the captured value within the ecosystem. Data and analytics are considered powerful tools for innovation and value creation (Kayser et al., 2019). This vision, combined with the fact that DT's generate a high amount of data provides a reason to review the literature on the role of data in the value creation process, which will be discussed in the next subsection.

2.1.3 Big Data

The generation of large amounts of data is a key characteristic of DT's (Kayser et al., 2019). Large amounts of data are also referred to as big data, which has gained in popularity over the last few years. The definition by Gartner (2012) is one of the most commonly cited ones: *"Big data is high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making".* A fourth relevant dimension that is often added to this definition refers to the uncertainty of the data, which addresses the reliability of the data (Schroeck et al., 2012). Data-driven value creation can be a result of smart innovation enabled by digital technologies (Nambisan, 2013; Anke et al., 2020). This can lead to the optimization of business processes and even lead to the innovation of business models, by providing new value propositions (Hartmann et al., 2016). It is proven that organizations that rely more on data-driven decision-making perform better in terms of productivity and profitability (McAfee and Brynjolfsson (2012). New technologies and innovation through the usage of big data are often commercialized through start-up companies (Criscuolo et al., 2012) since they are not bound by legacy systems built over some time (Hartmann et al., 2016). Literature on big data presents that it is important to have information systems designed to retrieve, process, analyze and store a large volume and variety of data (Blazquez & Domenech, 2018). This also highlights the importance of having an overview of the current situation, to be able to know what possibilities of data usage exist.

It is of high importance to identify what value can be generated out of collecting, storing and analyzing (big) data (Hartmann et al., 2016). The increasing use of digital technologies results in an increasing amount of generated data. The importance and potentials of leveraging data are widely discussed in the literature. However, in reality, it is still often seen that organizations capture only a fraction of the value resulting from the use of data (Manyika, 2017). This is caused by a lack of understanding of how to use data and analytics, a shortage of data science skills and methods, and a lack of interdisciplinary communication between the IT department, data analytics and business teams (Kayser et al., 2019). Therefore, Fruhwirth et al. (2020) emphasize the importance of a multi-disciplinary approach during the identification process of data-driven use cases. This collaboration is necessary, as it can prevent a disconnect between use case designers and the operational department, which can result in a source of tension that can pose additional barriers and delay the adoption of the new technology. Verhagen, de Reuver en Bouwman (2021) state that it is important that business model innovation should involve IT engineers and architects to align business model innovation with operation and organization's architectures, which is at least as important as high-level strategic brainstorming. This vision is shared with Iacob et al., (2012) who highlight the interrelatedness of a business model and the enterprise architecture. Especially when business models have been adjusted through DT's, organizations face problems to align their operations, architectures and technologies with newly created business models (Solaimani et al., 2018; Fritscher & Pigneur, 2011). However, the IT department should not do this task by itself, as it is more beneficial to explore new technologies by identifying use cases by an organization more broadly (Kaniadakis & Linturn, 2021). The lack of interdisciplinary communication will especially exist inside of an ecosystem-wide setting, as organizations are reluctant to share their data (Jernigan, Ransbotham, & Kiron, 2016; Richter & Slowinski, 2019). Organizations want to keep control over their data and prevent the situation where their data could be beneficial for their competitors which could be harmful to their business interests (Spiekerman, 2019). In addition, privacy regulations play a role in the decisions of organizations to share data (Khurana, Mishra, & Singh, 2011). This makes it hard to establish a data-sharing environment inside of an ecosystem (Richter & Slowinski, 2019).

2.1.3.1 Data Awareness

A fundamental step within the exploration phase of data-driven use cases is data awareness, which includes identifying and understanding data assets (Kayser et al., 2019). Organizations need to use theory and tools to support their ability to leverage data, to fully benefit from the vast amounts of data to support decision-making and business operations (Comuzzi & Patel, 2016). A limited understanding of data sources can result in a lack of knowledge on the opportunities of data-driven use cases. It is important to identify what data is available or have the knowledge on potential data sources as this is crucial input during the data-driven use case identification process (Bange, 2016). A key aspect of data awareness is identifying available and potential data sources (Günther et al., 2017) and what types of data they provide (Blazquez & Domenech, 2018). Data can be collected for one purpose but used for other purposes due to the usage of combining and analyzing the data (Aaltonen and Tempini, 2014). Data awareness is a valuable design input (Agrawal et al. 2018; Kollwitz et al. 2018; Kronsbein & Mueller 2019) which could inform data use case definitions right from the start (Kayser et al. 2018; Vanauer et al. 2015; Wirth & Wirth, 2017) or entail that initial use cases will be revised (Wirth & Wirth 2017). To create data awareness, a sound understanding of types of available data sources is required as well as the experience in exploring and identifying data (Sternkopf and Mueller, 2018). The challenges that arise when using data should be considered during the data awareness process, such as scalability, data availability, data integrity, data transformation, data quality, management of huge volumes of data, integration of data from different sources, data matching, availability of tools to analyze the data, privacy and legal issues and data governance (Blazquez & Domenech, 2018).

Once the data assets have been identified, the process of how to use this data to create value will start. To gain optimal benefits out of a DT, the characteristics of leveraging data to create benefits should be known. Different viewpoints exist in the literature on the benefits of leveraging data. Aaltonen and Tempini (2014) state that generating value out of data can be divided into two categories. In addition, Breitfuss et al. (2019) classified four categories and proposed a classification scheme that can be used during the development process of data-driven use cases. Nevertheless, the two categories that were mostly seen in reality corresponded with the two categories proposed by Aaltonen and Tempini (2014). First, one way of using data and analytics is to improve existing processes in terms of efficiency and effectiveness (Ghoshal et al., 2014). In this way, organizations can leverage data while generally continuing to function the same (Günther et al, 2017). Second, data can also be used to develop new value propositions, target different customers or interact with them differently. These two categories provide a basis for data usage to create value. However, specific ways and examples are not presented in their work.

Comuzzi & Patel (2016) emphasize that the big impact of using data lies in organizational decision-making processes. Better informed decisions can be made due to the processing of large amounts of data. Data can eventually be used to inform all phases of a product/service lifecycle, from marketing to optimizing maintenance if leveraged correctly (Comuzzi & Patel, 2016). This makes big data an organization-wide phenomenon, which results in it being hard to govern (Malik, 2013). It is already hard to manage within an organization, so managing big data will be especially a complex task on an ecosystem-wide scale. Etventure (2018) states that data should become part of the value creation process. Prior research has noted that the value creation of data-driven services for the logistics sector usually focuses on the visibility of the supply chain and optimizing resource deployment or routes (Möller et al., 2020). Visibility refers to tracking assets and the corresponding data-based value creation of this transparency and the generation of information and insights from this tracking process (Zrenner et al., 2017). Optimization refers to the data-based solution to find the best route based on objectives (Cattaruzza et al., 2017). Commuzi & Patel (2016) define five ways in which big data can enable growth opportunities to create value. The first way is to create a more holistic and transparent way of making decisions. Second, data experiments could be designed to discover needs to improve performance. The third way is to segment populations based on data to customize engagement. Another way is that decision-making can be automated due to the help of automated algorithms. Lastly, products, services, and business models can be innovated based on evidence from data.

These are just examples of how technologies could be used to capture value. However, to design an optimized value proposition, it is important to identify all cases of how technology could be used to bring the most value. Identifying use cases for a certain technology requires creativity and is a key part of a DT process. It is a way to generate concrete value from data (Hartman et al., 2016). Bange (2016) and Kayser et al. (2018) highlight the importance of having an ideation or creativity phase as an essential part of data-driven innovation. Therefore, methods and tools that can be used during the ideation phase will be reviewed in section 2.2.

2.1.4 Positioning this Research in Scientific Research

After reviewing the relevant concepts of DT's within ecosystems, the relations between the concepts have been identified and captured into a conceptual model *(see figure 2.1)*. The model presents relevant DT concepts and visualizes the relations between the concepts. The purpose of the model is twofold. First, it provides an overview of the scientific context of this research as it visualizes the key concepts of a DT. This provides insights in how this research needs to be approached, which will be discussed in chapter 3. Second, it guides the research by highlighting key challenges and needs that exist in a DT process within an ecosystem. What sets this research apart from the existing literature on DT's is that it combines the two research streams of DT literature with an ecosystem perspective. The research not only focuses on the impact or the process of a DT but also considers both aspects in combination with an ecosystem perspective. Existing literature mainly focuses on DT's within organizations. This research bridges the gap and applies an ecosystem perspective on both research streams of DT's.

The conceptual model consists of two dimensions, namely, the impact of a DT and the process of a DT. The model highlights the importance of three key concepts identified as challenges during a DT process. First, when facing a DT inside an ecosystem, the concept of ecosystem dependency is of high importance. It is important to identify dependencies between actors inside the ecosystem, as this can hold back innovations. Second, data awareness has been identified as a key challenge, as it is necessary to identify what data is available or know potential data sources since this is crucial input during the data-driven use case identification process. A lack of this awareness can hold back the identification of use cases and thereby a DT. A last key challenge is the concept of an established situation, which refers to legacy systems, inertia, path-dependency constraints, habits and institutions. The established situation can hold back the transformative process of a current situation. Furthermore, the conceptual model shows that DT's can lead to new value propositions or process optimization. It was found that a strategy is defined in the literature as a necessary condition for a successful DT, as this can guide the process towards the desired situation. Therefore, these three concepts have been classified as 'needs' during a DT process.

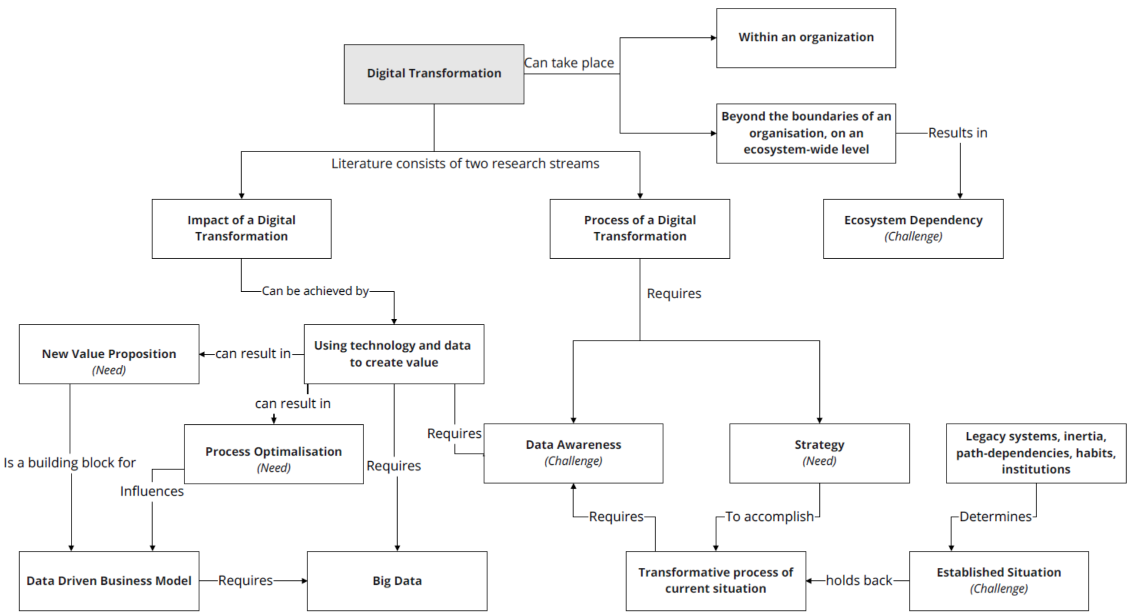

Figure 2.1: Conceptual Model

2.2 Tools and Methods

The second subsection will get more in-depth on reviewing existing methods and tools that can be used during the research. The methods and tools are reviewed based on their strong and weak points, applicability, and usefulness for this research. Literature has been found using (combinations of) keywords (digital transformation, tool, method, workshop, multi-disciplinary tool, ideation process use cases, data-driven technology, business model innovation, value proposition design, creativity) in both title and abstract through search engines Google Scholar and Scopus. This was followed up by back-referencing relevant sources cited by the found literature. In this way, a combination of searches in databases and backward snowballing is performed. By performing the literature review, an answer to the second sub-question of this research is provided:

"What state of art, methods and tools can be used during the exploration and identification of use cases and the design of the corresponding value proposition of data-driven technologies in an ecosystem setting?"

To take full advantage of digital opportunities, tools and methods are needed to support the DT process (Goerzig & Bauernhansl, 2018). Design thinking provides a tremendous opportunity for multi-disciplinary teams to create creative and innovation-oriented practices during the innovation process (Culén et al., 2016). It is proven that the use of design thinking methods and tools can guide as a way of incubating ideas and creating innovative solutions within multi-disciplinary teams (Chasanidou et al., 2015). Design thinking has a holistic nature and deals with problems especially focused on the interface between IT and business (Chasanidou et al., 2015). This holistic view is based on the fact that design thinking is focused on user-driven innovation, where relevant actors are involved during the design process to design value propositions that are meaningful and profitable for multiple actors (Baldasarre et al., 2017). This is a critical task since it requires balancing the needs and objectives across a network of multiple actors to create shared value (Allee, 2000). Geissdoerfer, Bocken and Hultink (2016) state that iterative involvement of relevant actors during the design process of the value proposition creates more extensive acceptance, commitment, and support for innovations that are not solely focused on technological efficiency.

Design thinking is placed at three overlapping spaces - viability, desirability and feasibility - where innovation can be reached when all three perspectives are addressed (Chasanidou et al., 2015). Viability refers to the business perspective; the user's perspective is represented in desirability, and feasibility reflects the technology perspective. Therefore, it is important to identify use cases that are placed at these three overlapping spaces. A key aspect of working with design thinking is the consideration of tools that are to be used during the process (Culén et al., 2016). This section provides an overview of tools and methods that can be used during a DT process. This process is divided into three steps of the design cycle of this research: the problem awareness, the suggestion and the validation step.

2.2.1 Problem Awareness Step

The problem awareness step focuses on creating an overview of the ecosystem by identifying its current challenges and needs. A method applicable to this step is stakeholder analysis, which is often used to work more effectively with stakeholders and facilitate transparent implementation of technologies and assess the feasibility of technologies with involved stakeholders (Reed et al., 2009). The analysis can be descriptive, normative, and instrumental. The methods used during the analysis determine the outcome of the analysis, such as which stakeholders are included or not. Popular methods are to draw a stakeholder map to create a visual representation of involved stakeholders (Chasanido, Gasparini & Lee, 2015), a power interest grid to classify stakeholders (Reed et al., 2009), and a relations diagram to define the interrelations between the stakeholders. Other methods are to design personas, which are used to analyze the desires, needs, and expectations of involved stakeholders (Chasanidou et al., 2015), or conduct interviews to generate the information required for the stakeholder analysis (Reed et al., 2009).

A key concept that the conceptual model highlighted was data awareness. Several tools are presented in the literature that can help during the data awareness process. The tools are often designed from within an organizational perspective. One way to do this is by filling in the Data Collection Map proposed by Kayser et al. (2019). This tool contains 11 blocks of different kinds of data as an inspiration and starting point to brainstorm on available or potential data. Another tool to detect data sources is the Safe-DEED data map, which is designed to help with identifying available or potential data sources that can be utilized to develop new data-driven services (Breitfuss et al., 2020). This is a tool that can be used during workshops to stimulate creativity and ideas. Data is divided into four categories: data owned by the organization, data created in collaboration with a 2nd party, data provided by a 3rd party provider and data created and owned by a 2nd party. This tool is designed to use within the perspective of one organization and is less applicable when facing an ecosystem-wide setting. As this tool consists of only four categories and does not come with 11 examples as the Data Collection Map, the Data Map can be combined with the Data Service Cards developed by Fruhwirth et al. (2020). This is a tool to facilitate creativity and co-creation amongst teams with different backgrounds, as this can be a challenge. The data sources cards can guide as an inspiration in the same way the data collection map can do. However, the data sources cards are also provided with a short description of the data sources. This makes it easier to use the cards in a multidisciplinary team of non-data experts. The data cards consist of five categories: data sources, data analytics, data services, benefits, revenue models. The Data Service Cards are also designed to be used within one organization. Nevertheless, the tool can be combined with a Data Service Canvas tool to ensure an ecosystem-wide approach. Multiple canvases can be filled in from a specific user perspective to generate a complete overview of data-driven services for the ecosystem. This Data Service Canvas tool is based on the Data-Driven Business Canvas tool, which is a building block for a DDBM. Thus, the output of using the Data Service Cards in combination with the Data service Canvas can be used within the design process of DDBM's. The figure below shows an overview of the available tools and their relation to the requirements of this research design.

Tool for the creation of Data Awareness	Can be used during a workshop	Can be used within a multi-disciplinary group	Incorporates an ecosystem perspective	Can be used for the ideation process of data-driven services
Data Collection Map (Kayser et al., 2019)	✓			
Safe-DEED Data Map (Breitfuss et al., 2020)	✓	✓		
Data Service Cards (Fruhwirt et al., 2020)	✓	✓		✓
Data Service Canvas (Fruhwirt et al., 2020)	✓	✓	✓	

Figure 2.2: Overview Tools Data Awareness

2.2.2 Suggestion Step

The identification process of use cases is executed in the suggestion step. Tools can be used during this step to incubate business ideas and create innovative solutions (Chasanidou et al, 2015). A core aspect of the innovation process supported by design thinking is using divergent and convergent thinking (Brown & Katz, 2011; Chasanidou et al., 2015). The first step is to broaden the view by making it divergent. Divergent thinking is seen as a relevant attribute for innovation, as it stimulates creativity and the identification of ideas. It allows actors to open their minds to new possibilities and solutions, to become more innovative (Black, 2019). A successful way of stimulating the generation of ideas and solutions is organizing workshops, where divergent thinking can be stimulated. Especially, when facing a DSR approach, workshops can be useful to co-create innovations (Thoring, Mueller & Badke-Schaub, 2020). Literature about workshops as a research method is scarce, but an important aspect mentioned widely is the importance of defining the workshop goals or objectives (Culén et al., 2016; Sufi et al., 2018; Thoring et al., 2020). Research by Culén et al. (2016) states that semi-structured tools work best during the innovation process within a workshop concerning generating a wide variety of outputs and ideas and engagement of participants. Semi-structured tools will allow for collaborative co-creation and improvisation by involved participants during the usage of the tools.

Thoring et al. (2020) propose five general principles for evaluating workshops, which are defined as focus definition, role allocation, triangulation, transparency, and reflection. To allow replicability for other researchers the evaluation goals, methods, selection criteria, participants' details and workshop content need to be described and published. This implies that not only the methods and tools used during the workshop need to be illustrated, but also the methods and tools used to analyze and evaluate the results of the workshop. Several evaluation methods are proposed by Thoring et al. (2020), such as observation and notes, photography, video and/or audio recordings, surveys, interviews, and group discussions. The suitability of these methods differs per purpose, as surveys are a suitable method for generating people's perception and opinion of the (outcome of the) workshop. On the other hand, recordings are suitable to analyze people's behavior, interactions and dialogues during a workshop.

Tools that are commonly used during business modeling processes are the Business Model Canvas (Osterwalder and Pigneur, 2010) and the Business Model Value Network (Chanal, 2011). These tools highlight the power of visual tools in facilitating communication, collaboration and allocation of resources. To incorporate data aspects, Breitfuss et al. (2020) developed the Data-Driven Business, Canvas tool, which can help develop a data-driven innovation based on the Data Product Canvas developed by Fruhwirth et al. (2020). This canvas tool consists of five main sections: the data sources, the needed analytics methods, the data product, the intended customer benefit and the financial implications (Breitfuss et al., 2020). Creating a data-driven business model can lead to more clarity of the value of data-related processes (Hartmann et al., 2016). A pitfall of the tools illustrated above is that the current situation (i.e. current challenges, needs and opportunities) is not part of the tools. A way to incorporate the current situation is by using the Data Innovation Board proposed by Kronsbein and Mueller (2019). This tool is designed to facilitate the development of data-driven products and services (Kronsbein & Mueller, 2019 and can be used by non-data experts. The structure of the tool follows the design thinking logic of exploring, ideating and evaluating. The explore phase focuses on the current situation, where it is important to draw a precise picture of the data that is already collected currently and what challenges occur, as illustrated above. The ideate phase refers to the brainstorming activities where ideas for data services will be generated. The last phase, evaluation, is to identify an action plan on how to measure the success of the data-driven service. It presents a holistic view of data projects. As this tool is useful to incorporate the current situation during the workshop, the defined data service will not be as complete and clear compared to when filled in the Data-Driven business canvas, where the data analytics and services are more extensively defined.

The Data Innovation Board could be filled in multiple times to represent the current situation for several actors, in which it can be applied in an ecosystem-wide setting. This is closely related to the user goal technique, a tool designed to identify use cases (Famuyide, 2017). This is an approach to list all the actors who interact with the system and identify their goals for the future system. Another way to get different perspectives of a multi-actor environment's current and desired situation is by utilizing the Value Mapping Tool. This tool was created by Bocken et al. (2013). It can be used to visualize the current situation of the value proposition and the value opportunities for different actors (Bocken et al., 2013). First, involved actors need to be determined. Next, the current value situation needs to be mapped and identified for each actor, followed by ideating for value opportunities where new opportunities for value creation can be identified. Thus, this tool can help to create ideas and use cases, as current pitfalls and challenges will be detected per user group and linked to opportunities (Lehman et al., 2015).

A taxonomy proposed by Rizk, Bergvall-Kareborn and Elragal (2018) can be helpful during the design process of data-driven services as it highlights how data and analytics can be utilized for service design (Rizk et al., 2018). It is a useful tool to understand the steps inside the process and how they are related. The first step refers to the data acquisition mechanisms which will generate data. This data can then be exploited with different processing and analytical activities employed on the data to add value. Next, the information and knowledge that arises from this data exploitation process will be utilized to generate insights. Lastly, the user interaction with the service is identified. These steps are interesting to consider during the development process of data-driven services. However, this scheme is not a helpful tool to use during a workshop to generate ideas for the development of data services. It is more a scheme to illustrate the development process. Thus, it could be helpful to describe this process at the beginning of a workshop so that attendees know the sequence of steps to come to the end goal.

An overview of the tools discussed can be seen in the figure below. It can be seen that none of the tools meet all requirements set for this research design.

Tools suggestion step	Describes the influence on the current situation	Describes analytics and data used for data-driven service	Is a building block for a DDBM	Incorporates an ecosystem perspective	Describes dependency on actors	Can be used to present use cases
Business Model Canvas (Osterwalder & Pigneur, 2010)						✓
Business Model Value Network (Chanal, 2011)				✓	✓	
Data-Driven Business Model Canvas (Fruhwirth et al., 2020)		✓	✓			✓
Data Innovation Board (Kronsbein & Mueller, 2019)	✓					✓
Value Mapping Tool (Bocken et al., 2013)	✓			✓		
Taxonomy (Rizk et al., 2018)		✓				

Figure 2.3: Overview tools Suggestion Step

2.2.3 Validation Step

Convergent thinking can be used in the last phase of the innovation process, where the generated ideas during the ideation phase will be considered to produce an innovative solution. During the ideation phase, multiple data-driven services can be designed. Convergent thinking can help to prioritize and analyze the services to come with the best possible outcome. There are multiple approaches to analyze different use cases, prioritize them and choose the best option. A radar chart is a tool that can be used during the selection of use cases, as it helps assess on a multi-dimensional scale (Chaudhary & Vrat, 2018). Actors can be plotted on the axes to present an overview of the value of use cases for every actor in the ecosystem. It thereby provides a sense of the big picture, as well as the detail for each individual use case and actors (Saary, 2008). The performance is indicated by the area of the polygon, where a larger area indicates better performance (Chaudhary & Vrat 2018). Symmetrical polygons indicate a relatively balanced system (Gareau et al., 2010), which means that the use case is approximately equally valuable for all actors. Another tool that can be used during the selection phase is the impact feasibility matrix, which visualizes the relationship between the impact of innovation and the effort needed to realize the implementation of this innovation (Lehman et al., 2015).

2.3. Conclusion Chapter 2

The goal of chapter 2 is to provide an overview of the scientific context of this research, whereas the purpose of this context is twofold. First, an answer is provided on the first sub-question:

"What types of challenges and needs exist in a digital transformation process within an ecosystem, and how do they relate to the key concepts of a digital transformation?"

A digital transformation can be defined as a process initiated by the increasing use of digital technologies and its corresponding generated data to influence value creation, resulting in process optimization or new value propositions within an organization or ecosystem. Thus, the transformation can take place within one organization and beyond the boundaries of an organization. A conceptual model was made to present an overview of relevant concepts to a DT within an ecosystem and to help classify different challenges and needs *(see figure 2.4).* Three key challenges have been identified: ecosystem dependency, established situation, and data awareness. These three types will guide as a structure for the identification process of the current challenges of the baggage handling ecosystem of Schiphol Airport. The model also highlighted three needs of a DT process: process optimization, new value propositions, and strategy. These three types will be used as a structure during the identification process of the current needs of the baggage handling ecosystem of Schiphol Airport.

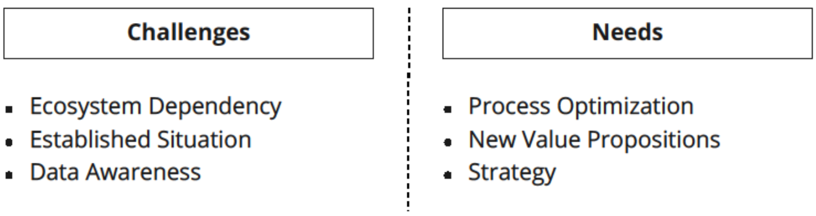

Figure 2.4. Types of Challenges and Needs

Second, this chapter has also provided an answer to the second sub-question:

"What state of art, methods and tools can be used during the exploration and identification of use cases and the design of the corresponding value proposition of data-driven technologies in an ecosystem setting?"

When facing an ecosystem-wide DT, other tools and methods are more important and applicable during the process than facing a transformation within an organization. The ideation process of identifying use cases needs to have a broader view towards all involved actors, in which the value of the digital transformation needs to be reviewed from a holistic perspective. Thus, tools are required that can be applied in a holistic value perspective. Tools that can be used during the ideation process of data-driven use cases must focus on the technical representation of the services or the implications for the current situation. A tool that combines these two specific characteristics does not exist. The overview of currently available methods and tools that can be used during the exploration and identification of use cases and the design of the corresponding value proposition of data-driven technologies within an ecosystem helps specify the methodology for this research, which will be illustrated next.

Chapter 3. Methodology

This chapter will illustrate the chosen methods to answer the research questions and why the methods are chosen. As illustrated in section 1.4, the DSR will be executed within a situated setting at Schiphol Airport. The methods that will be used during this research need to apply to this setting. Therefore, a context of this setting is first elaborated in section 3.1, followed by a discussion of the chosen methodology in section 3.2.

3.1 Introduction Situated Setting

Amsterdam Airport Schiphol (AAS) is a Dutch airport part of Royal Schiphol Group (RSG). A detailed description of the situated setting can be found in the Appendix A. A department of RSG is the Innovation Hub, which conditionally experiments to explore the distant future with new, innovative solutions and techniques to shape the future. A key focus point of the Innovation Hub is called 'Future Baggage', which focuses on baggage handling process innovations, to optimize the baggage flows and to provide a seamless passenger journey. This research will be executed within the Future Baggage team at the Innovation Hub.

AAS is facing baggage capacity problems. A peak in the baggage inflows higher than 80% of the capacity influences the airports' performance. It can lead to an increase in mishandled bags, which results in increased costs for the airport, airlines and handlers and dissatisfaction faced by passengers. AAS is working on implementing a new asset solution that will be ready in 2028 to increase the baggage capacity. Nevertheless, AAS estimates that even with the asset solution, a growth of the baggage handling peaks of 10% still needs to be covered via innovative solutions (Innovation Hub, 2021). The key challenge is to shave the high infeed peaks, in which the Innovation Hub formulated the following hypothesis: *"Prioritize baggage flows by looking at 'hot/cold' separation instead of 'first-in-first-out"*. Bags need to be identified in order to separate them. Figure 3.1 below presents an overview of the (dis)advantages of baggage identification technologies. A more detailed illustration per technology is added in the appendix.

Barcode Label

- \+ Widely adopted and used
- \- Relatively lower read rate
- \- Still uses physical product to scan and identify baggage

Radio Frequency Technology

- \+ Relatively higher read rate
- \+ Could potentially offer a multitude of use cases in the foreseeable future
- \+ Proven technology
- \+ A driver for ecosystem intelligence, as it allows for a large amount of data on the baggage
- \- Relatively expensive solution
- \- Still uses a physical product to scan and identify baggage

Computer Vision Technology

- \+ Requires no application of physical attributes to baggage
- \+ Relatively higher read rate
- \+ Could potentially offer a multitude of use cases in the foreseeable future
- \+ Proven technology
- \+ A driver for ecosystem intelligence, as it allows for a large amount of data on the baggage
- \- Technology is relatively unproven, needs additional research for application in this field

Figure 3.1 Baggage Identification Technologies

As can be seen, CVT sounds promising. During check-in, visual images will be made of baggage, which will be linked to the passenger information. In this way, the bags can be identified by validation cameras based on their visual characteristics during the baggage journey. The technology works with a self-learning system in which the identification process needs to be executed very precisely. The system needs to be able to identify similar-looking bags based on their individual characteristics such as small scratches and bulges (D.J. Kanters, Personal Communication, September 20, 2021). An assumption formulated is that the CVT infrastructure needed is flexible, as it is more easier and cheaper to install out of the BHS (Innovation Hub, 2021). This has led to the fact that the Innovation Hub has formulated the hypothesis that CVT is the best way to facilitate tagless baggage handling. Next to that, the Innovation Hub formulated that tagless baggage is the best way to facilitate baggage identification outside of the BHS to achieve hot/cold separation. The key hypotheses of CVT are as follows:

- CVT enables RSG to identify and handle baggage effectively, safely and intelligently,
- By integrating CVT, RSG can add additional value to the baggage handling ecosystem,
- CVT is a desirable alternative for printed labels for the baggage handling ecosystem.

To validate these hypotheses, the possibilities and the added value of CVT need to be explored. In cooperation with an airline, AAS identified a use case to start the exploration of CVT, namely the hot/cold separation of TRF baggage, where cold baggage is buffered and inserted into the BHS later. A pilot for this use case will be started at the beginning of 2022, where the potential for separation will be tested.

3.1.3 Positioning the research in the situated setting

AAS faces a multi-actor environment, as the baggage handling process is executed in collaboration with multiple actors. This environment is defined in this research as the baggage handling ecosystem of Schiphol Airport. Currently, the ecosystem mainly uses printed barcode labels attached to baggage to identify bags using a barcode scanner or hand scanner. This research aims to design a value proposition of computer vision baggage identification technologies for baggage handling ecosystems at Hub Airports. As CVT can potentially be implemented for more use cases outside of the hot/cold separation use case, this research focuses on identifying use cases for CVT that can be implemented in the situated setting in the baggage handling ecosystem of Schiphol Airport. The Innovation Hub of RSG will use the research outcome to determine the potential of CVT and which use cases will be prioritized to focus on and implement next. Figure 3.2 presents how this research is positioned within the situated setting at AAS. Chapter 7 will discuss the found results of the research to conclude on the transferability of the results towards other hub airports.

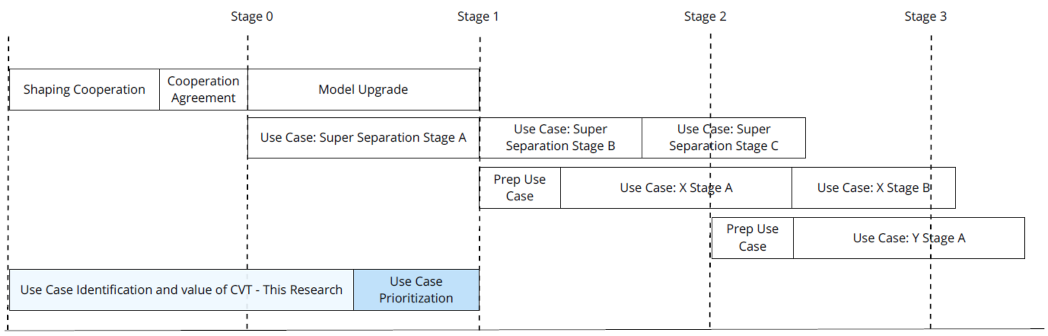

Figure 3.2: Position of this research within the situated setting

3.2 Research Methods

This section discusses the methods used within this research and how data is gathered and analyzed to conclude on the sub-questions *(see figure 3.3).* As can be seen, the product of the literature review is used as input for the methodology choices. The way of incorporating design thinking methods and tools in this research sounds promising, as this can guide as a way of incubating ideas and creating innovative solutions within multidisciplinary teams (Chasanidou et al., 2015). Thus, divergent and convergent ways of thinking will be incorporated within this research, which are key characteristics of design thinking methods.

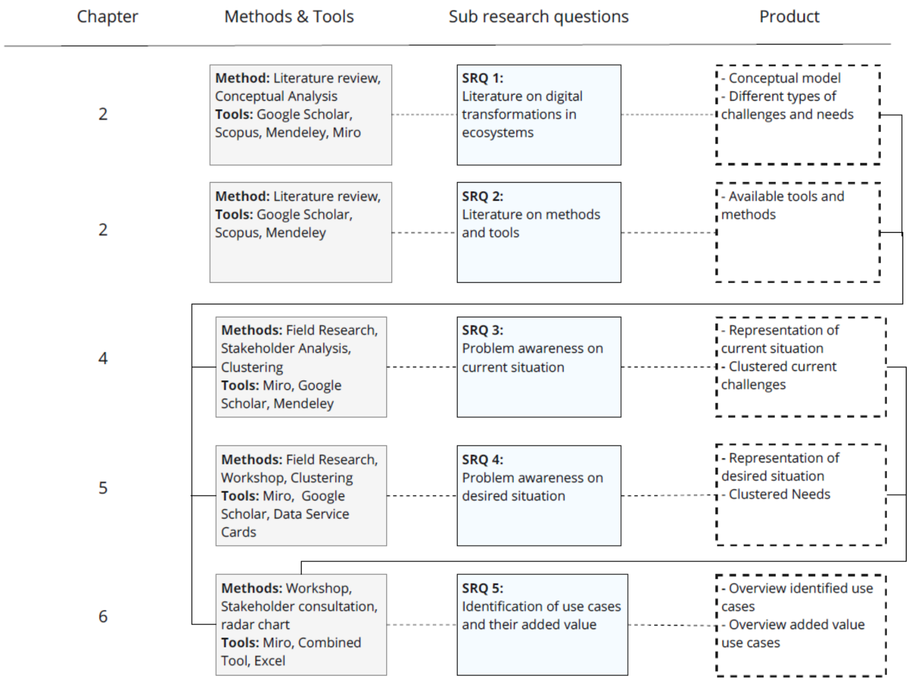

Figure 3.3: Overview of chosen methods and tools

3.2.1 Problem Awareness Step

The second step of the design cycle focuses on capturing the current and desired situation of the baggage handling ecosystem at Schiphol Airport by identifying the current challenges and needs. The required information is generated via executing field and desk research. In this case, field research is a suitable method, as this method can be used to conduct systematic and detailed research of daily practices in a specific setting (Yin, 2017). Field research cannot be neatly fitted into a linear model of steps (Burgess, 2006), as the researcher copes with a variety of social situations, perspectives, and problems. Therefore, the outcome of field research depends on the complex interaction between the researcher and those who are researched, which is a pitfall of field research. Essential aspects of field research are gaining access, selecting a wide variety of informants, and analyzing the data from different sources on its reliability and validity (Burgess, 2006).

For this research, informal interviews were conducted in combination with a workshop alongside observational work. Additionally, relevant documents and information were collected for research purposes. Access was provided to documents of RSG, which consisted of information on stakeholders and the processes of the BHS. In addition, the results of a graduation research performed in the first half of 2021 at the Innovation Hub were analyzed, which included an analysis on the current challenges occurring in the baggage handling processes at Schiphol Airport (van Wieren, 2019). These results were based on interviews conducted with representatives of all ground handler (GH) parties active at Schiphol Airport. In this way, the perspectives of all GH parties have been taken into account during the field research in such a way that this research builds upon previously performed research to avoid duplication of work. Next to the available information, informal interviews have been conducted. Due to limited time, it was chosen not to include GH parties and passengers within these interviews but to focus on RSG and airlines. The informal interviews were unstructured, and all focused on different aspects of the baggage handling process. Despite the downfall of this strategy, as this lowers the reliability, validity, and representativeness of the gathered information, it was preferred to gather a wide variety of information to create a firm understanding of the baggage handling process. A firm understanding was required as innovative improvement of the baggage handling process is a complex and holistic task (Koldkjær, 2017). Due to limited interviews per subject of the baggage handling process, criteria to include challenges and needs in the results did not include statistical generalizability or a certain level of agreement about challenges and needs. Rather, when challenges or needs were mentioned in convincing ways *(supported by data, argumentations or other reasons)*, they were included in the results. To analyze the reliability and validity of the results of these interviews, the results were validated and discussed during the use case workshop *(see section 6.1).* The following people were consulted to gather the required information:

- *Advisor Logistics & Innovation – RSG (Airport):* Basics of the baggage handling process, stakeholder validation, key performance indicators, data overview validation.
- *Process Manager Baggage Logistics – RSG (Airport):* Current identification processes of baggage, locations of barcode scanners, technical implications of identification of baggage.
- *Lead Data Analyst – RSG (Airport):* Currently available data sources, data analytics possibilities, data overview validation.
- *Data Scientist – RSG (Airport):* Currently available data sources, future data-driven applications and benefits, technical implications of computer vision technologies.
- *Architect Baggage Systems – RSG (Airport):* Technical implications baggage handling system, current baggage tracking possibilities, validating process steps of the baggage handling process.
- *Innovation Lead Eindhoven Airport – RSG (Airport):* Opportunities and benefits of CVT for the baggage handling process.
- *Security Policy & Process Developer – RSG (Airport)*: Validating security process step of the baggage handling process, opportunities and benefits of CVT for the security process step.
- *Advisor Strategy & Airport Development – RSG (Airport):* Strategy of the ecosystem, opportunities and benefits of CVT and its relatedness with the strategy.
- *Project Manager Baggage Services – KLM (Airline):* Validating process steps airline and ground handlers, opportunities and benefits of CVT.
- *Customer Management - Customs Schiphol Airport (Customs):* Process steps customs, current usage of barcode labels by customs.

It can be seen that only one airline has been consulted in this stage of the research, namely KLM. This is due to easy access to this airline compared to other airlines and the time limitations of the research. Consulting more airlines might have revealed other results. To minimize the limitations, another airline is consulted during the validation process of the use cases, which is illustrated in section 3.2.2. The interviews did not only guide as a way to generate the information required for this research. A way to accomplish a successful DT is by having a supportive culture where values such as openness and willingness to change are embedded (Osmundsen et al., 2018; Kraus et al., 2021), which can be achieved by actively and interactively involving actors during the DT process (Geissdoerfer et al., 2016). Thus, the interviews are not only useful for generating knowledge, but also to start the conversation about CVT in the ecosystem of Schiphol Airport. As CVT is new for most interviewees, a description of the technology and its implications was provided at the start of the informal interviewees to ensure that all had the same perception of CVT.

The field research is structured into the identification of the challenges and needs of the baggage handling ecosystem of Schiphol Airport. The conceptual model *(see figure 2.1, section 2.1.4)* highlights that both the challenges that can hold back a digital transformation and the needs of a digital transformation process can be divided into three categories. The categories guide the research as follows:

- **Ecosystem Dependency**

A DT that occurs beyond the boundaries of an organization but on an ecosystem-wide level can result in ecosystem dependency. When facing an ecosystem setting, it is crucial first to delineate the system (Carllsson et al., 2002). In addition, an ecosystem-wide value proposition is created as a result of interactions between actors (Galvago & Dalli, 2004; Adner, 2016; Baldasarre et al., 2017), which emphasizes the importance of identifying the interactions between the actors in the system. These requirements ask for the execution of a stakeholder analysis. The process and analysis of the results of this analysis can be found in section 4.1.

