Airport Collaborative Decision Making

Improving the information position of the turnaround coordinator in managing the Target Off Block Time.

Delft University of Technology
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by

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Preface

Dear reader,

This is the final report of my master thesis of the TU Delft master program Transport, Infrastructure and Logistics. The goal of the thesis was to get a better understanding of how turnaround coordinators manage the Target Off Block Time in Airport Collaborative Decisions Making (A-CDM) and explore how the information position of turnaround coordinators managing the TOBT can be improved. This report is the result of 10 months of research in close collaboration with To70 Aviation Consultants, the TU Delft and airport stakeholders at Brussels Airport Zaventem.

This research would not have been possible without the help of my colleagues at To70. I could always count on consultants with years of experience in aviation and A-CDM to share their knowledge with me. A special thanks to my supervisors Desley Kemper and Betty Samola, who helped me develop the research from the beginning and have provided me with constructive feedback for over a year.

I would like to thank my supervisors of the TU Delft, Bert van Wee, Jan Anne Annema and Milan Janić, for their constructive feedback. We have had fruitful discussions during the course of this research which I have always enjoyed.

A large group of people which I would like to thank is the airport community at Brussels Airport Zaventem. Without the help of all the involved managers, flight watchers, dispatchers and turnaround coordinators at Brussels Airport Company, Swissport and Aviapartner this research would have never had the important case study on which it is build.

Finally, I would like to thank my friends and family for their support and for regularly taking mind of the thesis.

I wish you a pleasant read.

Kind regards,

M.R. Verkerk

The Hague, June 21, 2018

Cover front page: `https://neontalent.mysmartjobboard.com/files/userfiles/DSC_4177.jpg`

Summary

Introduction

In each part of its journey, an aircraft uses capacity from either Air Traffic Control, the airport, the airline or the ground handler. These stakeholders are working together in Airport Collaborative Decision Making (A-CDM). With A-CDM, high quality operational data is shared among stakeholders through a single platform. This sharing of information allows for close monitoring of the interlinked events and helps the stakeholders to make more informed decisions on how to use their scarce resources and capacity more efficiently.

To allow for the close monitoring of the journey of the aircraft, 16 milestones in the journey are defined. These milestones provide a common definition which all stakeholders work with [22]. A key milestone in A-CDM is the Target Off Block Time (TOBT). The TOBT is the time at which the aircraft is estimated to be ready, with all doors closed and boarding bridges removed. The TOBT is used by airport stakeholders to plan their activities. ATC uses the TOBT for the pre-departure sequence planning system, which determines the most optimal order of planes taking off from the runway. The TOBT is updated by the turnaround coordinator based on the information he has on the progress of the turnaround processes such as catering, cleaning, fuelling and boarding of passengers. However, a large part of these TOBT updates take place within the last 10 minutes of the turnaround. These last minute updates cause disruptions to the schedules of the stakeholders at the airport, which makes it less efficient.

Scientific research has strongly focused on the pre-departure sequence planning system and on expanding the A-CDM concept. Expanding the A-CDM concept with more information is believed to further increase the predictability and therefore efficiency of the airport. In expanding A-CDM, research has focused on top-down, centralized concepts such as the airport operations centre. Opposite to this, limited focus has been on decentralized improvements. Turnaround coordinators at the aircraft are more proactive and knowledge driven when managing the TOBT than operators in a control centre [27]. Improving the information position of these proactive turnaround coordinator can therefore be an alternative approach in expanding A-CDM. The main question of this research is therefore:

To what extend can the information position of the turnaround coordinator in TOBT management be improved with relevant information?

To answer the main question in a clear and concise manner, several sub-questions are formulated to structure the research around. These sub questions are:

- Sub question 1: What processes in the turnaround are the main causes for TOBT updates and how does a turnaround coordinator establish a TOBT update?
- Sub question 2: What interface can be designed to potentially improve the turnaround coordinators information position when managing the TOBT?
- Sub question 3: How do turnaround coordinators assess the additional information presented in the TOBT management interface?

To answer the main question, this research conducted a case study at Brussels Airport Zaventem (BRU). Brussels Airport Zaventem (BRU) was the second airport in Europe to fully implement A-CDM into its daily operation. The research is conducted in three parts, with different techniques for each part to answer a sub question.

Part 1: The current practice of TOBT management

The first part uses data analysis and a field study to get an insight into the current situation at BRU. The data analysis used a data sample of delayed flights in the months August, September and October 2017. The analysis of this data showed that a lot can set a turnaround of schedule, causing TOBT updates. Main causes of

disruption in the turnaround which were identified were passenger transport by bus, the identification of bags due to a missing passenger, handling of passengers with reduced mobility, congestion at immigration and airline policies. Most of these causes are related to the passenger process, which happens outside of the turnaround coordinators direct line of sight and pop up late in the turnaround. This enhances the need for communication with other stakeholders in TOBT management.

During the field study, observations were conducted to get a complete view on TOBT management at BRU. In total, 46 TOBT updates were observed. 88% of the observed TOBT updates were conducted in the last 10 minutes or the turnaround and 46% of the updates were only by 5 minutes. The field study also showed that the turnaround coordinators have a variety of tasks which create a high workload. The service providers in the turnaround process increase the workload of the turnaround coordinator since they don't actively inform the coordinator. The turnaround coordinator has to actively pull information out of the turnaround process to make his assessment. In making this assessment, the turnaround coordinator does not have clear information on process times to rely on as a reference. Additional to these problems, it was found that the culture among the turnaround coordinators causes them to report small and last minute TOBT updates instead of larger and earlier updates.

Part 2: A potential improvement in the information position

The insight into the current situation at BRU showed that there is a need for improvement in the information position of turnaround coordinators. But these findings do not directly provide a foundation for a potential improvement. In the second part, the observations from the field study were used to conduct a Cognitive Work Analysis (CWA). CWA consists out of five steps of analysis, zooming in from the work domain to the individual actor. The work domain analysis showed that, to achieve its values of punctuality, predictability and efficiency, TOBT management requires interaction with many different physical objects scattered over the apron and its surroundings. To achieve the values of TOBT management, the control task requires iterative observations of the turnaround processes on both high and detailed levels. The analysis identified the interpretation of the system state as the key data processing activity in the control task. This interpretation of the system state is a complex activity, which requires the turnaround coordinator to have a clear mental model of the turnaround. This model is compared with the current system state and alter to predict the consequences of deviating processes on the TOBT. Using the six criteria for governing the division of work demands [41], a new division of work was proposed. The analysis proposed that individual service providers (such as cleaners and gate agents) take over part of the tasks of the turnaround coordinator by observing the work for which they are responsible and communicate the expected end time with the turnaround coordinator via an interface. The final analysis of the CWA focused on this interface and provided a set of design implications.

These design implications were the starting point for the design of an ecological interface. An ecological Interface supports all three types of behaviour, which are skill, rule and knowledge based behaviour. An ecological interface should not force cognitive control to a higher level than the task requires [52]. Based on the design implications, a list of information requirements was constructed. Through data scale analysis and visual scale matching these information requirements were translated to basic elements of graphic composition for a design. Through several iterations with aviation and design experts, a first design of the interface was made. The designed interface provides visual signals, high level information and detailed process information in one sight. The interface presents the turnaround processes and milestones along a time line, which are updated to provide a live overview of the turnaround. Colours, texture and brightness indicate the status of a process (scheduled, ongoing, delayed, critical. non-critical). An advised TOBT is calculated by the system based on the time indications from the service providers. When the current TOBT does not equal the advised TOBT, visual signals are given to the turnaround coordinator and the option to update the TOBT becomes available in the interface.

Part 3: Evaluation with end users

The last part of the research is an evaluation of the designed interface with ten turnaround coordinators. The evaluation was conducted in two parts: a simulation part and an evaluation part. In the simulation part the turnaround coordinators used the interface to manage the TOBT of five scenarios containing hypothetical turnarounds. In each scenario the turnaround coordinators were presented with an illustration of the interface on a tablet. Based on the information on the tablet, the turnaround coordinators had to choose how to react to the situation from a set of standard answers: update immediately to the advised TOBT, update the TOBT by a fraction of the advised TOBT, contact the service provider, ignore the alert or a different option (open answer). In the evaluation part, turnaround coordinators were given a set of statements on the usability and acceptance of the additional information provided by the interface. These statements were answered on a 5 point scale form strongly agree to totally disagree.

In the evaluation, the majority of the turnaround coordinators found the interface to be useful as an aid for managing the TOBT since it provides them a clear overview of the turnaround. Most turnaround coordinators stated that the layout and the usage of colours made the interface clear and easy to work with. The majority of the turnaround coordinators acknowledged that they would use this system as an aid in managing the TOBT and expected to use it in every turnaround once it is available. However, turnaround coordinators did not believe the interface would replace their tasks in TOBT management and therefore lower their workload. Finally, the turnaround coordinators identified a potential risk for the implementation of the system. Every service provider in the turnaround has to work with the system in a truthful manner for it to work. But the shared information can have negative side effects for them since the collected data can be used to identify the source of a delay more accurately. Currently, service providers causing a delay blame it on something else, which is known as the blame game. The turnaround coordinators expected that service providers who are currently playing the blame game in their favour might resist against the implementation of the system or won't use it truthfully after implementation.

From the 50 choices made by the turnaround coordinators in the simulation, only 10% of the choices involved updating the TOBT immediately. In the other 90% of the choices, the turnaround coordinators observed the information on the interface but chose not to follow the advised TOBT update. In most of the scenarios the majority of the turnaround coordinator chose to update the TOBT with a value according to their own believes (40% of the total choices). When this was the case, the value of the update was lower than the advised TOBT update presented on the interface. These choices made by the turnaround coordinators and their motivation showed that with the interface as an aid, there were no notable differences in how the TOBT updates were conducted.

Conclusions

This research designed an ecological interface which combines information from the service providers in the turnaround and existing systems at the airport. The interface provides high level information, detailed process information and visual signals in one overview to support the turnaround coordinator in each level of cognitive control during TOBT management. The evaluation of the interface with turnaround coordinators showed that the goals of the ecological interface design have been achieved. The turnaround coordinators thought the interface provided them with a clear overview of the turnaround and that it was easy to work with during the turnaround. With these results the research has shown that, from a technological perspective, an interface can be designed which improves the turnaround coordinators information position in managing the TOBT.

But, within A-CDM there is a saying: A-CDM is 10% technology and 90% people, process and culture [16]. This research also found several challenges related to people, process and culture. These challenges were discovered at both the input and the output side of the interface. At the input side, the interface requires an effort of the service providers, who are not yet included in A-CDM. The shared information can have negative side effects for them since the collected data can be used to identify the source of a delay more accurately. This excludes the blame game which some service providers are currently playing to avoid penalties. Because of this, service providers might not want to use the system or won't use it truthfully. And if not all service providers use the system in the correct manner this will undermine the idea of the interface and therefore its usability in TOBT management.

At the output side, the turnaround coordinators pose a challenge. For a well executed turnaround, values such as punctuality and predictability should be met. Keeping these values in mind, turnaround coordinators assess the costs of overestimating and underestimating the TOBT. The costs for overestimation are generally assessed as being high since overestimation can harm a flights punctuality. The cost of underestimating is assessed as low since, contrary to the other values, predictability is not enforced by a stakeholder.

This trade-off leads to a culture in which TOBT updates are made with a small amount of minutes and often last minute. With the introduction of the interface, updating the TOBT remains the responsibility of the turnaround coordinator. The culture therefore remains present, keeping its influence on the way the TOBT is managed. Without a change in culture, an improvement in the information position will not create a more reliable TOBT. Besides improving the information position of the turnaround coordinator, the measurement and enforcement of predictability is therefore the key in improving TOBT management.

Discussion

The case study at Brussels Airport has given a good insight into turnaround coordination. The conclusion has shown that the researched problem is strongly focused around people, process and culture. While this research focused on turnaround coordinators at Brussels Airport, turnaround coordinators at other airports might have developed a different culture and procedures among their own. It can therefore not be stated with full confidence that the technological and organizational aspects identified in this research are directly applicable to other A-CDM airports.

Since the research focused on a preliminary design only a limited number of iterations were made without delivering a working prototype. This was sufficient for the purpose of this study, but a working prototype would be required for further research. By focusing on the turnaround coordinators this research has been one sided in its design. The conclusion shows how important the service providers are as well. The conclusion therefore does not provide a complete overview of the expansion of A-CDM with these service providers.

Recommendations

Based on the findings and the discussion, this research gives several recommendations to stakeholders and the scientific community to further pursue the improvement of the A-CDM concept:

- **Compare ground operations of A-CDM airports**
  Future scientific research should compare the ground operations of different A-CDM airports through field studies. By comparing airport, best practices can be defined. When ground operations at airport are not deemed comparable, causes for these differences should be investigated further. Investigating these causes can be useful for high level organizations such as Eurocontrol in developing new EU wide concepts which incorporate these differences.

- **Measuring TOBT management behaviour with KPIs**
  It is recommended to Brussels Airport Company to measure TOBT management behaviour by defining and implementing new KPIs. These KPIs are facilitators, allowing the A-CDM stakeholders to have more informed discussions. During these discussions, stakeholders can address behaviour which is not in accordance with the A-CDM guidelines and monitor if a stakeholder is improving his behaviour. In defining these KPIs, the observations of this research can be used as a starting point since they illustrate the situation on the ground.

- **Researching enforcement schemes in A-CDM**
  Besides defining KPIs, research should also focus on the enforcement of predictability. Scientific researchers should investigate how enforcement mechanisms are currently set up at different A-CDM airports and what the impact and the risks are of such enforcement schemes. Besides focusing on A-CDM airports, research can also be widened to include collaborative frameworks in other industries.

- **Investigating the integration of service providers in A-CDM**
  Similar to this research, the work domain of each service provider should be analysed to determine how they can be introduced into A-CDM. On a higher level, a cost benefit analysis should be carried out to determine the added value of introducing the service providers into A-CDM. Besides the focus on the overall costs and the benefits for the system, focus should be on the distribution of these costs and benefits. If the analysis show positive results, the design proposed by this research can be further developed into a working prototype. Trialling this prototype in a small number of turnarounds, with all involved stakeholders, is expected to provide valuable information on how to develop the system further.

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List of Acronyms

A-CDM	Airport Collaborative Decision Making
AIBT	Actual In Block Time
AOBT	Actual Off Block Time
APOC	Airport Operations Centre
ASRT	Actual Start-up Request Time
ATC	Air Traffic Control
BAC	Brussels Airport Company
BRU	Brussels Airport Zaventem
CWA	Cognitive Work Analysis
EIBT	Expected In Block Time
EID	Ecological Interface Design
ELDT	Estimated Landing Time
EOBT	Estimated Off Block Time
KPI	Key Performance Indicator
MTT	Minimum Turnaround Time
PRM	Passenger with Reduced Mobility
SOBT	Scheduled Off Block Time
SLA	Service Level Agreement
STD	Scheduled Time of Departure
TAM	Total Airport Management
TOBT	Target Off Block Time
TSAT	Target Startup Approval Time
TTOT	Target Take Off Time

1
Introduction

With an expected near doubling of air travellers by 2035, airports need to increase their capacity to cater for this demand [30]. And since many airports around the world are limited in their options to expand their physical infrastructure, there is a growing need among airports to use their current infrastructure and resources more efficient. One way airports are increasing their airside efficiency is by implementing the concept of Airport Collaborative Decision Making (A-CDM). This research will focus on further expanding the concept of A-CDM to help airports increase their efficiency even more.

1.1. Airport Collaborative Decision Making

Several stakeholders are involved in getting a flight from A to B. The airline operator schedules a flight, sells tickets to passengers and provides a crew to operate the flight. The airport operator provides the flight with a stand on which to park and a gate from which passengers can board the aircraft. While at the stand, ground handling provides a wide range of services to prepare a flight for it's departure. When departing, Air Traffic Control (ATC) guides the flight over the taxiways and through the air towards the next ATC sector. And finally, the Network Manager Operations Centre (NMOC) coordinates the flight through these different ATC sectors.

In each part of its journey, an aircraft uses capacity in some sort from one or more stakeholders. When in the sky, it occupies a part of a route which can not be used by other aircraft at the same time. When at the airport, it occupies a gate and uses equipment and people to prepare for the next flight. And when it departs, it occupies the taxiways and the runway before taking off. With A-CDM, high quality operational data from the involved stakeholders is shared among each other through a single shared platform (see figure 1.1). This sharing of information allows for close monitoring of the interlinked events and helps the stakeholders to make more informed decisions on how to deploy their scarce resources and capacity.

Figure 1.1: The CDM platform [31]

An example of such operational data is the Estimated Landing Time (ELDT). A short example will show how useful this data can be. When an aircraft takes of at airport A for its flight to Airport B, the NMOC at Eurocontrol makes its ELDT available for all stakeholders at Airport B in a central database. When the flight encounters a delay since it has to avoid military airspace, the NMOC updates the ELDT to inform the stakeholders at Brussels. Upon approaching the airport, the local ATC provider (Belgocontrol) takes over from NMOC, reports that the flight is in local airspace and updates the ELDT with estimations based on the local radar. When starting its final decent, the ELDT is updated again until it is replaced by its touchdown time in the central database. Constant updating of this information to the current situation is valuable for the stakeholders at Airport B. The airport operator can for example better manage its gate planning since it knows when the aircraft is due to arrive. Using this data, the ground handler can better schedule its people and equipment. In the case of a delay the ground handlers can work on a different aircraft instead of waiting by the stand for the delayed aircraft.

An evaluation of A-CDM performed by Eurocontrol at 17 European airports showed that A-CDM has been successful at increasing efficiency. 7% in aircraft taxi time was saved and 10% less Air Traffic Flow Management related delays were achieved at the evaluated airports. These are large benefits for the aviation community, but also for the passengers. For society, these savings in time also caused large savings in the amounts of fuel burned and therefore emissions [10].

1.1.1. The key variable in A-CDM: the Target Off Block Time

The ELDT was just one example of the data which is shared during the inbound journey of the aircraft. The milestone approach [22] divides the journey of the aircraft into 16 operational events, so called milestones, which are shown in figure 1.2. This approach is one of the main elements of A-CDM since it provides a common definition which all stakeholders work with.