- **Established Situation**

Well-established ecosystems are often bound by legacy systems (Hartmann et al., 2016), where challenges exist such as organizational inertia or path-dependency constraints (Hunke et al., 2017). The established situation can hold back a DT, emphasizing the importance of identifying the current challenges related to the established situation. The identification process and analysis of the results of the established situation can be found in section 4.2.

- **Data Awareness**

A fundamental step in the DT process is to create data awareness (Kayser et al., 2019). It is important to identify what data is available or have the knowledge on potential valuable data sources as this is crucial input during the data-driven use case identification process (Bange, 2016). Therefore, the currently available data sources have been identified, which is a first step in creating data awareness (Rizk et al., 2018; Breitfuss et al., 2020). However, the literature review found this is a complex task within an ecosystem setting, as actors are often reluctant to share their data. It is, therefore, chosen to only identify and collect data types instead of the actual data within the ecosystem. In this way, actors only need to share what kinds of data they generate, instead of the data. The results of this identification can be found in section 4.3.

- **Process Optimization**

A DT can lead to process optimization (Westermann, Bonnet & McAfee, 2014), which results in the need to analyze which processes could be optimized by implementing CVT. An ecosystem is usually characterized by a common system-level goal (Appleyard & Chesbrough, 2017). The drivers of the system-level goal of the baggage handling ecosystem of Schiphol Airport are analyzed to identify which processes can be influenced by the implementation of CVT. The analysis and results can be found in section 5.1.

- **New Value Propositions**

Despite process optimizations, a DT can also lead to new value propositions (Westermann, Bonnet & McAfee, 2014). As the adaptation of CVT would produce (real-time) data, it is important to identify the possibilities of using this data to create value. Modern analytical methods open up possibilities to use this data to create value (Breitfuss et al, 2019). Organizations are not only using data to support decision-making to enhance process efficiency, but also to engage in new data-driven services (Enders, Schüritz & Frey, 2019). The understanding of the possibilities of data-driven value creation is needed to enable the design of new and improved services (Rizk, Bergvall-Kåreborn & Elragal, 2018), as the choice between analytics and services is a major driver for the output of the DT (Elgendy & Elragal, 2014).

Therefore, a workshop has been organized to identify desired data-driven services for the baggage handling service. One of the key reasons organizations currently capture only a fraction of the value of data is because of a lack of interdisciplinary communication between the IT department, data analytics, and business teams (Kayser et al., 2019; Fruhwirth et al., 2020). Therefore, the attendees of the workshop represented multiple departments of RSG. Given the time limitations and no contacts with different departments of airlines, it was chosen not to include other parties within this workshop. The multidisciplinary character of the group required a tool that could be used in an interdisciplinary setting, in which not all attendees had sufficient IT knowledge. In addition, creativity and inspiration needed to be stimulated during the workshop to guide the ideation process of identifying data-driven services. Next to these requirements, the tool required an ecosystem-wide approach instead of focusing on within an organization. Lastly, the research objective is to identify use cases for CVT that could guide as a building block for developing the required DDBM's. Therefore, it was required that the tool's output was a starting point for developing a DDBM.

After analyzing the currently available tools *(see section 2.2)*, the Data Service Cards (Breitfuss et al., 2020), combined with the Data Service Canvas, met all the requirements needed for a tool and were therefore used during the workshop. Cards inspire the ideation process of data-driven services and can be used within a multidisciplinary setting. Evaluation methods such as audio recording, a survey, and observation and notes have been applied to analyze the workshop results, illustrated in section 5.2. The specific content, invited attendees, and workshop planning can be found in Appendix F1. As CVT was new for most attendees, a description of the technology and its implications was provided at the start of the workshop *(see appendix F1)* to ensure that all had the same perception of CVT.

- **Strategy**

The strategy of the baggage handling ecosystem of Schiphol Airport is required to be included in this step, as having a strategy is defined as a must for the success of a DT (Hönigsberg, Dias and Dinter (2021). When facing a DT on an ecosystem-wide level, the strategy must include the objectives of the involved actors (Dias & Dinter, 2021). In reality, the objectives of actors can differ, therefore, the ecosystem-wide strategy is not as straightforward to determine as illustrated in the literature. The results of identifying the strategy are analyzed based on its representativeness for the whole ecosystem. The results and analysis can be found in section 5.3.

The output of the field research is an overview of the current challenges and needs of the baggage handling ecosystem of Schiphol Airport and will be used as input during the suggestion step. The challenges and needs are clustered into the six concepts highlighted by the conceptual model. The goal of clustering is to separate an unlabeled data set into structured data (Lam & Wunsch, 2014). Clustering can be used for various purposes. In this research, clustering is performed to present a classification of the current challenges and needs and to test if the six concepts identified in the conceptual model were present in reality. The process in which the challenges are clustered is illustrated in section 4.4, whereas the process of how the needs are clustered can be found in section 5.4.

3.2.2 Suggestion and Validation Step

The third step of the design cycle focuses on identifying use cases for CVT that could be implemented in the baggage handling ecosystem at Schiphol Airport. A workshop is organized to facilitate a brainstorm for this identification process, as workshops are often used to co-create innovations (Thoring et al., 2020). The challenges and needs identified during the first step of the design cycle have been guided as input during the workshop. The specific content, invited attendees and planning of the workshop can be found in Appendix G1. To analyze the reliability and validity of the workshop results, the results have been discussed and validated by various stakeholders during the validation step of the design cycle. As only one airline was consulted during the first step of the research, it was preferred to contact another airline during this step. It was chosen to include an airline with significantly different characteristics than KLM, namely Corendon. Corendon does not accommodate TRF flights and is relatively small compared to KLM. In this way, it can be seen if both types of airlines are positive towards CVT and the identified use cases. The following stakeholders have been consulted for a discussion on the identified use cases:

- Advisor Logistics & Innovation – *RSG (Airport)*
- Innovation Lead Future Baggage - *RSG (Airport)*
- Senior Process Developer Baggage - *RSG (Airport)*
- Architect Baggage Systems - *RSG (Airport)*
- Project Manager Baggage Services – *KLM (Airline)*
- Manager Airport Services – *Corendon (Airline)*
- Vice President Airline and Airport Development – *BagsID (CVT Provider)*
- Key Account Manager RSG - *Vanderlande (BHS Provider)*

A tool was needed to analyze and structure the workshop's outcome, a list of identified use cases for CVT. Several requirements were set for this tool. First, the influence of the use case on the identified challenges and needs needed to be visualized in the tool. A digital transformation can result in the creation of value. However, this value should also be identified and captured by the involved actors to optimize the value proposition (Bocken et al., 2013; Chesbrough et al., 2018;). Therefore, the tool needed to present the added value of the use case for more actors. In addition, the choice between analytics and services is a major driver for the output of the DT (Elgendy & Elragal, 2014). This choice needed to be specified in the overview of the use case. As the objective of this research is to provide a building block for the aviation industry to develop the required DDBM for CVT, the overview needed to align with the building blocks of a DDBM. Lastly, as written in the introduction, the dependency on other airports for the use cases is an important aspect, emphasizing the importance of including this in the use case overview.

This specific list of requirements required the design of a new tool, as no currently available tool met all of the requirements *(see section 2.2)*. Nevertheless, two existing tools guided as an inspiration for this design and were combined into a new tool. The exploration step of the Data Innovation Board (Kronsbein & Mueller, 2019) provided the basis for including the current established situation and a way to visualize the influence of the use cases on the identified challenges and needs. The Data-Driven Business Model Canvas (Breitfuss et al., 2020) provided a building block of a DDBM, where the needed data sources and analytics could be specified. As the holistic value of the use case is of high importance, the added value needed to be specified for the ecosystem instead of focusing on the key user of the use case. The choices that were made during the construction of the tool are illustrated in section 6.2.1. In addition, by filling in this tool, an elaborated overview of the use cases is provided, which is analyzed and visualized in various ways in chapter 6. Constructing and analyzing radar charts provided information to conclude on the value of CVT for the ecosystem.

3.2.3 Discussion and Conclusion of the Results

The results will be discussed in chapter 7 to make a strong case for the knowledge contribution of the research (Gregor & Hevner, 2013). This research focuses not only on the design of the value proposition by identifying use cases but also on the contribution to the knowledge base, following the principles of DSR (Hevner et al., 2004). A key feature of DSR is the relevance of the research results to applications in businesses (Gregor & Hevner, 2013). This research can be classified as an improvement research, where a new solution is investigated for a known problem (Gregor & Hevner, 2013). The output of this DSR is a designed value proposition. Chapter 7 also discusses if this value proposition can be used as a building block for the aviation industry and what further steps are recommended to develop the DDBM.

The value proposition is designed for Schiphol Airport as this research is executed in a situated setting. However, other hub airports could also benefit from this generated knowledge by using (parts) of the value proposition to develop their DDBM's. Nevertheless, it needs to be analyzed if the results apply to other hub airports. In this way, the scientific contribution of this research is identified if some aspects of the value proposition can be used in other contexts. Furthermore, learnings from the design process are identified and may guide as process principles or guidelines for future similar innovation design projects. The conceptual model is discussed based on the results of this research, as it is analyzed if the key concepts of the model were in fact present in reality. Recommendations for further research are added to chapter 7 to guide future researchers.

Chapter 4. Current Situation Baggage Handling Process

This chapter focuses on the current situation of the baggage handling process at Schiphol Airport and aims to answer the following sub-question:

"What are the current challenges occurring in the baggage handling ecosystem of Schiphol Airport?"

As found in the literature review, it is of high importance to delineate the system that will be investigated in this research. The system investigated in this research is referred to as the baggage handling ecosystem of Schiphol Airport. The ecosystem has a common objective, namely, to ensure that passengers' baggage is handled quickly and safely towards the right destination. Nevertheless, individual sub-objectives of actors in the ecosystem can differ, and contradictory objectives are needed to identify. A fundamental step in the delineating process of the system is to identify the components that the system consists of (Hekkert et al., 20017). As illustrated in the methodology, the field research to generate the required information was structured into three concepts based on the conceptual model.

4.1 Ecosystem Dependency

As illustrated in chapter 3, a stakeholder analysis is executed to capture the relations and dependencies between actors in the baggage handling ecosystem of AAS. The methodology of this analysis is illustrated next, followed by the results of the analysis.

4.1.1 Methodology Stakeholder Analysis

The stakeholder analysis has started with an illustration of the context, where the focus of the analysis and the system boundaries were identified. The methods used during a stakeholder analysis influence the outcome of the stakeholder analysis, i.e. the involved and not involved stakeholders (Reed et al., 2009). The objective of the stakeholder analysis of this research is twofold. First, the analysis was applied instrumentally to identify stakeholders, reveal their interests and influence, map their relations, and understand synergies and conflicts between the stakeholders of the baggage handling ecosystem at Schiphol Airport to provide a research context. This then allowed concluding on actions for the stakeholder engagement during the research. This second purpose has a normative character, suggesting that stakeholders need to be involved in the decision-making process (Reed et al., 2009). This is in line with the theory found in the literature review, as Geissdoerfer et al. (2016) states that actors need to be actively and interactively involved during a DT to enhance values such as openness and willingness to change.

The structure of the stakeholder analysis is as follow:

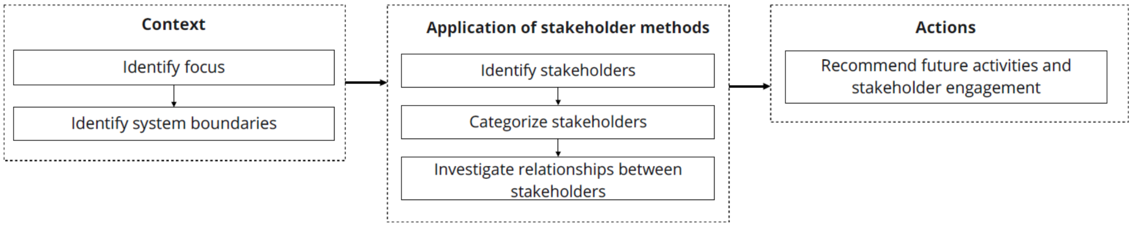

Figure 4.1 Structure Stakeholder Analysis

A range of methods was used to conduct the analysis by identifying stakeholders, categorizing them and investigating the relationships between actors in the ecosystem. The stakeholders were first put inside of a stakeholder map, which creates a visual representation of the involved stakeholders (Chasanido, Gasparini & Lee, 2015). Baldasarre et al. (2017) emphasize the importance of a participatory approach , such as validating with stakeholders, since the tool does not indicate if all stakeholders are found. Other relevant stakeholders can be found by consulting stakeholders on the map, which the researcher might not identify. The stakeholder map provides an overview of the involved actors, however, it does not present relations between stakeholders or categories of stakeholders. Therefore, a power/interest matrix was made to categorize the identified stakeholders. This is a popular method used to classify actors into key players, context setters, subjects and crowd (Reed et al., 2009). Key players are stakeholders who need to be actively involved since they have high interest and power in the project. Although such a matrix provides quantitative information about the relative interest and power of different stakeholders (Reed et al., 2009), the information may contain hidden assumptions that are not visualized in the matrix, which limits the replicability. To minimize these limits, the qualitative information about why stakeholders have a particular interest or why certain stakeholders have more power than others is gathered and presented in Appendix B which increases the replicability. Lastly, the relations between the stakeholders have been captured inside a relations diagram. This is done since the literature review presented that an ecosystem-wide value proposition is created as a result of interactions between actors (Galvago & Dalli, 2004; Adner, 2016; Baldasarre et al., 2017). This emphasizes the importance of identifying the interactions and relations between the stakeholders. The interactions and relations are analyzed thereafter to identify dependencies between actors since identifying the ecosystem dependencies is highly important during this research.

An iterative approach was taken to the analysis. Information on the stakeholders was mainly collected through the access to documents at RSG and by validating the results with involved stakeholders. A full participatory approach is costly in terms of researcher and stakeholder time. Therefore, the stakeholders had no active involvement in constructing the analysis, which might have revealed other results.

4.1.2 Results Stakeholder Analysis

This section covers a concise overview of the results of the stakeholder analysis. A detailed description of the stakeholders, relations, and dependencies can be found in Appendix B. Most important to notice is that the baggage handling ecosystem is defined as an ecosystem that consists of stakeholders who have a link to the baggage handling process. Therefore, this definition has set a requirement that stakeholders need to meet to be included in the stakeholder analysis. This identified the system boundaries and, for example, excluded stakeholders working in the stores at AAS, as they are not active in the baggage handling process.

An available stakeholder map created by the Innovation Hub formed the basis for the stakeholder map for this research. Together with the Innovation Lead of Future Baggage, this map was adjusted based on the context of this research. After validating this stakeholder map with the Advisor Logistics & innovation of RSG, a final map was created. A contradictory result was the role of insurance companies in this research context, as desk research illustrated that CVT would result in a high value for insurance companies since the technology would provide proof of damage of bags (Singh et al., 2016). Nevertheless, the Advisor Logistics & Innovation at RSG emphasized the responsibility of airlines in the claims of damaged bags and that the costs of damaged and lost bags are currently paid by airlines. After consulting the Project Manager Baggage Services of an airline, this assumption was validated. This resulted in the fact that insurance companies have been left out of the stakeholder map. The stakeholders were thereafter classified into four categories based on their interest and power in the possible implementation of CVT in the baggage handling process. This classification is not based on interviews with all stakeholders because of a shortage in time. The level of interest and power of a stakeholder is determined based on field and desk research, where the objectives and roles of the stakeholders have been analyzed, which formed the basis to classify them. The objectives and roles can be found in Appendix B. The power/interest matrix provides guidance on how stakeholders need to be engaged during the identification process of use cases for CVT during this research.

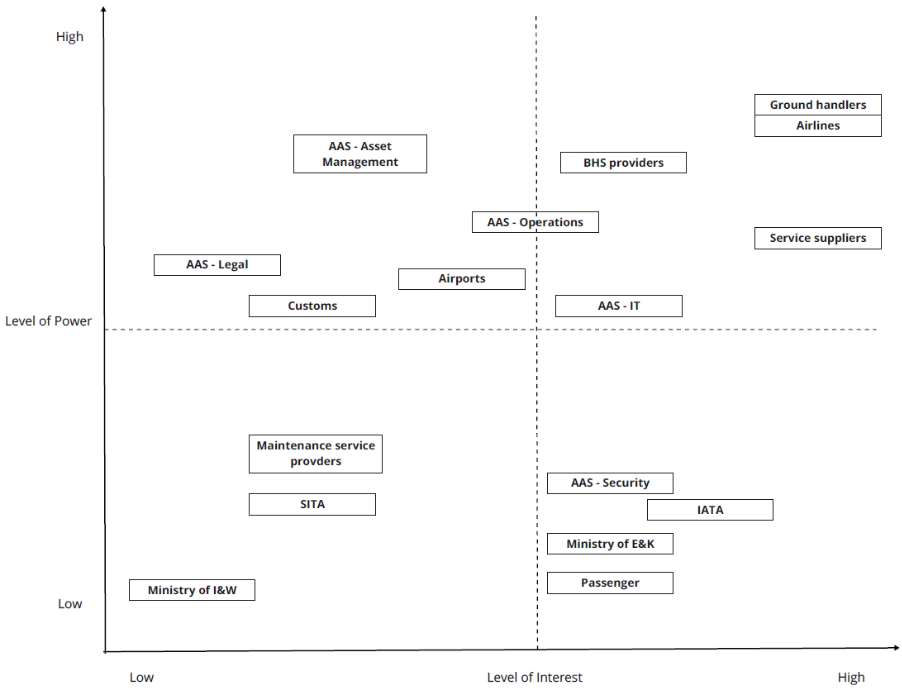

Figure 4.2: Power/Interest Matrix

Most important to notice is that the stakeholder fields are equally divided into the four categories of the power/interest matrix and no categories are underrepresented. The key players in this stakeholder field are the airlines, handlers, BHS providers, service providers and the IT department of RSG. Their power and interests are relatively high, which is why it is useful to actively include these actors during the identification process of use cases within this research (Reed et al., 2009). The value of CVT for these actors needs to be identified. Achieving a representative group consisting of these different actors will be emphasized during the research. The stakeholders presented in the left top of the research are also important to include, as they may be a risk since they have high power but little interest. These actors need to be informed and their needs need to be satisfied to prevent a situation where use cases are identified but will not be implemented in the end due to contradictory needs and wishes of these stakeholders.

After classifying the stakeholders, the relations between the stakeholders have been captured in a relations diagram, which can be found in the appendix. The choice for key relationships that will be captured determines the outcome and usefulness of the diagram (Carlsson et al., 2002). This diagram does not focus on a specific aspect of the system, such as financial or baggage streams. It was preferred to create a holistic perspective consisting of all kinds of relations, to be able to create a firm understanding of the stakeholder field within the baggage handling ecosystem, which is required during the innovative improvement of baggage handling processes (Koldkjær, 2017). The relations diagram showed the many relations between actors in the ecosystem, which led to identifying dependencies between actors. It was found that lots of (mutual) dependencies exist with a low level of replaceability (see figure 4.3). This means that actors are dependent on each other without the possibility of replacing them. A description of the most important dependencies for this research are illustrated in Appendix B.

Dependent on	Airport	Airline	Handler	BHS Provider	Customs	Passenger	CVT Service Provider
Airport	X	X	X	X	X	X	X
Airline	X		X			X	
Handler	X	X					
BHS Provider	X						X
Customs							
Passenger	X						
CVT Service Provider	X			X			

Figure 4.3: Stakeholder Dependencies

4.2 Established Situation

The literature review results showed that digital transformations occurring in established ecosystems, like AAS, can be held back by legacy systems, inertia, path-dependencies, habits, and institutions. Therefore, this section focuses on analyzing the current situation of the baggage handling ecosystem at Schiphol Airport. An appropriate level of analysis of this situation needs to be identified as it matters if the analysis is interested in a specific technology, product, or activity (Carlsson et al., 2002). As illustrated in section 4.1.3, a requirement for including stakeholders in the analysis was that they were linked to the baggage handling process. Therefore, the choice has been made to focus on analyzing the baggage handling process, including all key activities relevant to the whole baggage handling journey.

A detailed illustration of the individual process steps of the baggage handling process is reported in Appendix C. This section covers a concise overview of the analysis. The analysis of various documents regarding the baggage handling process at Schiphol Airport provided knowledge on how this process is divided into subprocesses. It was found that the baggage handling process consists of 14 subprocesses, which are visualized in figure 4.4 below. As this research focuses on the value of CVT, which can potentially change the way baggage is identified and tracked during the system, the current identification and tracking technologies within the baggage handling process were also analyzed. This analysis revealed that no single person had insights into the identification and tracking technologies within the whole baggage handling process, as a clear division was seen between processes inside and outside the BHS. A process manager of baggage logistics at RSG provided the information of the location of identification technologies within the BHS, whereas an architect baggage system provided information on the tracking technologies within the BHS. Nevertheless, both did not know how handlers and airlines used the identification and tracking technologies outside of the BHS. This knowledge was provided by a project manager of baggage services of an airline. This emphasized the divided baggage handling process and a lack of a holistic perspective on the process.

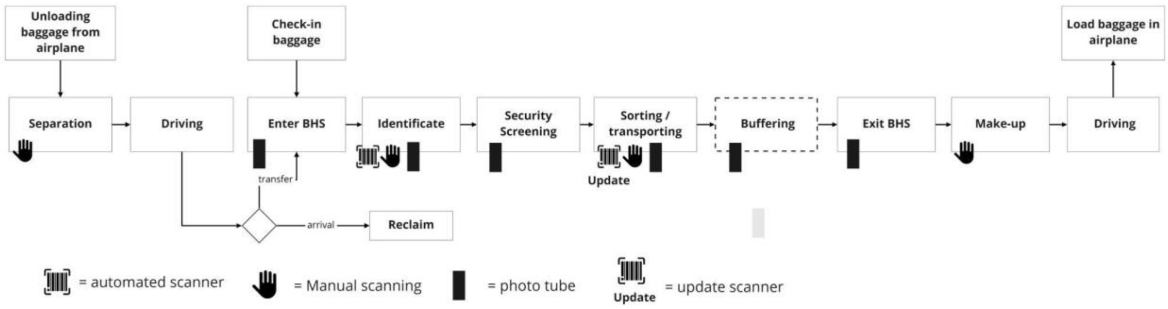

Figure 4.4: Process steps baggage handling process

4.3 Data Awareness

The third concept in which the field research was structured is the concept of data awareness. This refers to identifying current and potentially valuable data sources (Kayser et al., 2019). Therefore, this section analyzes the process and the results of identifying the current and potentially valuable data sources inside Schiphol Airport's baggage handling ecosystem. Identifying the data sources has been a complex task where the division of the baggage handling process was highlighted once more. The information of available data needed to be acquired from various sources, and no central database was identified. A lead data analyst at RSG highlighted his interest in identifying currently available types of data, as this is currently not all clear to the data and analytics department. The analyst did provide information on the most relevant data sources, which were later validated by an advisor logistics and Innovation and data scientist working at RSG. The most relevant data sources identified were the Bags Source Message (BSM), Baggage Handling System (BHS), Management Information System (MIS), Central Information System Schiphol (CISS). An illustration of these sources is added in the appendix. Excel sheets of the data sources have been analyzed to identify the different data types generated and stored inside these sources. This provided input for visualizing a data overview of the baggage handling process *(see appendix D)*.

4.4 Identified Challenges

Based on the field research, which was structured into the concepts of ecosystem dependency, established situation, and data awareness, various challenges have been identified that occur in the baggage handling ecosystem of Schiphol Airport. First of all, *the divided baggage handling process and a lack of holistic perspective stood out during the* field research. Knowledge on the baggage identification technologies had to be retrieved from multiple stakeholders, and knowledge on processes of other stakeholders was unknown. This lack of a holistic perspective can stagnate innovation in the baggage handling process.

Second, the analysis of the dependencies within the actors of the ecosystem led to the identification of some challenges the ecosystem faces. Airports face backward compatibility at other airports in which they are *dependent on the requirements and technologies used in the baggage handling processes* at other airports. Thus, if AAS wants to implement CVT, they depend on implementation at other airports, making it a complex project. This dependency is also seen with airlines, as they are dependent on AAS for CVT implementation. Airlines *cannot realize innovation by themselves* but require collaboration with the ecosystem. Lastly, the occurrence of *strategic behavior* is identified. AAS wants no entering of baggage that exceeds the limits to prevent failures of the BHS, but handlers wish to enter as much baggage into the BHS as handling it outside of the system is costly and time-consuming. In addition, handlers choose where to enter the baggage in the BHS, whereas the capacity of the BHS could be used more efficiently if other infeed points were used.

An analysis of the amount of baggage inserted into the BHS (Internal Analysis, 2021) presented a challenge regarding the large infeed of baggage at the input side of the process. During morning hours in the holiday season, *the amount of baggage entering the system exceeded the maximum of 80% of capacity.* This maximum of 80% has been set, as the system is prone to errors and mishandled bags when exceeding this percentage. An analysis has shown that 67% of mishandled bags occur during peak hours (Schiphol Airport, 2019). Thus, a large infeed of bags entering the BHS is pressuring the system, which results in *more mishandled bags* as it can bring late checked-in or short connection baggage at risk due to a long throughput time. The large infeed peak is not only seen in the BHS, but also in the terminal where *large queues can arise at check-in.* This challenge is not only acknowledged by AAS itself but airlines and handlers are also facing problems due to this *large infeed peak of baggage*. An airline's project manager baggage service agreed on this challenge since it can affect the number of mishandled bags.

A way to overcome this challenge is to insert only 'hot' baggage into the BHS, whereas 'cold' baggage can be buffered and inserted into the system later. Nevertheless, based on the interviews conducted by van Wieren (2021), handlers face the challenge that *baggage is not being separated well at the outstation*. This incorrect separation at outstations can result in the long duration of the separation process step, which is a result of ecosystem dependency. Nevertheless, if the baggage is separated correctly at the outstation based on a hot/cold basis, this separation is still *based on static flight information*. The fact that flights are delayed will not be seen in this separation, which can result in handling bags on a high priority basis that are 'cold' due to delays. This results in unnecessarily handling bags with priority by handlers and unnecessarily inserted into the BHS. This static-based separation can be overcome by scanning the barcode labels of the bags, as this will provide real-time flight information. However, in reality, this is not always done *since this has to be manually done* (J. Holst, Personal communication, October, 27, 2021). Manual processes are also seen in the tail-to-tail (TTT) process, where handlers need to *manually identify TTT baggage* to pick it up.

When baggage has entered the BHS, it is identified by a barcode scanner. Based on analyses, the read rate of a barcode scanner is 96% for check-in baggage and 88% for transfer baggage (R. Rooij, Personal Communication, September 28, 2021). This implies that 4% of checked-in bags and 12% of transfer bags *are not identified by a barcode scanner and need to be manually coded, resulting in high costs*. This low percentage can be explained by damaged or lost barcode labels, which results from weather circumstances for TRF baggage or the fact that *passengers do not attach labels correctly* to their bag at self-service bag drop. In addition, after consulting a security policy and process developer at RSG, this challenge was acknowledged by the security department. Transfer baggage from the EU does not need to be screened again at AAS. However, if the barcode scanner does not identify the baggage, *it will be screened unnecessarily twice*, which results in higher costs and a longer throughput time of baggage.

The results of analyzing the interviews conducted by van Wieren (2021) presented several challenges handlers face during the make-up process. The identified challenges have been validated by an airline's process manager baggage services. During the make-up process, handlers face the problem of *too few make-up positions during peak times*. In addition, make-up *laterals can only be used for one flight*, which decreases the opportunity to use the available capacity efficiently. During the make-up process, *baggage is being manually scanned* to identify the baggage and to ensure that the bags are authorized to load. This is done via a hand scanner, which decreases the efficiency of the make-up process. *A hand scanner is also used during the reconciliation process of baggage* if a passenger is not present in the aircraft, which decreases the speed of this process and can result in delays, which are costly for airlines.

The data awareness analysis highlighted challenges related to a lack of information collecting and sharing in the ecosystem. Based on the identified data sources, it can be concluded that lots of data are generated inside of the baggage handling process at Schiphol Airport. Nevertheless, based on stakeholder consultation, it can be concluded that storing and managing this data is not performed optimally. *A central database is lacking*, which results in the fact that it is currently not known *what data is stored at what location* and if this can be real-time analyzed or used (J. van der Veen & T. Noortman, Personal Communication, October, 14, 2021). Furthermore, when asking a Process Manager Baggage Logistics why the baggage handling system is currently not data-driven based on real-time baggage flows, he indicated that there simply is *not enough information available to ensure this. Information is lacking on expected baggage and the exact location of baggage in the system.* This lack of information also results in the fact that *not all process times of the head routes of the BHS can be automatically measured.* The information in CISS can be incorrect due to human errors, which makes it less useful to steer baggage flows. The lack of information on the exact location of baggage is not only relevant for steering the baggage flows but also relevant for passengers, as they experience stress whether their baggage is actually loaded in the aircraft and will be at reclaim (Lyngsoe Systems, n.d.).

Furthermore, AAS has *no barcode scanner located at the reclaim carousels*; it is, therefore, unknown what baggage has arrived at reclaim and if passengers have collected their bags. In addition, *airlines are unknown if claims about damaged or lost bags are valid*. If passengers claim that their baggage is damaged during the process, airlines do not have information about the specific step where this damage happened or if it happened during the process. Next to that, it is *difficult for handlers to allocate their resources without correct information* on the expected amount of baggage. Accurate information could inform the decision-making process of allocating handlers throughout the process steps on where they are most needed.

The identified challenges have been clustered based on the three concepts of the conceptual model. Clustering is performed to present a classification of the current challenges, as well as to test if the three types of challenges identified in the conceptual model were in fact present in reality. This clustering is based on requirements set for a cluster that the challenges needed to meet to belong to that cluster. The following requirements have been set:

- Ecosystem Dependency: this concept refers to the dependency on actors in the baggage handling ecosystem and challenges related to this dependency. Therefore, challenges will belong to this concept if a certain dependency on other actors is seen in a challenge. This means that actors cannot independently solve this challenge, as they are dependent on others. However, challenges that have a certain dependency on other actors, but are related to data awareness will be clustered into the concept of data awareness.
- Established Situation: this concept refers to legacy systems, organizational inertia, traditions or path-dependency constraints. Therefore, challenges will belong to this concept as it turned out that no ecosystem dependency is seen, but the challenges still exist. In this case, they can be clustered into the concept of an established situation.
- Data Awareness: this concept refers to the available data sources and information streams within the ecosystem. Therefore, challenges of a lack of information or missing data points are clustered to this concept.

The results of the clustering process can be seen in the figure below.

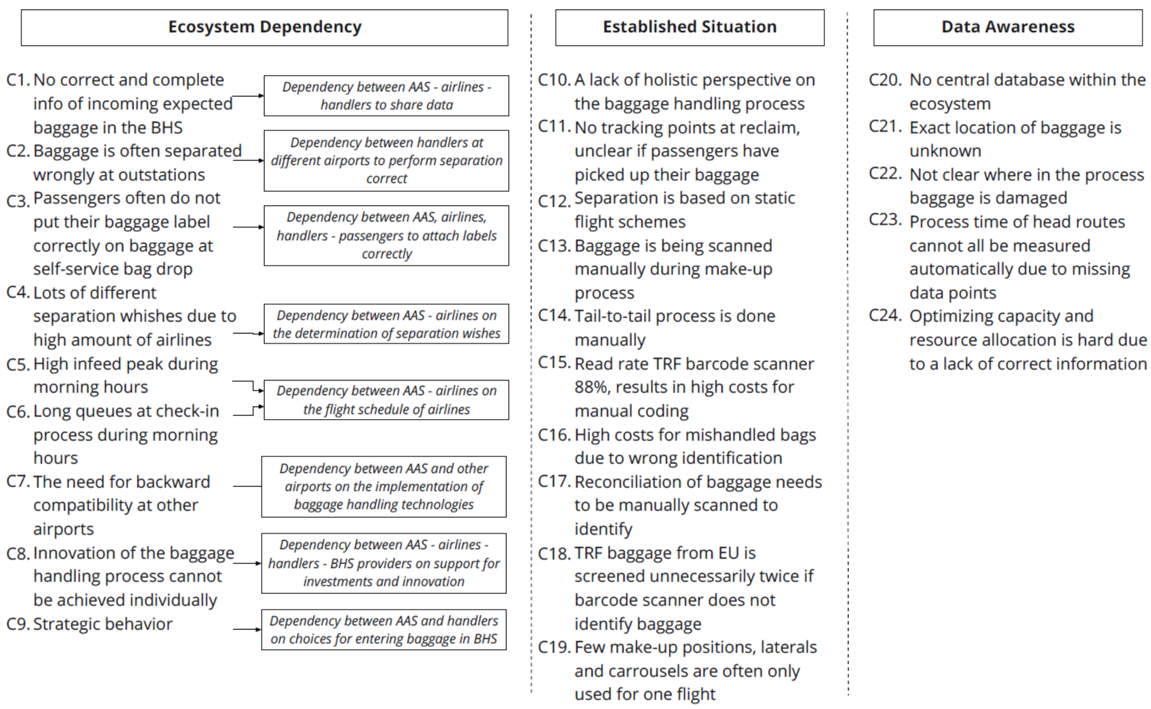

Figure 4.5: Clustered Identified challenge

4.5 Conclusion Chapter 4

This section aims to answer the third sub-question, which is:

"What are the current challenges occurring in the baggage handling ecosystem of Schiphol Airport?"

This chapter presents the current challenges occurring in the baggage handling ecosystem of Schiphol Airport. 24 challenges have been identified and clustered based on the three types of challenges that resulted from the conceptual model *(see chapter 2).* The results show the dependency in the ecosystem can be seen on a data-sharing level, incorrectly performed processes and the high infeed peak during morning hours due to preferences of airlines and passengers. The analysis on the process steps of the baggage handling process highlighted challenges occurring, such as a low read rate of barcode scanners, no tracking point at reclaim, and manual processes that increase the process times. Based on identifying the currently available data sources, it became clear that the exact location of baggage is unknown, which makes the capacity and resource allocation hard to optimize.

The challenges presented in this chapter will be used together with the identified needs of the ecosystem as input during the ideation process of use cases for CVT. Chapter 6 indicates whether the identified use cases will influence the challenges and needs. The needs of the baggage handling ecosystem ecosystem will be illustrated in the next chapter.

Chapter 5. Desired Situation Baggage Handling Process

This chapter focuses on the desired situation of the baggage handling process at Schiphol Airport and aims to answer the following sub-question:

"What are the current needs of the baggage handling ecosystem of Schiphol Airport?"

As illustrated in the methodology, the field research was structured into three concepts based on the conceptual model.

5.1 Process Optimization

A DT can lead to process optimization (Westermann, Bonnet & McAfee, 2014). This section, therefore, focuses on analyzing which processes could be optimized by the implementation of CVT. A detailed overview of this analysis can be found in Appendix E. This section covers an overview. The results of the stakeholder analysis, the conducted interviews to all handlers parties by van Wieren (2021), a report on the key performance indicators (KPI's) of the BHS, and an informal talk to a project manager of an airline provided information on the objectives of the actors in the baggage handling ecosystem of Schiphol Airport. The objectives and KPI's of the actors in the ecosystem are overlapping. The KPI's of airlines and handlers are to minimize the amount of mishandled bags and to have an on-time performance. Based on the interviews with handlers conducted by van Wieren (2021), handlers also prioritize a safe working environment. The KPI's of the BHS set by AAS are similar to the ones of airlines and handlers but face a different definition, which are correctness *(the number of baggage that entered in the BHS and arrived at its correct destination)*, process time *(the absolute difference in time between entering the BHS till the exit time of the BHS)* and capacity *(the number of baggage that can be handled in the system per unit of time).*

The literature review found that an ecosystem is usually characterized by a common system-level goal (Appleyard & Chesbrough, 2017). Based on the results above, it can be stated that the objectives of the actors have overlapping characteristics. The system-level goal of the baggage handling process was found in a document provided by RSG, which was defined as to have the baggage on time on board or at reclaim. This document also provided drivers behind this goal, which were useful to analyze to detect what drivers can be influenced by the implementation of CVT. However, this document was set up by RSG and did not indicate the participation of airlines, handlers, or other parties during its creation. Therefore, a project manager of baggage services of an airline has been consulted and validated that this was indeed the overarching goal of the baggage handling process faced by airlines and handlers. This increased the validity and representability of the document, which is why it was analyzed to detect what processes can be influenced by implementing CVT. The overarching goal is to have the baggage on time on board or at reclaim, which can be divided into three movements: a departing, transfer and arriving movement. The specific drivers of the three movements can be found in Appendix E2, an analysis of the influence of CVT on the drivers is illustrated below.

The implementation of CVT will not influence the capacity of the BHS. Nevertheless, the Innovation Hub has formulated the hypothesis that the system's capacity can be used more efficiently due to optimally steering the baggage flows by CVT. Furthermore, suppose baggage is being identified more accurately and less manual coding is required. In that case, the process time of baggage will be shorter, as indicated by a process manager baggage logistics at RSG. The correctness of identification is identified as an important driver. This correctness can either be measured on a BHS level or on a handler process level, which relates to the manual correctness of identification and loading of baggage by handlers. If the latter can be done automatically due to CVT, the correctness could potentially be increased. Another influence of implementing CVT mentioned by the vice president of airline and airport development of a CVT service supplier, is that the check-in process time could be decreased if barcode labels do not need to be printed and attached to baggage anymore due to the implementation of CVT. This is supported by an internal analysis which indicated that the process would be 20-30 seconds shorter in case of tagless baggage (Internal analysis, 2021). Lastly, based on the results of the interviews conducted by van Wieren (2021), handlers experience challenges at the unloading and separation step, as baggage is often separated incorrectly at the outstation. Manual separation is costly in terms of time. Thus, an automated separation step could potentially positively influence the process time of the unloading and separation step.

5.2 New Value Propositions

Digital transformations cannot only lead to process optimization but also to new value propositions. A value proposition can be defined as the offered value of a product or service (Wormald, 2015), which needs to be defined as the product or service enrichment combined with a definition of how technology will be used to achieve this enrichment (Hrustek et al., 2019). A data workshop has been organized to identify desired data-driven value propositions for the baggage handling ecosystem. An analysis of the results of the workshop is illustrated below.

5.2.1 Results Data Workshop

The purpose of the data workshop was to identify data-driven services that could be valuable for the baggage handling system at Schiphol Airport with the usage of the Data Service Cards. The planning and specific content of the workshop can be found in Appendix F1. This section covers an overview of the results of the workshop. Observations and notes, an audio recording, and a survey have been applied as evaluation methods to analyze the workshop results. When the workshop attendees were asked during a quick brainstorm at the beginning to mention the potential of data usage, a lot of possibilities were mentioned. Examples of the possibilities that were mentioned: steering baggage flows, enhanced decision-making, using data to analyze delays, track-and-trace, adaptability, customer products, inform, sharing data, real-time planning, input for a machine learning algorithm, predict, real-time dashboard, creating value, govern, liability. After asking the attendees why these possibilities were not realized yet, the answers were divided between the attendees working at the data & analytics department and Innovation Hub compared to attendees working at the operations department. The first group had a positive attitude towards the possibilities but mentioned that a shared urgency between all stakeholders was missing: "*We don't know if there is a shared urgency between all the different stakeholders to have more information or share more data to accomplish this.".* The attendees of the operations department were more focused on the current situation. *"Everything is going well the way it is now."* This attitude stagnated the brainstorm, whereafter they were asked to think more out of the box and more towards the future. When talking about the future, all attendees agreed that a data-driven future where data-sharing is stimulated and optimized is needed and foreseen, which was contradictory to the attitude of the operations department at the beginning of the workshop.