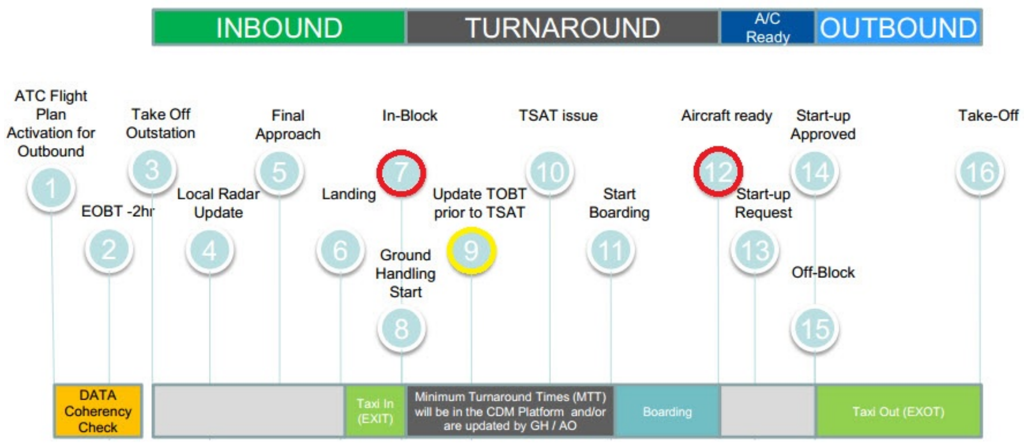


Figure 1.2: The 16 milestones of A-CDM [17]

This research focuses on the Turnaround section, from the moment the aircraft is at the gate at milestone 7 until it is ready to leave the gate again at milestone 12 (indicated in red). The key variable in this turnaround is the Target Off Block Time (TOBT) (indicated in yellow). The TOBT is the time at which the aircraft is estimated to be ready, with all doors closed and boarding bridges removed. The TOBT is updated by the turnaround coordinator based on the progress of processes such as catering, cleaning, fuelling and boarding of passengers.

Figure 1.3 shows why the TOBT is such a key variable in the turnaround and in A-CDM. The TOBT is the input for the pre-departure sequence planning system, which determines the most optimal order of planes taking off from the runway. The system uses the TOBT to determine the earliest possible moment for take off, the Target Take-Off Time (TTOT). This is done by adding the expected taxi time of the aircraft from the gate to the runway to the TOBT. The earliest TTOT of each flight is input for an algorithm which calculates the most optimal order of flights taking off, creating a new TTOT for each flight. By subtracting the taxi time again, the optimal window for the aircraft to start its engines and leave the gate is calculated. This window is the Target Start Up Approval Time (TSAT) window and is 10 minutes wide (TSAT +/- 5 min). Every time the TOBT of a flight is updated to a new time which is later than the TSAT, the system needs to calculate a new TTOT and TSAT. Other reasons for a recalculation are for example a change in runway usage or a drop in runway capacity due to weather conditions.

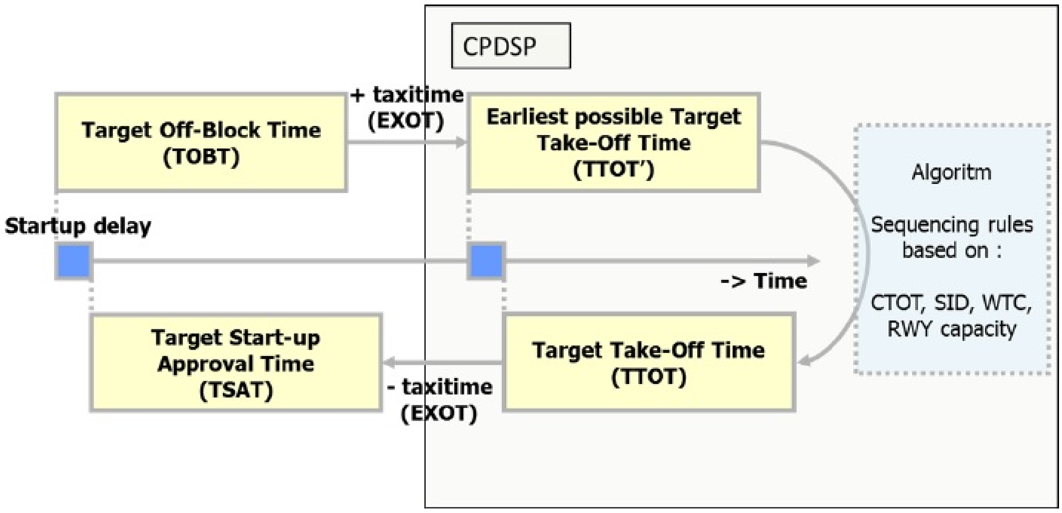


Figure 1.3: The pre-departure sequence planning system [3]

1.2. Problem statement

After having introduced the core principles of A-CDM and having highlighted the importance of the TOBT, this section will describe the problem of last minute TOBT updates and the current knowledge gaps in the academic literature. After establishing the problem and the knowledge gaps, the objective, main research question and sub questions of the research are presented.

1.2.1. Last minute TOBT updates

The turnaround involves many processes such as (un)loading baggage, cargo and passengers, refuelling, cleaning and occasionally small maintenance. As mentioned before, the TOBT is updated by the turnaround coordinator based on the progress of these turnaround processes. Figure 1.4 shows the average number of TOBT updates at Brussels Airport Zaventem (BRU), with on the Y-axis the number of TOBT updates conducted per day. On the X-axis the number of minutes prior to the best known actual block time, when the aircraft is expected to take of, is shown. Figure 1.4 shows that a large part of the TOBT updates at the airport take place within the last 10 minutes of the turnaround.

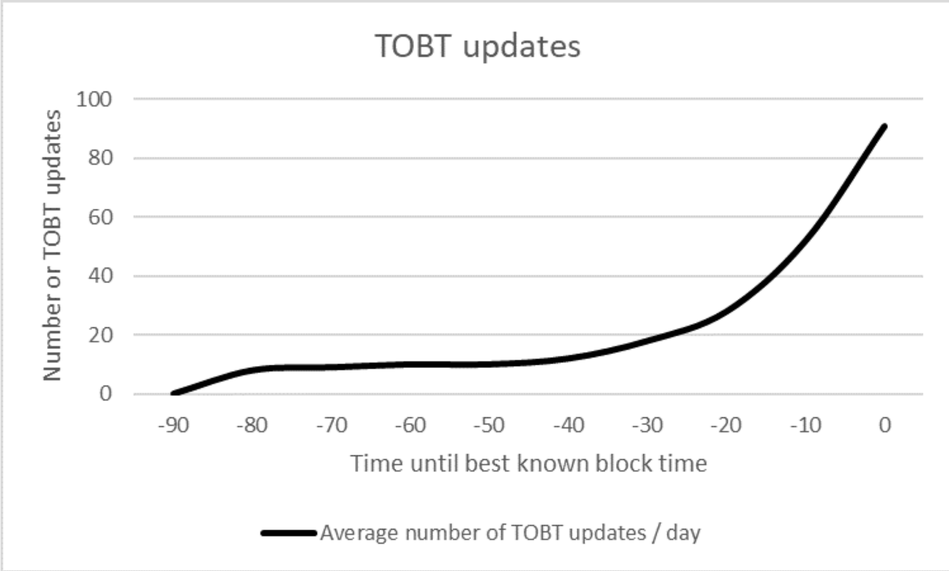


Figure 1.4: Average number of TOBT updates per day in intervals of 10 minutes before best known actual block time

When a TOBT is updated last minute, the pre-departure sequence planning system updates the TSAT for the aircraft and often several other aircraft at the last moment as well. These last minute changes can cause disruptions to the schedules of stakeholders at the airport, especially during peak hours when everything is tightly planned. Examples of such disruptions are:

- The runway slot reserved for the flight can't be filled in time by another flight. This causes the runway capacity to not be utilized completely.
- A push back truck which was already on standby at the gate has to wait for the new TSAT. This can have a knock-on effect on other flights now waiting for push back.
- An incoming flight needs to wait for the gate to become available, causing delay for the passengers and possible knock-on effects for other flights.

This last minute updates therefore bring unpredictability into the A-CDM system, causing resources and capacity to not be deployed with maximum efficiency.

1.2.2. The knowledge gaps

The literature overview in chapter 2 shows that academic researchers who have conducted research in the field of A-CDM mostly focus on the ATC perspective in A-CDM and how A-CDM could be improved. In their 2010 study, Groppe, Pagliari and Harris clearly express the problem for achieving an accurate and reliable TOBT: the turnaround process has a critical path of sequential sub-processes which all, individually, need to be predicted precisely to get an accurate TOBT. TOBT inaccuracy arises since the ground handler does not have sufficient information to foresee these problems on time and make an estimation of a TOBT update. The researchers argued that additional monitoring and communication tools should be designed for TOBT management [27].

It is clear that the A-CDM framework in its current form does not make use of all the available data streams at the airport. Widening the scope of A-CDM by considering these additional data streams has therefore been identified by several experts in the field as one of the next steps to get more value from A-CDM [39] [21]. Research into this expansion of A-CDM mainly comes from the Single European Sky ATM Research Joint Undertaking (SESARJU). SESARJU developed the Total Airport Management (TAM) concept to lead this expansion. This concept focuses strongly on developing Airport Operations Centers (APOC) which brings all data streams and stakeholders together at a central operations centre [29].