After discussing the realization of such a data-driven future, the identification of the added value of data-driven services was emphasized. *"The added value is really important compared to the investment needed to come to a data-driven environment. The investment is high since a data-sharing environment is currently lacking due to decentralized data sources and access, no single data owner, problems with data sources integration and the high complexity that is currently already faced when maintaining the currently available data. To overcome these problems a high investment and effort needs to be made. But, to do that, the added value should be known.".* A data scientist present supported this emphasis on the added value but had a more pragmatic view. *"You may think that the data is too complex to maintain, but our team can develop and maintain the system to accommodate your processes. So, if the added value is known and big enough, we have the people to develop and manage the complexity of the data aspects".*

The last part of the workshop focused on identifying desired data-driven services for the baggage handling ecosystem at Schiphol Airport. The Data Service Cards (fruhwirth et al., 2020) were used for this part. Half of the attendees were present in real life, but the other half followed the workshop online due to last-minute reasons. It was, therefore, chosen to let the physically present attendees work together as well as the online attendees. This resulted in the fact that the offline group did not consist of an attendee of the operational department and the online group did not consist of a data scientist or analyst. More mixed groups might have revealed other data-driven services. The identified data-driven services during the workshop can be divided into two groups: 'automated actions' and 'information and knowledge gain'. A description of the services can be found in Appendix F2. The following data-driven services were identified:

Automated actions:

- Automate tail-to-tail separation
- Automate reclaim and remote reclaim separation
- Automate loading process

Information & Knowledge gain:

- Track-and-Trace
- Information on the damage of baggage
- Root-cause analysis of delays
- Predictive maintenance

At the end of the workshop, a survey was sent to the attendees focused on generating their experience and opinion about using the Data Service Cards. The questions of the survey and an overview of the results can be found in Appendix F3. The results revealed that the attendees were positive regarding using the cards, as it was a useful tool, clear and easy to understand and to use in a group. Nevertheless, the results were divergent regarding if the cards were a useful tool to present a data-driven service out of a specific user perspective. This was also experienced during the workshop as attendees mentioned that most of the services were valuable for more users. This made it challenging to present the service from a specific user perspective as it was more relevant what the benefits were all users. Therefore, the data-driven services were not presented from a particular user perspective during the workshop but from the ecosystem as a whole. Lastly, the survey results indicated that the attendees were in favor of multidisciplinary groups as this would have stimulated the data-driven services ideation process as knowledge would be present of data, operations, and innovation.

5.3 Strategy

The last concept in which the field research was structured was the strategy. Having a strategy is defined as a must for the success of a DT (Hönigsberg, Dias and Dinter (2021). This section focuses on analyzing the strategy of the baggage handling ecosystem to see if the implementation of CVT could contribute to achieving this strategy. When facing an ecosystem-wide approach, the strategy must be supported by the ecosystem as a whole. If individual strategies of actors in the ecosystem differ, a widely supported overarching strategy can be complex to identify. An Advisor Strategy & Airport Development at RSG provided information on the strategy of RSG. A detailed analysis of the strategy of RSG can be found in Appendix E3. The vision of RSG is that the number of passengers will increase in the coming years. The interview focused on sustainable and autonomous process goals for the future of RSG. Autonomous operations will be necessary, as RSG is already facing a staff shortage and the prediction is that these shortages will grow. This staff shortage and the need for more autonomous processes are desired by RSG and supported by handlers and airlines. This is extracted from the interviews to handlers parties conducted by van Wieren (2021) and a talk to a process manager of an airline. *"It makes the operation easier if you can mitigate human factors". "We should not be afraid of mitigating jobs; other opportunities will come if we join innovations".* However, this is based on talks with a limited number of airlines and handlers representatives and can provide bias of the results.

In this analysis, the strategy of the ecosystem is analyzed. This differs from the definition of the strategy as identified in the literature review and presented in the conceptual model, which covers more the strategic planning and goals of a DT. Nevertheless, it is chosen to analyze the strategy of the ecosystem since it is important to conclude on the potential of CVT if implementation could help achieve the strategy.

5.4 Identified Needs

Based on the field research that was structured into process optimization, new value propositions, and strategy; various needs have been identified in Schiphol Airport's baggage handling ecosystem.

The document analysis of the system-level goal of the baggage handling process at Schiphol Airport gave insights into the drivers to achieve that goal. The drivers are to *optimize the routes in the BHS, increase the correctness of baggage identification, and decrease the check-in, make-up, and (un)loading process times.* If these drivers are met, baggage is more likely to be on time on board or at reclaim. Based on the analysis of the KPI's of actors in the ecosystem, one objective applied for all actors, namely to *minimize the amount of mishandled bags.* Another important KPI that needs to be included is providing a safe working environment, as this was mentioned in almost all interviews conducted to handler parties by van Wieren (2021).

As illustrated in section 4.4, a challenge has been identified that capacity and resource allocation is hard to optimize due to lacking information. Based on discussions with stakeholders *(employees of RSG, airlines, handler parties and a BHS provider)*, it became clear that a desire exists to *optimize capacity and resource allocation* in the future. The consideration of the strategy of the baggage handling ecosystem resulted in the identification of six needs. The strategy is divided into a focus on the quality of network, life and service. The first focus results in the need to *handle the increasing amount of baggage* in the future since the aviation industry is expected to grow. A vision of the ecosystem to accomplish this is to *increase the number of autonomous processes.* Second, quality of life refers to sustainable needs like having *zero emissions and zero waste in 2030, a net-zero carbon-free aviation sector in 2050, and implementing the principles of a circular economy.* Lastly, the quality of service refers to providing a *hassle-free personalized passenger experience.*

Based on an analysis of the workshop results, it was identified that all attendees foresee the need for a *data-driven baggage handling process* in the future. This is extended with the wish for *an end-to-end baggage journey.* The identified needs have been clustered based on the three concepts. This clustering is based on requirements set for a cluster that the challenges needed to meet to belong to that cluster. The following requirements have been set:

- Process Optimization: this concept refers to improvements of current processes. Therefore, needs that are related to the improvement of existing processes will belong to this concept.
- New Value Propositions: needs that will not only lead to an improvement of existing processes, but that will result in changed processes, new services or a new value will belong to this concept. The needs can still be vague, as the specific required new services or added value may be unknown yet.
- Strategy: this concept refers to the existing long-term goals determined by the baggage handling ecosystem. Thus, needs that are already specified and for example need to be accomplished before a specific timeframe belong to this concept. This concept seems to be overlapping with new value propositions. Nevertheless, the key difference between the concepts is that needs that belong to the strategy concept are required to be met and more specified, whereas needs that belong to new value propositions can still be vague.

The results of the clustering process can be seen below:

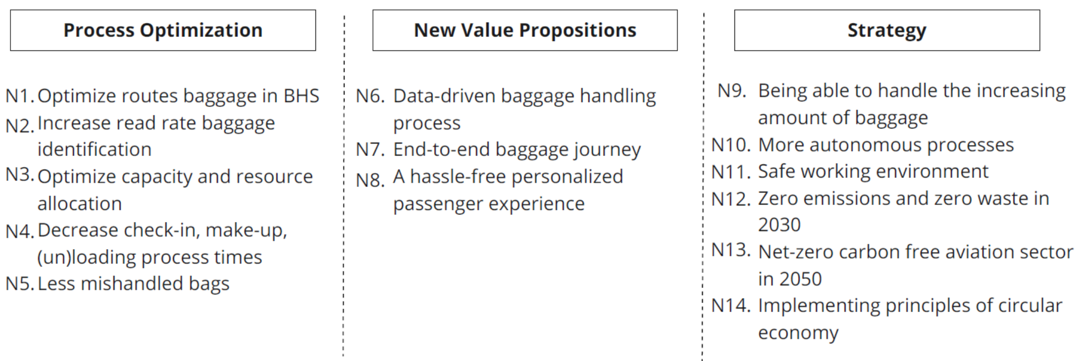

Figure 5.1: Clustered identified needs

5.5 Conclusion Chapter 5

The goal of this chapter was to provide an answer to the following sub-question:

"What are the current needs of the baggage handling ecosystem of Schiphol Airport?"

This chapter presents the current needs of the baggage handling ecosystem of Schiphol Airport. Fourteen needs have been identified and clustered based on the three types of challenges that resulted from the conceptual model *(see chapter 2).* The results show that needs exist in the ecosystem, ranging from process improvement to new value propositions such as providing an end-to-end data-driven baggage journey. In addition, the ecosystem has a common strategy that consists of keeping up with the expected growth, providing a safe working environment, and the achievement of sustainable goals. Thus, all three concepts *(process optimization, new value propositions, and strategy)* have been identified in the current needs of the baggage handling ecosystem of Schiphol Airport.

The needs presented in this chapter will be used in combination with the identified challenges *(see section 4)* as input during the use case workshop. An analysis of the results of this workshop will be presented in the next chapter.

Chapter 6. Use Cases

This chapter presents an analysis of the results on the identification process of use cases for CVT that could be implemented in the baggage handling ecosystem of Schiphol Airport. The previous two chapters provided the results of the identification of the current challenges and needs of the ecosystem. This has guided as input during the identification process of use cases, to inspire in which CVT could be a solution to current challenges or a way to achieve certain needs. The findings that this chapter presents provide an answer to the following question:

"What use cases for computer vision baggage identification technologies could be implemented in the baggage handling process at Schiphol Airport and to what extent do they provide value for the baggage handling ecosystem of Schiphol Airport?"

6.1 Results Use Case Workshop

The initial purpose of the use case workshop was to identify use cases for tagless identification via CVT that could be implemented in the baggage handling ecosystem of Schiphol Airport. The planning and specific content of the workshop can be found in Appendix G1. This section covers an overview of the analysis and the workshop results. Observations, notes, and an audio recording have been applied as evaluation methods to analyze the general parts of the workshop. Since no audio recording or notes could be made of the online break-out rooms, the results of this part are the constructed use cases in Miro. The results can be found in Appendix G2. A concise overview will be illustrated next.

The workshop results showed that the baggage handling ecosystem of Schiphol Airport is reluctant towards tagless identification of baggage. The brainstorm stagnated as the risks of CVT outweighed the benefits for the majority of the attendees. A division was seen again between the attitude of employees of the Data & Analytics department and Innovation Hub at RSG compared to the operations departments of RSG and an airline. The focus of the first group was more towards the future, whereas the latter had an emphasis on the current situation and feasibility of tagless identification. The workshop's focus shifted from tagless identification via CVT towards CVT as an addition to current identification technologies. This shift provided insights into the fact that CVT as an addition to current identification technologies would eliminate most of the disadvantages, as illustrated above. In this way, the attendees had the perception that the ideation process would be more useful, as ideating for tagless identification seemed useless since this would not be feasible at all: "*I can not think of use cases for tagless identification, as I just simply do not see it working in real life".* Another attendee agreed on this and indicated that it was too hard to think of use cases if he did not believe in the actual possibility of implementation. An attendee working at an airline concluded his opinion on CVT for the baggage handling process: *"My first reaction is that it is quite a difficult subject, but relevant to investigate. We saw that the focus shifted from tagless identification using CVT towards CVT. I think that CVT does offer opportunities when applying it in a manageable environment as an addition, but in a global network, there will be many reservations.".* This brought attention to the importance of identifying the dependency on other airports when thinking of use cases.

The identified challenges and needs, as illustrated in chapters 4 and 5 guided as input during the brainstorm process of CVT use cases. An attendee indicated that this was useful as it guided in thinking of use cases: *"When the brainstorm stagnated, we went through the current challenges, which inspired us to think of ways to solve these challenges."* The list of the identified use cases can be found in the next section, which focuses on analyzing and validating the use cases to provide the final overview of identified use cases. The workshop concluded that CVT as an addition to the current technologies could mitigate the risks, but research is needed on the actual added value of this addition. This conclusion resulted in a further analysis of the added value of CVT in the identified use cases, in which the results are illustrated in section 6.3.1. The fact that the attendees were reluctant towards CVT implementation and the importance of the feasibility resulted in a feasibility analysis of the use cases, which is illustrated in section 6.4.

6.2 Overview Use Cases

The workshop's outcome was a list of use cases for CVT that can be implemented in the baggage handling process. The identified use cases were further analyzed, elaborated and discussed with various stakeholders. An overview of the transformation process of the list of use cases can be seen below, followed by argumentation of why these changes have been made.

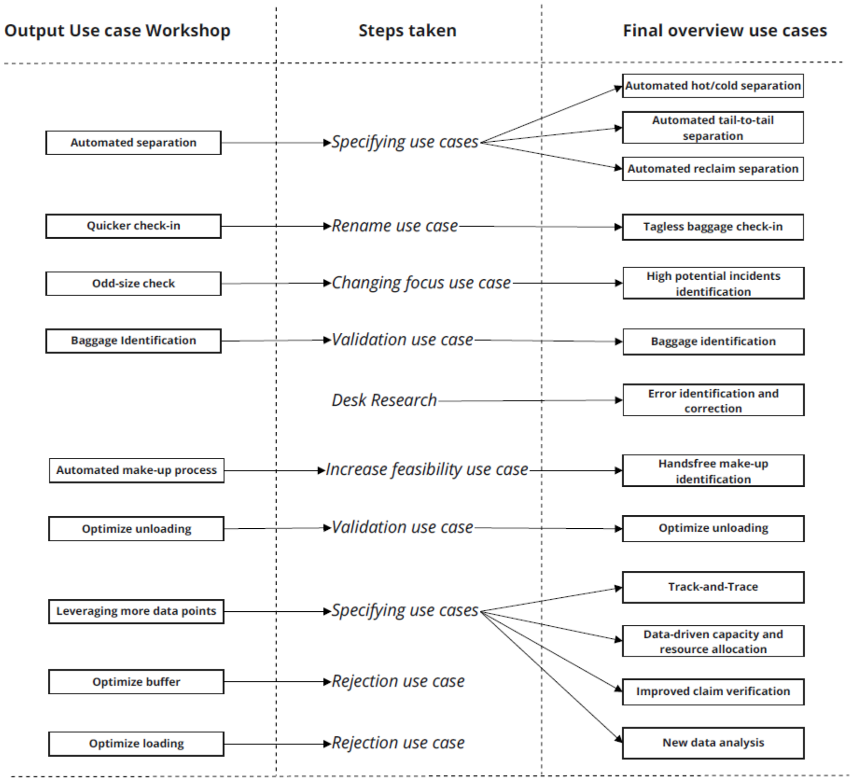

Figure 6.1: Transformative process of overview use cases

An Innovation Lead at RSG indicated the importance of delineating use cases to make them more specific. This resulted in dividing the 'Baggage separation' use case into three different use cases, each focused on a different separation: hot/cold, tail-to-tail, and reclaim separation. After consulting a baggage service manager working at an airline, the use case 'Optimize loading process' was removed from the overview. This was based on previous research done by TNO who investigated the potential of optimizing the loading process based on baggage dimensions. The results of this research showed that this was hard to realize, as this required handling bags in a specific order. In addition, the added value of the optimized loading process was minimal, as it was found that handlers perform this job well enough already (J. Holst, Personal communication, December 1, 2021). The second use case that was removed from the overview was the 'Optimize buffer' use case. Optimizing the buffer was mentioned during the workshop in a way that the physical space of the buffer would differ so that more bags could be buffered. Nevertheless, this requires a complete adjustment of the buffer infrastructure, which is not implementable at the moment and, therefore, removed from the list.

During the workshop, a use case was identified where CVT would provide visual images of bags to optimize the unloading process of baggage when passengers are not present in the aircraft. The visual images would support and thereby speed up the process of removing loaded baggage. Nevertheless, an attendee present at the workshop indicated that this process is currently already done based on the physical characteristics of bags, so CVT would not provide added value. However, this was rejected by baggage service managers of two different airlines consulted afterward as they stated that baggage is currently manually scanned and identified by handlers. The need exists to speed up this process, as this is currently a major reason for delays, resulting in airlines' high costs (Y. van der Wel, Personal Communication, December 21, 2021). Therefore, this use case is included in the overview and requires additional research on its actual added value.

A discussion with a key account manager of Vanderlande *(BHS provider)* and Vice President Airline and Airport Development of BagsID *(CVT service provider)* provided information on the feasibility of the use case 'Automated make-up process.' A fully automated process requires significant adjustments to the current BHS infrastructure, which is costly. Therefore, the use case has shifted its general focus from automation towards automated identification of baggage via Google Glasses. This does not require a major adjustment to the infrastructure but still automates the process of manual scanning of baggage.

Desk research provided an additional use case, namely 'Error identification and correction.' Based on a pilot executed at the Frankfurt Airport, it was found that CVT can be implemented to identify mismatched and misrouted baggage to correct this. The pilot results showed that 92% of all tracking errors were detected and corrected, which resulted in a major decrease in manual re-checks (Talbot, 2021). This use case is added to the overview and requires additional research on its added value and feasibility. After validating and discussing the identified use cases with stakeholders, as illustrated above, a final list of use cases was constructed. This list is placed inside the process steps of the baggage handling process to provide an overview of where the use cases will be implemented in the process. In this way, it can be seen that the complete set of use cases has implications for the input, throughput, and output steps of the baggage handling process.

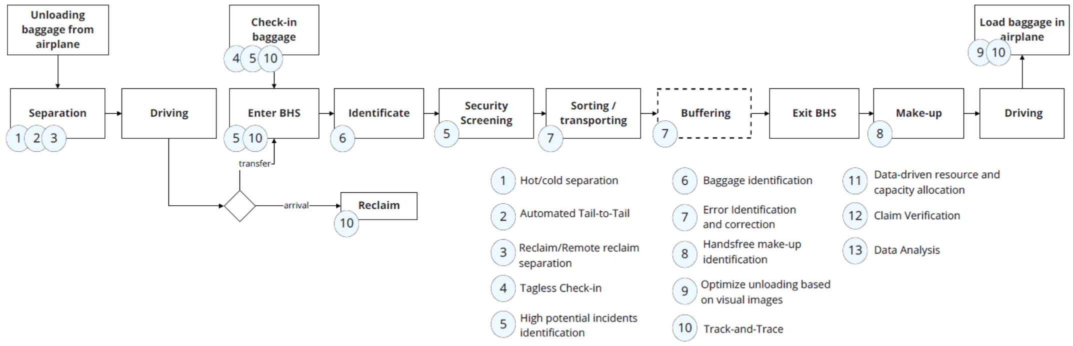

Figure 6.2: Overview use cases within process steps

6.2.1 Use Cases in Combined Tool

As illustrated in section 3.2.2, a tool was needed to present the use cases in more detail. The Combined Tool is constructed, which supports the exploration of data-driven use cases within established ecosystems more specifically. The tool complements and extends Kronsbein & Mueller (2019) Data Innovation Board and Breitfuss et al. (2020) Data-Driven Business Canvas with new blocks and layers to include the established ecosystem perspective *(see figure 6.3)*. An argumentation of why specific additional blocks and layers have been chosen will be illustrated, as decisions have been made during the construction of the tool.

The results of the data workshop *(see section 5.2.1)* presented that it was hard to present the use cases from one user perspective, as more actors would be key users of the use case. During the workshop, it was concluded not to present use cases from a specific user perspective but from the ecosystem as a whole. Therefore, it was chosen to exclude the block 'user' from the Data Innovation Board but to include a 'current functionality' block. This functionality represents the current situation of the ecosystem of where the use case will be implemented. To indicate how the CVT use case will be different from this current situation, a block 'Added value CVT' is added, where this can be specified. Furthermore, the block 'User needs' of the Data Innovation Board guided as an inspiration to construct the two blocks of how the use case influences the identified challenges and needs. The building blocks of the Data-Driven Business Canvas have been analyzed and adjusted towards the needs of the tool. The Data sources, analytics, and product blocks were useful blocks to illustrate the data-driven use case and, therefore, added to the Combined Tool. As the Combined Tool needs to be filled in from an ecosystem perspective, the 'Customer Benefit' block has changed towards 'Ecosystems benefit', where different actors in the ecosystem can be filled in. Based on the results of the stakeholder analysis, the value needed to be identified for AAS, airlines, handlers, and the BHS provider. In addition, the results of the analysis on the objectives of the ecosystem *(see section 5.1)* showed that airlines act in the interest of passengers, in which passengers were also added to the Combined Tool. This eliminated the need for the block 'Financial implications', as the benefits for all actors will already be filled in the benefits block. This block now represents the feasibility of the use cases, where the level of dependency on other airports and the required investments per use case can be filled in on the right side of the tool. By making these decisions, the Combined Tool is used to provide an overview of a data-driven use case, which illustrates the added value of this use case compared to the current situation, the influence on current challenges and needs, the data and analytics needed, the impact for the whole ecosystem and the feasibility of the use case. In this way, all relevant aspects of a data-driven use case that will be implemented in an established ecosystem can be presented in one overview.

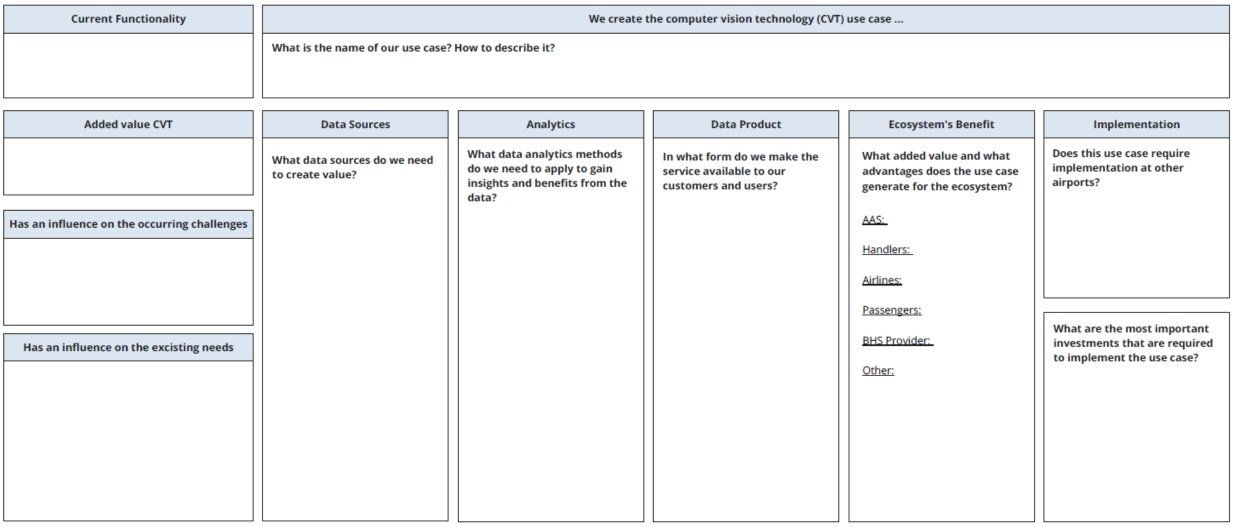

Figure 6.3: Combined Tool

All of the use cases have been filled individually in the Combined Tool, which can be seen in appendix H. It was seen that all needs and 20 out of 24 challenges are influenced by the complete set of use cases. Schematic representations *(see figure 6.4 & 6.5)* of the use cases are also added in the appendix to provide quick insights into the use case.

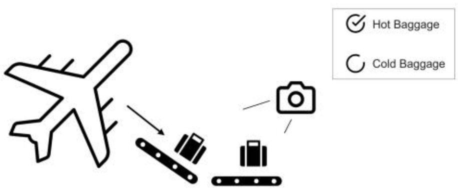

Figure 6.4: Schematic representation Hot/cold use case

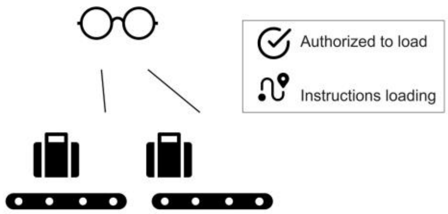

Figure 6.5: Schematic representation handsfree make-up identification use case

The Combined Tool quickly provides an overview of the value for the ecosystem, as it specifies the value for individual actors. It can be stated that no use cases are beneficial for only one actor in the ecosystem. The value of the use cases, split into the added value of CVT and the value specified for actors in the ecosystem, is illustrated in the next subsection. Most important is that by using the Combined Tool, insights were provided in the technical specifications of the use case as well as the implications for the current situation. The specification of the 'Data Product' forced thinking of the actual implementation of the use cases. By filling in the 'Current Functionality' and 'Added value CVT' blocks it is directly known how the use case will influence the current situation. An advisor logistics & innovation at RSG emphasized the importance of specifying the added value of CVT compared to the current situation, which is ensured when using the Combined Tool.

6.3 Value Use Cases

This section provides an overview of the results on the value of the identified use cases. Section 6.3.1 focuses on the added value of CVT per use case, whereas 6.3.2 covers the value of the use cases for the actors within the ecosystem.

6.3.1 Added Value CVT

As found in the literature review, identifying the added value of new technology is of high importance. The added value is a critical design issue and needs to be known for all involved actors as this can contribute to achieving agreements on investments for a new technology (Bouwman et al., 2008b). This was validated by the results of the organized data workshop, where attendees highlighted the importance of identifying the added value of computer vision technology *(see section 5.2)*. Especially since attendees indicated that they are content with the current situation, knowing how CVT could provide added value to the current situation is of high importance. This resulted in an analysis of the added value of CVT for every identified use case compared to the current situation. The stakeholder validations which supported the process of transforming the list of use cases *(see figure 6.1)*, were also used to discuss the added value of CVT. The added value is specified per use case in Appendix H. The analysis on the added value of CVT presents that the added value can be divided into four dimensions:

- **Autonomous processes:** CVT allows for more autonomous processes since it can automatically identify baggage. This is for example, valuable for the separation use cases, as currently, baggage needs to be manually scanned to separate bags. This is labor-intensive, which is a major reason why hot/cold separation is currently not performed. Autonomous identification could stimulate that separation will be actually carried out. This dimension has a link to the category 'Strategy', in which one need is defined as 'more autonomous processes'. Implementing CVT can contribute to achieving this need.
- **Process improvement:** The added value can be seen in quicker process times or a higher read rate, resulting in fewer mishandled bags. In this way, the implementation of CVT will lead to process improvements. This dimension refers to the category 'Process Optimization'. Thus, by implementing CVT, various processes of the baggage handling process could be optimized.
- **More (types of) data:** CVT generates more data and more data types of baggage, which can be used in different ways. One way is to create a data-driven baggage handling process, where real-time data is used to steer baggage flows optimally. This is linked to the category 'New Value Propositions', in which one need is defined as 'Data-driven baggage handling process'. Implementing CVT could generate more real-time data to provide such a data-driven environment.
- **More sustainable:** This dimension is only seen in the use case 'tagless baggage check-in,' as CVT will not be implemented as an addition to the current identification techniques there. This use case is a stand-alone use case, where physical attributes attached to baggage are not needed anymore. This results in a high added value on sustainable aspects. This is linked to the category 'Strategy', where sustainable needs are specified. The implementation of the tagless baggage check-in use case can contribute to achieving the sustainable goals of RSG.

6.3.2 Value for the Ecosystem

The literature review results presented that a digital transformation within an ecosystem needs to focus on value co-creation (Galvagno & Dalli, 2004), where the value proposition of the transformation allows value creation for multiple actors (Baldasarre et al., 2017). The impact of use cases needs to have a multidimensional view, rather than focusing on a single organizations' business goals (Hönigsberg et al., 2021). Therefore, the added value per use case is defined not only for Schiphol Airport itself but also for the BHS provider, handlers, airlines, passengers, and other involved actors. The detailed information can be found in Appendix H. Most important to notice is that there are no use cases only valuable for one actor in the ecosystem. All use cases provide benefits for more actors in the ecosystem.

Radar charts have been constructed to provide an overview of the relative added value per actor. The charts are not based on calculations, as the specific value per actor is not quantified. Nevertheless, the charts provide an overview of the relative value of the use cases per actor, based on indications of the value discussed with involved stakeholders. All radar charts, including an argumentation per score, can be found in the overview in appendix H. The use case with the highest total value for the ecosystem is tagless baggage check-in *(see figure 6.6).* The use case is not only valuable for AAS, the BHS provider, handlers, airlines and passengers, but also for the environment, due to the sustainable implications of this use case. On the other hand, the use case with the least total value is baggage claims verification since this is mostly only valuable for airlines and passengers. Airlines are currently responsible for the costs of claims of damaged or lost bags, so they will benefit the most from this use case. The use case 'Data-driven capacity and resource allocation' brings a lot of added value for AAS, the BHS provider handlers and airlines as can be seen below. The use case that is most valuable for handlers is the 'Handsfree make-up identification'. However, this brings not only value for handlers but also for AAS. Currently, challenges occur regarding the physical space in the make-up area. Innovative solutions are necessary to prevent costly renovations or expansions of these areas. It was found that the value of CVT for the BHS provider mostly lies in the fact that they can possibly offer the additional service or the improved system to other airports.

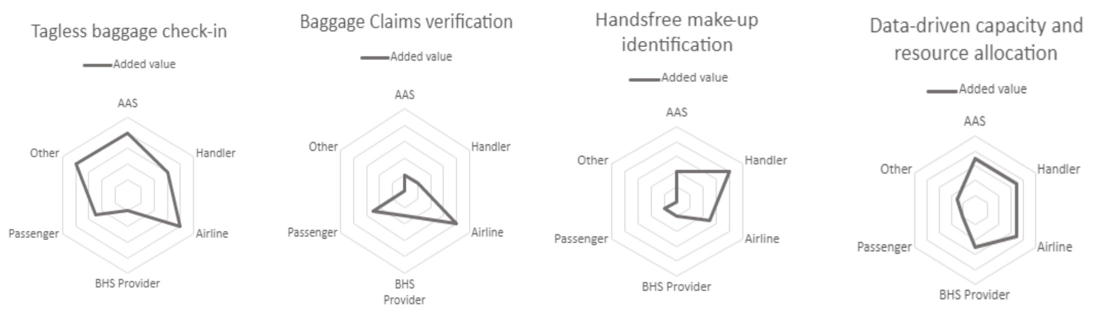

Figure 6.6: Radar charts of four use case

6.4 Feasibility Use Cases

The identified reluctance towards CVT during the use case workshop resulted in a feasibility analysis, as the implementation risks need to be known beforehand. A detailed illustration of the feasibility analysis, including the investments required per use case can be found in the Appendix I. Four aspects influenced the level of feasibility of the use cases:

- Dependency on implementation at other airports. Five use cases require implementation at other airports, which lowers their feasibility. This challenge is linked

to the category 'Ecosystem Dependency', as the feasibility of CVT is dependent on implementation at other airports.
- Establishment of a real-time data sharing environment. Some use cases require a real-time data sharing environment to generate optimal value. However, such an environment may be hard to establish, which lowers the feasibility of the use cases. It is already known what kinds of data are required and, therefore, this challenge is not linked to the category 'Data Awareness', but to 'Ecosystem Dependency' as the feasibility changes if a data-sharing environment is created within the ecosystem.
- The availability of required technologies. The technology of two use cases is not developed yet, which lowers the feasibility of these use cases. This challenge is related to the category 'Ecosystem Dependency', as a certain dependency exists on technology providers to be able to implement some use cases.
- A lack of ecosystems' support. Some use cases require more investments than others. One use case requires a significant adjustment to the current infrastructure, which lowers the feasibility of this use case, as it will be hard to achieve support for this. This challenge can be linked to the categories 'Established situation' and 'Ecosystem Dependency'.

Based on the results discussed in this section, practical recommendations to RSG on the potential of CVT for their baggage handling ecosystem have been made. The detailed recommendations can be found in Appendix J. CVT seems valuable for RSG, as it can provide thirteen use cases throughout the baggage handling process, which implies that CVT will provide more benefits than only increasing the read rate of the identification of bags. The future and strategy of the ecosystem must be emphasized to enhance ecosystems' support, as implementing CVT could contribute to achieving the strategy and long-term vision of RSG. The current baggage identification technologies, barcode labels, have not changed for a long time. CVT could be a relatively cheap *(compared to infrastructure needed for RFID)* technology to enable the achievement of a real-time data-sharing environment, more autonomous processes and the sustainable goals of the ecosystem.

6.5 Conclusion Chapter 6

The goal of this chapter was to provide an answer to the following sub-question:

"What use cases for computer vision baggage identification technologies could be implemented in the baggage handling process at Schiphol Airport and to what extent do they provide value for the baggage handling ecosystem of Schiphol Airport?"

This chapter presents the ideation process of use cases, which resulted in a final overview of thirteen use cases that are implementable in the input, throughput and output step of the baggage handling process. A critical shift occurred during the ideation process, as workshop attendees did not believe in the feasibility of CVT implementation. This resulted in a shift from CVT as a replacement of current identification technologies towards an addition.

Based on the results, it can be concluded that implementing CVT will not only be valuable for AAS itself but brings value to the whole ecosystem. All of the identified use cases bring value for a multitude of actors. The complete set of identified use cases influences all needs and almost all challenges as found in chapters 4 and 5. These results imply that CVT will not only lead to process optimization, but also to new value propositions and a contribution to achieving the long-term strategy of the ecosystem.

This chapter illustrates the relative importance of the types of challenges seen in reality. Ecosystem dependency and the established situation are identified in reality as challenges to implementing CVT in the ecosystem. The challenge 'data awareness' was seen as a relevant challenge during the identification process of use cases but is more easily to overcome if time and effort are spent to create a firm understanding of the available data sources. A new challenge of the importance of the establishment of a real-time data-sharing environment is identified, as the optimal value of CVT will only be achieved if the generated data is shared within the ecosystem. The research results will be discussed and concluded in the next chapter.

Chapter 7. Discussion and Conclusion

This research has focused on the design of use cases for Computer Vision Technology (CVT) that can be implemented in the baggage handling process at hub airports and its corresponding value proposition for the ecosystem. The results presented in the previous chapters will be discussed to clarify the results' meaning and what can be learned from them. This chapter aims to identify contributions made to the knowledge base and to practice, clarify limitations that may have been relevant to the research, and present recommendations for further research.

7.1 Main findings

The motivation for this research is the growing aviation industry, which leads to an increasing amount of baggage that needs to be handled at airports. This requires innovative solutions, in which CVT could be a suitable option. As indicated in chapter 1, a two-layered knowledge gap was identified. First, a practical knowledge gap was seen in the aviation industry as the value of CVT is unknown for the baggage handling ecosystem of hub airports. This research has investigated possible CVT use cases to design the technology's value proposition. The results of this design will be discussed in section 7.1.1. The second gap was seen in the literature on digital transformations, as knowledge is lacking on the DT process within established ecosystems. This research has gained insights from a real-world situation to contribute to this knowledge base which will be discussed in sections 7.1.2 and 7.1.3.

7.1.1 Value Proposition CVT

The research set out with the objective to design a value proposition for baggage handling ecosystems at hub airports by identifying use cases for CVT to provide the aviation industry a building block to further develop the required DDBM's to realize potential implementation in the next phase. To achieve this objective, an answer to the main research question is formed:

"What use cases can be included in the data-driven business model (DDBM) to capture the value proposition of implementing computer vision baggage identification technologies for Hub Airports?"

A DSR approach was used to answer this question, in which the design cycle was executed within a situated setting at Schiphol Airport. Challenges and needs of the baggage handling ecosystem of Schiphol Airport were identified. This identification process was based on stakeholder consultations, available documents, and the results of a workshop focused on the identification of desired data-driven services. Thereafter, a second workshop was organized which focused on the ideation process of CVT use cases, in which the identified challenges and needs were used as input. The workshop's outcome was evaluated and discussed with stakeholders, which led to a final overview of use cases. Figure 7.1 shows thirteen use cases that CVT could provide for the baggage handling ecosystem at Schiphol Airport, its added value and its relation to the challenges and needs of the ecosystem.

	Use Case	Added Value CVT	Influence on Challenges	Influence on Needs
1	Hot/cold separation	Autonomous identification could stimulate that separation will be actually carried out	C2, C5, C12	N1, N3, N5, N6, N9, N10
2	Tail-to-tail separation	Autonomous identification of TTT baggage	C2, C5, C14	N1, N3, N5, N6, N9, N10, N11
3	Reclaim separation	Autonomous identification could stimulate that remote reclaim separation will be actually carried out	C16	N5, N7, N8, N10
4	Tagless check-in	Quicker process time, no physical attribute needed attached to bags, more sustainable	C3, C6, C16	N2, N4, N8, N9, N12, N13, N14
5	High potential incidents identification	Automated identification, less manual mistakes and subjective decisions	C9, C16	N5, N6, N9, N10
6	Baggage identification	Higher read rate baggage identification	C15, C18	N3, N5, N9, N10
7	Error identification	Visual images misrouted bags, combined with AI more easier to detect and correct misrouted baggage	C16	N5, N9, N10
8	Handsfree make-up identification	Handsfree identification of baggage	C4, C13, C19	N3, N4, N5, N9, N10
9	Optimize unloading	Visual images of bags, in combination with camera quicker identification of bags to remove them to prevent delays	C17	N4, N8, N9
10	Track-and-Trace	Stimulates that Track-and-trace will be actually carried out and shared due to more data points	C11, C21, C23, C24,	N3, N5, N7, N8
11	Data-driven resource and capacity allocation	More data points and types will generate the required information needed to be able to perform this allocation	C1, C21, C23, C24	N1, N5, N6, N7
12	Claim verification	Visual images of bags during journey, proof of liability, less fraud claims	C9, C22	N5, N7, N8
13	Data Analysis	Visual images of bags during journey, more data points and types	C1, C24	N1, N3, N6, N9

Figure 7.1 Overview Use cases, added value, influence on challenges and needs

The results show that the complete set of use cases is applicable throughout the whole baggage handling process, namely in the input, throughput, and output steps. This implies that CVT will provide more benefits than only increasing the read rate of the identification of bags. It was found that CVT will provide benefits for AAS, the BHS provider, airlines, handlers, the passenger, and society. This aligns with the expectations beforehand, written in the literature on value co-creation, where a value proposition allows value creation for multiple actors (Baldasarre et al., 2017). Sustainable benefits were only seen in one use case, which is contradictory to the hyped expectations of the technology, in which sustainability was mentioned as a key benefit. This result can be explained because the focus has shifted during the research from CVT as baggage identification technology towards CVT as an addition to the current identification technologies. This shift was caused by the interests of actors in the ecosystem. Thus, ecosystems' interests have played a significant role in the design choices of the value proposition, which is currently less focused on sustainable benefits than expected beforehand. The results of the analysis on the added value of CVT within the use cases led to the design of the value proposition of CVT:

"The value proposition of CVT for the baggage handling ecosystem of hub airports is the automated identification of baggage based on visual images that provides thirteen use cases applicable throughout the whole baggage handling process, which leads to more autonomous processes, process improvement, the generation of more (types of) valuable data compared to the current baggage identification techniques and can contribute to the achievement of sustainable goals if it replaces the current identification techniques."

Figure 7.1 shows that the complete set of use cases influences all needs. This suggests that CVT suits the ecosystem's needs well and could, therefore, be a suitable option to accommodate a digital transformation to achieve the desired future situation of the baggage handling process. In addition, 20 out of 24 challenges can be influenced by the total set of use cases. However, it is found that use cases often influence only one or two challenges, as the challenges are more specifically illustrated compared to the needs. This means that more use cases are needed to implement to influence a significant amount of challenges compared to the needs. The implementation of CVT will not influence four challenges:

- *C7. The need for backward compatibility at other airports:* the ecosystem is still dependent on implementation at other airports to gain optimal benefits out of CVT. However, eight use cases can be implemented independently of implementation at other airports.
- *C8. Innovation of the baggage handling process cannot be achieved individually:* collaboration between actors in the ecosystem is still required. Only implementing CVT will not gain optimal benefits. Collaboration is required, in which the next two challenges play an important role.
- *C10. A lack of holistic perspective on the baggage handling process:* the ecosystem must collaborate to achieve a holistic perspective to gain optimal benefits from CVT. A real-time data sharing environment is required, where siloes in the process need to be removed.
- *C20. No central database within the ecosystem:* a central database needs to be created to accommodate a real-time data sharing environment.