Several researchers have developed prototypes of new information tools for this APOC. In 2008, researchers of the DLR institute built an experimental prototype of an APOC at a midsize European airport to test the usability of the Total Operations Planner (TOP). TOP is an assistance tool which provides forecasts of the traffic situation based on flight plan data and the capacity of several stakeholders. In a set of simulation interviews, subject matter experts agreed that the information from the system was usable for preventive actions. But the experts also thought the system did not include some of the relevant mechanisms and dependencies of airport processes, such as the landside processes [38]. A 2016 study by University College London and the University of Virginia in cooperation with London Heathrow Airport has focused on one of these landside processes. The researchers developed a predictive model using passenger and flight information, with historical information as a reference, to predict transferring passenger's connection times. These connection times were used to pro-actively advice stakeholders on the TOBT, helping them to deploy their resources more efficiently[18].

These research efforts have provided important insight for developing information tools for the APOC. TAM has a large scope and research on the expansion has been focusing on top-down, centralized concepts. Groppe, Pagliari and Harris have shown in their 2010 research that control centers suffer from a combination of poor monitoring capabilities, missing input from actors and unsupportive interfaces. This causes TOBT updates made at an operations centre to be reactionary, while a turnaround coordinator at the aircraft is proactive [27]. Strengthening the information position of this proactive turnaround coordinator can be an alternative for improving A-CDM. However, it is unclear what information turnaround coordinators precisely lack when managing the TOBT and if this information is available at the airport. It is also unclear how the introduction of new information tools would fit into the ground handlers work environment.

1.2.3. Research objective, question and sub-questions

Given the identified knowledge gaps above, the goal of this research is to get a better understanding of how turnaround coordinators manage the TOBT in A-CDM and explore how the information position of turnaround coordinators managing the TOBT can be improved. The research problem and objective are summarized in the following research question, which is:

To what extend can the information position of the turnaround coordinator in TOBT management be improved with relevant information?

To answer the main question in a clear and concise manner, several several sub-question are formulated to structure the research around. These sub questions are:

- Sub question 1: What processes in the turnaround are the main causes for TOBT updates and how does a turnaround coordinator establish a TOBT update?
- Sub question 2: What interface can be designed to potentially improve the turnaround coordinators information position when managing the TOBT?
- Sub question 3: How do turnaround coordinators assess the additional information presented in the TOBT management interface?

1.3. Research methodology

To answer the main question, this research conducts a case study at Brussels Airport Zaventem. The research is conducted in three parts, which each apply different techniques to answer a specific sub questions. The rest of this section will go further into details on the setup of the research and the motivation behind this setup.

1.3.1. Case study: Brussels Airport Zaventem

This research tries to get insight into the way individuals and groups of stakeholders interact with each other and cope with problems in an environment which is difficult to simulate. This setup makes it a typical field of study for case study research [46]. Given that this study focuses on A-CDM, only airport who have A-CDM operational are suitable as a potential case. At the moment of this research, 28 airports in Europe have A-CDM fully implemented [23]. Since the methods of this research require regular site visits, only airports which are within a feasible travel distance (making a round trip within a day) from Delft were considered. Within this travel distance only Amsterdam Airport Schiphol and Brussels Airport Zaventem are A-CDM airports. For feasibility reasons, a single case study is conducted. A case study into A-CDM requires collaboration with several of stakeholders at the airport. Conducting a case study at two airports would make the number of involved parties and interests unmanageable for this thesis research. Brussels Airport Company was willing to cooperate and was therefore selected as the case study for this research.

Brussels Airport Zaventem (BRU) was the second airport in Europe to fully implement A-CDM into it's daily operation. BRU lies at the heart of the European Union, 12 km north-east of Brussels city centre. Just under 25 million passengers travelled through BRU in 2017, which was 5.6% more than in record-year 2015. BRU has a large network of European flights and intercontinental flights to Africa, the US, the Middle East and Asia. The main airline at BRU is Brussels airlines, which uses the airport as its hub for transferring passengers between intercontinental and European flights [13]. Other mayor airlines at Brussels airport are TUI fly Belgium and Ryanair. Since 2010 the airport operator Brussels Airport Company (BAC) and the other airport stakeholders are using A-CDM in their operations to increase their efficiency. In the upcoming decades, BRU wants to continue to grow and eventually reach 40 million passengers by 2040. In order to achieve this ambition BRU is planning to expand its infrastructure (new piers and taxiways) and also aims at further optimization of its operational efficiency [12]. In this further optimization A-CDM plays an important role.

Figure 1.5: Overview of Brussels Airport Zaventem (source: Google Earth)

1.3.2. Research approach

This research is conducted in three parts, each focusing on one sub question. Before a proposal for the improvement of the information position of a turnaround coordinator can be made, the current practice of TOBT management need to be understood better. This is therefore the focus of the first part. The results of each part provides important input for the next part. The second part uses the understanding of the current practice to determine how the information position of a turnaround coordinator potentially can be improved. In the last part this potential improvement is evaluated with the end users, providing all the needed information to answer the main question. The following subsections will further elaborate on the methods used in each part.

Part 1: The current practice of TOBT management

The goal of the first part is to get insight into the current practice of TOBT management at BRU. The turnaround process produces two flows of data. One data flow is CDM data, which consits of the timestamps when each milestone is reached. The overview in figure 1.4 can be made with this data. The other data flow consists of delay codes. When a flight is delayed, the cause of a delay is reported by the turnaround coordinator via a delay code and logged in a database. A flight can have up to three delay codes when the delay has multiple causes. For each delay code, the amount of minutes delay is declared. Since delayed flights require TOBT updates, this data can be used to identifying what processes in the turnaround are the main causes for TOBT updates. For the analysis of delay codes, a data sample of all reported delays at BRU in the months

August, September and October 2017 is used. By analyzing the delay codes and other characteristics of delayed flights, this data analysis provides a high level overview of processes which often cause a TOBT update. Knowing which processes often cause a TOBT update provides insight into what additional information a turnaround coordinator might need to better manage the TOBT.

After the data analysis, a descriptive field study is conducted to get more details on how the turnaround coordinator establishes a TOBT update when a delay occurs. During the field study, observations are conducted at both ground handler companies at BRU. The observations focus on the moments when turnaround coordinators updated their TOBT, the magnitude of the update and the reason for the update. From the control center, 80 turnarounds are observed via camera displays and other interfaces. Besides these high level observations, 8 turnarounds are observed in detail by following turnaround coordinators during the turnaround. These high level and detailed observations provide a good mix of both data quantity and quality. Besides obtaining knowledge on how the TOBT is updated, additional causes for last minute TOBT updates are identified as well as information which the turnaround coordinator currently lacks in managing the TOBT.

Part 2: A potential improvement in the information position

The insight into the current situation at BRU are valuable, but do not directly provide a foundation for a potential improvement in the information position. To get to this foundation, a Cognitive Work Analysis (CWA) is conducted. CWA is a formative approach which has been developed in the 1970's by the Riso National Laboratory in Denmark to guide the analysis of human-information interaction in order to design new information systems [33]. CWA identifies the constraints that shape a workers purposeful goal-directed behaviour, making it useful for a complex socio-technical system such as turnaround coordination [33]. This research conducts a CWA to get a deeper understanding of the cognitive mechanisms behind TOBT updates and to determine how this can potentially be improved.

The CWA exists out of 5 steps and is based on the observations of the field study. The first step in CWA is to conduct a work domain analysis to describe the constraints that the work domain imposes on a operators actions. Second, a decision ladder is constructed to describe the control tasks which are used to achieve the goals of TOBT management. In the third step the strategies used to perform these control tasks are modeled using information flow maps. In the fourth step of the CWA, an alternative allocation of tasks between human operators and computers is proposed based on a set of criteria. The final step focuses on worker competencies, identifying the level of cognitive behaviour required to perform the tasks allocated to the worker [52]. With the analysis completed, the CWA provides the foundation for the design of a new ecological interface for TOBT management.

Using this foundation, a first design of an ecological interface is made. An ecological interface is more suitable than a standard interface when dealing with a complex sociotechnical system, which the turnaround of an aircraft is. The goal of ecological interfaces is to not force cognitive control to a higher level than the task requires. At the same time the interface should also accommodate all three types of behaviour: skill and rule based behaviour for expected situations and knowledge based behaviour for unexpected situations [52]. To guide the design process, the visual design methodology of Upton and Doherty is used. Based on the CWA, a list of information requirements is set up and matched with basic elements of graphic composition through their data scale. These basic elements are brought together in a design which is evaluated with subject matter experts. Three iterations are made based on the evaluation sessions to come to a first design of an ecological interface.

Part 3: Evaluation with end users

In the last part of the research, the proposed interface is presented to 10 turnaround coordinators for evaluation. This evaluation will focus on the usability, acceptance and possible implementation challenges of the interface. In the first part of the evaluation, a simulation is run with 10 turnaround coordinators in which they use the interface to manage the TOBT of 5 different fictional flight. This simulation will make the turnaround coordinators familiar with the interface and provides an insight into how the turnaround coordinators use the interface. After the simulation, turnaround coordinators are asked to answer a set of standardized statements in a small survey. These statements are constructed using the Unified Theory of Acceptance and use of Technology (UTAUT). Besides answering in a standardized manner, the respondents are asked to motivate their answers. The results of this evaluation will show to what extend the information position of the turnaround coordinators can be improved with relevant information.

1.3.3. Conclusions and recommendations

With the aforementioned parts, the research creates a clear overview on the technological and organizational aspect of improving the information position of the turnaround coordinator. Based on this overview, recommendations are made to stakeholders and the scientific community to further work towards expanding and improving the A-CDM operation.