Thus, a dependency on other airports to implement CVT and other actors to share required data has been identified to gain optimal value out of the CVT use cases. This implies that implementing CVT cannot be achieved by AAS itself but requires collaboration and support of the ecosystem.

7.1.1.1 Transferability of the Results

Since the research is restricted to a single context investigation at Schiphol Airport, caution is required in generalizing the findings towards other hub airports. Following van Aken (2004), the situated research learnings need to be further developed into general solutions to a class of problems, which can be achieved via generalizing the results. Generalization in qualitative studies differs from quantitative studies, wherein the latter it is a major criterion for evaluating the study (Kerlinger, 1996). In qualitative studies, generalization can be more complicated or controversial, as it requires extrapolation that is hard to justify since findings are embedded within a context (Polit and Beck, 2010). Due to this specific context, generalization can be impossible since the context is not necessarily representative of the larger population (Barnes et al., 2004-2022). This is, therefore, a first criticism of qualitative research (Rodon and Sesa, 2008). When facing qualitative research executed in a situated setting, the transferability of the results may be more suitable. Transferability allows the option of applying the results to other contexts (Barnes et al., 2021). The process of identifying the transferability of the results consists of delineating the characteristics of the setting under which the results hold (Rodon and Sesa, 2008). A detailed analysis of this delineating process can be found in Appendix K, which also concludes how different characteristics can result in a different value propositions of CVT for hub airports. The results of this analysis show that the following characteristics of the situated setting may have influenced the research results and may differ across the aviation industry:

- Challenges of the hub airport
- Available physical space of the hub airport
- Currently implemented identification technologies
- Institutional field of the hub airport
- Baggage handling process of the hub airport
- Size of the hub airport

Thus, these characteristics need to be analyzed and compared to the setting at AAS *(see Appendix A for a detailed description of the situated setting of this research*) when transferring the research results to other hub airports.

7.1.2 Design Process

A reflection of the design process touches upon the process of the design as well as the artefact resulting from it (Walls et al., 1992). The main results on the artefact, which is designed value proposition of CVT, are illustrated in the previous section. This section will focus on the main insights generated during the design process of the artefact.

During the workshops and interviews, it was seen that almost all attendees and interviewees foresee a real-time data-driven tagless baggage handling process in the future. This insight supposed that there would be ecosystems' support for a DT of the baggage handling process via CVT as this could lead to such a real-time data-driven tagless process in the future. This support was seen from actors working in innovation or data departments but was lacking from actors working in operations departments. It was found that this lack of support stagnated the ideation process of use cases. Their support was needed during the ideation process, as they had crucial knowledge of processes that inspired the ideation of use cases. Two main aspects were identified that caused this lack of support:

1. A missing shared urgency to change

The attendees of the data workshop indicated that the desired future state of the baggage handling process was not yet realized due to a missing shared urgency to change. During the research process, two process choices were found to be of high importance that had a positive influence on the creation of a shared urgency:

- The identification of the current challenges and needs of the ecosystem

The initial purpose of identifying the challenges and needs of the ecosystem was to stimulate the ideation process of use cases as it could be used as input during this process. However, it was found that indicating how the use cases could solve current challenges or help to achieve certain needs of the ecosystem would make the impact of the CVT use cases more tangible. It showed the importance of CVT as it was shown how it could provide a shift from the current situation towards the desired situation. In this way, the urgency to change was created as the impact of CVT was made more concrete.

- The identification of the added value of CVT within the use cases

It was found that it was of high importance to identify the added value of CVT per use case. Most use cases could also be carried out with other technologies. Nevertheless, the added value of the specific use of CVT within the use case needed to be indicated to show how the technology could improve the current situation. This added value ensured the possibility to design the value proposition of CVT. Without the added value of CVT compared to the current situation, the proposition would not be a designed specifically for CVT, but for an improvement in general. This would not provide a realistic overview of the value of CVT to create urgency to change, as actors indicated that CVT was not necessarily required to generate the value.

2. A reluctance towards the feasibility of the change

During the research process, a reluctance towards the feasibility of CVT implementation was identified within the ecosystem. It was seen that this reluctance could be decreased by means of two process choices:

- Focusing on the holistic perspective of the ecosystem

During the research process, it stood out that actors in the ecosystem were not fully aware of processes and capabilities of each other. The operational department of RSG did not know what kinds of identification technologies and processes were used outside of the BHS. A focus was seen on innovation and improvements within own processes, in which the lack on a holistic perspective stagnates innovation of the whole ecosystem. Furthermore, innovation could be stimulated if actors were more aware of the capabilities and desires of other actors. It was seen that the operations department of RSG was reluctant towards CVT as they emphasized the difficulties regarding the complex data aspects. However, a data scientist had a more pragmatic view and indicated that his department would be capable of handling these difficulties but was not aware of this need. Multi-disciplinary workshops can ensure that the perception of the feasibility of CVT can be improved, as complexities indicated by one actor can be solved directly by other actors present.

- Making sure that the ecosystem thinks the change is a realistic option

The use case workshop stagnated because the attendees could not think of use cases for CVT as they did not see it working in real life. The attendees did not believe in the actual possibility of implementation of CVT and therefore thought that the ideation process of use cases was useless and a waste of time. The shift towards CVT as an addition to the current identification technologies resulted in less reluctance. These findings suggest that an incremental transformation would be a more realistic option than a radical one. The lesson learned is that value proposition designers should not be carried away by the hyped expectations of technologies. It is important to show and present the digital transformation as realistic within the ideation process of use cases, to stimulate creativity.

Another main result of the design process was the construction and use of the Combined Tool. The literature review results indicated that no tool existed that met the requirements needed for this research. This led to the creation of the Combined Tool. Using the tool ensured a more realistic and detailed specification of use cases, as it indicated how the use case would be implemented and used in the situated setting. It provided a quick overview of the technical details as well as the implications for the established situation. It helped to specify use cases thoroughly, as all important aspects of use cases needed to be filled in the tool.

7.1.3 Conceptual Model

During the design cycle's theoretical background step, a literature review was performed to construct a conceptual model of digital transformations within established ecosystems. The model presents the concepts relevant to a DT within an ecosystem and highlights the different types of challenges and needs of a transformation that were mentioned in the literature. These types were used as a structure to guide the field research during the problem awareness step. When analyzing the value and feasibility of the use cases, the results were linked to the conceptual model. The results indicated that the use cases could influence all types of needs as identified by the model. Thus, the DT would result in process improvements, new value propositions and a contribution to achieving the strategy of the ecosystem.

Furthermore, it was shown that the challenge of ecosystem dependency and the established situation were mostly seen in reality when analyzing the feasibility of the use cases. The first challenge, ecosystem dependency, was identified twofold. First, the dependency on other airports if they will implement CVT. This result can be explained by the complex characteristics of the baggage handling ecosystem. Airports are dependent on other airports, due to backward compatibility at other airports (Marcellin, 2019). This is especially seen at hub airports, where many transfer flights are accommodated, which requires backward compatibility. It can also be seen in the stagnating adoption of RFID technologies worldwide, as airports, handlers and airlines delay RFID implementation until they see others implementing the technology (Koldkjær, 2017). Second, the dependency on actors in the ecosystem to share required data. CVT generates a vast amount of real-time data. However, this data must be shared within the ecosystem to create actual value out of this data. This is a plausible result as currently, a real-time data-sharing environment is lacking in the aviation industry (Rencher, 2019). A data-sharing environment is hard to establish due to the reluctance of parties to share and make data accessible (Jernigan et al., 2016; Richter & Slowinski, 2019). This is especially seen in the aviation industry, where the overall industry remains reluctant to share data (Amin, 2019; Bublitz & Neuser, 2020), mostly due to technical and regulatory challenges (The Open Data Institute, 2018). However, the conceptual model did not include the specific concept of the need for a data-sharing environment. This can be explained by the fact that most literature reviewed had an organizational viewpoint, in which the need for data sharing within the ecosystem was not specifically mentioned.

The other type of challenge that was seen when analyzing the feasibility of the use case, was the challenge of an established situation. It was found that use cases needed to be implementable in the current infrastructure without major adaptations. Thus, the established situation determined the outcome of the value proposition. If the value proposition was designed for a new hub airport, the value proposition would be different. This result was expected, based on prior work on the importance of the established situation (Abrell et al., 2016; Hunke et al., 2017). The aspects mentioned in the literature; legacy systems, organizational inertia, path-dependency constraints, and habits, were all seen during this research and determined the value proposition of CVT. The use case of 'Optimize Buffer' was removed as this was not compatible with the current buffer facilities at AAS. The level of inertia and habits impacted the choice of presenting CVT as an addition to the current technologies, compared to a radical implementation that would replace the current technologies. Path-dependency constraints were seen when analyzing the transferability of the results. The value proposition of CVT differs for airports who already chose for RFID implementation in the past.

The analysis results on the feasibility of the use cases indicated that data awareness is not a challenge holding back the implementation of the use cases but was indicated as a challenge throughout the design process. Without the constructed data overview, the ideation process of data-driven use cases was hard to perform during this research. This is in line with the expectations, based on the work of Kayser et al. (2019), who present that a lack of data awareness can result in a lack of knowledge on the opportunities of data-driven use cases and thereby identify it as a key challenge during the process. Thus, a lack of data awareness can hold back the identification of use cases. These results have shown that this challenge differs from the previous two, as this challenge is easier to overcome during the process. Constructing a data overview must be prioritized, but once this is performed, the challenge can be solved. However, only solving the challenge of data awareness will not lead to value creation within an ecosystem setting, as the data needs to be shared within the ecosystem. Therefore, the concept of a Data Sharing Environment is added to the conceptual model to indicate the importance of this concept. The adjustments compared to the initial model are highlighted in color in figure 7.2 below.

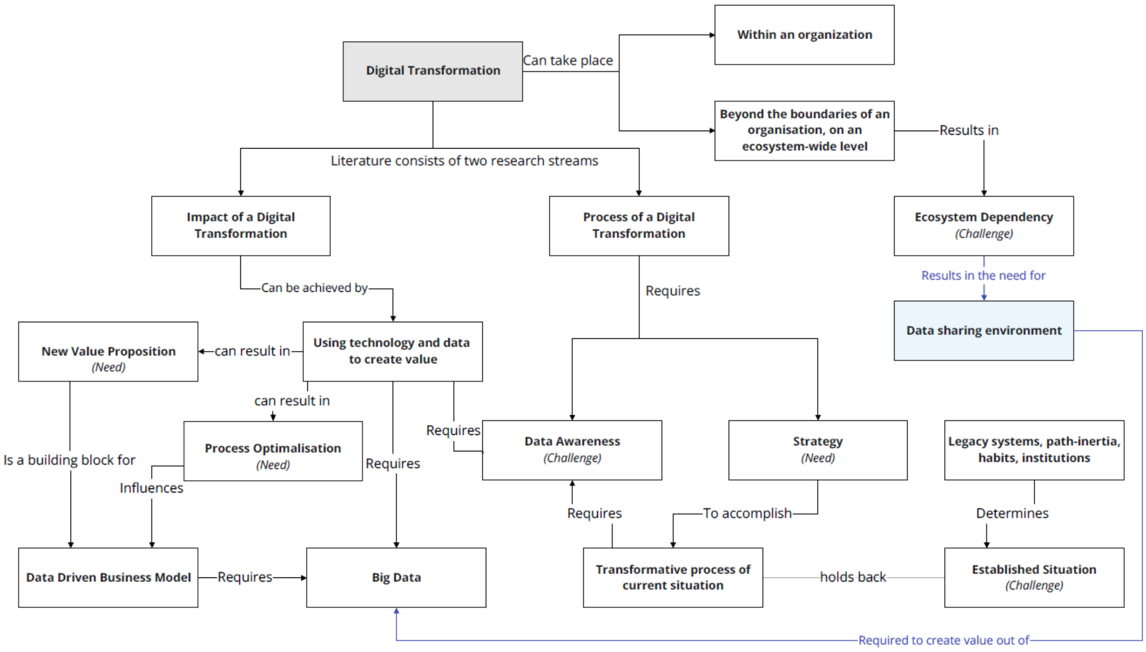

Figure 7.2 Revised Conceptual Model

7.2 Limitations

The limitations of this research and their implications for the results will be discussed next, as this will guide future research and help understand the value of the research results.

7.2.1 Value Proposition CVT

A limitation of the designed artefact is regarding the reliability and completeness of the results. The added value of the use cases is based on qualitative research. A first attempt was made to quantify the value, where assumptions have been made. However, the radar charts representing represent the relative value of the use cases for the ecosystem are not based on calculations but on qualitative findings. This research only focused on the exploratory task of mapping out the general value of CVT for the baggage handling ecosystem instead of focusing on the actual calculations. Further research is recommended on quantifying the value and investments per use case so that agreements on the actual DDBM can be made in the next steps of the investigation.

7.2.2 Design Process

The main purpose of DSR is typically the design of an artefact, while for this research the actual design was not feasible given the time limits. The choice was made to focus on the first two steps of the design cycle of Vaishnavi and Kuechler (2004). This choice influenced the research outcomes, as the tentative design was not evaluated during this research. To minimize this limitation, a validation step has been included where the results were discussed with stakeholders to come to final results. In hindsight, an exploratory study on the value of CVT for baggage handling ecosystems at hub airports might have been suitable. Nevertheless, the design cycle did provide a structured approach to get a grip on the complex design challenge. The specific combination of scientific theories with developing awareness of the problem situation was useful. By using insights from scientific research, a structure was formed to develop an awareness of the problem situation.

The reliability of the results is impacted by the choices made during the design process. The time frame of this research restricted the methodological choices. Firstly, it was out of scope for this research to consider all objectives and values of the ecosystem. It was impossible to meet with all airline and handler parties given the time restrictions. In addition, the passenger's perspective is not elaborately investigated during this research. This was determined based on the stakeholder analysis, where passengers were identified as having low power and medium interest in the project. However, during the research, airlines indicated their main interest is providing services that meet passengers' demands. If it turns out that passengers are not ready for tagless baggage, airlines may be reluctant to invest in CVT. Thus, the results show that passengers indirectly have more power than expected beforehand and need to be considered more during the investigation of the potential of CVT. Secondly, the discussions and brainstorms during the two organized workshops determine the research results. A representative group was chosen to the best of the researchers' ability. However, a different composition of attendees might have generated other results. During the workshop, it was chosen to use the identified challenges and needs as input to inspire attendees to think of use cases to solve or accommodate these challenges and needs. However, this choice might have given a direction towards certain results. To minimize bias, tunnel vision, and subjective ideas originated during the workshop, the workshop results were discussed afterward and transformed towards a final outcome. Nevertheless, other design process choices might have revealed other results.

7.2.3 Conceptual Model

The completeness of the model relies on the thoroughness of the literature review performed. It cannot be guaranteed that all of the important concepts of DT's are included in the model. The conceptual analysis has been performed to the best of the researchers' ability. Nevertheless, the model does give a good representation of the concepts relevant to a digital transformation within an ecosystem setting. Furthermore, the conceptual model is constructed with a general context of DT's within ecosystems rather than the specific context of baggage handling ecosystems. This makes the model more generically applicable as it can be used to study digital transformations in other industries as well. Nevertheless, it is still possible that certain factors will become apparent when applying the model in other industries. This also applies to the relative importance of the concepts of the model, which can differ per industry. The results showed that ecosystem dependency and the established situation were mostly seen in reality, which can differ when facing other data-driven technologies within other ecosystems.

7.3 Contributions and further research

This section will elaborate how the research results contribute to the practice and knowledge base. By indicating this contribution, directions for recommended future research will be addressed. The knowledge gap of this research was two-layered, in which the research results have led to practical *(see section 7.3.1)* and scientific contributions *(see section 7.3.2).*

7.3.1 Practical Contributions

The main contribution of this research is the designed value proposition of CVT for the baggage handling system of hub airports based on the analysis of thirteen identified use cases. This study is the first to design a value proposition of CVT for the baggage handling ecosystem of hub airports. Results of the literature review indicated that the value proposition is the first thing that needs to be designed during the design process of a business model (Richardson, 2005; Johnson et al., 2008; Osterwalder & Pigneur, 2010; Teng & Lu, 2016; Hrustek, Tomicic Furjan, & Pihir, 2019; Rachinger et al., 2019), as this is viewed as a central building block for the development of business models for an identified technology. Therefore, the value proposition designed in this research can guide as a building block for the aviation industry as it can be (partly) re-used at other hub airports to design the required business models to implement CVT. It is recommended to finalize the design cycle to develop and evaluate the actual business model to implement CVT. The airport is recommended to take the lead in completing the design cycle, using multi-disciplinary meetings with representatives from the BHS provider, airlines, and handlers. The following steps are recommended:

- **Quantification of the use cases:** financial research is recommended to quantify the expected value of CVT compared to the investments needed, which is required to come to agreements for the DDBM.
- **Additional research** is recommended on the implications of achieving a real-time data-sharing environment in the baggage handling process. Issues like data standards, quality, protection, access, and data ownership are highly important. The latter is especially a challenge for the aviation industry as ownership of passenger data is hard to determine, which is a key characteristic of the aviation industry (Dou, 2020). The coordination and management processes are complex because passengers come in contact with airports, airlines, and customs. In addition, the structure of the aviation industry is highly complex due to the international scale of connected organizations consisting of multilayer patterns of competitions relations and cooperation clusters (Hrinchenko, 2020). It is a big step for airports to open up their data. Nevertheless, data sharing does not mean that the airport has to provide all of its data at once. Benefits of data sharing can already be generated even if a small amount of information on specific focus areas will be shared, as it can change an organization's culture to achieve a better reputation for data sharing (Bublitz & Neuser, 2020). Thus, if stakeholders in the aviation industry will open up their data in the baggage handling process, this could contribute to a broader shift towards data sharing in the industry.
- **Create ecosystems' support:** Once the financial research results are available and the outcome is positive, the next step is to create ecosystems' support for investment and implementation of CVT. Section 7.1.2 illustrates ways to increase ecosystems' support for a digital transformation.
- **Development of the DDBM:** in order to reach agreements on the investments, the business model needs to be created. This research provided insights into the relative value of the use cases for the individual actors in the ecosystem. The filled-in Combined Tools (see appendix H) describe the technical implications, the added value compared to the current situation, the implications for current challenges and needs, and the investments needed of all use cases. In combination with the

quantification of the results, this could form the basis for developing the business model. In this way, the study contributes with a building block to further develop the DDBM for CVT implementation at hub airports.

The knowledge gained in this research is valuable for the aviation industry and society. Implementation of CVT could help solve capacity problems airports are facing, minimize the amount of mishandled bags, increase the transparency of the process and lower the environmental impact of the baggage handling process. Specific characteristics of the situated setting that may have resulted in certain research results have been discussed, which is valuable knowledge in future studies on the value of CVT at other hub airports. Detailed research at another hub airport with similar characteristics is recommended to internally validate the set of use cases and its value. In addition, future research is needed if the value proposition differs for regular airports compared to hub airports, in which no transfer flights are accommodated. Some of the use cases may be less applicable or less valuable for regular airports, which needs additional investigation.

7.3.2 Scientific Contributions

This study is one of the first to specifically focus on the design process of a value proposition for a data-driven technology that will be implemented within an established ecosystem. Previous studies focused on different aspects, like the organizational implications of a DT (Schallmo & Williams, 2017; Kayser et al., 2019), value proposition design (Oosterwalder & Pigneur, 2010; Chesbrough et al., 2018; Talmar et al., 2020), and the creation of innovation ecosystems rather than the transformative process of an established ecosystem (Carlsson et al., 2002; Dedehayir et al., 2018).

The process of designing a value proposition for a data-driven technology within an established ecosystem context is observed within this research, which resulted in the identification of four process choices that positively influenced the level of ecosystems' support towards the digital transformation. This extends the work of Heaving & Power (2018), Osmundsen et al. (2018), and Kraus et al. (2021), who state that a supportive organizational culture is essential for the success of a DT. In their work, it is mentioned to actively and interactively involve actors during the transformation process to achieve support. Still, no specific guidelines or process choices have been mentioned on how this process needs to be arranged. The process choices, as illustrated in section 7.1.2 inspired the formulation of process guidelines for this arrangement. Guidelines provide guidance and advice for researchers based on practical experiences gained in real-world environments. In this way, the learnings from the research are conceptualized into process guidelines for a class of other researches (Rossi et al., 2012). The results contribute to the DT knowledge base as follow:

Process Guideline 1: Identify the current challenges and needs of the ecosystem

This study is one of the first to review digital transformation literature combined with an established ecosystem perspective to create a conceptual model. This model forms a theoretical contribution to the DT knowledge base for two reasons. First, it represents an overview of the relevant concepts of digital transformations within ecosystems. It bridges a literature gap of combining the process and impact research streams of DT's with an ecosystem perspective. Second, the model highlights different types of challenges and needs of a digital transformation within ecosystems that were experienced as a helpful structure during the design process of a value proposition. Previous work highlighted the importance of identifying the established situation (Hartmann et al., 2006; Hunke et al., 2007). The types of challenges and needs provided a clear approach to get grip on a complex established ecosystem so that this identification process could be performed. In addition, the impact of the DT can be made more tangible as it can be specified how it influences current challenges or needs. This can increase the ecosystems' urge to change as the impact of the change is made more clear. The approach of this research can be used during the analysis of other digital transformations within ecosystems. However, it is beyond the scope of this study to analyze the generalizability of the conceptual model towards other industries and this, therefore, requires additional research.

Process Guideline 2: Identify the added value of the new technology per use case
This finding is consistent with the existing knowledge on the importance of the added value of technologies (Bouwman et al., 2008b). Breitfuss et al. (2020) indicate that in order to generate concrete added value out of data the way how a data-driven use case is developed must be clearly specified. On the other hand, actors in the ecosystem must know its role in the use case (Bahari et al., 2015), to be able to monetize the added value in revenue streams (Schüritz & Satzger, 2016). Although these aspects are acknowledged, no tool existed to specify a data-driven use case on a detailed technical level in combination with the implications for an established ecosystem to accommodate the identification of the added value of the technology. Most tools have an organizational viewpoint or do not include the relation to the established situation (*see section 2.2)*. This can be explained as literature is lacking on the DT process within established ecosystem, as illustrated in chapter 1. This study contributes to the data-driven business model tooling literature with the Combined Tool, which is a contribution for future ideation and validation processes of data-driven use cases for ecosystems. More specifically, the tool can be used during ideation and evaluation steps of use cases to design a value proposition, as it illustrates the added value of the use case compared to the current situation, the influence on current challenges and needs, the data and analytics needed, the impact for the whole ecosystem and the feasibility of the use case. In this way, all relevant aspects of a data-driven use case that will be implemented in an established ecosystem can be presented in one overview. This tool can serve as a first step to further develop tools necessary in the data-driven use case ideation process within ecosystems. Further research is recommended on the development and validation of the tool, as the tool is currently only used by the researcher as a way to specify and illustrate use cases.

Process Guideline 3: Focus on the holistic perspective of the ecosystem
This finding broadly supports the work of other studies in the area on the importance of multi-disciplinary collaboration to achieve creativity (Lehman et al., 2015; Chasanidou et al., 2015; Culén et al., 2016; Kayser et al., 2019; Fruhwirth et al., 2020; Kaniadakis & Linturn, 2021). But, this study contributes to the importance of multi-disciplinary collaboration by indicating that it can also lower the reluctance towards the feasibility of a DT to enhance ecosystems' support. It was seen that this support was necessary during the ideation process, as the brainstorm stagnated without this support. This result concludes on the importance of multi-disciplinary support during the ideation process, which differs from the work of Kayser et al. (2021). This work only emphasizes the importance of support from the top management team during the DT process. Especially when facing an ecosystem-wide DT, multi-disciplinary collaboration is key to identify use cases that capture the value proposition for the ecosystem as a whole rather than only for one organization within the ecosystem.

Process Guideline 4: Ensure that the digital transformation is seen as realistic
The results suggested that an incremental transformation would be seen more realistic than a radical one. This corresponds to the illustration of radical innovations made by Markides (2006), who states that radical innovations can be perceived as novel, disruptive and hard to adopt, disturbing habits and behavior. Prior studies have discussed the implications and differences between radical and incremental innovations (Furr & Shipilov, 2019; Dugstad et al., 2019; Gupta & Bose, 2019; Gong & Ribiere, 2021). However, these studies do not indicate the importance of presenting the digital transformation as realistic to stimulate the ideation process of use cases, which was seen during this research. The implementation of technologies is only a small part of a DT (Gupta & Bose, 2019), as the ideation phase is identified as an essential part of a digital transformation within previous studies (Bange, 2016; Kayser et al., 2018). This research contributes to the literature on the ideation process by concluding on the importance of presenting the transformation as realistic to stimulate the ideation process of use cases based on insights from a real-world situation.

To conclude, these guidelines are a contribution to the DT knowledge base as they provide insights in ways how to enhance ecosystems' support for DT's within ecosystems, in which it guides future digital transformation processes. In addition, it provides an approach to get grip on a complex established ecosystem and a tool to specify data-driven use cases in combination with its implications for the established ecosystem.

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Appendix

A. Situated Setting Schiphol Airport

This appendix provides additional information on the situated setting in which the research is conducted.

Amsterdam Airport Schiphol (AAS) is a Dutch airport part of Royal Schiphol Group (RSG) located in Amsterdam. AAS provides direct connections to 316 international destinations, making it one of the best-connected airports in the world (Cusmano, 2021). In addition, it is the second-largest hub airport in the world, which means that the airport accommodates a large number of transfer flights (Schiphol Airport, n.d.). RSG focuses on innovations by leveraging more digital products and services that improve daily challenges and will make fundamental changes to existing processes. A department of RSG is the Innovation Hub, which conditionally experiments to explore the distant future with new, innovative solutions and techniques to shape the future. A key focus point of the Innovation Hub is called 'Future Baggage', which focuses on baggage handling process innovations, to optimize the baggage flows and to provide a seamless passenger journey. This research will be executed from within the Future Baggage team at the Innovation Hub.

A1. Baggage Capacity Problems

AAS is already facing baggage capacity problems, as in the summer of 2019, the BHS could barely handle the peak of incoming baggage flows. The BHS at AAS handles bags that are inserted into the system either via checked-in baggage (CI) or baggage that arrived via transfer flights (TRF). On the busiest day in the summer of 2019, an infeed peak that exceeded the maximum was seen between 8:00 till 11:00 of approximately 50% CI and 50% TRF baggage that needed to be handled by the BHS (Internal analysis, 2019). A peak in the baggage inflows higher than 80% of the capacity influences the airports' performance and can lead to an increase in mishandled bags, which results in high costs for the airport, airlines and handlers and dissatisfaction faced by passengers. AAS estimates that these high infeed peaks are likely to happen more often in the future due to the growing aviation industry and a planned renovation of the D-pier in 2029 where 30% of the baggage currently is being handled (Innovation Hub, 2021). AAS is working on the implementation of a new asset solution that will be ready in 2028 to increase the baggage capacity. Nevertheless, AAS estimates that even with the asset solution, a growth of the baggage handling peaks of 10% still needs to be covered via innovative solutions (Innovation Hub, 2021). The key challenge is to shave the high infeed peaks, in which the Innovation Hub formulated the following hypothesis: *"Prioritize baggage flows by looking at 'hot/cold' separation instead of 'first-in-first-out".*

Baggage needs to be identified in order to separate them. Several baggage identification technologies exist. Currently, baggage is mostly being identified via printed barcode labels, which is a technology widely adopted and used in the aviation industry (IATA, 2019). It has a relatively low read rate, in which human interference is needed at some points. In addition, it still uses a physical product to scan and identify baggage (IATA, 2019). Another technology to identify baggage is Radio Frequency Technology (RFID), in which the printed barcode labels are equipped with a small electronic chip that can store and transmit real-time baggage data (Koldkjær, 2017). By using real-time information, operation efficiency can be improved and mishandled bags can more easily be tracked and restored. Furthermore, RFID labels have a higher read rate than barcode labels and therefore require fewer manual adjustments. Despite all these promising effects of baggage identification based on RFID labels, the widespread adoption of this technology in the aviation industry has been slow, as it requires high investments for the infrastructure combined with relatively high costs per RFID label (Hemmings, 2021).

Next to RFID identification, baggage can also be identified via CVT. This technology requires no application of a physical attribute *(bags are therefore called tagless)* to baggage and could potentially offer a multitude of use cases in the foreseeable future (DJ. Kanters, Personal Communication, September 20, 2020). During check-in, visual images will be made of baggage, which will be linked to the passenger information. In this way, the bags can be identified by validation cameras based on their visual characteristics during the baggage journey. The technology works with a self-learning system in which the identification process needs to be executed very precisely. The system needs to be able to identify similar-looking bags based on their individual characteristics such as small scratches and bulges (D.J. Kanters, Personal Communication, September 20, 2021). Compared to RFID, the cost assumptions per suitcase are relatively low when using CVT, since no physical baggage labels are needed. Another assumption formulated is that the CVT infrastructure needed is flexible, and therefore, easier and cheaper to install out of the BHS (Innovation Hub, 2021). This has led to the fact that the Innovation Hub has formulated the hypothesis that CVT is the best way to facilitate tagless baggage handling. Next to that, the Innovation Hub formulated that tagless baggage is the best way to facilitate baggage identification outside of the BHS to achieve hot/cold separation. The key hypotheses of CVT are as follows:

- CVT enables RSG to identify and handle baggage effectively, safely and intelligently,
- By integrating CVT, RSG can add additional value to the baggage handling ecosystem,
- CVT is a desirable alternative for printed labels for the baggage handling ecosystem.

To validate these hypotheses, the possibilities and the added value of CVT need to be explored. In cooperation with an airline, AAS identified a use case to start the exploration of CVT, namely the hot/cold separation of TRF baggage, where cold baggage is buffered and inserted into the BHS at a later moment. A pilot for this use case will be started at the beginning of 2022 where the potential for separation will be tested.

A2. Institutional Field of the Situated Setting

The situated setting at Schiphol Airport needs to comply with various institutions. Where institutions can be a driver for innovation, they can also hold back innovations (Rasiah, 2011). Some institutions influenced the scope of this research. Therefore, a short overview of the relevant institutions and their relation to this research is illustrated next.

Competition rules EU

Due to European Law, AAS cannot refuse new ground handler parties. It can only refuse new parties based on safety standards set by the EU (Sajet, 2020). This has led to the fact that there are multiple ground handler parties active at AAS. This can lead to conflicts due to the shared limited space at AAS used by many different parties. This structure cannot be changed quickly and easily due to European competition rules, in which this research is scoped on the current situation of multiple handlers at AAS. Thus, the option to change this structure is not being considered during this research.

General Data Protection Regulation (GDPR)

The GDPR is established in 2019 to protect personal data and privacy of EU citizens (GDPR.eu, 2019). Organizations need to comply with strict rules about protecting customer data. Linked to the baggage handling process at AAS, this regulation requires the deletion of personal information of passengers after three days (R. Rooij, Personal Communication, September 28, 2021). This limits possibilities of data use cases and is therefore relevant to consider during this research.

IATA Resolution 753

As illustrated in the introduction, the aviation industry is still expecting to grow in the coming years (IATA, 2018). In order to keep track of all baggage and to minimize the amount of mishandled bags, the IATA Resolution 753 was introduced in June 2018. This resolution is mandatory and demands a minimum set of tracking points in key locations during the whole baggage journey process, at the check-in, loading, transfer and arrival process step (IATA, 2019). Nevertheless, these four points are often still not tracked nowadays in the aviation industry (IATA, 2019). CVT could possibly enhance tracking at AAS so that this resolution will be met.

Aviation Law

A part of the aviation law is the determination of the airport charges. This determination is regulated by law (Schiphol, 2018). Next to the take-off and landing rates, the airport charges cover the costs incurred by AAS for the facilities used by airlines. This includes the costs for security and services, such as baggage handling for travelers. AAS determines the airport charges after consulting all airlines active at the airport and they are valid for three years (Schiphol, 2018). This consulting process consists of an explanation and discussion of why the charges have changed based on financial calculations and proof of increasing costs and how the costs are related to the airlines. So, in case of innovations in the baggage handling process, it is possible that these investments can be charged in the airport charges. It is therefore interesting for AAS to analyze the value of CVT not only for AAS itself but also for airlines and handlers so that the investment costs can potentially be charged in the airport charges. The holistic value of CVT is therefore of high importance instead of focusing on the value of CVT for AAS itself, which presents the ecosystem scope of the situated setting.

B. Stakeholder Analysis

This appendix provides additional information on the stakeholder analysis presented in chapter 4. Figure B1 visualizes the stakeholder field of the baggage handling ecosystem at Schiphol Airport. A short description of the identified actors is illustrated next. The different departments of Royal Schiphol Group are also shortly analyzed in order to identify the involvement of them in this research. These descriptions have been used to construct the power/interest grid, relations diagram and the dependencies between the actors.

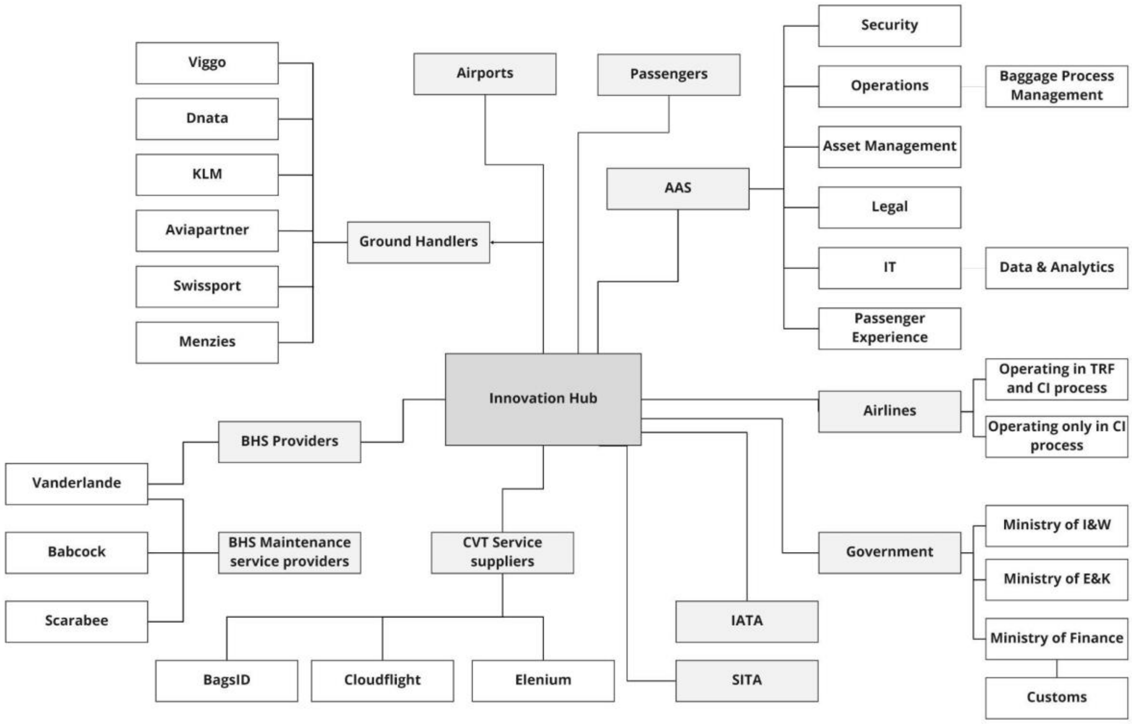


Figure B1 Stakeholder Map

B1. Stakeholder Descriptions

This section provides a description per actor.

Royal Schiphol Group

Royal Schiphol Group (RSG) has an important socio-economic function, since airports of RSG create value for either society as economy. RSG's mission is to connect the Netherlands with the rest of the world (Schiphol Airport, 2021) and the Group's Dutch airports serve this mission. It is in Royal Schiphol Group's (RSG) interest to invest in research, concepts and experiments to improve the processes at RSG's airports, with Amsterdam Airport Schiphol (AAS) as the most important and complex airport. AAS is a major European Hub airport that handles thousands of passengers and bags every day. AAS is the second largest hub airport in the world (Schiphol, n.d). This results in the fact that almost 40% of all baggage handled at AAS originates from transfer flights. With a growing travel demand, the number of bags will rise, putting AAS's baggage capacity under an increasing pressure. The ambition of AAS is to become the most sustainable and high-quality airport. Projects that support this ambition are therefore in their interest (Royal Schiphol Group -k-, 2021). The passenger experience is of great interest for AAS. As facilitator of all processes and flows, the airport will often be pointed at in case of delays and mishandling of the baggage (Scholing, 2014). This makes it incredibly important for AAS to maintain and improve quality. Therefore, AAS has a high interest and power in this project.

Innovation Hub
The Innovation Hub of RSG is created to coordinate and accelerate not only incremental innovation projects, but also long-term transformational and disruptive innovation projects. In order to keep growing and improving, it is crucial to keep searching for innovations. The Innovation Hub seeks projects that belong to the overlapping space of the three dimensions - desirability, viability and feasibility, where innovation can be reached. As the Innovation Hub takes the lead in investigating the potential of CVT, their interest is high.

Baggage Process Management
Baggage Process Management (BPM) is part of the operations department at AAS. The operations department facilitates all processes required for the passengers and airlines, such as the baggage handling. BPM has a high interest in this project, as it aims to improve the performance measures of the baggage handling processes. Improvements of technologies or processes could lead to better operations, which is in favor of BPM. In addition, this stakeholder has high power as support is needed to achieve innovation in the baggage handling process.

Asset Management
The Asset Management (ASM) department plans, develops, realises and manages all of Schiphol's operational assets. Their main objective is the customer and end-results, which enable the ASM team to contribute to Schiphol's overarching objectives. They balance the user needs, the desired quality-outcomes and the associated risks during innovation projects. Their interest in this project is low-to-medium, as new assets have to be procured. This also gives this stakeholder high power, as support is needed to achieve innovation in the baggage handling process.

Legal
The legal department of AAS advises on concerns relating to various laws, such as corporate, aviation, procurement, privacy, IT, intellectual property, real estate and public law. Legal has little interest in this project, but high power, as it can disapprove projects based on legal offences.

IT
The IT department advises on IT applications in an innovative and integrated way. It enables information exchange within the organization as well to the environment. Data and Analytics (DnA) is part of the IT department and executes data analyses, which can be of value for this innovation project. This stakeholder, therefore, has high power as insights via their analyses are of high importance to determine the value of CVT. In addition, their interest in the project is high since they also want to create data awareness and insights in the baggage handling process.

Security
The security department at AAS is responsible for the screening process of passengers and their baggage. This screening process is focused on identifying dangerous materials, such as

bombs and weapons, to ensure a safe operation at the airport and during flights. Their main objective is that this screening process is done correctly by minimizing costs. This stakeholder has medium-to-high interest in the process as they have the desire to optimize the security process step in the baggage handling process, which can potentially be achieved via CVT solutions. Security has low power.

Customs

Customs is part of the Ministry of Finance and responsible for the supervision of all goods entering, passing through or leaving the EU border. This is executed risk-oriented by mainly checking flights from countries with a high customs risk. Thus, the main activities of Customs is to identify illegal import and export of materials transported in baggage. Customs have low-to-medium interest in the project, as they have the desire to quickly identify baggage. Currently it is indicated on barcode labels whether bags come from Schengen countries or not. This gives this stakeholders high power, as the need exists for them to quickly identify non-Schengen bags, which may be more difficult with tagless baggage.

Airlines

Currently 108 airlines operate at AAS. Airlines are the contact person of passengers and therefore, the passenger experience is one of the most important pillars for an airline. Due to the high number of airlines operating at AAS, competition is high. Thus, airlines want to differentiate themselves by offering better or other services to passengers than other airlines. Furthermore, airlines tend to minimize costs and maximize the utilization and On Time Performance. As passengers book their flight at the airline, passengers will contact and claim airlines in case of lost or damaged baggage. This results in the fact that it is in the interest of airlines that the amount of mishandled bags is as low as possible. In order for an airline to operate at AAS, they must have a contract with AAS. This contract also contains the financial agreements between the airlines and AAS, which are called airport charges. These airport charges are determined every three year and cover the costs that AAS makes for the facilities that airlines make use of. Furthermore, airlines hire ground handlers to be responsible for the baggage handling process of their flights and pay a fixed amount per handled bag. There are airlines who only operate in the check-in process and airlines who also operate in the transfer process. Airlines have high interst and high power in this project.

Airports

Airports are also included in the stakeholder map, as baggage is coming from and going to other airports from an to AAS. A dependency is seen here, as backward compatibility is required in order to be able to handle baggage. Therefore, airports have high power. If other airports will not implement CVT, this will have an influence for AAS. Airports have little-to-medium interest in the project.

Ground handlers

Ground Handlers (GH) operate on behalf of the airlines, as they are contracted by airlines to execute baggage handling processes. GH's act upon the agreed performance expectations, signed in contracts between the parties. An important interest of GH's is the creation of a safe working environment. Next to that, GH's have to pay a fee to airlines for all mishandled bags, thus, their interest is to minimize the mishandled baggage (MHB). Thereafter, the on time performance is of interest for ground handlers, as they want to be able to (un)load all baggage on time. At AAS there are six GH parties: Viggo, Dnata, KLM, Aviapartner, Swissport and

Menzies. This makes the coordination process challenging. GH's can operate both in the transfer process as the check-in process, but the transfer process is mostly operated by KLM. Handler parties have high interest and high power in this project.

Baggage handling system providers

The infrastructure of AAS is provided by baggage handling system providers. These organizations mostly provide systems to multiple airports. Thus, it is in their interest to test innovations at AAS. If results are positive, this can be shared with other airports. Thus, their interest is relatively high in this project. A big baggage handling system provider at AAS is Vanderlande. Their power is also high, as CVT needs to be installed onto the systems of the providers.

BHS maintenance service providers

The BHS is managed and monitored by BHS maintenance service providers. This role is divided into the service control, where Scarabee is responsible, and the hardware control, in which this responsibility is shared by Babcock and Vanderlande. As Vanderlande is also a BHS provider, this actor has a double role in the ecosystem. It is in their interest that the systems work well and less errors or technical failures occur. As Scarabee is responsible for the service control, they generate lots of data about the system in order to execute this control. Their interest and power is low-to-medium.

Service suppliers

Service suppliers is a broad actor group when speaking in terms of the baggage handling process at AAS. However, as this research focuses on the value of tagless CVT, the service suppliers in this research are defined as the suppliers of CVT. Their interest in this project is high, as their objective is that their service will be implemented at more airports. Eventually, these parties will be responsible for the performance measures of the technology and therefore the system is dependent on the quality of the services that they provide. In addition, they have high power as the ecosystem is dependent on the service suppliers what services and added value they will provide.

Passengers

An important group that needs to be incorporated in the system delineation is the passengers, since the objective of the system is to handle the bags of passengers correctly and safely. Passengers book their flight and services at the airline and their main interest is to have a seamless travel experience. An experience of losing baggage or receiving damaged baggage decreases the passengers' experience significantly. It is therefore in the passenger's interest that the amount of mishandled bags is minimized. Furthermore, passengers also prefer to know where their baggage is (Singh et al., 2006). Passengers do not have a lot of power, as they will not have an influence on the decision to innovate the baggage handling process.

Government

The government is also included in the baggage handling ecosystem. The ministry of I&W and E&K has agreements with AAS. Furthermore, customs is included as they have set up certain rules and requirements that the security department of AAS needs to meet during their screening process.

IATA
Airlines are represented by IATA, which is a trade association that supports many aviation activities by helping formulate industry policy on critical aviation processes. For example, IATA established IATA resolution 753, which demands a minimum set of tracking points in key locations during the baggage journey process. IATA has medium-to-high interest in the project, as CVT could ensure a more easy way of baggage tracking.

SITA
SITA is an IT provider for the air transport industry and delivers solutions for airports, airlines, aircraft and governments. It has low-to-medium power and interest in the project.

B2. Relations Diagram

The actors have been placed inside this relations diagram. The role of the security department and customs ask for an explanation about their division in roles and tasks at AAS. This explanation was provided by employees working at the security and customs department. The security department is responsible for screening bags on dangerous materials, such as bombs and weapons, to ensure a safe operation at the airport and during flights, whereas customs focuses on identifying illegal import and export of materials transported in baggage (J. Granozio, Personal communication, December, 8 2021).

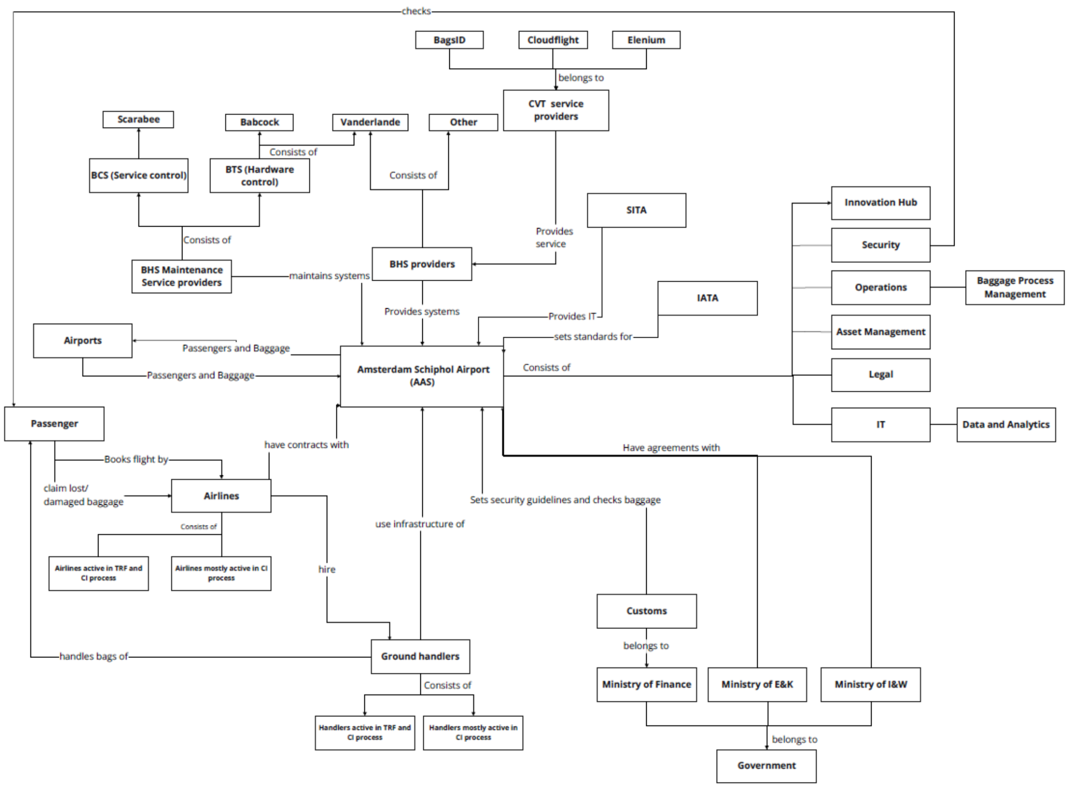


Figure B2 Stakeholder Relations Diagram

B3. Actor Dependencies

The most important dependencies for this research have been illustrated below complemented with the indication if this dependency is mutual and the level of replaceability of the dependent party.

- AAS - Airports, *mutual dependency, low replaceability*

AAS is dependent on requirements and technology implemented at other airports, which also applies the other way around. Thus, airports require backward compatibility at other airports to be able to handle the baggage coming from other airports. In addition, if AAS implements CVT, other airports need to follow this implementation to create optimal value.

- AAS - Airlines - Handlers, *mutual dependency, low replaceability*

A triangular dependency exists between AAS, the airlines and handlers. The baggage handling process is a process where all three interfere in different steps, which results in a scattered total process. All three want to have as few mishandled bags as possible and are dependent on each other to realize that objective. In addition, due to the scattered process, information may lack between the parties which is required to optimize the process. Thus, they are dependent on each other to receive the correct information.

- Airlines - Handlers, *mutual dependency, high replaceability*

Airlines are dependent on the quality of the work of handlers. If handlers perform their job incorrectly, the amount of mishandled bags will increase which will decrease the reputation of the airlines towards passengers. On the other hand, handlers are dependent on airlines to be able to have work, since they are hired by airlines. This dependency faces a high replaceability since there are many airlines and handler parties active at AAS. This results in a competitive sphere.

- AAS, Airline, *mutual dependency, high replaceability*

AAS is dependent on the flight schedules of airlines. The current schedules result in high infeed peaks during morning hours as lots of flights are scheduled during the morning. Based on a discussion with a Manager Airport Services of an airline a dependency of airlines on AAS was identified. Airlines are dependent on AAS to implement CVT, as they cannot realize it themselves.

- AAS - handlers*, single dependency, low replaceability*

AAS is dependent on handlers as handlers choose where to enter baggage in the BHS. The capacity of the BHS may be used more efficiently if handlers enter baggage in a certain infeed area. However, handlers may decide to use another infeed area if this results in a quicker process time or fewer costs.

- AAS - Customs, *single dependency, no replaceability*

AAS is dependent on the rules and guidelines set by customs. If customs need to see printed barcode labels to check whether bags are coming from the EU or not, AAS needs to comply with that or come with a solution.

- Airline - Passenger, *mutual dependency, high replaceability*

Airlines are dependent on passengers since passengers book flights which is the main revenue stream of airlines. In addition, airlines are dependent on the level of strategic behavior of passengers, as passengers can make false claims of damaged or lost bags. Currently, airlines have no proof of the correctness of the claims and have to rely on the reliability of passengers. The other way around, passengers are dependent on the quality of airlines' work, as passengers hand in their baggage and rely on the fact that they will not be damaged or lost. This dependency reflects a high replaceability, as there are many different airlines from which passengers can choose. This results in competitive behavior of airlines and the desire to provide additional services to passengers.

- AAS - CVT Service Providers*, mutual dependency, low replaceability*

AAS is dependent on the possibilities of the services that are provided by the CVT service providers. It could be that AAS wants certain CVT implications that CVT service providers cannot provide yet. Currently, this dependency has a low replaceability, as there exist only a few CVT service providers. CVT service providers are also dependent on AAS, as their technologies will only be implemented at AAS with the consent and investment of AAS.

- CVT Service Provider - BHS provider, *mutual dependency, low replaceability*

The CVT Service Provider has a mutual dependency with the BHS provider. On the one hand, the CVT service provider relies on the infrastructure of the BHS provider as certain characteristics of the infrastructure can exclude CVT possibilities. On the other hand, the BHS provider wants to provide the CVT possibilities at other airports too. Thus, it is in the interest of BHS providers to implement and test CVT at AAS to be able to provide additional services to more airports in the future.

- Innovation Hub - Departments AAS, *mutual dependency, no replaceability*

The Innovation Hub is dependent on other departments of AAS, as collaboration is required in order to achieve innovation. AAS has a high-level goal in which the goal is shared between all departments, however, all departments have different individual objectives. The Innovation Hub thinks more about the distant future, whereas the operational department thinks more about the current situation and the short term. Nevertheless, all departments are dependent on each other to realize improvements in the baggage handling process.

Dependent on	Airport	Airline	Handler	BHS Provider	Customs	Passenger	CVT Service Provider
Airport	X	X	X	X	X	X	X
Airline	X		X			X	
Handler	X	X					
BHS Provider	X						X
Customs							
Passenger	X						
CVT Service Provider	X			X			

Figure B3 Stakeholder Dependencies

C. Baggage Handling Process

This appendix provides additional information on the baggage handling process at Schiphol Airport.

C1. The Process Steps

The baggage handling process consists of several subprocesses, which are visualized in a schematic version in figure C2. The ways in which baggage is being identified and tracked throughout the system can also be seen by means of symbols represented in certain process steps. The process steps will be illustrated in more detail next. The responsible actor per process step is mentioned for every step.

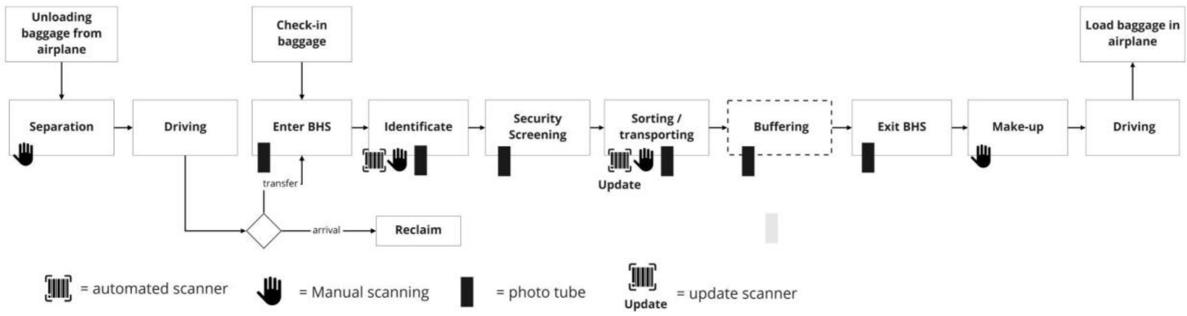


Figure C1. Schematic visualization baggage handling process

1. Unloading baggage from aircraft (GH's)

When the aircraft has arrived at the apron, the unloading process step can start. The apron is the area where the aircraft is parked, (un)loaded, refueled and boarded. The baggage will be separated and thereafter loaded to loading units (LU's). The separation process will be illustrated next.

2. Separation (GH's)

Baggage can either be in wide bodies, which are containers in which baggage is grouped, or in narrow bodies which means that baggage is put individually in the aircraft. Depending on the flight, the baggage can be separated into tail-to-tail (TTT), short-connection (SHOCON), regular transfer (cold), reclaim baggage (PRIO and NON-PRIO). This happens at the apron. The separation is often already done at the outstations, which results in the fact that TTT and SHOCON baggage often is located at the front. In that way, the prioritised baggage can quickly be transported to the right destination. However, often outstations do not pre-separate the baggage well, which makes the unloading and separation process challenging. In that way, baggage needs to be scanned manually to check its destination. In case of TTT baggage, an extra GH searches the specific bags and drives directly to the departing aircraft. The decision-making process of handling TTT baggage is not based on static scheme times, but on actual flight times. However, the decision-making process of handling the other baggage is based on static scheme times. This can result in outdated separations, as baggage can for example be separated as SHOCON baggage while it can never make their connection on time. Separation based on real-time data is therefore an opportunity to optimize this process step.

3. Driving (GH's)

Once the aircraft has landed, drivers (with the LU's) are sent to the apron. The driver has to wait for the platform handlers to finish the unloading and separation processes. Once the LU's are fully loaded, the drivers can go to their assigned area to deliver the baggage. This can either be the assigned infeed TRF area or to the reclaim areas.

Baggage that has a reclaim destination, will be brought towards the assigned reclaim area. The baggage is not identified or scanned at this process step. In addition, it is not known if bags are picked up by their owners or by someone else, as passengers do not need to show proof of owning the bag. When passengers arrive at reclaim, they will get to see the time it will take until their baggage will arrive. However, this information is not known when passengers are still in the shopping and eating area of the airport.

4. Check-in baggage (GH's)

Baggage is being checked-in at the check-in desks. This can either be manually assisted desks or self-service check-in desks containing baggage drop-off points. During peaks, often too few check-in desks are opened. This is due to the aim of GH's to maximize system efficiency vs. labor costs. An opportunity is to have baggage checked in remotely on another timeslot or to shorten the check-in process, to make more efficient use of the check-in capacity. During the check-in process, a Baggage Source Message (BSM) is generated which consists of the flight number, flight data, flight destination, the name of the passenger and a Licence Plate Number (LPN). The LPN consists of 10 digits visualized as text and as a barcode, which is printed on the baggage label (Roland Karch, n.d.). The baggage label is put on the baggage by either the GH or passenger itself (in case of self-service desk). It has been identified that passengers often do not attach their labels well, which results in a higher rate of lost labels during the baggage handling process.

5. Enter BHS (GH's)

Baggage can enter the BHS in two ways. It is either inserted in the system through CI desks or through TRF infeed quays. It is of high importance that the correct CI desk or TRF infeed quay is used, as this can have an influence on the throughput of the BHS. KLM can make use of three infeed areas: UQE, TSD and Zuid. It is desired that baggage with an international destination will be entered at UQE, baggage with an European destination will be entered at TSD and baggage resulting from the B/C pier will be entered at Zuid. The other handlers enter their baggage in the TRF loskade West. The CI desks are distributed in three terminals. This choice is made based on the destination of the baggage and the capacity of the different areas compared to the expected flights and baggage. However, a challenge occurs that GH's often prefer to drive to the nearest quay, which is not optimal for the throughput time of the BHS. Another challenge of this process is the large infeed peaks occurring during morning hours. These peaks are caused both by TRF infeed peaks as well as CI infeed peaks. Peak shaving could be a solution to this challenge, which can be achieved via entering baggage at another time in the BHS. For CI baggage, this can be achieved if baggage is being checked in remotely at another time. For TRF baggage, hot/cold separation would be valuable where cold baggage can be entered later into the BHS.

6. Identificate (AAS)

Once the baggage has entered the BHS, the identification process starts. This process is not only to calculate and identify the route of the baggage throughout the BHS, but also to track the baggage. The identification process at AAS is mostly based on barcode identification, as currently all baggage is labeled with a barcode. This technique is cheap and easy to use, as this technology is widely adopted in the aviation industry. Its operation is proven as it is widely being used for years (Koldkjær, 2017). After entering the BHS, the baggage is being scanned by a 360 degree barcode scanner. This is a scanner which can automatically scan baggage with a vision of all sights of the baggage. However, the read rate of these scanners is not optimal, as the read rate of CI baggage is 96% and TRF baggage 88%. The differences in these rates can be explained by the fact that TRF baggage is labeled at outstations and has already traveled from that station to AAS, while CI baggage labels are just recently printed and adjusted to the baggage. The baggage that can not be read automatically, will go to the manual coding identification process. Here the baggage is manually scanned with a hand scanner. If the baggage has lost its barcode label, other identification points such as written names or addresses need to be found. This is a time consuming job and leads to high costs and an increased risk in missed baggage on flights. The costs of this manual coding process at AAS are approximately 1.4 million euros per year.

From the moment the baggage is being identified, the baggage can be tracked throughout the BHS. All routes in the BHS are equipped with photocells. If baggage passes these photocells, the baggage is tracked. If baggage is not tracked within a certain timeframe at the following photocell, the baggage is being marked as an ufo. In that case, the baggage needs to be scanned again manually. Due to this tracking system of photocells, it is always known if baggage is on the right route as planned. Next to that, the sorting systems of the South, West and E-base contain barcode scanners to identify the baggage in these areas. In addition, between all the areas of the BHS, barcode update scanners will identify the inter-area baggage flows. Only when baggage is lost in tracking, identification is executed again. GH can base their decision making during the handling process upon this location information. Nevertheless, the precise location of baggage is not known. It is known in what area baggage is located or where it is scanned last, but the exact location is not tracked. Therefore, GH's only know where the baggage is approximately located, but are not aware of the precise time it will take the baggage to be at the make-up location.

Another technique to identify baggage is with the use of Radio Frequency Identification (RFID) labels. These labels are printed labels just as barcode labels, but contain a small electronic chip that can store and transmit real-time baggage data (Koldkjær, 2017). By using real time information, operation efficiency can be improved and mishandled bags can more easily be tracked and restored. Furthermore, RFID labels have a higher read rate and therefore require less manual adjustments. Despite all these promising effects of baggage identification based on RFID labels, the widespread adoption of this technology in the aviation industry has been slow. This adoption requires investments for the needed infrastructure to support the identification technology and the costs per RFID label are relatively high. Furthermore, optimal benefits out of the technology will only be reached if airlines and airports both adopt the RFID technology. This has led to the fact that many parties delay the implementation and wait to see others implement RFID technology. However, hybrid solutions where RFID technology and barcode labels will be used both can be a step towards full implementation of RFID labels in the aviation industry. These hybrid solutions typically have a higher read rate as the technologies will be combined, which will result in less mishandled bags. RFID technologies are supported in terminal two at AAS, but are currently not being used often.

7. Security screening (AAS)

Directly after the identification process, the baggage is automatically screened by security. This screening is based on a three-level concept. The first level is executed automatically. If the baggage is not clarified as clear after the first level, it will be screened at the second level where the scans are being checked manually. Once this screening is still not clarified as clear, the baggage will be screened again with different technologies combined with a manual check.

TRF baggage that is already screened at the outstation according to EU standards, does not need to be screened again at AAS. This is called One Stop Security (OSS), where the baggage is automatically identified as clear and transported to the aircraft after the first screening level. However, if the barcode scanner cannot read the barcode label and the baggage is not identified, the baggage will be screened again while this is not necessary. This leads to higher costs, as the technologies and manually screening processes will be executed more.

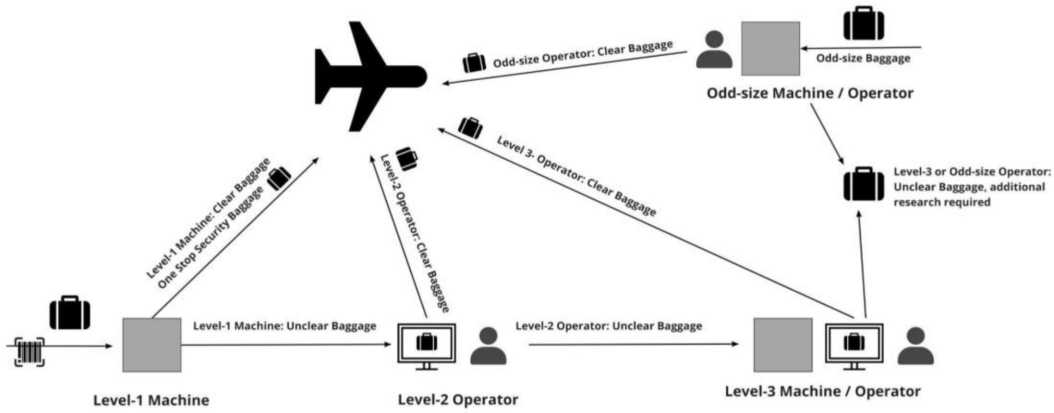


Figure C2: Security Process Step

8. Buffering (AAS)

Depending on the check-in time of baggage, or the transfer connection time, baggage can be buffered at one of the three in-system buffers, which are allocated at South-base, D-base and E-base. The West-base does not have its own in-system buffer, which means that the handlers at the West-base make use of buffers in other areas or do not use a buffer at all. The result of not using a buffer is a direct flow from the baggage entry point of the BHS towards the make-up area. In order to handle this direct flow, make-up positions need to be opened for a longer time. This results in a decrease in flexibility which lowers the capacity of the make-up positions. Rules have been defined for the use of the buffer capacity, which are based on area rules, time rules, group rules and occupancy rules. Operators can temporarily change the buffer rules during the process, so that the buffers will be used differently.

9. Sorting / transporting (AAS)

The sorting/transporting process step is responsible for transporting baggage towards the correct end point of the BHS. The route of the baggage is on beforehand identified and is not yet real-time updated on the bases of flows. Baggage can be sorted and transported to other areas in the BHS, which is defined as inter-area baggage handling. Inter-area is undesirable for the system throughput as this increases the baggage throughput distance and time time, which brings late CI and SHOCON baggage under higher risks. The baggage is being transported in tubs through the BHS, with the exception of the West-base, which uses conveyor belts to transport baggage. In order to guide the baggage to the correct destination, the BHS is equipped with sorters. The sorters in the South, West and E-base are equipped with barcode scanners to identify the baggage. If the route of the baggage is being updated due to a gate change or flight delay, it will receive another route in the sorter.

10. Exit BHS (AAS)

After being transported throughout the BHS, the baggage will arrive at the correct exit points of the BHS depending on the flight destination.

11. Make-up (GH's)

During the make-up process, the baggage is being loaded on LU's. This loading is being done based on separations which they get assigned by airlines. Due to the fact that there are many different airlines and flights, the separation during the make-up process can sometimes be challenging for GH's. During this process, the baggage labels are manually scanned or read to verify if the right baggage is loaded on the LU's. In the South area, several robots are being used during the make-up process to load LU's. A challenge during this process step is that there are too few make-up positions during peak hours. This is being strengthened by the long opening times of the make-up positions, which decreases the flexibility and therefore lowers the capacity. The positions can either be laterals and carousels. Using carousels increases the efficiency, as one handler can handle more flights at the same carousel. However, to avoid human mistakes such as wrongly reading labels, difficult flight separations will not be planned on the same carousel. Due to the small make-up area, the area is often crowded with (un)loaded LU's which results in little space to operate during this process.

12. Driving (AAS)

Once the baggage is loaded onto the LU's, GH's will drive them to the correct apron.

13. Load baggage in aircraft

At the apron, the baggage is being loaded from the LU's on the aircraft.

Based on the stakeholder and technical analysis of the system, challenges currently occurring in the baggage handling process at AAS are identified. The relation between these challenges and the actor that faces these challenges the most are visualized in figure B3. Furthermore, it is indicated with a green, orange or red dot if tagless CVT could have an influence on the challenges. This has been done to identify which challenges are needed to include further during the ideation process of use cases for tagless CVT.

C2. Areas of the Baggage Handling Process

This divided view was also seen after analyzing the physical areas of the baggage handling process. The areas of the baggage handling process are schematically visualized in figure C3 below. The physical areas are divided using the so-called 3+1 concept, which means that three areas (South, D and E) will be equipped for primarily transfer flights. Next to the three areas, there is one area where primarily origin-destination flights take place, which is assigned to the baggage handling area West. From a terminal point of view, AAS is divided into three areas. Terminal 1 is directly connected with the South base. This base is primarily for KLM GS, but other GH's can also use this base. Terminal 2 is directly connected with the D-base and the E-base, where both exclusively KLM GS baggage is handled. The other handlers are mainly stationed at the West base, which is connected to terminal 3 (van Wieren, 2021). Since many different handlers are operating in the West base, it can be challenging to operate in that area. This can lead to increased difficulties in position planning of the make-up process and too many LU's of all different handlers present in the area. These difficulties have been experienced by handlers, which is extracted from interviews conducted by van Wieren (2021).

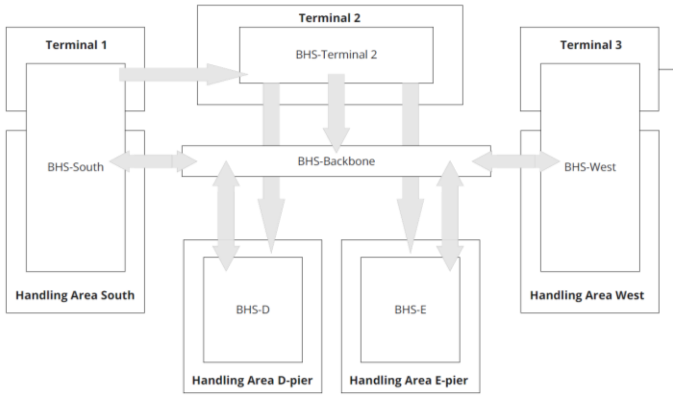


Figure C3: Areas of the baggage handling process

D. Data Overview Baggage Handling Process

The process of identifying the data sources has been a complex task where the division of the baggage handling process was highlighted once more. The information of available data needed to be acquired from various sources and no central database was identified. A lead data analyst at RSG highlighted his interest in the identification of currently available types of data, as this is currently not all clear to the data and analytics department. The analyst did provide information on the most relevant data sources, which were later validated by an advisor logistics and Innovation and data scientist working at RSG. The most relevant data sources identified were:

- Bags Source Message (BSM) contains flight and passenger information. The BSM is linked to a barcode label. Thus, once baggage is being scanned via a barcode scanner, the BSM is known. The BSM is shared between airports and can be accessed real-time, via an API.
- Baggage Handling System (BHS): When baggage is being scanned in the BHS by a barcode scanner, the BSM and time of scanning is saved. This data is real-time accessible and can be accessed via SPLUNK. Currently, data is unstructured, thus, not ready to use directly.
- Management Information System (MIS): a baggage management information system has been set up containing multiple data points in the baggage process, including check-in, storing and make-up processes. This gives the possibility to track and analyze the journey of baggage in the BHS. This data is made accessible after a day, thus, it is not real-time accessible.
- Central Information System Schiphol (CISS): flight data is stored in CISS. This includes arriving and departing times of a flight and its corresponding baggage. This data is real-time accessible.

This appendix provides the constructed data overview of the baggage handling process. The colored actors illustrated next to the data types represent by whom the data is managed.

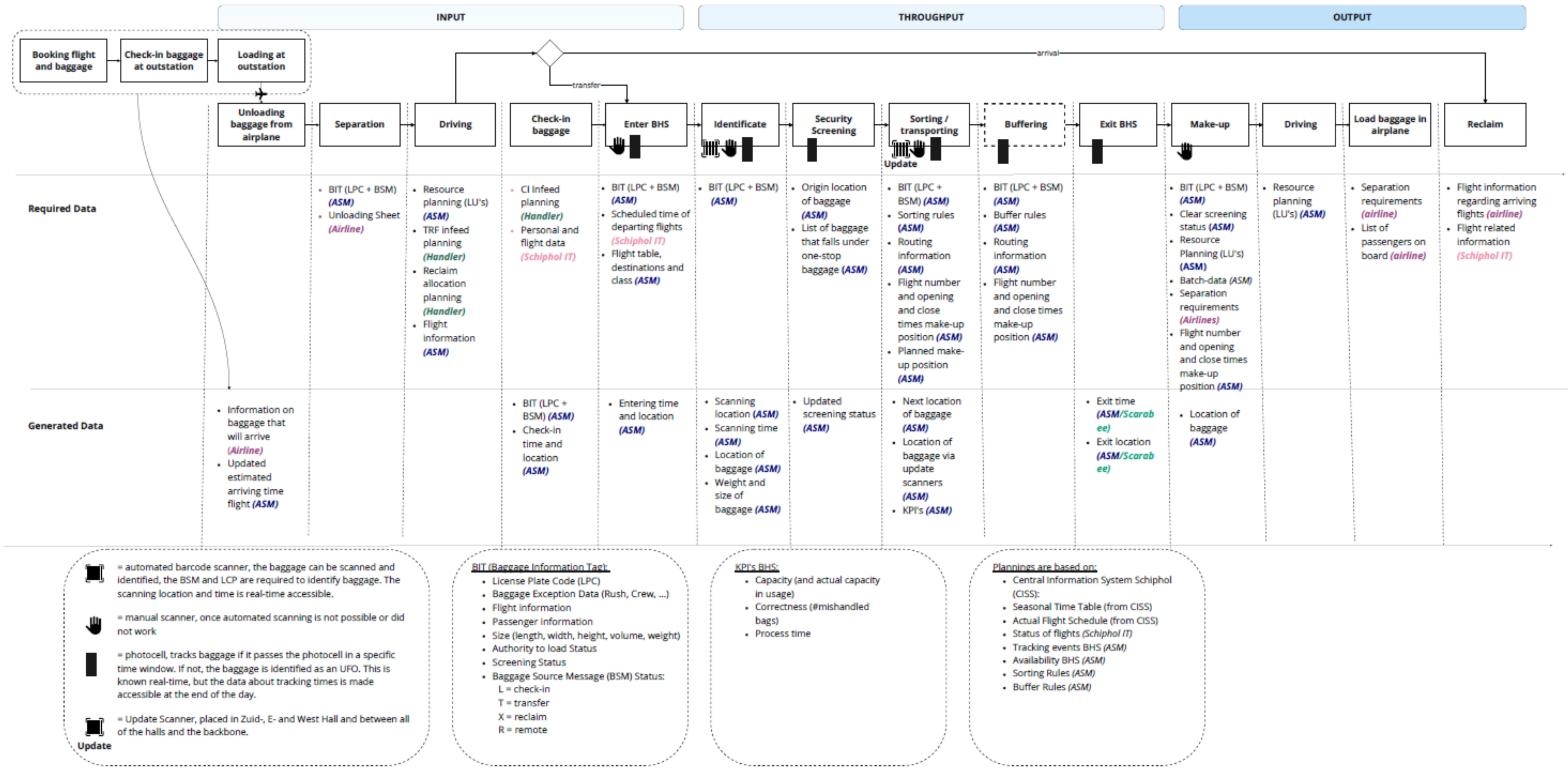


Figure D1: Data Overview Baggage Handling Process

E. Desired Situation

This appendix provides additional information to chapter 5. E1 provides information on the KPI's of AAS, whereas E2 does into depth on the drivers behind the system-level goal of the ecosystem. Lastly, the results on the analysis on the strategy of the ecosystem are illustrated in E3.

E1. Key Performance Indicators

The performance of the baggage handling process is being determined on several aspects. First, the performance of the baggage handling system (BHS) is being measured via three key performance indicators (KPI). The BHS is the system responsible for identifying, screening, sorting, buffering and transporting the baggage towards the correct exit. Thus, it starts at the entering process step and ends at the exit process step. The Key Performance Indicators (KPI) of the BHS are capacity, correctness and process time.

<u>Capacity:</u>

The capacity is defined as the number of baggage that can be handled in the system per unit of time. This KPI is being measured per head route of the BHS. Thus, every route can have another measurement for this KPI. A shortage in capacity can lead to higher process times, since baggage needs to take other (longer) routes or congestions in the system can arise and to a decrease in correctness.

<u>Correctness</u>

Correctness is defined as the number of baggage that entered in the BHS has arrived at its correct destination. To calculate this, the total number of baggage is reduced with baggage that is being handled incorrectly. Incorrected handled baggage can either be:

- baggage that needs to be identified via manual coding
- baggage that has a flow-garbage exit point
- baggage that has an Out of Gauge exit point, this is odd size baggage that has entered the BHS in the regular infeed quays and not via the odd size infeed area.
- Baggage that is not delivered on the correct exit point

<u>Process time:</u>

The process time is defined as the absolute difference in time between entering the BHS till the exit time of the BHS. This is measured in seconds. The time that baggage is buffered, is not taken into this measurement. For some head routes, this process time cannot be measured, since the entering and exit times are not linked to a database. This will be manually measured.

E2. System-level goals baggage handling process

As written in the literature review, an ecosystem is usually characterized by a common system-level goal (Appleyard & Chesbrough, 2017). This system-level goal is in reality divided into multiple goals which differ per actor in the ecosystem. Nevertheless, the existence of a system-level goal can guide the ecosystem towards achieving it. The overall system-level goal at the ecosystem of Schiphol Airport regarding the baggage handling process is to have the baggage on time on board or at reclaim. Since the baggage handling system consists of three movements, each movement has an overarching goal.

The departing movement has the goal to have the baggage on-time on board, which is visualized in figure E1. The blocks to the right of this goal represent the drivers behind this goal. The drivers have been marked with a green dot if tagless CVT could have an influence on those drivers. For example, the capacity of the BHS will not be influenced by the implementation of tagless CVT. Nevertheless, the capacity of the system can be used more efficiently due to optimally steering the baggage flows by tagless CVT. Furthermore, if the baggage is being identified more accurately and less manual coding is required, the process time of baggage will automatically be shorter. This identifying process is already seen in the bottom of the figure, where correctness of identification is an important driver. This correctness is either at the BHS level, as well at the handler proces level, which relates to the manual correctness of identification and loading of baggage by handlers. If the latter can be done automatically due to tagless CVT, the correctness could potentially be increased. This would result in a higher amount of baggage that will be on the right flight, which is a driver for the overarching goal to have the baggage on-time on board. Next to that, the check-in process time could probably be decreased if baggage labels do not need to be printed and attached to baggage anymore due to the implementation of tagless CVT. The combination of these three influences, could increase the amount of baggage that will be on time at the lateral for the make-up process. Thus, the first drivers that can be influenced by tagless CVT, will be identified as a need to improve the drivers for the ecosystem. In this way, during the use case workshop, it can guide as an inspiration how tagless CVT could help to fulfill these needs, which will eventually lead to achieving the common system-level goal.

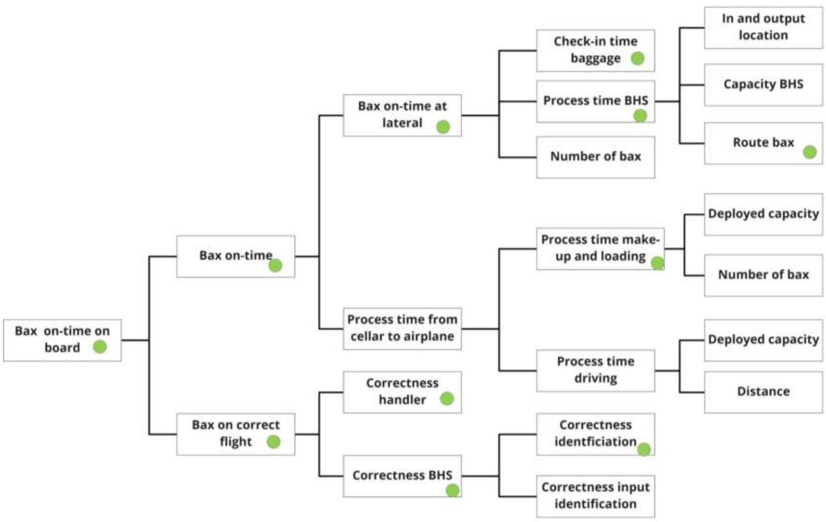


Figure E1 Overarching goal departing movement

The arrival movement has a different overarching goal, which is to have the baggage arrived on time at reclaim. The drivers behind achieving this goal are presented in the figure below. Tagless CVT could have a positive influence on the process time of unloading the baggage and getting it to reclaim. This can be achieved, as the technology could support the separation process, which results in more baggage separated correctly.

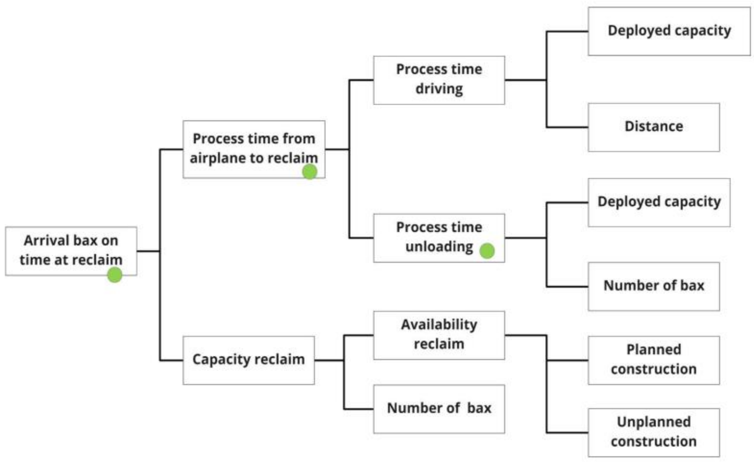


Figure E2 Overarching goal arriving movement

The transfer movement is a combination of the departing and arriving movement, in which the overarching goal is to have the bax on-time on board. The illustrations of how tagless CVT could influence the drivers behind this goal are therefore the same as above.