1.4. Contribution of the research

This research will make both a scientific and practical contribution, which are discussed below.

1.4.1. Scientific contribution

Obtaining knowledge on the challenges and opportunities of this bottom up A-CDM expansion is valuable for the literature on the expansion and improvement of the A-CDM concept. Within current literature, only limited attention is paid to the turnaround in A-CDM and its role in the expansion of A-CDM. It is important to gain insights at this level before more and more airport start expanding A-CDM. This research creates a detailed understanding on how turnaround coordinators currently operate in A-CDM. Focusing on the expansion, this research identifies both technical and organizational opportunities and challenges of the proposed bottom up expansion. These findings results in a better understanding of a bottom up A-CDM expansion, filling a gap in the current literature. Besides filling a gap, substantiated recommendations on future research directions are made which could contribute to the A-CDM concept.

Although this research is conducted with a single case study of BRU it is expected that the identified technological and organizational aspects will also be applicable to other medium to large size A-CDM airports. It is assumed that this generalization is possible because, behind the architectural differences, airport systems and procedures are quite similar due to international standard and recommended practices.

1.4.2. Practical contribution

For the stakeholders at BRU the research will give an overview of what opportunities and challenges there are for improving the information position of the turnaround coordinator in managing the TOBT. This overview can help the airport in determining how to further improve TOBT management. The research also gives a realistic insight into how A-CDM is conducted on the ground at the airport. The observations provide insight into how turnaround coordinators update a flights TOBT and how they handle information. This insight in some tacit knowledge of ground handlers gives an insight into the ground operation which is currently lacking at the management level. Finally, the evaluation provides useful information on how ground handlers value information interfaces, which can be of use for future interface developments.

1.5. Structure of the report

This chapter has introduced the current gap within A-CDM and formulated the research objective and questions. **Chapter 2** presents previous research conducted on A-CDM and the expansion of A-CDM. The chapter also elaborates on the usage of CWA. In **chapter 3** the first part of the research is discussed, focusing on the current practice of TOBT management. **Chapter 4** then uses cognitive work analysis to come to a potential improvement in the information position in the form of an interface. **Chapter 5** uses the output of the previous chapter and evaluates this with the end users. **Chapter 6** will conclude the research by answering the research question and recommendations on the expansion of A-CDM and other A-CDM research.

Five appendixes are included in this report to support the different analysis. Appendix A provides background knowledge on BRU such as the airport layout and the arrival and departure patterns at the airport. Appendix B presents output from the delay code analysis in support of chapter 3. The notes made during the field study are included in appendix C. The iterative design process which is elaborated on in chapter 4 is included in appendix D. The last appendix, (appendix E) includes the evaluations conducted with the end users in support of chapter 5.

2
Literature overview of A-CDM and Cognitive Work Analysis

The introduction has already touched upon several important pieces of literature on A-CDM. The goal of this chapter is to provide an overview of the current A-CDM body of knowledge. The literature is gathered using Google Scholar, ScienceDirect and Scopus. This literature overview first goes into the different approach angles which have been taken in researching A-CDM. Secondly, the overview focuses on multiple pieces of research which focused on the expansion of A-CDM. With this overview several knowledge gaps are identified. The second part of this chapter explains how a Cognitive Work Analysis, an important method in this research, is carried out.

2.1. Previous research on A-CDM

Implementing A-CDM at an airport has shown to be characterized by both technological and organizational challenges [22]. On the technological part, existing data systems need to be connected and new automation applications need to be developed. But as one stakeholder is quoted in the 2014 research of Corrigan and others: *A-CDM is 10% technology and 90% people, process and culture.* This research identified several key challenges for implementing A-CDM, which are summarized as followed [16]:

- Benefits: All actors need to be able to understand and quantify the benefits of A-CDM for their own organization to get them motivated. At the same time, imbalance in rewards and efforts between stakeholders will occur.
- Understanding: A-CDM awareness is not sufficient among most stakeholder organizations. Some stakeholders for instance still see A-CDM just as an IT project instead of a new way of thinking. The biggest organizational challenge lies with changing the deeply rooted working methods of the operational staff working on the ground.
- Leadership: An efficient implementation of A-CDM requires clear leadership in this multi-stakeholder environment. But this leader (often the airport operator) usually does not have the tools to actively enforce the use of A-CDM on a stakeholder.
- Trust: There needs to be both trust in the A-CDM concept as well as trust in each other. Trust in the system can be damaged due to an inequity in (perceived) benefits. And although mistrust between stakeholders is believed to be limited, stakeholders are reluctant to share more sensitive data with each other.

Where the research of Corrigan and others provides a broad overview of the challenges in the A-CDM concept, other literature often researched A-CDM from the point of view of a single stakeholder.

2.1.1. ATC focused A-CDM literature

A substantial amount of researchers have focused on A-CDM from the perspective of ATC. When focusing on ATC in A-CDM, a dominant focus among researchers is on algorithms to support ATC in managing the pre-departure sequence planning (shown in figure 1.3 in chapter 1).

Malik and others [35] developed an algorithm for the optimization of the ground movements at the airport. Using a list of potential departures and known constraints, such as wake vortex separation, the algorithm provides a time window when the aircraft is released from the gate. By controlling these release times, unnecessary congestion on the taxiways is avoided and aircraft can taxi more smoothly with less stop-and-go instructions. The algorithm was tested in a simulated environment under nominal and high traffic scenario's.

The simulation showed an average improvement of 10% in throughput. This result showed the potential of the algorithm for a simple layout. The researchers emphasized that the algorithm should be expanded to accommodate for multiple runways and arriving traffic as well[35].

Research by Tancredi and other of the university of Naples [47] developed an algorithm which seeks minimal taxi times for both arriving and departing aircraft. The developed algorithm first calculates an individual shortest path between the stand and the runway or the other way around. This creates an EIBT for an ariving aircraft and a TSAT for a departing aircraft. The individual shortest paths are brought together and are amended by a conflict detection and resolution task which attempts to resolve all conflicts with the minimum increase in taxi time. When there is a conflict between aircraft, the algorithm determines the priority of the involved aircraft. Aircraft with the lower priority can then be held at a certain holding point or at the gate with a change in TSAT. The researchers tested the algorithm on a hypothetical airport representing Milan Malpensa airport. The test showed that the algorithm was able to find conflict free solutions in high traffic situations [47].

Much more researchers have focused on algorithms to support ATC in managing the pre-departure sequence planning. Schaper, Tsoukala and Stavrati have developed and trailed the ADEO-tool (Controller Assistance through Departure Optimization) at Athens Eleftherios Venizelos Airport where they were able to reduce the taxi times [45] . Atkin and others also developed an algorithm which predicted the delay for each departing aircraft and calculated a pushback time in which an appropriate amount of the delay was absorbed at the stand at Heathrow Airport. This algorithm was later used by ATC in the UK in a system for pre-departure sequence planning [6]. With more examples which can be given [44] [9], this overview shows how extensive the journey between the stand and the runway and the calculation of the TSAT has been researched. This extensive body of knowledge leaves no large knowledge gaps.

2.1.2. A-CDM literature focusing on the turnaround

Contrary to ATC literature, research which focused on the turnaround process in A-CDM is rather thin. Following the amount of milestones (16) in A-CDM, there are several KPIs in the A-CDM framework. Okwir and others have researched how A-CDM operates in the turnaround. The researchers proposed a new method for managing the collaborative turnaround performance of all actors by predicting the most critical factors. The analysis was done using Classification And Regression Trees with sets of KPIs as independent variables and an aircraft's on time performance as the dependent variable. The analysis showed that the main delay pares (difference between two KPIs) for predicting delay were: AOBT-TOBT, ASRT-TOBT and TSAT-TOBT. This again showed the central role of the TOBT in A-CDM and highlights the importance of the TOBT quality. After analyzing the KPIs, the researchers noted that there is still a lack of feedback mechanisms in CDM. KPIs could be used more by management of different stakeholders to push for more enhanced decision making [37].

Researchers Groppe, Pagliari and Harris have conducted two studies focusing on the information in the turnaround. Their 2009 research focused on the information requirements of pilots in the A-CDM framework. Via a questionnaire pilots were asked to report events where they encountered problems in the operational information sharing. After analyzing the response of the pilots, the researchers concluded that the current approach to A-CDM does not completely satisfy the pilots information requirements. Pilots are missing A-CDM information sharing elements such as the TTOT and compliance alarms. Pilots also lack a complete overview of the participating actor's performance, status, knowledge level and their available resources [26]. Although the researchers only focused on the pilots it is expected that other stakeholders also lack this complete overview. Groppe, Pagliari and Harris therefore encourage further research to identify information requirements of other participating actors.

In their second study into A-CDM, the researchers focused on the turnaround process and used Cognitive Work Analysis (CWA) as the main method. The researchers clearly express the problem for achieving an accurate and reliable TOBT: the turnaround process has a critical path of sequential sub-processes which all, individually, need to be predicted precisely to get an accurate TOBT. The researchers conducted 122 hours of field observations at airline operation centres. They organized the observations in a qualitative cognitive model to identify the influences of different turnaround monitoring modes on TOBT accuracy. With the cognitive model, the research concluded that controllers monitoring a turnaround from a remote operations centre have different strategies for creating or extracting information than turnaround coordinators standing next to the aircraft. The controllers at the operations centre apply a data-driven approach. But a combination of poor monitoring capabilities, missing input from actors and unsupportive interfaces causes their TOBT updates to be reactionary instead of proactive. The researchers found turnaround coordinators at the aircraft are more proactive and knowledge driven when managing the TOBT, resulting in more reliable TOBT predictions [27].