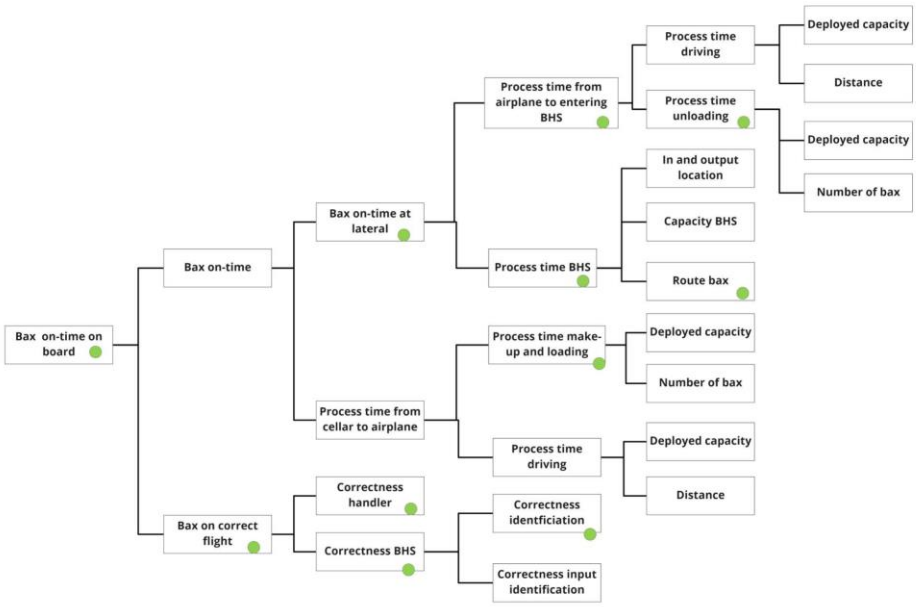


Figure E3 Overarching goal Transfer movement

As it can be seen that the number of baggage is a driver in all three movements, it is interesting to review the expected numbers of baggage for the coming years. This will be illustrated in the next subsection in combination with the vision of the ecosystem of Schiphol Airport for 2050.

E3. Strategy

The table below represents a quick overview of the future situation at AAS regarding the number of passengers and sustainability goals. The vision of Royal Schiphol Group for the future concerns the balancing between strengthening the Quality of Network, improving the Quality of Life, and enhancing the Quality of Service. This vision is drafted on the basis of the current performance and analyses of the future external environment.

	2019	2030	2050
# Passengers / year	72 million	88 million	105 million
Percentage TRF	36%	36%	30%
Quality of Life		Zero emissions and zero waste at Schiphol Airport	Net-zero carbon emissions aviation sector

Table 1: Strategy of RSG

- **Quality of Life**

Royal Schiphol Group has the ambition to make Schiphol Airport the most sustainable airport in the world. The main targets are to become energy positive, advocating sustainable aviation, implementing the principles of a circular economy and securing a healthy living environment around Schiphol Airport. In order to create a net-zero carbon emission aviation sector, innovation is key. New technologies are needed to facilitate this transition.

- **Quality of Network**

Due to the envisioned improvements in the quality of life, the vision is to grow the capacity of Schiphol Airport in a controlled manner. Because of the Dutch airport capacity scarcity, the capacity needs to be used as efficiently as possible. The hub operation is still a strong pillar in the future. Although the percentage of transfer flights is likely to decrease in 2050 (see table ?), the absolute amount of transfer flights is still higher in 2050 than in the current situation. The reason why the percentage of transfer flights will decrease is it is foreseen that airlines will offer more short European flights in the future due to sustainable reasons compared to intercontinental flights.

- **Quality of Service**

A seamless passenger journey is an important vision of the ecosystem of Schiphol Airport. The vision is to have stress free airports with a healthy environment. Through innovations, early adoption of new technologies and extensive use of data, the airport process will be largely self-running by 2050. Autonomous operations will be a large part of airport processes, in which artificial intelligence plays a central role. These autonomous operations will also be necessary, as currently AAS is already facing a staff shortage and the prediction is that these shortages will grow.

The increasing number of passengers traveling at Schiphol Airport in the future, demand a higher capacity of the baggage handling system. Currently, Schiphol Airport is already facing capacity problems due to the large infeed peaks of baggage during morning hours. Figure 21 below sketches a scenario forecast of the capacity of the BHS in the coming years. The green blocks represent an increase in capacity, which can either be an asset solution or innovative solutions. Even with the forecast of more capacity in the South-hall in 2028, there are still years of a capacity shortage. This shortage should be decreased, by making innovative use of the available capacity.

F. Data Workshop

This appendix provides additional information on the data workshop. First, the planning and content are illustrated in F1, followed by the notes of the workshop in F2. Lastly, the survey sent to the attendees afterwards is presented including the results in F3.

F1. Planning and Content of the Workshop

Date: 04-11-2021 13:30 - 16:00
Participants: representatives of the following departments of Schiphol Airport: operations, IT, Data and Analytics, Innovation Hub.
Location: C232 room at SHG

Goal of the workshop: to identify how currently available and potential data sources in the baggage handling process at Schiphol Airport could be used to create value. Thus, the goal is to brainstorm on ways how data could be used more in the baggage handling process to create value. End product of this workshop will be multiple identified data-driven services for the baggage handling process filled in the Data Service Canvas (Breitfuss et al., 2021). This will be an input and starting point for the second workshop that focuses on identifying use cases for tagless CVT. The researcher will be the responsible party in organizing, preparing, leading and evaluating the results of the workshop. Thus, during the workshop, the researcher will not be part of a group, but will guide the process and take notes.

The following supplies will be present during the workshop:
- Screen for sharing the presentation slides
- Office supplies: post-its, pens, markers
- Printed representation of current data assets (4x) *(see figure D1)*
- Two sets of the Data Service Cards
- A1 format printed Data service Canvas (8x)

In order to prepare the participants of the workshop, the planning of the workshop including the digital Data Service Cards and visualization of the current data assets will be sent to them a couple of days in advance.

Planning of the workshop:
13:30 - 13:40 1. Introduction of the content and goal of the workshop
13:40 - 13:50 2. Quick brainstorm on future data-driven baggage handling process
13:50 - 14:15 3. Overview current data sources and identifying potential data sources
14:15 - 14:45 4. Filling in the Data Service Canvas, part 1
14:45 - 15:00 5. Break
15:00 - 15:30 6. Filling in the Data Service Canvas, part 2
15:30 - 16:00 7. Discuss results + evaluate identified results

The program parts will be more elaborately illustrated next.

1. **Introduction of the content and goal of the workshop**

A small introduction of the background covering the basics of tagless CVT will be given in order to be sure that all attendees know why this workshop is organized. The goal of the workshop will be discussed. This part of the program is to introduce the attendees with the purpose of why this workshop is organized and what is planned to achieve after the workshop.

The following information will be shared:

This research focuses on identifying the value of tagless identification of baggage. That means that the baggage will be recognized and identified by computer vision technology and cameras. In this way, printed barcode labels will no longer be necessary. So, this research is broad and exploratory to investigate the benefits and value of tagless baggage for the ecosystem of Schiphol Airport. Thus, the focus will not only lie on benefits for Royal Schiphol Group itself, but also for the other relevant partners such as the airlines, handlers and the passengers.

A way in which tagless identification of baggage could be valuable is by separating transfer baggage on a hot/cold basis, where cold baggage will not be inserted in the baggage handling system yet to reduce infeed peaks to make optimal use of the capacity. Based on real-time flight data, baggage can be separated. In addition, this tagless computer vision technology could potentially make it easier to identify the baggage to accommodate such automated separations based on flight information data. In this example, real-time flight data is used to create value. Thus, it is interesting to brainstorm whether there are other ways in which data could be beneficial for the baggage handling process. Which is the focus of this workshop. Therefore, the goal of the workshop is to brainstorm on the potential of currently available data, but also to identify desired data that is needed to achieve certain valuable data-driven processes or decisions. The results will in the end be linked to tagless identification of baggage, as we conclude if these identified data-driven processes will be more feasible with tagless baggage.

During the workshop, ways on how currently available or potential data sources could be used to create value will be identified. These ways in which data could be used will not only relate to tagless baggage identification, but in the end the link will be made between the identified data service and tagless identification to detect if this would make the service more feasible to implement.

At the end of the introduction, the attendees will be asked to share their expectations of the workshop and what they want to have achieved at the end of it. In this way, it can be seen if the expectations are aligned and if the participants all share a mutual goal for the workshop. If not, this is also interesting knowledge as the workshop could still be steered towards their expectations in order to generate optimal results out of it.

2. Quick brainstorm on future data-driven baggage handling process

In order to kickstart the brainstorm process and inspire the attendees, a quick brainstorm will take place at the beginning of the workshop. Attendees will get the assignment to write down things that come to mind when thinking about data usage for the baggage handling process on yellow post-its. This does not need to be realistic, it is meant to be as creative as possible to also think about things that are currently not possible. On blue post-its, attendees will write down why this data situation as written on the yellow post-its is yet realized. A realistic possibility is that attendees will write down on the blue post-its that the required data is simply not available yet. This makes the bridge towards the next program part. The researcher will cluster the post-its in relevant groups and discuss the result with the attendees.

3. Overview current data sources and identifying potential data sources

An overview of the current data sources will be presented *(see figure D1).* This overview is visualized in combination with the different process steps of the baggage handling process in order to give an overview what data is present in what steps. The Data Service Cards (category Data Sources) can be used to identify more potential data sources. The link to tagless CVT will be made here, as data that will be generated due to the implementation of tagless CVT will also be thought of. This category consists of the following cards: weather data, geographic data, product-generated data, usage behaviour, web content, marketing & Sales data, logistics and mobility data, Process data, user-generated data, open data. An example of every sort of data source is illustrated on the card. The cards have been sent to the attendees in advance, however, the cards and how they can best be used will be explained during this part of the workshop. By using the cards, attendees will be inspired for other data sources than the sources that are currently being used. In addition, the concept of an end-to-end baggage journey will be explained, where there will be thought of additional data or tracking points required to achieve such an end-to-end journey.

The group will be divided into two groups who will brainstorm on data sources that could be valuable or useful for the baggage handling process. Five minutes before the end of this program part, the results will be discussed and a list of all identified data sources will be presented on the wall. This will guide as an inspiration and input for the next part of the workshop.

4. Filling in Data Service Canvas, part 1

The two groups will fill in the Data Service Canvas. This canvas will be filled in for different user perspectives: Royal Schiphol Group, airlines, handlers and passengers.

5. Break

The attendees will get the opportunity to get a short break. During this break, the researcher will already take a look at the Data Service Canvases and will create an overview of the already identified data-driven services. This overview will be amplified at the end of the next part to create a complete overview. However, by preparing this overview, the evaluation and discussion part of the identified data-driven service can be done quicker.

6. Filling in the Data Service Canvas, part 2

Filling in the Data Service Canvas will be continued after the break.

7. Discuss Results + evaluate identified services

The last half hour of the workshop will be focused on the results of the brainstorm. The identified services will be presented on the wall. The groups will give a short description of the service, whereafter the attendees get the assignment to rate the services. All attendees will get three colors of post-its and they need to assign the post-its to the service that scores best in their opinion on value creation on the short term and value creation on the long term. Furthermore, the attendees will also need to assign a post-it to the services in which they see a link with tagless CVT. For example, if the implementation of tagless CVT would make the service more feasible to execute.

At the end of the workshop, the attendees will be asked to fill in a survey to evaluate the workshop. This survey will include questions on the workshop in general, as well on the usefulness of the tools used during the workshop.

F2. Notes Data Workshop

- Brainstorm

A lot of possibilities are mentioned of data usage in the baggage handling system, such as: steering baggage flows, enhanced decision-making, using data to analyze delays, track-and-trace, adaptability, customer products, inform, sharing data, real-time planning, input for machine learning algorithm, predict, real-time dashboard, creating value, govern, liability.

This is added with terms like an end-to-end journey and that baggage can in the future travel without a passenger, due to track-and-trace services. So, if you have more data points in your end-to-end journey, you will have a securer system. This sounds all promising, but why are we not there yet? The biggest reason is a missing sense of urgency, as we don't know if there is a sense of urgency with all the different stakeholders to have more information or to share data. In addition, it is fine the way it is now, things are going well. We do need it in the future, but it is fine the way it is now.

This missing sense of urgency combined with the uncertainties of the added value of data results in the fact that there is no business case for it. The added value is really important compared to the investment needed. The investment is really high, since currently stakeholders do not share their data, there are decentralized data sources and access, problems with data sources integration, a high complexity already to maintain currently available data, no single data owner. To overcome these problems, a high investment and effort needs to be made. In order to do that, the added value and the benefits should be known.

Data scientist: working with other departments is new for me, I am not really sure what is happening at operations and in the baggage handling process. You may think that the data is too complex to maintain, but our team can develop and maintain the system to accommodate your processes. But only if the added value is known. I can see how this extra data can create an impact. If you have more data, you can for example identify if delays are correlated with certain characteristics of baggage, then we can do something about the delays. So, if the added value is big enough, we have the people to develop and manage the complexity of the data part.

- Conclusion Brainstorm:

There are definitely a lot of **benefits and value** of data usage, nevertheless, the added value should be known beforehand. The **investment is very high** to create such a data-driven environment, so the added value and benefits should also be every high to create a business case. Currently **no shared sense of urgency** about the need for a data-driven environment. It is fine the way it is now. Nevertheless, it was concluded that we need such an environment **in the future**, so when will this urgency come and will that not be **too late?**

- Valuable Data Sources

- Visual images of damage on baggage
- Volume of the baggage
- Geographical data
- Season Data
- Parking Data
- Traveling trends
- Downtime of systems
- Timestamp
- Material of baggage
- Flight information
- Historical baggage data
- Meta data
- User generated data → passengers make photos of the baggage at home

- End-to-end journey

We talk about this a lot, but what is the definition?

It starts at check-in baggage and ends at reclaim. However, these processes can be geographically at another point than currently happening. So, check-in can be done at home, when passengers will upload a photo of the baggage and reclaim can also be at home, where the baggage is being delivered. So, an end-to-end journey will always start at check-in of baggage and end with reclaim of baggage. The question is, where will these processes be geographically located in the future? In order to minimize mishandled bags, an end-to-end journey is important, where baggage is identified in the BHS, but also during loading, unloading and reclaim. In that way, proof of the journey.

- Identify Data Services

The identified data services can be divided into two categories: automated actions & information and knowledge gain.

Automated Actions:

Automate tail-to-tail separation

When unloading the baggage from the aircraft, tail-to-tail baggage is manually identified and picked up. This process could be automated to speed up the process.

Automate reclaim and remote reclaim separation

A future is foreseen where not all passengers get their baggage at the current reclaim area at the airport, but at the parking spot or at home. An extra separation step is therefore needed. This step could be automated.

Automate loading process

Automating this process can have various purposes. Currently all bags are manually scanned to see if it can be loaded, if this step can be automated, this would speed up the process. This could also result in the fact that carousels can be used for more than one flight, which would ensure more efficient use of the make-up capacity. In addition, load errors can be recognized if the process is automated. This can minimize wrongly loaded baggage. Lastly, it could speed up the reconciliation process. If a passenger has not entered the aircraft, the baggage needs to be unloaded. Visual images of the bags could speed up the process.

Information & Knowledge Gain

Track-and-Trace

Geographical data of the location of baggage can provide a track-and-trace service. This could enhance the possibility of passengers to remotely drop off their baggage, since they have insights into the location of their baggage. This could result in the fact that passengers will travel separately with their baggage in the future.

Information on damage of baggage

Visual images of baggage can provide insights into the steps where baggage was damaged during the process. This results in the fact that it is known who is liable for that damage.

Root-cause analysis of delays

With more data points of baggage, a root-cause analysis of delays can be executed. Currently, we have data on when the aircraft arrives and when suitcases arrive in the system. Nevertheless, we want more information on the process in between these two data points. We do not know what happens now and why delays are happening.

Predictive Maintenance

Data could provide insights into error times and capacity utilization, in order to prevent unplanned disruptions of the systems.

- Evaluation

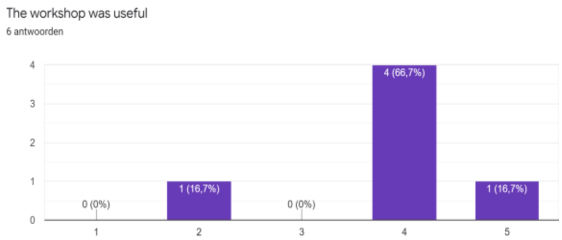
The services that were indicated as providing the most value on the short term:
Track-and-Trace, automating tail-to-tail separation, automate loading process.

The services that were indicated as providing the most value on the long term:
Predictive maintenance, Information on damage of baggage, automate loading process.

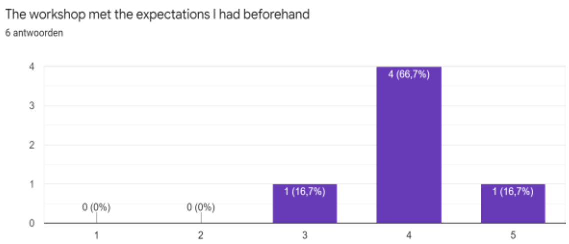
All of the services had a link with tagless baggage.

F3. Results Survey Data Workshop

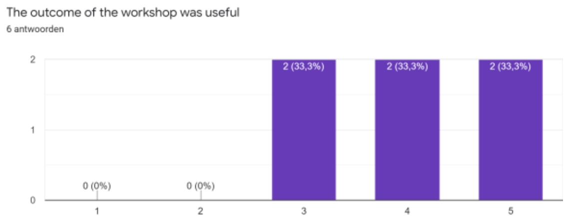
The survey is made in Google forms and shared online with the attendees. The questions including the results are illustrated in this section.



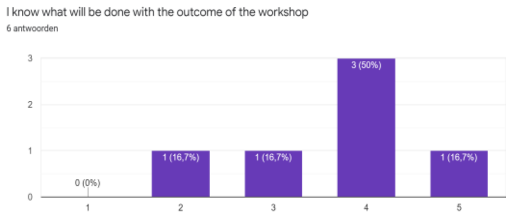
F1. Results Survey Question 1



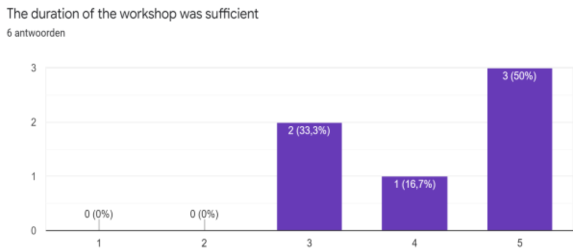
F2. Results Survey Question 2



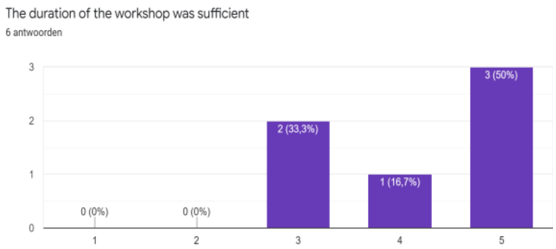
F3. Results Survey Question 3



F4. Results Survey Question 4

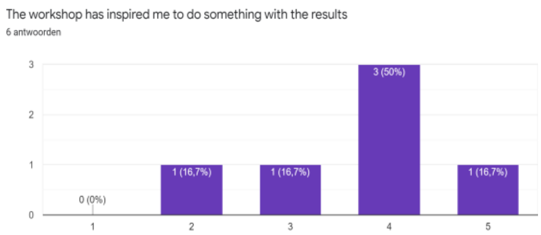


F5. Results Survey Question 5

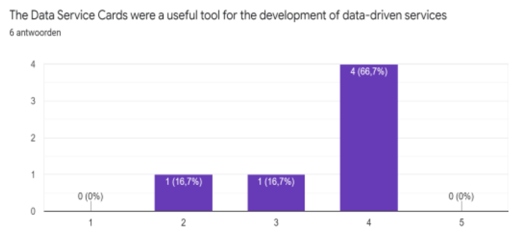


F6. Results Survey Question 6

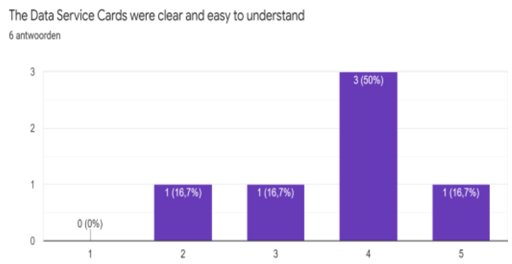
F7. Results Survey Question 7



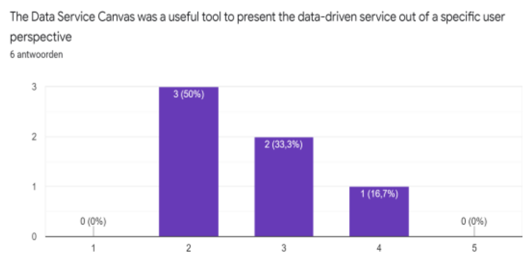
F8. Results Survey Question 8



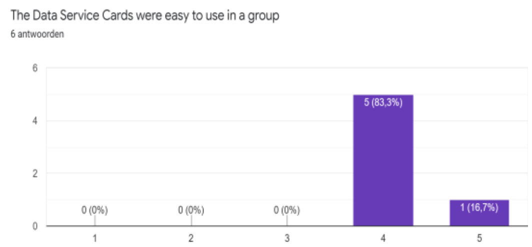
F9. Results Survey Question 9



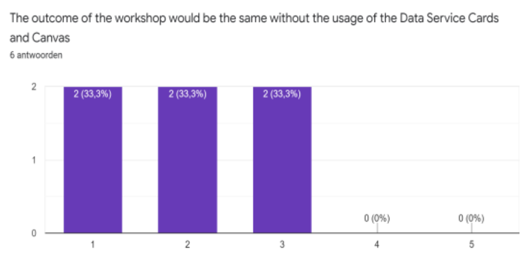
F10. Results Survey Question 10



F11. Results Survey Question 11



F12. Results Survey Question 12



F13. Results Survey Question 13

Do you have some overall feedback or comments about the workshop / tools that were used during the workshop?

5 antwoorden

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No

-

Good work Evelien!

I would prefer to start the brainstorm session with some business cases, selecting the most promising and then defining what is needed to make them a reality.

Fantastic job Evelien in organising this workshop! The data service cards definitely added an interesting spark to the real-life discussion. I am not sure if this spark was also there in the online discussion. When everything will be online next time, it might be useful to predefine the smaller subgroups such that all expertises are included per group (innovation, baggage and data). Looking forward to the next one!

F14. Results Survey Question 14

G. Use Case Workshop

This appendix provides additional information on the use case workshop. First, the planning and content are illustrated in G1, followed by the results of the workshop in G2.

G1. Planning and content of workshop

Date: 16-11-2021 9:30 - 12:00
Participants: representatives of the following departments of Schiphol Airport: operations, IT, Security, Data and Analytics, Innovation Hub, Security. Representatives of airlines and ground handlers.
Location: Online, in Teams and Miro.

Goal of the workshop: to identify ways in which tagless CVT could be used or create value for the ecosystem of Schiphol Airport. This will be done by brainstorming on the general benefits of tagless CVT combined with specifying use cases for the technology. This goal shifted towards ways in which CVT could be valuable as an addition to the current technologies.

The researcher will be the responsible party in organizing, preparing, leading and evaluating the results of the workshop. Thus, during the workshop, the researcher will not be part of a group, but will guide the process and take notes.

In order to prepare the participants of the workshop, the content and planning of the workshop is sent a couple days in advance.

Planning of the workshop:
09:30 - 09:40: 1. Introduction of the content and goal of the workshop
09:40 - 09:50 2. Quick brainstorm on benefits of tagless identification
09:50 - 10:00 3. Desired situation baggage handling process
10:00 - 11:00 4. Identification of use cases in break out rooms
11:00 - 11:15 5. Break
11:15 - 11:45 6. Evaluation use cases
11:45 - 12:00 7. Discuss results

1. Introduction of the content and goal of the workshop

A small introduction of the background will be given in order to be sure that all attendees know why this workshop is organized. The goal of the workshop will be discussed. Furthermore, the output of the data workshop and the link with this workshop will be elaborated.

2. Quick brainstorm on benefits of tagless identification

In order to kickstart the brainstorm process and inspire the attendees, a quick brainstorm will take place at the beginning of the workshop. Attendees will get the assignment to write down things that come up in mind when thinking about tagless baggage identification. In advance, three categories are set up to guide the brainstorm: the benefits, risks and applications of tagless identification. This brainstorm can be very broad and is meant to be an inspiration for the rest of the workshop. The researcher will cluster the post-its and identify a conclusion.

3. Presentation Desired Situation

A short movie will be shown about the desired situation of the baggage handling process in 2050. The alluring perspective of the baggage handling system in the future will be illustrated, in order to give the attendees the idea of what kind of future is foreseen. This can guide the ideation process of use cases.

4. Identification of use cases in break out rooms

In order to generate ideas for use cases supported by tagless identification of baggage, the attendees will be divided into two break out rooms. One group will start thinking of use cases based on the current challenges of the ecosystem, whereas the second group will think of use cases based on the identified needs of the use cases. After twenty minutes, the groups will change and work upon the work of the previous group.

During this step, the attendees need to fill in the table (see below), indicate if there exist a dependency on implementation at other airports and place the use case inside the impact/feasibility matrix.

Use case	Desciption	For whom is this use case the most valuable?	Is this use case also valuable for other actor?	Is the use case also implementable with barcode or RFID labels?

Table 2: Use Case workshop Table

5. Break

The attendees will get the opportunity to have a short break. The researcher will make sure that the overview of the found use cases is complete and that the evaluation of the use cases can properly start after the break.

6. Evaluation of use cases

Once all use cases are presented in an overview on the wall, it is important to receive everyone's opinion on the use cases. The results of the use cases and impact/feasiblity matrices will be discussed.

G2. Results Use Case Workshop

Observations, notes and an audio recording have been applied as evaluation methods to analyze the general parts of the workshop. Since no audio recording or notes could be made of both break-out rooms, the results of this part are the constructed use cases in Miro.

The workshop results showed that the baggage handling ecosystem of Schiphol Airport is reluctant towards tagless identification of baggage. The original approach and goal of the workshop were to think of benefits and use cases for tagless identification of baggage. Benefits were mentioned by the attendees such as a higher read rate, no physical tags needed, a shorter check-in process time, more sustainability, more data points and possibly an enabler of data sharing in the ecosystem. Nevertheless, the results of the brainstorm on the risks of tagless identification showed that the risks outweigh the benefits for the majority of the attendees. A division was seen again between the attitude of employees of the Data & Analytics department and Innovation Hub at RSG compared to the operations departments of RSG and an airline. The focus of the first group was more towards the future, whereas the latter had an emphasis on the current situation and feasibility of tagless identification. The disadvantages of tagless identifications that were mentioned were the following:

- No backup: if there is an outage and the technology stops working, how to identify baggage? If a suitcase is not recognized by a camera, how can we still identify it?
- Reliability: What if two bags are identical, is the technology reliable enough to separate them? What if the baggage is damaged throughout the process, is the technology still able to identify the bag?
- Scalability: Implementation is needed at other airports. If not everyone implements, double investments are needed.
- Added value: Does tagless baggage really provide added value?

The emphasis on the objections concerning the risks and low feasibility stagnated the brainstorm on use cases for tagless identification. The brainstorm was stimulated by indicating that the last part of the workshop would focus on the feasibility of the use cases and that during the ideation process the critical eye needed to be minimized. This did not work comprehensively and the focus of the workshop shifted from tagless identification via CVT towards CVT as an addition to current identification technologies. This shift also provided insights into the fact that CVT as an addition to current identification technologies would eliminate most of the disadvantages as illustrated above. In this way, the attendees had the perception that the ideation process would be more useful, as ideating for tagless identification seemed useless since this would not be feasible at all: "*I can not think of use cases for tagless identification, as I just simply do not see it working in real life".* Another attendee agreed on this and indicated that it was too hard to think of use cases if he did not believe in the actual possibility of implementation. The shift to thinking of CVT as an addition allowed attendees to brainstorm on use cases for CVT in the baggage handling process. The identified challenges and needs of the baggage handling ecosystem as illustrated in chapters 4 and 5, were used as input during the brainstorm process. An attendee indicated that this was useful as it guided in thinking of use cases: *"When the brainstorm stagnated, we went through the current challenges, which inspired us to think of ways to solve these challenges".* During the workshop, several use cases were identified. The list of the identified use cases can be found in the next section which focuses on the analysis and validation of the use cases to provide the final overview of identified use cases.

At the end of the workshop, an attendee working at an airline concluded his opinion on CVT for the baggage handling process: *"My first reaction is that it is quite a difficult subject, but relevant to investigate. We saw that the focus shifted from tagless identification using CVT towards CVT. I think that CVT does offer opportunities when applying it in a manageable environment as an addition, but in a global network there will be many reservations.".*

Ideation process use cases

Round 1: ideation of use cases based on current challenges

- Liability damage of bags
- Bags who lost labels or can't be read can be identified via CVT
- Using images of bags during loading process
- Automated make-up process
- Off-loading based on visual images
- Home check-in

Round 2: ideation of use cases based on needs

- Quicker check-in process
- Based on visual images, identify high risks for BHS
- Optimize buffer
- Shorter waiting times terminal

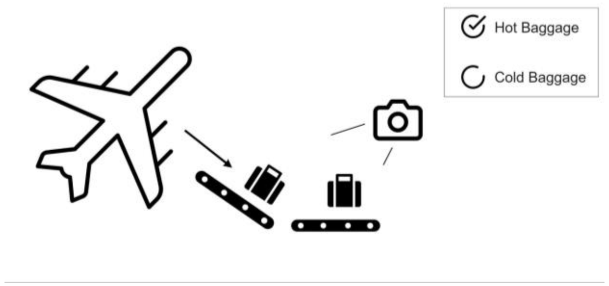
Conclusion workshop:
The risks of CVT can be mitigated if it is an addition to the current identification technologies. Relevant use cases have been identified which can provide additional value for the ecosystem, but require future research on the actual added value. Any global large-scale implementation can follow in the long run. This can provide even more value, which also requires further research.

H. Use Cases

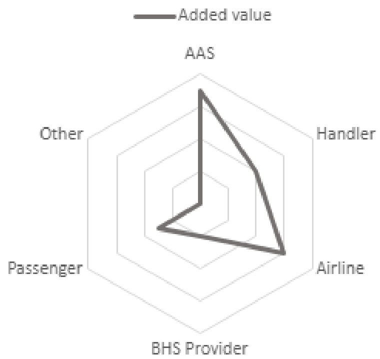
This appendix provides additional information on the final overview of the use cases. The use cases will be individually illustrated in more detail. A visual representation of the use case, the filled in Combined Tool and a first attempt to quantify the value of the use case is illustrated in this section. Lastly, the argumentation behind the constructed radar charts is complemented.

H1. Hot/cold Separation

CVT will identify baggage and tell the handler if baggage is hot or cold in order to be separated. Hot baggage will be inserted into the BHS first, whereas cold baggage will be buffered and inserted into the system later. Currently, baggage needs to be manually scanned in order to separate bags. This is labor-intensive, which is a major reason why hot/cold separations are currently not performed. Added value CVT: autonomous identification could stimulate that separation will be actually carried out.



H1. Schematic Representation Hot/Cold use case



H2. Radar Chart Hot/Cold use case

This use case is mostly valuable for RSG and airlines operating in TRF flights. The capacity of RSG can be used more efficiently, without the need for costly renovations. Most mishandled bags occur during peak hours. If the peak will be flattened by this use case, the amount of mishandled bags is likely to decrease, which results in less costs for airlines, handlers and RSG. This also results in value for the passenger, as less bags will be mishandled. The use case will lead to an extra step to be performed by handlers, which changes their current way of working. The added value is, therefore, less compared to airlines. The BHS provider also receives benefits, as they can provide this use case at other airports as well if it seems valuable at AAS.

Current Functionality	We create the computer vision technology (CVT) use case ...
Hot/cold separation, to flatten the infeed peak in the BHS and the TRF infeed quays	**What is the name of our use case? How to describe it?** Autonomous hot/cold separation: CVT will identify baggage and tells handler if baggage is hot or cold in order to be separated. Hot baggage will be inserted into the BHS first, whereas cold baggage will be buffered and inserted into the system later.

Added value CVT

Autonomous real-time based identification, stimulates that hot/cold separation will be actually carried out (since it is currently labor intensive)

Has an influence on the occurring challenges

- Separation is based on static flight schemes *(CVT allows real-time based separation)*
- Baggage is often separated wrongly at outstations *(less relevant if CVT allows autonomous correct real-time separation)*
- High infeed peak during morning hours (*peak will be flattened)*

Has an influence on the excisting needs

- Less mishandled bags *(67% of mishandled bags occur during peak hours, less peaks = less mishandled bags)*
- Optimize routes in the BHS *(less infeed peaks result in less congestion in the BHS)*
- Optimize capacity and resource allocation (*BHS capacity and TRF infeed quays can be used more efficiently)*
- Data-driven baggage handling process (*real-time based separation)*
- More autonomous processes *(autonomous separation)*
- Being able to handle the increasing amount of baggage *(more efficient usage of current capacity allows more baggage being handled)*

Data Sources

What data sources do we need to create value?

- Baggage Information Tag (BIT) (BSM + LPC) *(ASM)*
- Unloading sheet *(Airline)*
- Flight Information *(Schiphol IT)*
- Visual images bag *(New)*

Analytics

What data analytics methods do we need to apply to gain insights and benefits from the data?

- Classification

On beforehand, business rules need to be set to determine when baggage will be identified as 'hot' and 'cold'. Visual images need to be linked to the BIT, so that the CVT visually identifies bags and determines if it is hot or cold based on real-time flight information schedules.

Data Product

In what form do we make the service available to our customers and users?

Decision support for handlers if the baggage needs to be inserted in the BHS at that moment or can be buffered and inserted later. This information needs to be visualized on a screen next to CVT installation.

Ecosystem's Benefit

What added value and what advantages does the use case generate for the ecosystem?

AAS: Flattened infeed peak in the BHS, more efficient usage of the capacity of the BHS.

Handlers: Less handlers needed to perform separation, less mishandled bags, less costs

Airlines: Less handlers needed to perform separation, less mishandled bags, less costs

Passengers: Less mishandled bags

BHS provider: Possibility to offer this service at other airports

Other: -

Implementation

Does this use case require implementation at other airports?

Yes, visual images need to be linked to BIT at outstations.

What are the most important investments that are required to implement the use case?

Validation arches at the apron, screen or other way to visualize if bags are hot or cold place where cold baggage can be stored.

H3: Combined Tool Hot/Cold use case

The impact of the use case:

- If very cold bags (>3 hours connection time) are separated during peak hours, this could on average result in a 18% reduction of TRF bags loaded into the BHS during the peak. 67% of mishandled bags occur during peak hours. Costs per mishandled bag is approximately €100. If the peak is flattened, the amount of mishandled bags may be lowered, which results in lower costs.
- 18% reduction of TRF bags loaded into the BHS during peak hours will result in an innovative increase of the capacity of the system with 22% (if the full 18% of TRF bags are separated). Inserting cold bags off peak will not introduce new peaks.
- To be able to identify bags by CVT in order to separate them, the visual images need to be linked to baggage information at the outstation, thus, a dependency is seen. To accommodate this, CVT infrastructure needs to be installed during check-in at the outstation

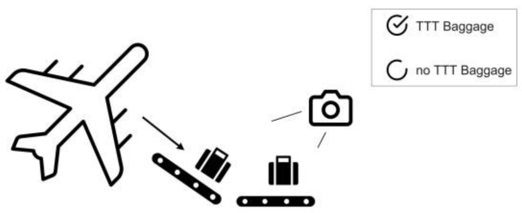
(or at the identification step in the BHS). As TRF baggage arriving at Schiphol Airport is mostly coming from KLM, this lowers the complexity of the dependency, as only KLM needs to use CVT during check-in at other airports.

- Bags with a high potential to separate are coming from 78 different airports. An analysis was performed to identify the share of high potential baggage per airport. Milan Airport has the highest share (3,08%). Thus, if CVT is only implemented at Milan Airport, 0,684% of TRF baggage can be put into the BHS later, which increases the capacity with 0,69%. This is not a significant impact. However, if CVT is installed at fifteen identified airports*, 30,9% of TRF baggage that has high potential to be separated can be separated, which results in 5,56% decrease of TRF baggage inserted in the peak, which increases the capacity with 5,88%. Thus, implementation at only a few other airports will already have an impact on the value of hot/cold separation for Schiphol Airport.

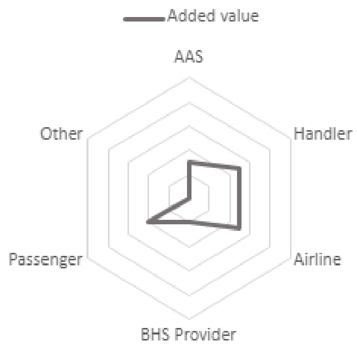
**Identified airports: MXP, SVO, FCO, BCN, WAW, ATH, TXL, TLV, VCE, BUD, LIS, MAN, CPH, HAM, DUS.*

H2. Tail-to-Tail Separation

Tail-to-tail (TTT) baggage will be identified via CVT automatically, instead of manually scanning and separating TTT baggage by a handler. This use case can be implemented complementary to the hot/cold separation without more investments.

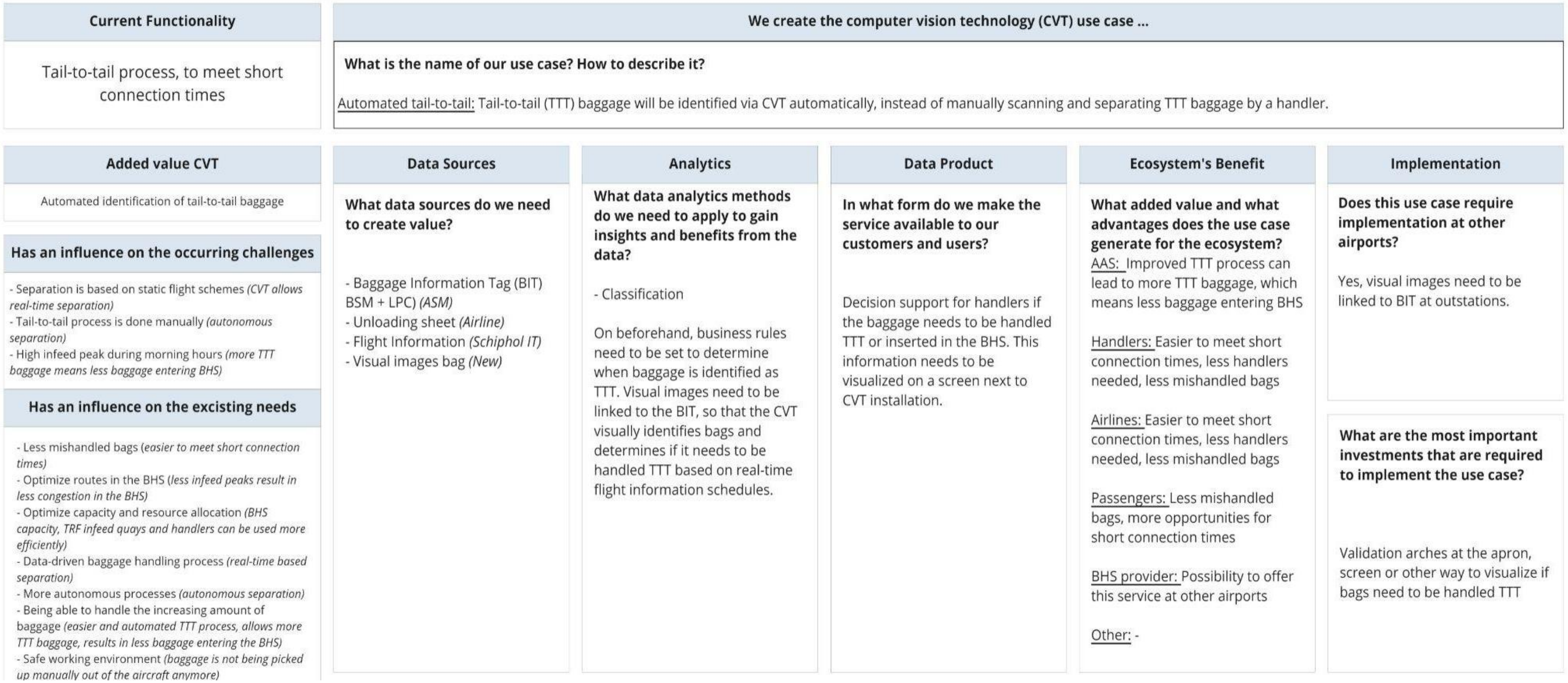


H4. Schematic Representation TTT use case



H5. Radar Chart TTT use case

This use case is mostly valuable for handlers and airlines operating in TRF flights, as it automates (a part of) the TTT process. Currently, the process is labor intensive and therefore not always executed. If the process is easier to execute, more bags could potentially be handled TTT. This also results in benefits for AAS, as less bags need to be handled within the BHS. Value is provided to the passenger, as more short connections can potentially be offered to the passenger if the TTT process is optimized.



H6. Combined Tool TTT use case

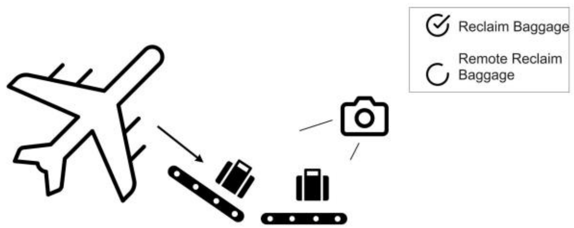
The impact of TTT separation:

- The share of TTT differs widely per flight. Currently, a handler manually identifies and picks TTT baggage. The identification and separation process can be automated by CVT. This could lead to more baggage that can be handled TTT, since it is currently a labor-intensive action.
- More TTT baggage will result in less baggage entering the BHS, which will contribute to lowering the infeed peak.

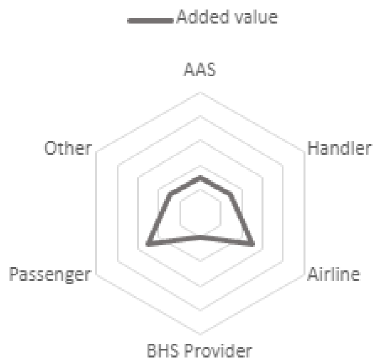
- To be able to identify bags by CVT in order to separate them, the visual images need to be linked to baggage information at the outstation, thus, a dependency is seen. To accommodate this, CVT infrastructure needs to be installed during check-in at the outstation (or at the identification step in the BHS). As TRF baggage arriving at Schiphol Airport is mostly coming from KLM, this lowers the complexity of the dependency, as only KLM needs to use CVT during check-in.
- An analysis is recommended to identify the share of TTT per aircraft to identify if this use case has significant value. In addition, research could be done in collaboration with airlines if the amount of TTT baggage could be increased if separation will be performed automatically.

H3. Reclaim/Remote-Reclaim Separation

Reclaim and TRF baggage needs to be separated. In addition, a future is foreseen where not all passengers receive their baggage at the current reclaim area at the airport, but at the parking spot or at home. An extra separation step is therefore needed. This step could be automated via CVT baggage identification.



H7. Schematic Representation Remote-Reclaim use case



H7. Radar Chart Remote-Rexlaim use case

This use case is mostly valuable for the passenger and airlines. Airlines can provide an additional service to passengers in order to attract them. Passengers are able to choose for remote reclaim if that matches their preferences. If many bags will be handled remotely, less capacity is required at AAS, which is valuable for AAS. In addition, less TRF bags will end up at reclaim, which lowers the amount of mishandled bags. Lastly, third parties can gain benefits out of this use case by providing the remote reclaim service.

Current Functionality	We create the computer vision technology (CVT) use case ...
Reclaim separation	**What is the name of our use case? How to describe it?** Automated reclaim separation: Reclaim and TRF baggage needs to be separated. In addition, a future is foreseen where not all passengers receive their baggage at the current reclaim area at the airport, but at the parking spot or at home. An extra separation step is therefore needed. This step could be automated via CVT baggage identification.

Added value CVT	Data Sources	Analytics	Data Product	Ecosystem's Benefit	Implementation
Autonomous reclaim separation (and providing reclaim and remote reclaim separation) **Has an influence on the occurring challenges** - High costs for mishandled bags due to wrong identification *(if TRF bags end up at reclaim, likely to miss connection)* **Has an influence on the excisting needs** - Less mishandled bags *(less TRF bags end up at reclaim)* - More autonomous processes *(autonomous separation)* - End-to-end-baggage journey *(providing extra service to passenger)* - A hassle free personalized passenger experience *(providing extra service to passenger)*	**What data sources do we need to create value?** - Baggage Information Tag (BIT) (BSM + LPC) *(ASM)* - Unloading sheet *(Airline)* - Flight Information *(Schiphol IT)* - Visual images bag *(New)* - Choice for reclaim or remote reclaim by passenger *(New)*	**What data analytics methods do we need to apply to gain insights and benefits from the data?** - Classification Visual images need to be linked to the BIT, so that the CVT visually identifies bags and determines if it needs to be at reclaim or at remote reclaim based on the choice for reclaim or remote reclaim made by the passenger.	**In what form do we make the service available to our customers and users?** Decision support for handlers if the baggage needs to be handled TTT or inserted in the BHS. This information needs to be visualized on a screen next to CVT installation.	**What added value and what advantages does the use case generate for the ecosystem?** AAS: Less passengers at reclaim, more efficient use of reclaim capacity Handlers: Less mishandled bags, less handlers needed to perform separation Airlines: Less mishandled bags, less handlers needed to perform separation, providing extra service to passengers Passengers: Less mishandled bags, possibility to use remote reclaim service BHS provider: Possibility to offer this service at other airports Other: Third parties can benefit by providing transport of baggage to homes of passengers	**Does this use case require implementation at other airports?** Yes, visual images need to be linked to BIT at outstations. **What are the most important investments that are required to implement the use case?** Validation arches at the apron, screen or other way to visualize if bags need to end up at TRF of (remote) reclaim, infrastructure to facilitate remote reclaim process

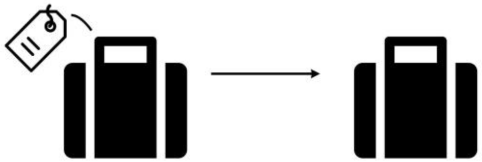
H8. Combined Tool Remote-Reclaim use case

The impact of the separation:

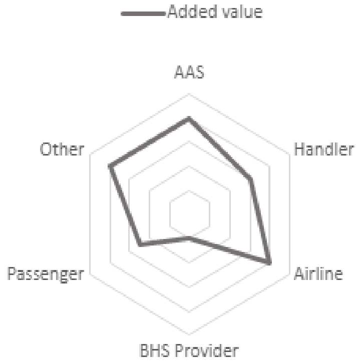
- Currently it can happen that TRF baggage accidentally ends up at reclaim, in which it will be defined as mishandled if the TRF connection cannot be met anymore. If separation will be done automatically, TRF baggage will not end up at reclaim anymore, which results in less mishandled bags and less costs.
- Reclaim baggage that will be handled remotely, will result in less baggage at reclaim. Further research is necessary on passenger's demand on the specific impact this will have on the reclaim capacity.

H4. Tagless Baggage Check-in

Baggage will be checked-in tagless, which means that labels do not need to be printed and attached to the bags anymore during the check-in process. Added value CVT: quicker process time, no physical attribute needed to attach to baggage, more sustainable.

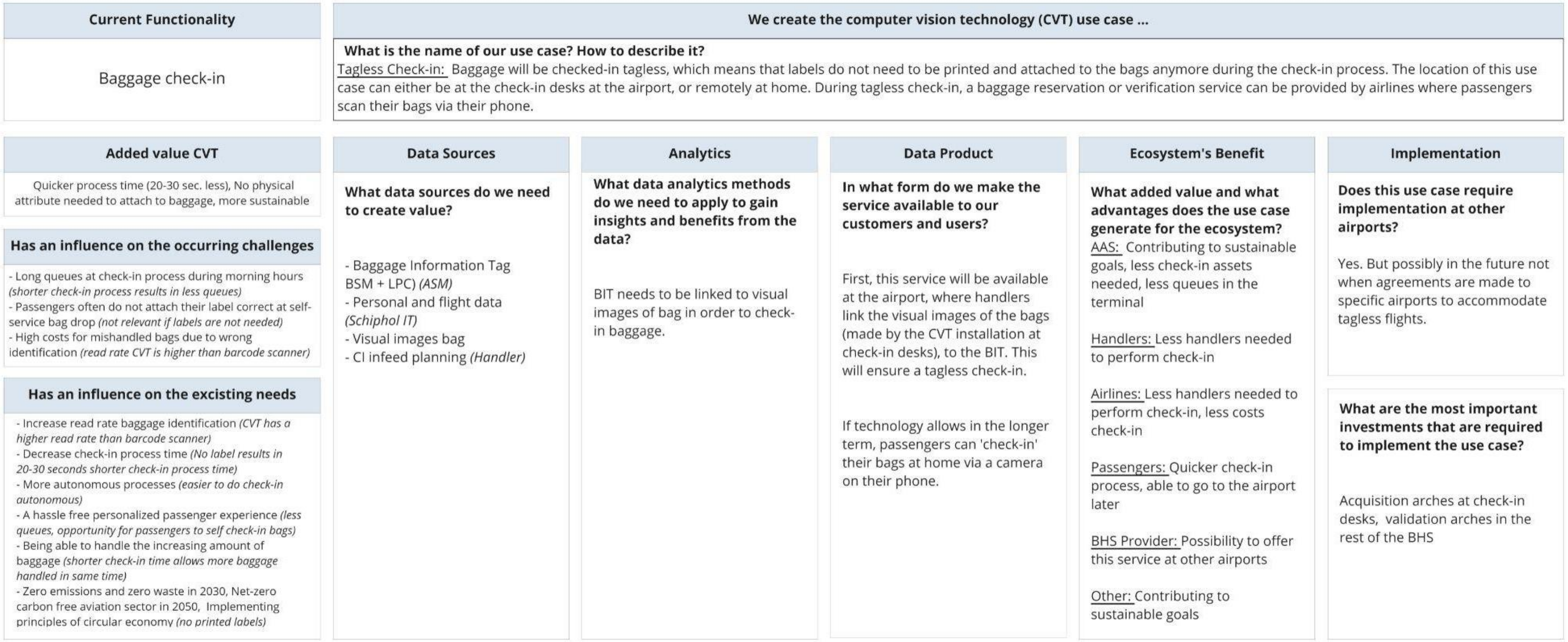


H9. Schematic Representation Tagless Baggage use case



H10. Radar Chart Tagless Baggage use case

The use case is not only valuable for RSG, handlers, airlines, the BHS provider and passengers, but also provides value for the environment, due to the sustainable implications of this use case.



H11: Combined Tool Tagless Baggage use case

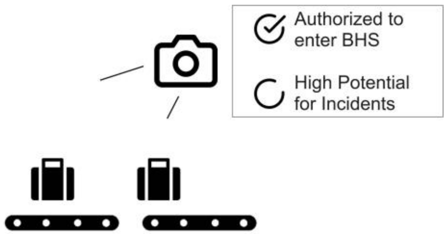
Impact of tagless baggage check-in:

- The check-in process time can be 20-30 seconds shorter due to not printing and attaching barcode labels.
- Printed barcode labels are not needed for this use case. Currently 25 million bags are checked-in at Schiphol yearly. This will not only result in a major C02 reduction (no paper needed, no printers needed, less electricity needed), but also in a major cost reduction per bag.
- Implementation of CVT installation is needed throughout the baggage handling process to identify tagless baggage. But, this installation will make implementation of other use cases also possible.

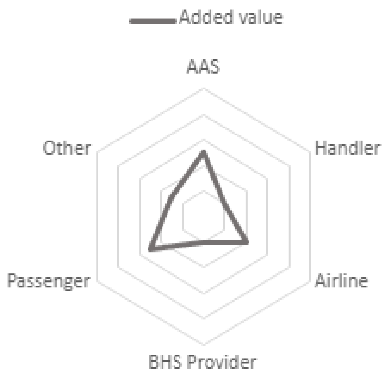
- The outstation needs to have installed CVT to be able to receive and handle tagless baggage, so dependency is identified. Nevertheless, some airports may be able to handle tagless baggage without installing CVT, if reclaim baggage is not handled within their BHS. This acquires further research and agreements need to be made with other airports if tagless flights can be possible.

H5. High Potential Incidents Identification

CVT will identify bags who are classified as high potential for incidents in the BHS. By determining business rules, the CVT system could identify high potential incidents bags during check-in to prevent these bags from entering the system. This use case could also be implemented at the security process step, where high risk bags can be identified. In the future: a self-learning system will identify patterns of similar baggage characteristics that result in system errors, to adjust the business rules.



H12. Schematic Representation High Potential Incidents use case



H13. Radar Chart High Potential Incidents use case

The use case is valuable for all actors, as errors can be prevented due to high potential for incidents baggage will be denied to enter the BHS. This can potentially result in less mishandled bags. It can be seen that the use case is less valuable for handlers, as more bags need to be manually handled by handlers due to this use case. This will lead to more costs and is time consuming.

Current Functionality

Out-of-Gauge Identification, to avoid wrong baggage into the BHS

We create the computer vision technology (CVT) use case ...

What is the name of our use case? How to describe it?
High potential incidents identification: CVT will identify bags who are classified as high potential for incidents in the BHS. By determining business rules, the CVT system could identify high potential incidents bags during check-in to prevent these bags from entering the system. This use case could also be implemented at the security process step, where high risk bags can be identified. In the future: a self-learning system will identify patterns of similar baggage characteristics that result in system errors, to adjust the business rules.

Added value CVT

Automated identification, less manual mistakes and subjective decisions

Has an influence on the occurring challenges

-

Has an influence on the excisting needs

- Less mishandled bags *(less wrong baggage in BHS results in less congestion and mishandled bags)*
- Data driven baggage handling process *(self-learning system will adjust business rules based on historical data)*
- More autonomous processes *(autonomous identification)*
- Being able to handle the increasing amount of baggage *(less manual actions needed, more time to handle baggage)*

Data Sources

What data sources do we need to create value?

- Visual images bag *(New)*
- Business rules *(New)*

Future:

- Error data (on baggage that resulted in errors or congestion) *(New)*

Analytics

What data analytics methods do we need to apply to gain insights and benefits from the data?

- Classification, outlier detection

Based on determined business rules, CVT can scan baggage entering the BHS, to identify if it is allowed to enter or not.

In the future:
- Reinforcement learning, cluster analysis, classification, outlier detection

Based on historical error data, a pattern of similar baggage characteristics can be identified to adjust the business rules. This will be a self-learning system.

Data Product

In what form do we make the service available to our customers and users?

Decision support if baggage are allowed to enter the BHS. This information needs to be visualized on a screen next to the CVT installation.

Ecosystem's Benefit

What added value and what advantages does the use case generate for the ecosystem?
AAS: Less wrong baggage into the system, less mishandled bags, no subjective decisions made by handlers

Handlers: Less handlers needed to perform check, less mishandled bags
Airlines: Less handlers needed to perform check, less mishandled bags
Passengers: Less mishandled bags
BHS Provider: less errors BHS, possibility to offer service at other airports

Other: Less errors to BHS, beneficial for service maintenance providers

Implementation

Does this use case require implementation at other airports?

No, baggage can be checked without a link to their BIT.

What are the most important investments that are required to implement the use case?

Validation arches at infeed quays BHS.

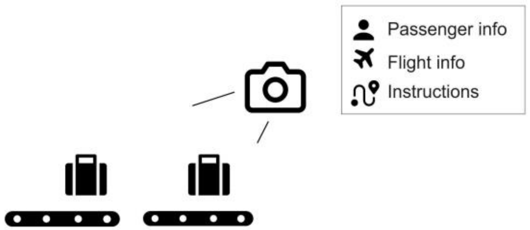
H14: Combined Tool High Potential Incidents use case

The impact of the use case:

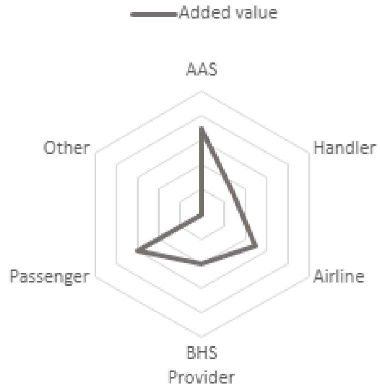
- There are currently three different ways to check the input in the BHS. Odd size is mostly easily manually recognizable (buggies, skies). Out of Gauge baggage is identified via the BHS (based on its dimensions). The last category: ‘non conveyable’, can be identified subjective as opinions differ if this baggage can be inserted in the BHS or not. Handlers prefer to put as much baggage in the BHS as manually sorting is time consuming and costly. By implementing a CVT system at the enter, the subjective process will be deleted as the system will make the decision automatically.
- Further research is needed on the specific impact of this use case.

H6. Baggage Identification via CVT

CVT will identify baggage based on its visual characteristics. An acquisition arch at the start will make visual images and links this with information of the bag, whereas validation arches later in the system will be used to validate and identify the bags along its way.

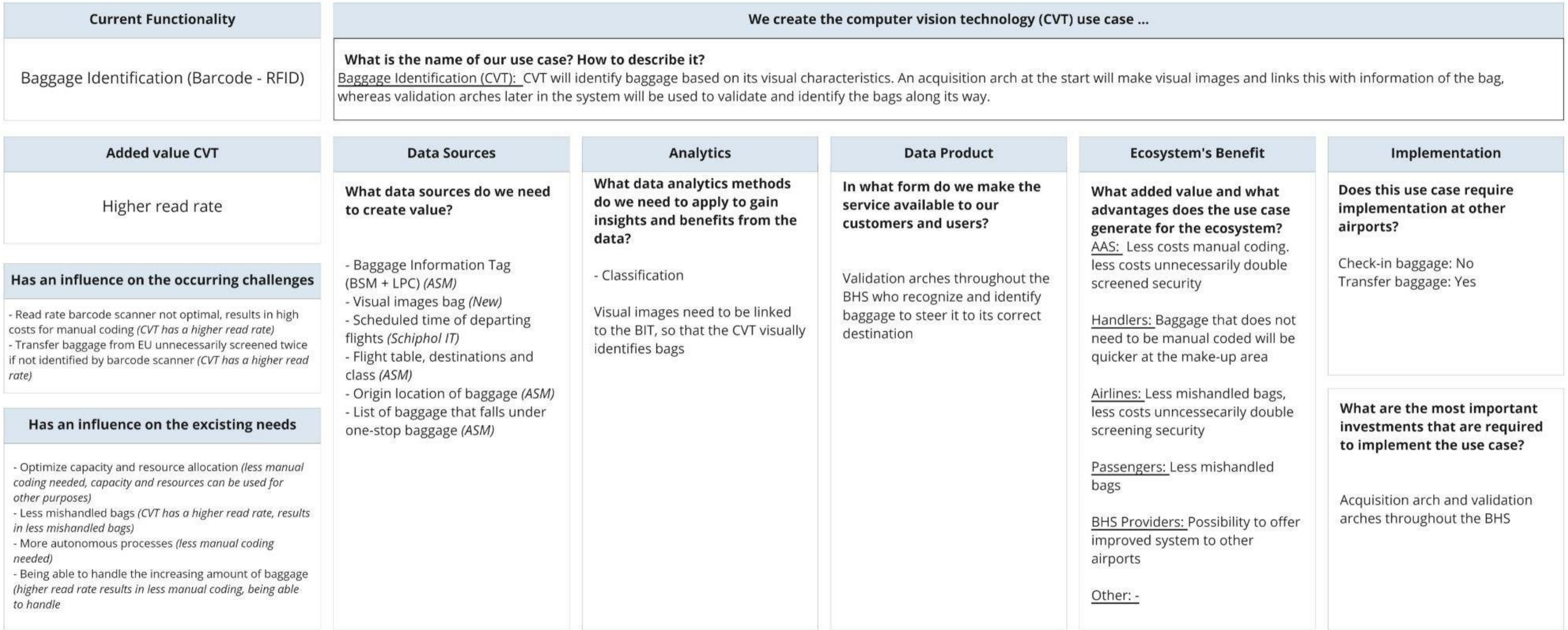


H15. Schematic Representation Baggage Identification use case



H16. Radar Chart Baggage Identification use case

This use case brings the most value to AAS, as manual coding costs will be significantly decreased. In addition, less bags will be mishandled, which is valuable for the passenger and airline. The BHS provider has the possibility to offer a system to other airports with an improved read rate (if it is proven at AAS).



H17. Combined Tool Baggage Identification use case

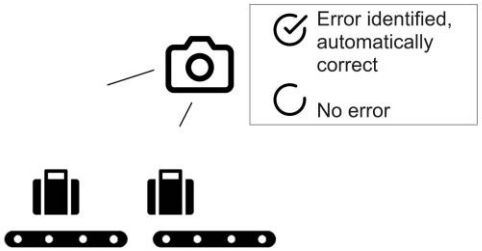
Impact of baggage identification via CVT:

- Based on a pilot at Eindhoven Airport, the read rate of CVT is 99,14%. The current read rate of barcode scanners at Schiphol Airport is 96% for checked-in baggage and 88% for TRF baggage. Baggage is approximately equally divided into CI and TRF baggage which results in a total read rate of 92%. Thus, 8% of all baggage needs to be manual coded, which results in high costs (approximately €1 million per year).
- To be able to identify TRF bags by CVT, the visual images need to be linked to baggage information at the outstation, thus, a dependency is seen. But, if this use case is only implemented for CI baggage, 25% of manual coding costs can be decreased (€250.000/year).

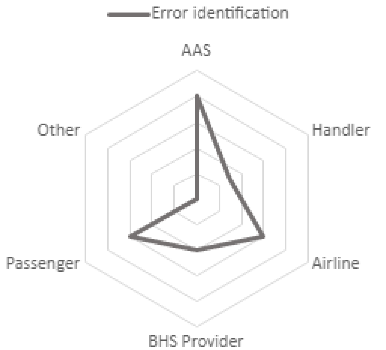
- If only 10% of TRF baggage can be identified via CVT, this would result in a decrease in TRF manual coding costs of €75.000 per year. This is a yearly saving and will increase if more airports implement CVT.
- More costs can be saved by this use case, as currently TRF baggage from the EU is unnecessarily screened twice by security if not identified by a barcode scanner. This results in more manual actions and higher costs. If more TRF baggage is identified by CVT, the capacity and resources of the screening process can be used more efficiently. Future research is needed on the quantification of the impact on this aspect.

H7. Error Identification & Correction

Leveraging cameras that create a "digital fingerprint" of baggage, the system identifies mismatched bags in the BHS and automatically corrects any errors, hence minimizing the need for manual re-checking.

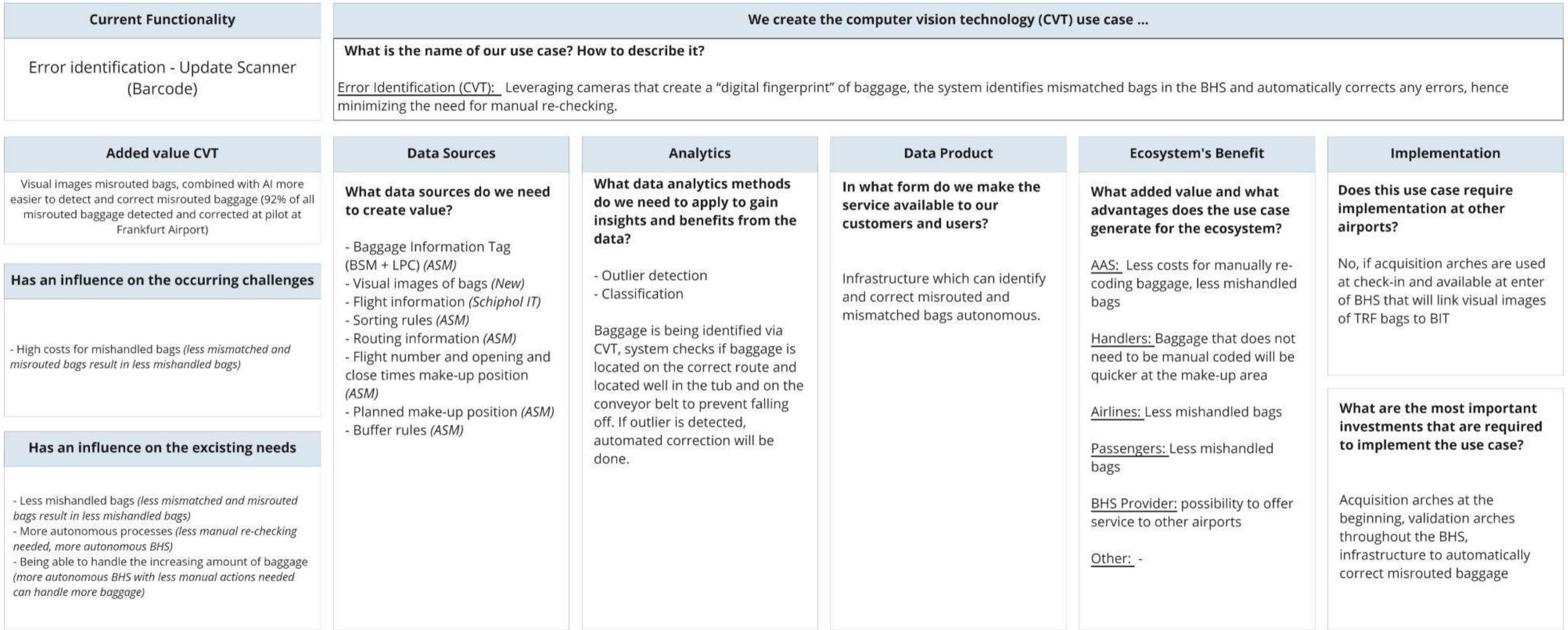


H18. Schematic Representation Error Identification use case



H19. Radar Chart Error Identification use case

The use case brings the most value for AAS, as it can minimize and automatically correct misrouted baggage, which results in less costs for manual coding. It will also potentially result in less mishandled bags, which is valuable for the airline and passenger. BHS providers gain benefits as they can provide this service to other airports if it seems valuable at AAS.

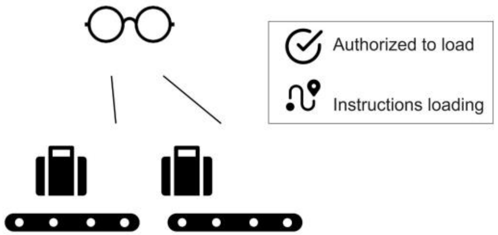


H20. Combined Tool Error Identification Use Case

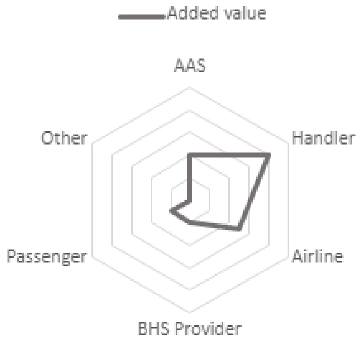
Impact of the use case:

- Misrouted baggage can lead to mishandled baggage and the need for manual coding, which results in high costs.
- A pilot at Frankfurt Airport showed that 92% of all misrouted baggage was detected by CVT and automatically corrected.
- Future research is needed on the number of misrouted baggage in the BHS at Schiphol Airport to quantify the impact of this use case.

H8. Hands free make-up identification
During the make-up and loading process, handlers will wear glasses that are able to identify and scan the baggage. Handlers will get an 'okay to load' status and instruction on which LU to load. When baggage is loaded, proof of loading on the correct LU is stored.

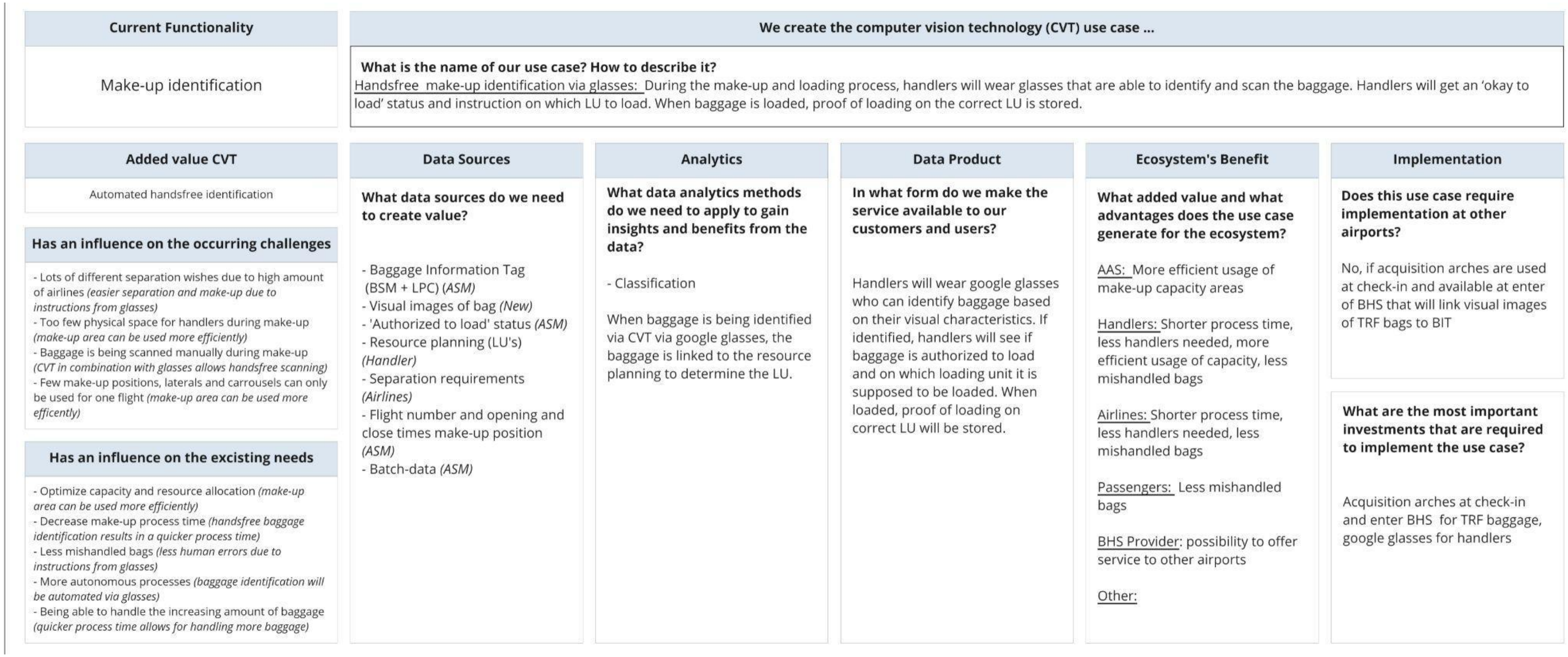


H21. Schematic Representation Handsfree Make-up use case



H2. Radar Chart Handsfree Make-up use case

This use case mostly provides benefits for the handler. Next to that, the use case can be valuable for AAS. Currently, challenges occur regarding the physical space in the make-up area. Innovative solutions are necessary to prevent costly renovations or expansions of these areas.



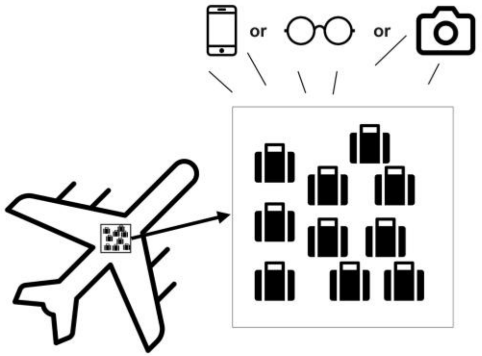
H23. Combined Tool Handsfree Make-up use case

Impact of the use case:

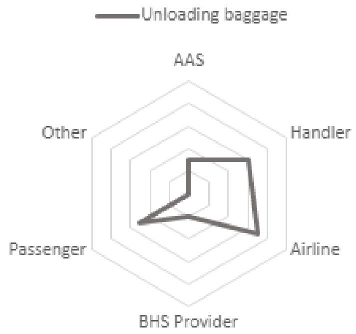
- Laterals can carousels may be used for more than one flight, which increases the efficient use of the current make-up capacity.
- Quicker process time, manual scanning is not needed anymore which can reduce the make-up process time per bag. This results in being able to handle more bags within the same time.
- Automatic proof of loading on the correct LU will be stored. The LU does not need to be manually scanned anymore, which lowers the process time.
- Due to the automatic verification, proof and instructions, mishandled bags during the make-up process may be lowered.
- Future research is needed on the willingness of handlers to wear Google glasses and the implications this will have for their activities.

H9. Optimize unloading

CVT will provide images of baggage that can help to optimize the (un)loading process. When baggage needs to be unloaded due to a missing passenger, images can optimize the identification process. In combination with a Google glasses or smartphone who visually identifies the bag, the baggage can be identified way quicker. Added value of CVT: visual images bag, automatically handsfree verification of bag.

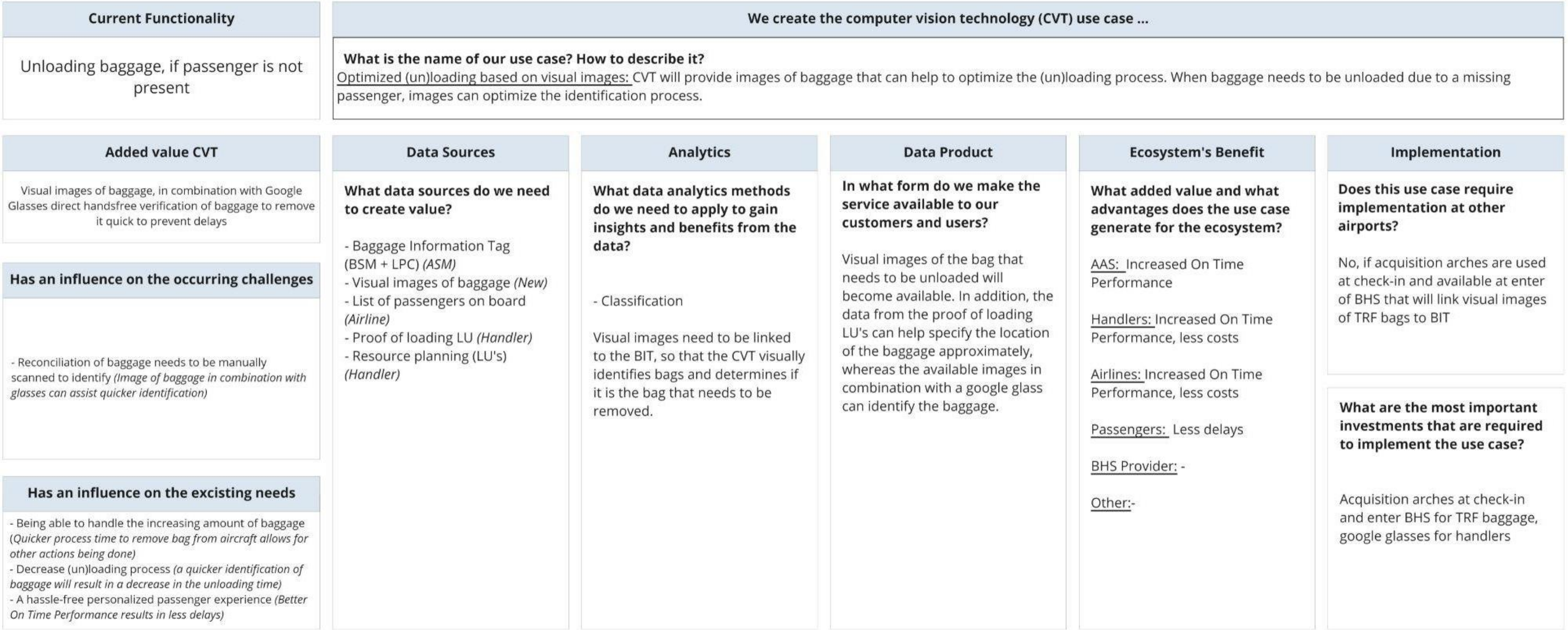


H24. Schematic Representation Optimize unloading use case



H25. Radar Chart Optimizing unloading use case

This use case mostly provides value for the handler and airline, as it will be easier and quicker to identify bags that need to be removed from the aircraft. Delays caused by searching for bags that need to be removed are costly for airlines. This use case could optimize the On-time-Performance of airlines, which is also beneficial for the passenger and AAS.



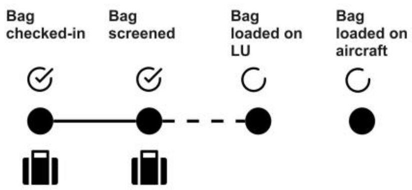
H26. Combined Tool Optimizing unloading

Impact of the use case:

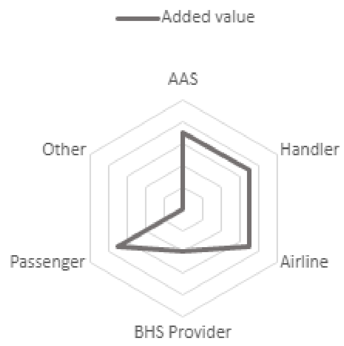
- The unloading process of a bag is currently costly for airlines. The process takes time, which results in delays. Delays are not only disadvantageous for airlines, but also for Schiphol Airport and the passenger.

H10. Track-and-Trace

The tracking points of CVT during the baggage handling process will be shared to handlers, airlines, and passengers so they can track their baggage along its journey. This will ensure a transparent baggage journey and allows the ecosystem to allocate their resources and capacity based on real-time baggage flows.