2.1.3. Research on the expansion of A-CDM

Currently, A-CDM does not make use of all the available data streams at the airport. Widening the scope of A-CDM by considering these additional data streams has been identified by several experts in the field as one of the next steps to get more value from A-CDM [39] [21]. The expansion of A-CDM is included in the concept of Total Airport Management (TAM). Developed by Eurocontrol and the German aviation research institute DLR, TAM widens the scope of A-CDM in both the level of detail and space. This widening of scope is visualized in figure 2.1 [29]. At the centre of this concept lies the Airport Operations Centre (APOC). The APOC combines all relevant information of the airports access systems, land and air side traffic, ground operations and weather conditions. This data enables continuous monitoring of the joint plan, the Airport Operations Plan, and enables better detection / anticipation of deviations.

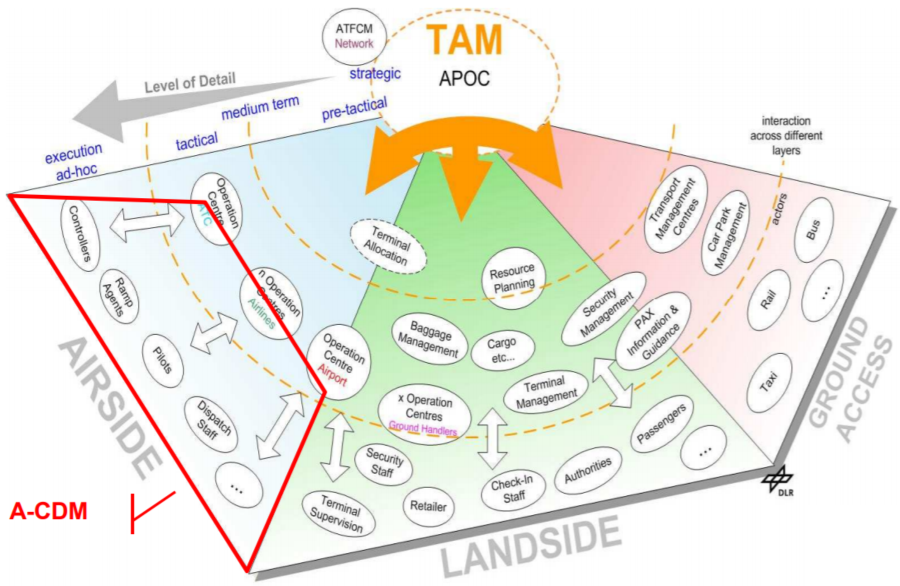


Figure 2.1: The scope of Total Airport Management [29]

BRU has implemented an initial APOC, as well as London Heathrow and Paris Charles de Gaulle. The airports take different approaches in their APOC setup. At Heathrow, ATC representatives are present in the APOC but the ground handlers are not. At BRU it is the other way around: the ground handlers are represented in the APOC and ATC is not. These APOCS require much more research and innovations to achieve this large scoped system of TAM [25]. TAM is therefore a large step considering the current scope of A-CDM at airports. Each bullet in figure 2.1 is a research area on its own which will contribute to the expansion of A-CDM towards TAM. Only limited academic research has been done on the actual real life details of this expansion.

In 2008, researchers of the DLR institute investigated the feasibility of traffic prognosis for an APOC. An experimental prototype of an APOC was built at a midsize European airport to test the usability of the Total Operations Planner (TOP). TOP is an assistance tool which provides forecasts of the traffic situation based on flight plan data and the capacity of several stakeholders. In a set of simulation interviews subject matter experts were led through a simulation of a disrupted day at the airport and they had to use the information of the TOP system. The experts agreed that the information from the system was comprehensible and definitely usable for preventive actions. But the experts also thought the system did not include some of the relevant mechanisms and dependencies of airport processes, such as the landside processes [38].

Another study into an APOC tool was conducted by the University College London and the University of Virginia in cooperation with Heathrow Airport in 2016. The researchers showed how big data techniques such as regression trees can be used to introduce the transfer passenger process into the APOC [18]. Using historical passenger and flight information the researchers build a predictive regression tree model. This model used live flight characteristics from the inbound and outbound flight to predict a transfer passengers connection time. These connection times were used to provide advice for TOBT updates. A live trail at Heathrow's APOC showed that the model gave useful input for improving the accuracy and stability of the TOBT.

2.1.4. Conclusions on literature review

The goal of this literature overview was to provide an overview on the current state of the art in A-CDM. Extensive research has been done on A-CDM from perspective of ATC, but literature on the turnaround in A-CDM is rather thin. One explanations for this can be that the National Air Navigation Service Providers (such as LVNL and Belgocontrol) and Eurocontrol have more budget for research than ground handling companies or airlines who work in a competitive market. This competitive market also means that the ground handling companies and airlines usually have a smaller horizon then the National Air Navigation Service Providers, not focusing much on long term improvements. Another reason for limited scientific papers could be that most research is conducted by private companies, which for commercial reasons don't publish their work.

The literature overview showed that A-CDM is on the move towards TAM, expanding the concept with more information to further increase the predictability of the airport and the network. TAM has a broad scope and focuses on top-down, centralized concepts such as the APOC. Opposite to this centralization, limited focus has been on decentralized improvements. Turnaround coordinators at the aircraft are more proactive and knowledge driven when managing the TOBT than operators in a control centre. Strengthening the information position of these proactive turnaround coordinator can therefore be an alternative approach in expanding A-CDM. Groppe, Pagliari and Harris have shown the importance of good interface design and how human factor issues should be kept in mind at all time when designing an information tool. This research will therefore address these human factors by applying a full CWA. Since a full CWA is conducted, the CWA theory is discussed in the second section of this chapter.

2.2. Cognitive Work Analysis

CWA is a formative approach which has been developed in the 1970's by the Riso National Laboratory in Denmark to guide the analysis of human-information interaction in order to design new information systems [33]. Vicente developed the widely used CWA method which consists of five steps [52]. The method follows an ecological approach, zooming in from the constraints set by the environment (ecological) to the constraints of worker competencies (cognitive). Each layer inherits the constraints of the previous step, constraining the number of possibilities for action further.

2.2.1. Step 1: Work Domain Analysis

A Work Domain Analysis (WDA) is a logical first analysis since it defines the system boundary, its parts and the interactions between these parts. The tool for conducting a WDA is an abstraction decomposition diagram. An abstraction decomposition diagram has two orthogonal dimensions: the abstraction dimension and the decomposition dimension. In the abstraction dimension the work domain is structured in an abstraction hierarchy diagram with five levels, as can be seen in figure 2.2. The abstraction hierarchy diagram is constructed by first defining the functional purpose of the domain and the physical functions available in the domain. With these first and last levels set, asking the "why" question, one works up from the object related processes and by asking “how?” one works down from the functional purpose level, creating means-ends links between the levels [34]. The decomposition dimension structures the work domain on three levels of resolution, from whole system via subsystem to components. In general, not all 15 field of the abstraction decomposition diagram are filled. Workers tend to adopt purposive models at a whole level and physical models at the components level, moving diagonal through the diagram. These levels are therefore recommended to be filled in [36].

	Whole System	Subsystems	Components
Functional Purposes			
Values and Priority Measures			
Purpose-related Functions			
Object-related Processes			
Physical Objects			

Figure 2.2: Generic abstraction decomposition diagram[36].

2.2.2. Step 2: Control Task Analysis

The Control Task Analysis (CTA) is closely linked to the work domain. The work domain provides information to the control task, which acts on the work domain to achieve its system (sub) goals. The CTA is constraint based, it specifies what constraints must be dealt with to achieve the control task reliably and effectively [52]. It does not provide an idealized sequence of tasks, actors can develop their own ways of carrying out the tasks. The control task analysis uses the template of the decision ladder, of which the basic structure is shown in figure 2.3. The decision ladder shows a basic linear sequence that goes from perception (left side) to decision making (top) to action (right side). Each information processing activity (rectangles) result in a state of knowledge (round rectangle) which is input for a new information processing activity. One can walk the entire ladder to get from activation to execution but a cognitive activity can also start at a different point in the ladder (at the target state for example when starting a system). Experts are known to take shortcuts while moving through the ladder. Experts can for example observe the work domain and perceive the information immediately as a task, taking a shortcut from the observe activity straight to the task state of knowledge. These shortcuts always take place between an activity and a knowledge state (see figure 2.3. Besides shortcuts, experts can also take leaps (which are not shown in figure 2.3). Leaps connect two circles in the decision ladder since an expert associate one state of knowledge directly with another one (for example knowledge state and task).

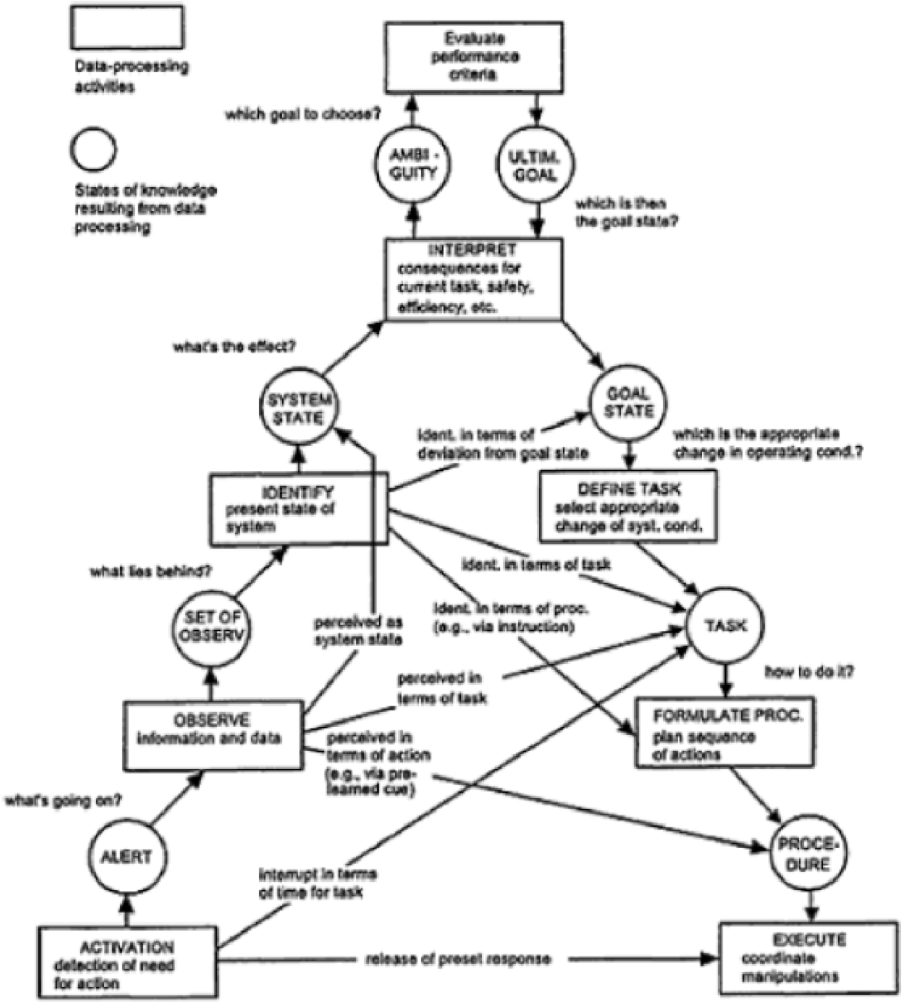


Figure 2.3: Basic structure of a decision ladder [52]

2.2.3. Step 3: Strategies Analysis

The CTA identified numerous tasks together with their input and output knowledge states. The tasks themselves remain a black box. These black boxes are the research area for the strategies analysis. For each of the control tasks identified in the CTA, often multiple strategies can be applied to go from the same input to the same output. Actors can select a strategy based on their competencies or the context in which the control task needs to be carried out. Actors can also switch between different strategies when one strategy is taking to much resources to carry out. Strategies analysis focuses on these possible and effective strategies to complete a task. This strategy analysis is conducted using Information Flow Maps (IFMs) as a modeling tool. These strategies are actor independent, they are not allocated to a specific worker or automation. This allocation is the topic of the next step (social organization and cooperation analysis).

2.2.4. Step 4: Social Organization and Cooperation Analysis

Where the strategies analysis focused on the how, the Social Organization and Cooperation Analysis looks at the identified tasks and strategies and focuses on the possible allocation between different actors. The goal of this analysis is determine how the social and the technical aspects of a sociotechnical system can work together to increase system performance. Rasmussen has established 6 criteria for governing this division of work [41]. All three previously used modeling tools (Abstraction-decomposition space, Decision ladder and IFMs) can be used as a tool for this analysis.

2.2.5. Step 5: Cognitive Competencies Analysis

This final analysis is conducted to identify the level of cognitive behaviour required by the actors to effectively conduct the tasks allocated to them in the previous Social Organization and Cooperation Analysis. This analysis is carried out using the skills, rules, knowledge (SRK) taxonomy. A SRK taxonomy describes for each information processing step how an operator may carry out this step using skill-, rule- or knowledge-based behaviour [34]. Figure 2.4 shows the basic distinction between these three types of behaviour [34]:

- Skill based behaviour requires the least amount of cognitive resources since it is based on highly integrated patterns of behaviour which are conducted automatically. An example of this kind of behaviour is braking on your bike when a person suddenly crosses the street in front of you.
- Rule based behaviour is characterized by the recognition of a familiar work situation and the application of a set of formal/informal rules. By recognizing a situation and applying these rules an operator does not need to understand the underlying system in order to preform rule based behaviour. An example of this is braking when a traffic light turns red.
- Knowledge based behaviour requires the highest cognitive workload of the three types of behaviour. It requires fundamental knowledge of the system, which needs to be analyzed and assessed against a set of goals. Knowledge based behaviour has to be deployed when a new or unexpected situation arises, since the operator then can't act on the signs given by the system. An example of this knowledge based behaviour is assessing if you can cross a road on your bike while being on the wrong side of the road.

An interface which accommodates all three of these levels of behaviour is called an ecological interface. An ecological interface does not force cognitive control to a higher level than the task requires, but the interface does accommodate all three types of behaviour: skill and rule based behaviour for expected situations and knowledge based behaviour for unexpected situations [52]. The SRK inventory therefore provides a first set of requirements which the design of a ecological interface should accommodate.

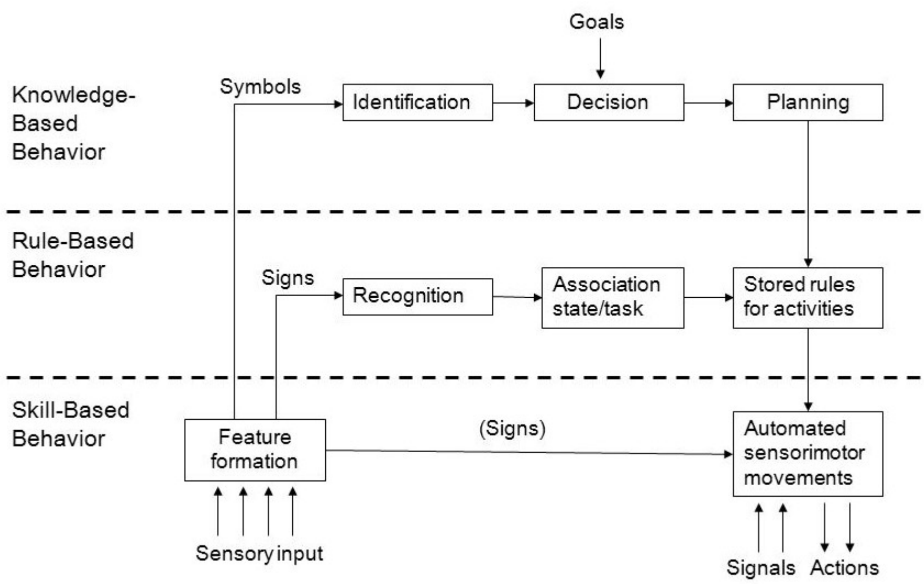


Figure 2.4: The flow of information between different levels of cognitive control [40]

This section has provided a walk trough on how a CWA is conducted. In part 2 a CWA is conducted on turnaround coordination to get a deeper insight into TOBT management and a possible ecological interface. Before the CWA is conducted the first part will elaborate on the current practice of TOBT management at BRU.

3
Part 1: The current practice of TOBT management

The goal of this first part is to get an insight into the current situation at BRU and answer the first sub question: which processes in the turnaround are the main causes for last minute TOBT updates and how does a turnaround coordinator establish a TOBT update? To answer this sub question, first, data from a set of delayed flights at BRU is analyzed. This data analysis provides a high level overview of processes which cause TOBT updates. After the data analysis, a descriptive field study on the current practices in turnaround coordination at BRU is conducted. The field study provides detailed information on how turnaround coordinators establish TOBT updates.

3.1. Analysis of delay code data

An aircraft is delayed when the Actual Off Block Time (AOBT) occurs later than the Scheduled Time of Departure (STD). The cause of a delay is reported by the turnaround coordinator via a delay code. These delay codes are established by the airline based on the IATA (International Air Transport Association) standard. A flight can have up to three delay codes when the delay had multiple causes (for example 60 minutes due to late arrival of the aircraft and 10 minutes due ATC delay). Since each airline has it's own deviations from the IATA standard, Brussels Airport Company (BAC) translates all the different delay codes of the airlines to BRU delay codes (which closely resembles the IATA standard) so they can be combined in statistics. Figure 3.1 gives an example of why these BRU codes are needed.