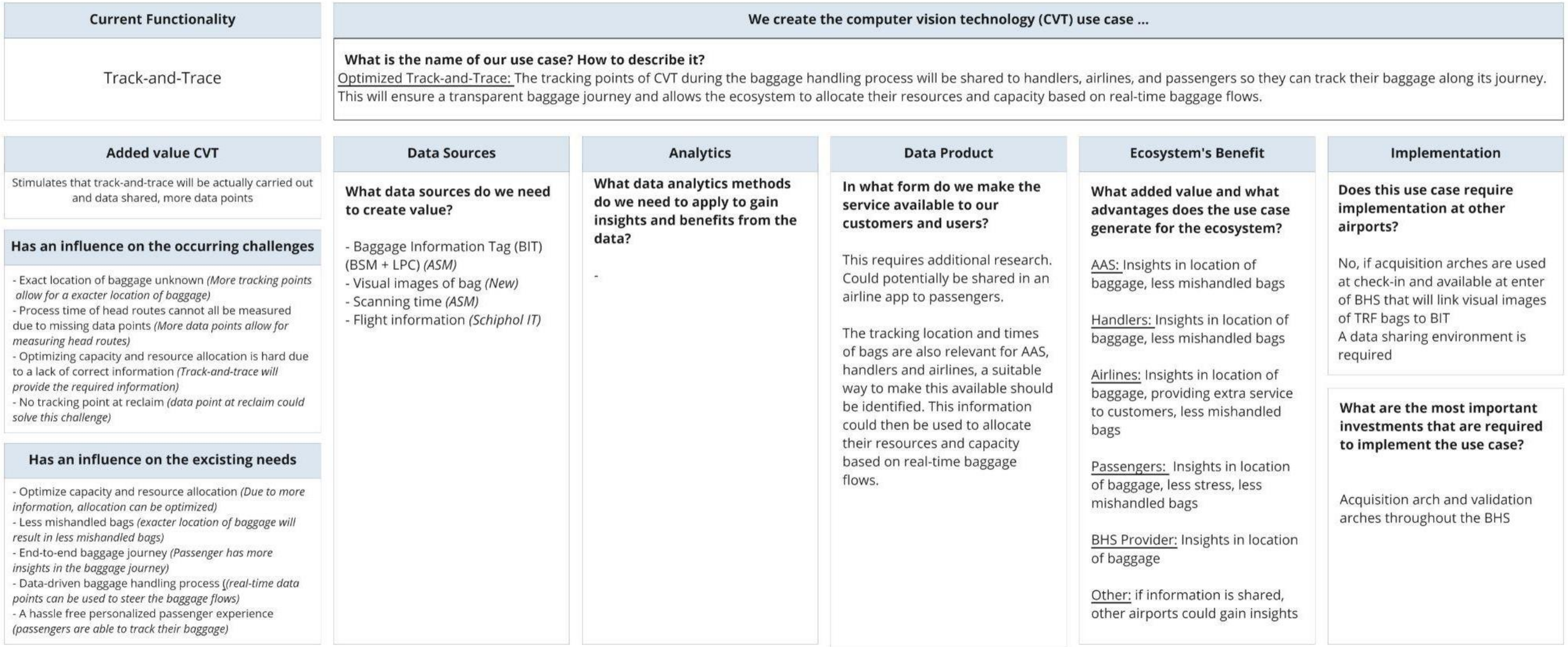


H27. Schematic Representation Track-and-Trace use case



H28. Radar Chart Track-and-Trace use case

This use case is valuable for the whole ecosystem, as it provides insights on the status and location of bags. This can be used for real-time data-driven capacity and resource allocation, which will be elaborately illustrated in the next use case. In addition, it possibly gives passengers less stress if the location of their baggage is known.

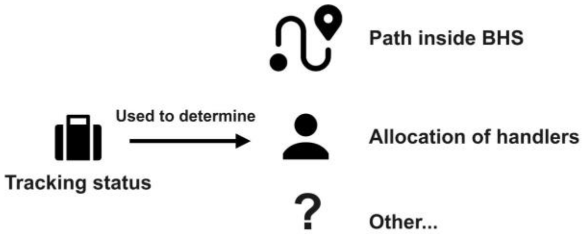


H29. Combined Tool Track-and-Trace use case

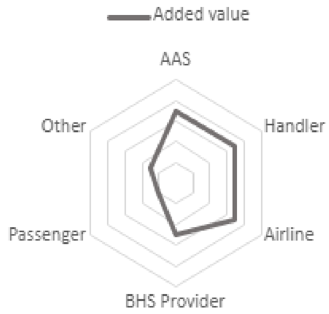
This use case requires further analysis on the points needed to be tracked and shared and the implications of this information sharing. What if a passenger does not receive proof of loading on aircraft, but the aircraft has to leave?

H11. Data-driven resource and capacity allocation

Based on tracking information from the use case 'Track-and-Trace', the resource and capacity can be real-time data-driven allocated as efficiently as possible based on real-time baggage flows.



H30. Schematic Representation Resource and Capacity Allocation use case



H31. Radar Chart Resource and Capacity Allocation use case

This use case brings value to a lot of actors in the ecosystem. It is identified that the current resource and capacity allocation could be improved, as it is not based on real-time flows. If it is known what baggage can be expected, the ecosystem can prepare itself to operate in a most optimal way.

Current Functionality

Resource and capacity allocation, to allocate as efficient as possible

We create the computer vision technology (CVT) use case ...

What is the name of our use case? How to describe it?

Data-driven resource and capacity allocation: Based on tracking information from the use case 'Track-and-Trace', the resource and capacity can be real-time data-driven allocated as efficient as possible based on real-time baggage flows.

Added value CVT

More data points and types will allow for enough information to be able to perform this allocation

Has an influence on the occurring challenges

- No correct and complete info of incoming expected baggage in BHS *(if data sharing is stimulated)*
- Exact location of baggage unknown *(if data sharing is stimulated)*
- Process time of head routes cannot all be measured due to missing data points *(more data points allow for measuring head routes)*
- Optimizing capacity and resource allocation is hard due to a lack of correct information *(more data points allow for allocation)*

Has an influence on the excisting needs

- Optimize capacity and resource allocation *(Due to more information, allocation can be optimized)*
- Less mishandled bags *(data-driven allocation results in more efficient use of BHS capacity, less mishandled bags)*
- End-to-end baggage journey *(based on data-driven allocation)*
- Data-driven baggage handling process *(real-time data points can be used to steer baggage flows)*

Data Sources

What data sources do we need to create value?

- Baggage Information Tag (BSM + LPC) *(ASM)*
- Visual images of bag *(New)*
- Scanning time *(ASM)*
- Flight information *(Schiphol IT)*
- Passenger information *(Schiphol IT)*
- Sorting rules *(ASM)*
- Routing information *(ASM)*
- Buffer rules *(ASM)*
- Flight number and opening and close times of make-up position *(ASM)*
- Information on baggage that will arrive *(Airlines)*

Analytics

What data analytics methods do we need to apply to gain insights and benefits from the data?

-

Data Product

In what form do we make the service available to our customers and users?

This requires additional research.

A suitable way to make the tracking location and times of bags available should be identified. This information could then be used to allocate their resources and capacity based on real-time baggage flows.

Ecosystem's Benefit

What added value and what advantages does the use case generate for the ecosystem?

AAS: More efficient usage of capacity and resources, less mishandled bags

Handlers: More efficient usage of capacity and resources, less mishandled bags

Airlines: More efficient usage of capacity and resources, less mishandled bags

Passengers: Less mishandled bags

BHS Providers: More efficient usage of capacity and resources

Other: -

Implementation

Does this use case require implementation at other airports?

No, but does require data sharing

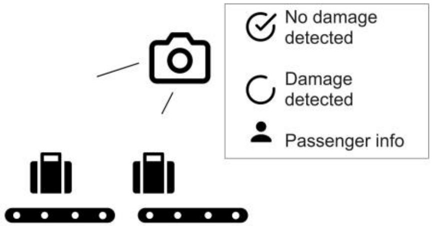
What are the most important investments that are required to implement the use case?

Acquisition arches at check-in and enter BHS for TRF baggage, creating and facilitating a data-sharing environment, systems and analyses that can allocate on real-time flows

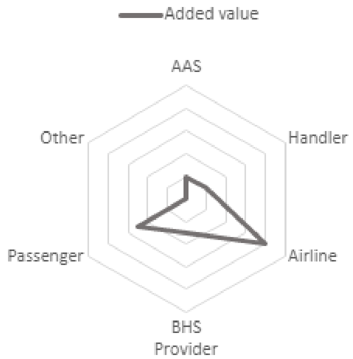
H32. Combined Tool Resource and Capacity Allocation

H12. Improved claim verification

CVT will provide images of baggage to identify where damage happened or if it is stolen/lost during the baggage handling journey. In addition, a bag who lost its barcode label can be scanned via cameras to identify its information.



H33. Schematic Representation Improved Claim Verification use case



H34. Radar Chart Improved Claim Verification use case

The value of this use case lies mainly in the airlines and passengers. Airlines are currently mostly responsible for the costs of claims of damaged or lost bags, so they will benefit the most from this use case. The use case could be less valuable for AAS and handlers, as it can be provided that they are liable for the damage in which they may need to pay more costs for damaged bags. However, this does increase the transparency and knowledge on the baggage handling process, which reduces strategic behavior and information asymmetry.

Current Functionality

Claim Verification (World Tracer)

We create the computer vision technology (CVT) use case ...

What is the name of our use case? How to describe it?
Improved Claim verification : CVT will provide images of baggage to identify where damage happened or if it is stolen/lost during the baggage handling journey.

Added value CVT

Visual images of bags during journey, proof of liability, less fraud claims

Has an influence on the occurring challenges

- Not clear where in the process baggage is damaged *(CVT will provide images with proof of damage happened)*

Has an influence on the excisting needs

- Less mishandled bags *(false claims of passengers who claim that their bag is lost, can be prevented due to link to visual characteristics if label is lost)*
- End-to-end baggage journey *(insights in damage during whole journey)*
- A hassle free personalized passenger experience *(Insights in damage during whole journey)*

Data Sources

What data sources do we need to create value?

- Baggage Information Tag (BSM + LPC) *(ASM)*
- Visual images of bag *(New)*

Analytics

What data analytics methods do we need to apply to gain insights and benefits from the data?

- Outlier detection

System needs to identify where bags are damaged during the process.

Data Product

In what form do we make the service available to our customers and users?

Decision support on liability of claims made by passengers. A system should be able to detect changes in the visual characteristics and automatically shows the process in which damage happened.

Ecosystem's Benefit

What added value and what advantages does the use case generate for the ecosystem?

AAS: More insights in processes where bags were damaged

Handlers: More insights in processes where bags were damaged

Airlines: More insights in processes where bags were damaged

Passengers: More insights in processes where bags were damaged

BHS Provider: Possibility to offer service at other airports

Other:

Implementation

Does this use case require implementation at other airports?

No, if acquisition arches are used at check-in and available at enter of BHS that will link visual images of TRF bags to BIT

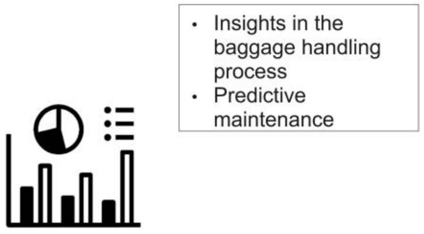
What are the most important investments that are required to implement the use case?

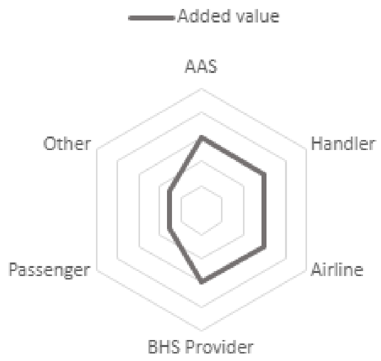
Acquisition arches and validation arches throughout the BHS. System and analysis that is able to detect damages during the way and automatically reports the timeframe of damage.

H35. Combined Tool Improved Claim Verification

H13. New data analysis

Due to more data points, data can be analyzed more to provide insights in the baggage handling process. Think of root-cause analysis of delays or predictive maintenance.





H36. Schematic Representation New Data Analysis use case   H37. Radar Chart New Data Analysis use case

Based on the discussions with stakeholders, performing new data analyses can bring value to all involved actors. It even provides value for other actors, as third party could benefit of data generated in the ecosystem (and shared with consent.

Current Functionality

Data Analysis, to gain insights in the baggage handling process

We create the computer vision technology (CVT) use case ...

What is the name of our use case? How to describe it?
New Data Analysis: Due to more data points, data can be analysed more to provide insights in the baggage handling process. Think of root-cause analysis of delays or predictive maintenance.

Added value CVT

Visual images of bags during journey, more data points and data types

Has an influence on the occurring challenges

- Optimizing capacity and resource allocation is hard due to a lack of correct information *(Insights from data analysis can be used to optimize allocation)*
- No correct and complete info of incoming expected baggage in the BHS *(Insights from data analysis can provide information on expected baggage)*

Has an influence on the excisting needs

- Optimize routes in the BHS *(Insights from data analysis can be used to optimize routes)*
- Optimize capacity and resource allocation *(Insights from data analysis can be used to optimize allocation)*
- Data-driven baggage handling process *(Insights from data analysis can be used to steer baggage flows)*
- Being able to handle the increasing amount of baggage *(A more efficient usage of capacity and resource will allow for more baggage that can be handled)*

Data Sources

What data sources do we need to create value?

- Baggage Information Tag (BSM + LPC) *(ASM)*
- Visual images of bag *(New)*
- Scanning time *(ASM)*
- Location of baggage *(ASM)*
- Exit time *(ASM)*
- Information on baggage that will arrive (*Airline)*

Analytics

What data analytics methods do we need to apply to gain insights and benefits from the data?

Needs additional research

Some ideas:
- Outlier detection
- Cluster analysis
- Association analysis

Data Product

In what form do we make the service available to our customers and users?

Needs additional research

Some ideas:
- Automated report
- Decision support
- Notifications
- Dashboard
- Key Performance Indicators (KPI's)

Ecosystem's Benefit

What added value and what advantages does the use case generate for the ecosystem?

AAS: More insights in the baggage handling process

Handlers: More insights in the baggage handling process

Airlines: More insights in the baggage handling process

Passengers: Improved process

BHS Provider: More insights in the baggage handling process, developing additional services to handlers/airlines

Other: More insights in the process

Implementation

Does this use case require implementation at other airports?

No, but requires data sharing for some analyses

What are the most important investments that are required to implement the use case?

Acquisition arches and validation arches throughout the BHS.

Data sharing environment

H38. Combined Tool New Data Analysi

I. Feasibility Analysis Use Cases

This appendix provides additional information on the feasibility analysis of the use cases. The results of the analysis can be divided into four dimensions:

- **Dependency on other airports**: some use cases have lower feasibility since they require implementation of CVT at other airports. For example, the separation use cases of TRF baggage can only be implemented if the visual images of the baggage are already linked to the BIT at the outstation. Otherwise, the CVT at AAS cannot identify bags at the apron. This challenge is linked to the category 'Ecosystem Dependency', as the feasibility of CVT is dependent on implementation at other airports. Some use cases do not require this implementation, as acquisition arches can be installed linked to barcode scanners in the BHS to link the visual images of the baggage to the BIT. In this way, all baggage that enters the BHS can be identified by CVT further in the process.

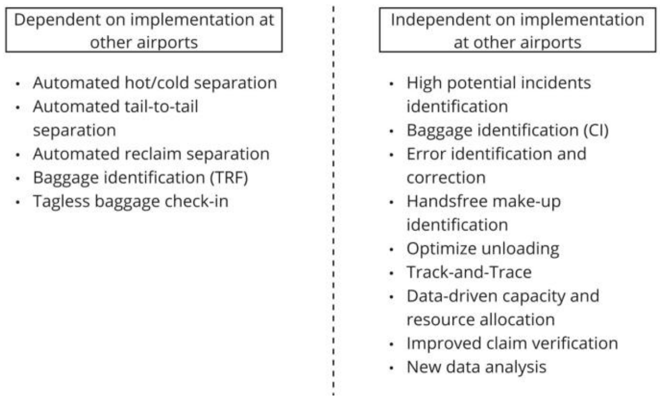


Figure I1: Dependency on implementation at other airports per use case

- **Data sharing needed:** some of the use cases require certain types of data that need to be shared by other actors in the ecosystem. For example, the use case 'Data-driven resource and capacity allocation' seems very valuable, but data sharing is required. CVT could generate more types of (real-time) data. However, optimal benefits of CVT will only be reached if this data is shared between the ecosystem. It is already known what kinds of data is required and therefore this challenge is not linked to the category 'Data Awareness', but to 'Ecosystem Dependency' as the feasibility changes if a data-sharing environment is created within the ecosystem.

- **Availability of required technologies:** two use cases are identified as having low feasibility because the required technology is not yet available. Based on a conversation with a vice president of a CVT service supplier, the technology required for the use cases 'Improved Claim Verification' and 'High Potential Incidents Identification' is not yet developed and ready to be implemented. With the currently available technology, images of the damage that happened during the journey are available but need to be scanned manually to detect in which process this damage happened. This is labor-intensive. Software to do this process automatically will be available in the future. The technology is available to identify high potential incident bags based on determined business rules beforehand. The system is not yet able to recognize business rules by itself to automatically improve the system. This challenge is related to the category 'Ecosystem Dependency', as a certain dependency exists on technology providers to be able to implement some use cases.

- **Ecosystems' support:** CVT requires an investment in infrastructure, as specific cameras and systems are needed to identify baggage. The ecosystem needs to be supportive in order to be able to realize these investments. The biggest reluctance towards CVT was identified within RSG itself, at the operations and ASM department. However, not only RSG needs to be supportive but also the BHS provider, airlines and handlers to achieve agreements on the investments. This challenge is related to the category of 'Established Situation'. The investments that are needed differ per use case. The use case 'Error identification and correction' requires a significant adjustment to the current infrastructure to provide autonomous corrections. The feasibility of this use case is therefore relatively low. This challenge can be linked to the category 'Established situation'. Some of the use cases would be easier to implement in a new airport, which does not consist of legacy systems. A short overview of the investments needed per use case can be seen below *(see figure 6.9).* Appendix H provides additional information on these required investments. The analysis on the required investments showed that with the same investments or some small additions of investments, multiple use cases can be implemented. Thus, the CVT infrastructure will provide the added value of more use cases. This results in the fact that the added value of one use case is less relevant, but the added value of CVT in general needs to be considered more.

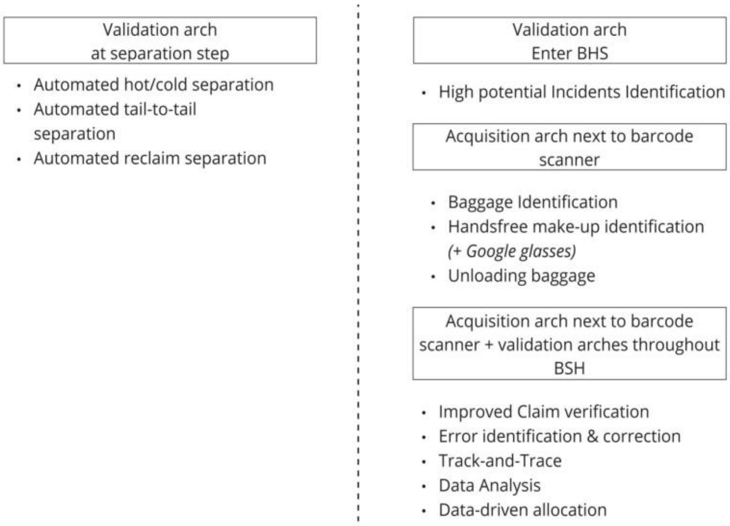


Figure I2: Investments needed per use case

Acquisition Arch

An acquisition arch consists of five cameras and can be used to make the first scan of bags in order to link them with the passenger and flight information. Therefore, acquisition arches can be used during check-in. In addition, acquisition arches can be added next to the barcode scanner in the BHS, since it is able to link he information on the barcode label to the visual images of the baggage, which allows visual recognition further across the process.

Validation Arch
A validation arch consists only of two cameras and is able to identify bags that have been scanned and linked to the information at an acquisition arch before. Validation arches can be used in various ways. First, at the apron in order to identify bags coming from an aircraft, as a way to support the separation use cases. Second, within the baggage handling process in order to track baggage and identify the bags' location.

Google Glasses
Google Glasses can be used within the 'Handsfree make-up Identification' and 'Optimize Loading' use case as the glasses can automatically identify bags based on their characteristics. Future research is needed on the specific requirements for glasses, handlers' preferences and more applications of the glasses. For example, Customs could use glasses as well to quickly identify if a bag comes from the EU or not.

J. Recommendations Royal Schiphol Group

This appendix provides recommendations to Royal Schiphol Group based on the research outcomes.

The baggage handling ecosystem is elaborately investigated in this research, which resulted in the identification of the current challenges and needs of the ecosystem. Challenges are identified, such as the need for manual coding of bags due to a low barcode scanner read rate, the need for handlers to manual scan bags to identify them during loading processes, a vast amount of mishandled bags, the unclarity of the exact location of bags in the process and a lack of information sharing between actors in the ecosystem. In addition, needs exist like the desire to increase the number of autonomous processes, to have a data-driven baggage handling system, to improve the individual process steps and to achieve sustainable goals, such as implementing the principles of a circular economy. Innovation is needed to influence these challenges and needs. Innovations can be seen in other processes and aspects of the ecosystem, but are not seen in the way bags are being identified. Barcode labels as a way to identify bags have been in place since the early 1960s and '70, and have not changed significantly since then. This can be a result of the complex characteristics of the baggage handling process, as it faces a multi-actor environment which makes the entire coordination and management process complex. However, based on the research outcomes, it can also be caused by a lack of holistic perspective on the process, which is identified in two ways:

- Between departments of RSG: a lack of insights into the work and ability of other departments was identified during the organized workshops. Issues that arise may be solvable by other departments, in which multi-disciplinary communication and meetings are key.
- Between actors in the ecosystem: a lack of data-sharing and insights into the work of other actors in the ecosystem was identified during the field research. The baggage handling process is highly siloed, which holds back a transparent process.

This research has investigated the potential for Computer Vision Technology (CVT) for the baggage handling ecosystem at Schiphol Airport. It was unknown for whom in the ecosystem this technology would provide value and what its added value is compared to the current situation. Based on the research results, CVT is identified as valuable for the baggage handling ecosystem of Schiphol Airport and it is, therefore, recommended to further investigate the possibilities and potential of CVT. The research outcomes present thirteen CVT use cases that can be implemented in the input, throughput and output steps of the baggage handling process, which conclude that the implementation of CVT will provide more benefits than only increasing the read rate of the identification of bags in the process. The total set of use cases provides value for AAS, as well for airlines, handlers, passengers and the environment. However, most of the use cases can also be executed with other baggage identification technologies, such as the currently used printed barcode labels or RFID technologies. Thus, the added value of CVT in the use cases is analyzed compared to other technologies. A first attempt to quantify the value of CVT has been performed, in which several assumptions have been made. The results on the added value can be divided into four dimensions:

More autonomous processes

Autonomous operations at AAS can contribute to accommodate the increasing amount of passengers and baggage, to ensure a safe working environment and to be a frontrunner of innovation. CVT will lead to more autonomous processes, since it minimizes the need for manual coding, manual scanning and manual separation of baggage. For example, the potential of hot/cold separation of TRF baggage seems big, as it could result in an innovative increase of the BHS capacity by 22% *(with the assumption that all TRF baggage that has a high potential to separate is separated).* Nevertheless, separation is currently not executed since this is labor intensive. CVT could automate the separation step, in which this process could be more easily executable.

Process improvement

The added value of CVT can be seen in quicker process times (check-in, make-up, (un)loading, separating) or a higher read rate which results in less mishandled bags. This can lead to cost savings and a more efficient use of resources and capacity. For example, the check-in process time can be shortened with 20-30 seconds if printed barcode labels are eliminated. This will not only result in less queues in the terminal for AAS, but also in annual savings of €250.000 euros by airlines *(with the assumption of 25 million checked-in bags annually, costs of €0,01 per label).* Furthermore, less manual coding is required due to the relatively high read rate of CVT *(based on a pilot at Eindhoven Airport).* This could result in a saving of almost 1 million euros per year for RSG *(with the assumption that TRF baggage can be identified via CVT, if only checked-in baggage at AAS can be identified via CVT, it would still result in an annual saving of almost €250.000).*

More data

The implementation of CVT will generate more (types of) data. This can be used to ensure a data-driven end-to-end baggage handling process, to optimize resource and capacity allocation based on real-time baggage flows and to create new insights into processes. This can also be achieved with RFID technologies, however, CVT will also provide insights in the visual characteristics of baggage. In addition, the assumption has been made that CVT infrastructure could ensure more data-points, in which an end-to-end process will be more easily provided. Currently, photocells are used to track baggage inside of the BHS. Once baggage is not tracked at the expected photocell, it is identified as an UFO. CVT installation throughout the BHS could easily track and identify misrouted baggage in order to automatically correct them. This has resulted in an automated detection and correction of 92% of all misrouted baggage at a pilot at Frankfurt airport. Furthermore, the real-time information about the location of baggage can be used to steer baggage flows on real-time flows, which could ensure a more efficient usage of the capacity and resources, which is required given the capacity shortages at AAS.

Sustainable

Royal Schiphol Group has the ambition to exploit the most sustainable airports by 2050 and to implement the principles of a circular economy. Printed barcode labels are currently not re-used, which is contradictory to this strategy. RFID technologies also require physical attributes including small chips. The implementation of the tagless baggage check-in use case contributes to achieving the sustainable goals of RSG as 25 million baggage labels do not need to be printed anymore on an annual basis *(with the assumption of 25 million bags checked-in annually).*

The dimensions of the added value of CVT sounds promising for the baggage handling ecosystem of Schiphol Airport. Nevertheless, an analysis of the feasibility of implementing the CVT has shown relevant insights:

Dependency on implementation at other airports

Some use cases face lower feasibility, since they require implementation of CVT at other airports. This dependency is seen at the use cases related to the identification and separation of incoming baggage, and the tagless baggage use case where the outstation needs to be able to identify bags without tags. It is therefore of high importance to investigate the willingness of other airports to implement CVT. This research analyzed the transferability of the results towards other hub airports. The results on which use cases can be implemented and their added value to the ecosystem are influenced by the characteristics of AAS. Characteristics of hub airports that influence the added value and feasibility of CVT are the identified challenges, the available physical space to expand, the currently implemented identification technologies, the institutional field, the baggage handling process and the size of hub airports. If these are similar to AAS, the results are likely to be transferable towards other hub airports. However, it is improbable that a high share of airports will implement CVT in the short term. Nevertheless, significant impact *(an innovative increase of the BHS capacity of 5,22%)* of for example the 'hot/cold separation' use case can also be reached if only a share of the total airports will implement CVT *(with the assumption that 15 identified airports* have implemented CVT and all baggage that has a high potential to be separated is separated).* Furthermore, eight use cases provide value independently of implementation at other airports. Therefore, implementation only at Schiphol Airport will also result in value for the baggage handling process. Further research is needed if this value outweighs the investments needed.

**identified airports: MXP, SVO, FCO, BCN, WAW, ATH, TXL, TLV, VCE, BUD, LIS, MAN, CPH, HAM, DUS.*

Data-sharing environment is lacking

Some of the use cases require certain types of data that need to be shared by other actors in the ecosystem. Thus, optimal impact of certain use cases will only be reached if data is real-time shared between airlines, handlers and airports. However, a lack of data awareness inside the ecosystem was observed during the research. No central database exists and it is unknown by the D&nA department what data is available and if it can be real-time accessed. It is important to investigate what is needed to establish a real-time data sharing environment in the baggage handling process. During the organized workshops, a lot of issues like decentralized data sources which results in problems with data sources integration, no single data owner, and a high complexity that is currently faced were mentioned. However, a data scientist present indicated that his team could manage the complexity of the data aspects. It is, therefore, recommended to organize multi-disciplinary meetings in the future to overcome challenges that seem impossible to solve, but doable by other departments. In addition, the results of the workshops resulted in the identification of a lack of shared urgency of the ecosystem to share more data with each other, which needs to be created in order to generate optimal value out of CVT.

Availability of required technologies

Some use cases are identified as having low feasibility due to the fact that required technologies are not yet available. Some technologies or systems need to be developed first before implementation of the use case is possible. However, this only applies to two use cases (Improved claim verification and High potential Incidents identification).

Ecosystems' support
CVT requires an investment in infrastructure, as specific cameras and systems are needed to identify baggage. The investments that are needed differ per use case. The analysis on the required investments showed that with the same investments or some small additions of investments, multiple use cases can be implemented. Therefore, the CVT infrastructure will provide added value for more use cases. This results in the fact that the added value of one use case is less relevant, but the added value of CVT in general needs to be considered more when determining the potential of CVT for the baggage handling ecosystem. However, in order to achieve agreements on the investments needed, ecosystems' support is required to establish.

Recommended next steps
Based on the results of this research, a roadmap is recommended on the future steps needed in the investigation of the potential of CVT for the baggage handling ecosystem of Schiphol Airport.

1. **Test hypotheses Hot/Cold Separation**
   The pilot of the hot/cold separation use case will be performed first. Thus, the hypotheses set by the Innovation Hub on the potential of hot/cold separation by CVT need to be tested during the pilot. As the infrastructure needed for the hot/cold separation can also be used for the other separation use cases, these can be prepped during this step. The TTT separation use case requires further research on its impact, as this is currently not quantified yet. The TRF/reclaim/remote-reclaim use case requires further research to identify passengers' demand, airlines' willingness to provide this service and on the operational implications of the use case.
2. **Quantify the Use Cases**
   The recommendations are based on qualitative research in combination with a first attempt to quantify the value of CVT, based on assumptions. Financial research is recommended to quantify the expected value of CVT compared to the investments needed.
3. **Additional Research**
   Additional research is recommended in two ways. First, the implications of the achievement of a real-time data-sharing environment need to be investigated. It must be known how such an environment can be achieved, what data aspects are desired and how this shared data can be secured. Second, the willingness of other airports to implement CVT can be explored, to indicate on the potential on worldwide adoption of CVT.
4. **Create Ecosystems' Support**
   Once the results of the financial research are available and the outcome is positive, the next step is to create ecosystems' support for investment and implementation of CVT.
   - A sense of urgency needs to be created that innovations are necessary to solve the capacity problems, to minimize the amount of mishandled bags and manual coding costs, to achieve the sustainable goals, and to achieve a real-time data-driven environment.
   - Multi-disciplinary meetings could contribute to the discussion of CVT within the ecosystem and to overcome challenges or issues identified by one actor/department.

- Emphasize a holistic perspective on the baggage handling process and the importance of collaboration to achieve innovation.

5. **Create the Business Model**

In order to achieve agreements on the investments, the business model needs to be created. This research provided insights into the relative value of the use cases for the individual actors in the ecosystem. The filled in Combined Tools could be used, as this already describes the technical implications of the use cases, the added value compared to the current situation, the implications for current challenges and needs and the investments needed. In combination with the quantification of the results, this could form the basis for the business model.

6. **Implement the use cases**

Once agreements have been made on the business model of implementing CVT, more use cases can be implemented. A next step after the separation use cases would be to install validation arches at the enter of the BHS to accommodate the use case 'High potential incidents identification'. This use case is not dependent on implementation at other airports and does not require a major investment. Thereafter, acquisition arches could be installed at check-in and next to the barcode identification scanners. In this way, three new use cases will be supported: hands free make-up, optimize unloading, and baggage identification. The last investment step refers to the installment of validation arches throughout the BHS. This would lead to possibilities for the following use cases: improved claim verification, error identification & correction, data analysis and data-driven allocation. Further research is needed in collaboration with airlines on the use case 'Track-and-Trace'. If CVT is installed during the make-up and loading process, a proof of loading could be shared with passengers. However, it needs to be further investigated if implementing CVT installation would support 'track-and-trace' or if a certain data-sharing environment is needed.

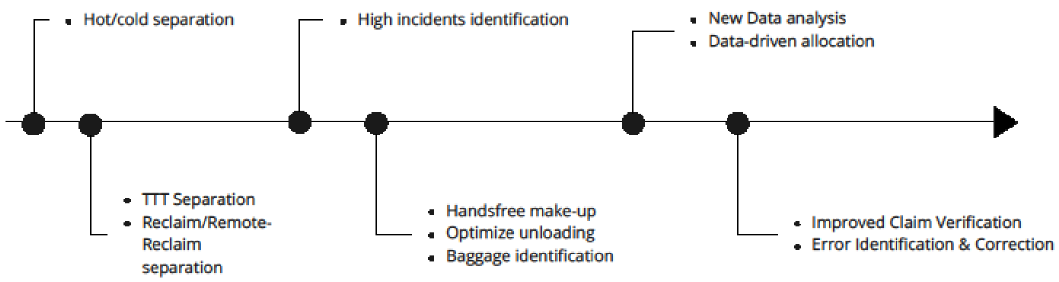


Figure J1: Recommended planning implementation use cases

To conclude, based on the research outcomes, CVT seems valuable for the baggage handling ecosystem of Schiphol Airport. If CVT will be first implemented as an addition to current identification technologies, issues regarding the need for scalability and no back-up will be solved. During the next steps, the future and strategy of the ecosystem must be emphasized, as implementing CVT could contribute to achieving the strategy and long-term vision of Royal Schiphol Group. The current baggage identification technologies, barcode labels, have not changed for a long time. CVT could be a relatively cheap (compared to infrastructure needed for RFID) technology to enable the achievement of a real-time data-sharing environment, more autonomous processes and the sustainable goals of the ecosystem.

K. Transferability of the research results

K1. Characteristics Hub airports

Characteristics of the situated setting which may have influenced the research results and may differ across the aviation industry will be discussed to analyze under which characteristics the results hold.

Challenges of hub airports

The research on the potential of CVT was a result of the baggage handling capacity shortage at Schiphol Airport and the expected increasing passenger numbers in the future. This is not only seen at Schiphol Airport, as the whole aviation industry is expected to grow in the coming years (IATA, 2018). This will lead to an increase in passenger volume and bags that need to be handled by baggage handling ecosystems worldwide. The growing passenger numbers set airports under extreme pressure to expand their capacity (Lyngsoe Systems, 2019). Not only at Schiphol Airport *(see section 3.1)*, but also at other major airports, substantial growth in delays and queues can be seen if the demand exceeds about 80% of the available capacity of the system (Herrera García, 2017). The growth will also make it harder for airports to manage and keep track of all baggage, which can lead to more mishandled bags (Joshi, 2018). Mishandled bags has been one of the major challenges for aviation authorities over the years (Mordor Intelligence, 2021). The lack of sufficient airport capacity is, therefore, already seen as a challenge at major airports in the world (Herrera García, 2017). However, airports that do not face a lack of sufficient airport capacity or do not have a high number of mishandled bags may receive less value in some CVT use cases. For example, the main purpose of the hot/cold separation use case is to make more efficient usage of the baggage handling capacity. If there are no capacity problems, the use case will be less valuable for the ecosystem of that hub airport.

Available physical space hub airports

The solution to accommodating a baggage handling shortage is twofold. First, the physical baggage handling area can be expanded to increase the capacity. Nevertheless, at Schiphol Airport physical space is limited which stagnates the expansion of the baggage handling capacity. This limited physical space can also be seen at other airports. In nearly every US airport, the physical space is already insufficient to accommodate current needs, let alone future additional needs (Birenbaum, 2021). Most airports are surrounded by residential and commercial development, which holds back expansion opportunities. Even in cases where physical space is available, it is often impossible to expand due to the given environmental impact regulations and community resistance (Birenbaum, 2021). However, some hub airports do still have the possibility to expand their physical capacity (Beresnevicius, 2020), in which the option to physically expand the baggage handling capacity might be more beneficial than implementing innovative solutions such as CVT.

Currently implemented identification technologies

Hub airports that do face limited physical space to increase their capacity need to think of other solutions, which can be to use the currently available capacity more efficiently. This desire is seen at Schiphol Airport, which states that a 10% of capacity increase needs to come as a result of innovative solutions *(see section 3.1).* However, the implementation of such innovative solutions is not yet realized at Schiphol Airport. This is not different from hub airports in general, as the way that baggage is being handled at airports has not substantially improved in decades and it relies on the same basic legacy systems that have been in place since the 1960s and 1970s (Marcellin, 2019). This is mostly due to dependency on other airports, airlines, customs, baggage handlers and passengers, which makes the coordination and management process complex (Dou, 2016). In addition, the value of these innovative solutions is often not clear yet. Without the specification of the added value, agreements on investments for new technologies will be hard to achieve. This can also be seen in the stagnating adoption of RFID baggage tracking technologies in the aviation industry (Koldkjær, 2017). Nevertheless, some airports have implemented RFID technologies inside their baggage handling processes, namely Hong Kong Airport (Swedberg, 2018). Implementing CVT would, therefore, be less valuable for that hub airport. The added value of CVT will be less at Hong Kong Airport as certain benefits of CVT are already provided by RFID. Thus, the implementation of the current baggage identification technologies influences the added value of CVT for a hub airport.

Institutional field Hub airports

While hub airports worldwide have a number of similarities, there are also significant institutional differences. The relevant institutional field at Schiphol Airport is illustrated in section 3.1. Hub Airports outside of the EU face different laws. For example, bags coming from the EU do not need to be checked by customs at Schiphol Airport and are not needed to be screened again by security. This differs outside of the EU, where baggage resulting from the EU needs to be scanned and screened by customs. Thus, the value of the 'Baggage Identification' use case where the value is that fewer bags will be screened unnecessarily twice, will not be seen at hub airports outside of the EU. Furthermore, the competition rules of the EU have resulted in the fact that there are many handler parties active at Schiphol Airport. Outside of the EU, other competition rules exist which may allow the exclusion of new handler parties. This would result in other stakeholder fields, in which it may be different to implement CVT.

Baggage handling process Hub airports

The use cases identified in this research have been identified and selected based on their fit in the baggage handling process steps at Schiphol Airport. Most process steps will be seen in other hub airports, like check-in, identification, screening, make-up and loading. However, these processes can be executed in different ways. In addition, the buffering process step may not be present or performed differently at other hub airports. The use case 'Optimize Buffer' has been removed from the use case list in this research, as it is not implementable at Schiphol Airport. However, this may be implementable at other hub airports, which would result in another value of CVT. Furthermore, baggage can only be separated via CVT if they are not transported inside of containers within aircrafts. Airports that have contracts with airlines that have aircrafts that require container transportation, may not be able to separate bags at the apron. This would result in the fact that the three separation use cases cannot be implemented, which leads to a lower added value of CVT. The baggage handling process, therefore, influences the added value of CVT at hub airports.

Size of Hub airports

The value of some of the use cases has been determined based on the size of Schiphol Airport, such as the amount of bags handled annually. If more bags are checked-in, the added value of removing printed barcode labels will be higher compared to a hub airport where fewer bags are checked-in. Schiphol Airport is the second-largest hub airport in the world in which 50% of the handled bags are TRF baggage (Schiphol Airport, n.d.). Other hub airports with a different distribution of checked-in and TRF baggage may face a different added value of CVT. Therefore, the value of hub airports and the distribution of flights influences the added value of CVT for a hub airport. Appendix ? shows a concise comparison of the applicability of the research results for three hub airports.

J2. Comparing hub airports

Based on the characteristics that will influence the research results at other hub airports as described above, three hub airports will be shortly compared in this section. It will cover an analysis of the applicability of the research results on different hub airports.

Lisbon Airport is a relatively small hub airport in Europe, which served approximately 30 million passengers in 2019 (Lisbon Airport, n.d.). It faces extreme capacity problems, where plans for a second airport in Lisbon are rejected based on environmental concerns (Demony, 2021). Thus, a need exists to implement innovative solutions to make more efficient use of the current capacity. However, Lisbon has implemented RFID technologies for their transfer flights in 2008, which resulted in near-perfect results of the baggage handling process (Airport Business, 2011). With the characteristics of capacity problems and no option to expand physically, Lisbon Airport seems like a suitable airport for the implementation of CVT. However, the fact that RFID is already installed lowered the added value of CVT significantly, in which it would be less suitable.

The hub airport of Barcelona served approximately 50 million passengers in 2019 (Barcelona Airport, n.d.). The ambition of the airport is to use this airport more as a connection point to make it a bigger international hub (Shields & Doherty, 2021). However, there are many opponents in physically expanding the airport. Therefore, innovative solutions such as using the current capacity more efficiently with hot/cold separation could be very valuable for this hub airport. In addition, the airport faces a high amount of mishandled bags and has no RFID technologies installed yet. The characteristics of this hub airport, therefore, are similar to Schiphol Airport which makes the value of CVT also potentially similar.

A hub airport outside of the EU, Atlanta Airport, located in the United States served approximately 110 million passengers in 2019 (Gilbert, 2021). The airport accommodates many international (transfer) flights. It faces a desire to increase efficiency during check-in, security screenings and to make air travel a little greener. In addition, the ambition of US airports, in general, is to ensure that the airports meet the needs of the 21st century, as often this is currently not provided (Birenbaum, 2021). Facing these characteristics, the value and feasibility of CVT would differ from this research. It is a relatively large airport, in which investments for the CVT infrastructure would be bigger compared to Schiphol Airport. On the other hand, environmental benefits and cost savings would increase as the number of bags is also higher. CVT fits the desires of the airport, in which it seems valuable for Atlanta Airport, but requires additional research.