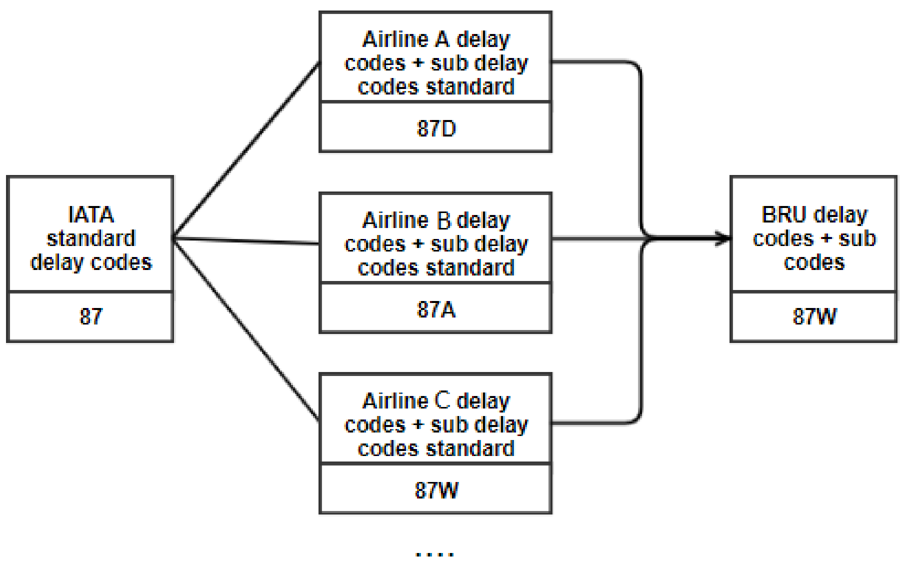


Figure 3.1: IATA codes, Airline codes and BRU codes for reporting a delay due to gate limitations (own creation)

Some of the delay codes are broadly defined with multiple causes of delay. The system of sub delay codes (main delay code with an additional letter for a sub category) is needed to carry out in-depth analysis. Restrictions at the airport of departure (delay code 89) is for example a broadly defined delay code which mainly involves ATC. It therefore has over 10 sub codes (89K, 89L etc.) which are linked to more precise causes surrounding ATC. However, these sub codes are not used on a regular basis by turnaround coordinators when reporting a delay: of the delay code 89 reports only 13.3% were reported with a sub delay code. Sub delay code usage varies per airline and is not a standard practice at the airport. How a turnaround coordinator reports a delay also depends on the airline. It is noteworthy that for flights of Brussels airlines the turnaround coordinators often write comments on the delays during the turnaround. An example of such a comment: "*towing on time but late AOP as boarding bridge wrongly positioned by Aviapartner (TWI456/04aug) = acft on pos at 0900 = late clean*". At all the other airlines there are no comments made.

The data analysis uses the sub-delay codes and comments when this is of sufficient quality and quantity. At some parts it will however remain on the higher level of main delay codes. Each analysis will clearly state what level is chosen and why.

3.1.1. Notes on the delay code system

According to Groppe, Pagliari and Harris, operators at the action level are not keen on sharing their failures because there is often a penalty system connected to the delay code system. This involves financial penalties for the actors who are identified as being responsible for the delay. It can therefore be questioned if it is possible to reach a level of mutual trust in which all information, including the reason of delay, is shared[27]. Brussels Airlines evaluates the delay codes on a daily basis, checking their validity. Of the 1525 flight of Brussels airlines which issued a delay code in the three months, 55 flights had delay codes which, when reviewed, were assessed as invalid. This means 3,6% of the delayed Brussels Airlines flights were assigned an invalid delay code. Invalid delay codes where mainly referring to bus boarding (delay code 87D) and reduced mobility (delay code 19). Post ops remarks made by Brussels Airlines show that in 18 occasions late buses were blamed while the process at the gate itself was actually the bottleneck. In the delay code data, it was reported on 16 occasions Axxicom caused a delay when offloading passengers with reduced mobility. Axxicom on its turn contests being the cause of the delay, putting blame on late inbound flights or the large amount of PRMs.

These observations show that the delay code system is not a perfect system. Not all airlines apply the same checks in the same way as Brussels Airlines.This can have an effect on the data sample used in this analysis. It is impossible for this research to further validate the delay code data. With the differences in the used delay codes and the 3,6% rejection rate at Brussels Airlines the effects of possible misuse is estimated as small.

3.1.2. Data sample

For the analysis of delay codes, a data sample of all reported delays at BRU in the months August, September and October 2017 was used. The analysis focuses on scheduled and charter passenger flights (flight categories C, G and J), with more than 4 minutes delay. Although the international standard for delay is 15 minutes, the minimum for this research is placed much lower at 4 minutes. This much lower value has been chosen since the impact on the CDM system can already be significant when less than 15 minutes delay is encountered. CDM procedures require ground handlers to communicate any change to the TOBT by +/- 5 minutes, this 5 minute margin can also be found in other CDM procedures. To account for the rounding off of time, 4 minutes is chosen as absolute minimum for this analysis.

Table 3.1 shows the amount of delayed passenger flights reported in the delay code system and the total amount of passenger flights in the three months under analysis. Delays are a daily occurrence at an airport, in the three months under analysis there were on average 45 delayed flights a day (std. dev. = 12), with the average delay of a flight being 22 minutes (std. dev = 6).

Table 3.1: Passenger flights and delayed flight reported at BRU [15]

	August	September	October	Total
Passenger flights	19.100	18.870	18.139	56.109
Delayed flights in sample	1208	1384	1532	4124
Percentage delayed flights	6.32%	7.33%	8.45%	7.35%

3.1.3. The main causes of delay

The 4124 analyzed flights gave 6612 causes for delay via the delay code system. Table 3.2 shows the top 10 delay codes which were reported the most as a cause for delay. Besides the report frequency, table 3.2 also shows the total amount of delay in minutes created by the cause. These top 10 causes account for 90% of all reported delay causes. Apart from delay 34 (aircraft cleaning) these most reported delays also cause the highest amount of delay in minutes. Table 3.2 does not present the average minutes delay per declared delay code. These values can be found in table B.1 in appendix B. This table shows that most of the delay codes have a large standard deviation, making the averages unreliable.

Table 3.2: Top 10 reported causes of delay retrieved from data sample

Delay code	Definition	Reported as a cause	Total minutes delay caused
89	Restrictions at airport of departure (ATC)	2426 (36.7%)	16286 (17.7%)
93	Late arrival of aircraft from another flight	1208 (18.3%)	30880 (33.7%)
87	Airport facilities	625 (9.5%)	8606 (9.4%)
85	Mandatory security	524 (7.9%)	7278 (7.9%)
19	Boarding/deboarding passenger with reduced mobility	407 (6.2%)	4744 (5.2%)
86	Immigration, costums and health	403 (6.1%)	9671 (10.5%)
16	Commercial publicity / Passenger convenience / VIP	142 (2.1%)	1261 (1.4%)
81	Air Traffic Flow Management en-route capacity restrictions	111 (1.7%)	1724 (1.9%)
91	Awaiting load from another flight	83 (1.3%)	1495 (1.6%)
35	Aircraft cleaning	81 (1.2%)	654 (0.7%)

A clear division is observed in the top 10 between the top six and bottom four, based on the number of times delays are reported as a cause and the amount of minutes delay are caused. These bottom four are therefore not classified as a main cause for delay. Figure 3.2 gives an example of how the top 6 delay codes effect the schedule of a turnaround. The example uses a standard turnaround on an A320 [1](the most operated type at Brussels) and a delay of 5 minutes for each delay code.

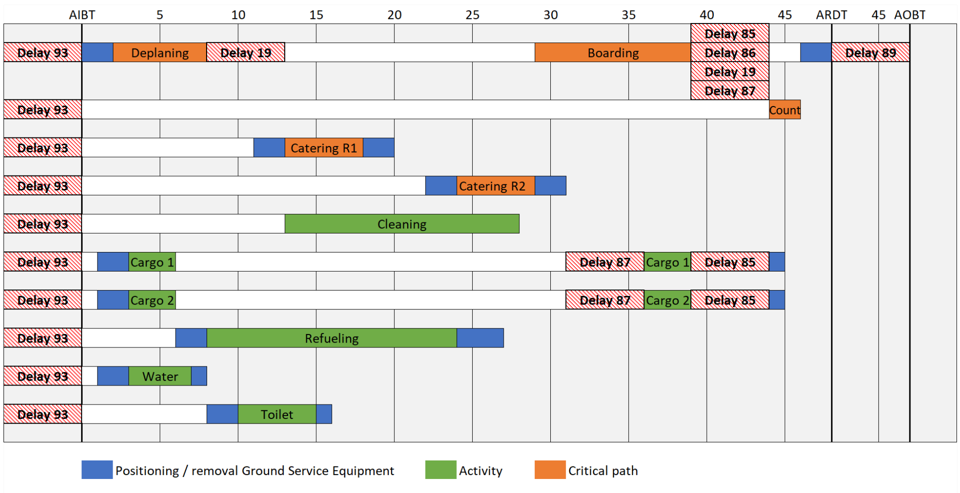


Figure 3.2: Example of were delay codes take place in the turnaround (own creation)

Based on figure 3.2 it is concluded that the top cause of delay, delay code 89, falls outside the direct scope of this analysis. Delay code 89 occurs after the ground handling is finished, and is therefore not a delay on which the turnaround coordinator has to anticipate by updating the TOBT. The late arrival of the aircraft (93) is a delay which requires the turnaround coordinator to update the TOBT. But this event occurs at the very beginning of the turnaround. This analysis focuses on the delays which can cause a TOBT update last minute. This demarcates the research to delay codes 87, 85, 19 and 86. The following sections will focus on these delay codes individually. By looking at the sub codes (if applicable), comments (if applicable) and flights which often report the delay codes, a deeper understanding of these delays is created. Supporting tables and graphs of this analysis can be found in appendix B.

3.1.4. Delay 87: Airport facilities

Delay code 87 is used to report airport facilities as the cause of a delay. Brussels airlines is the only large airline which reports on a sub level. Table B.3 in appendix B presents the 214 reported delays by Brussels Airlines in category 87. As can be seen in the table, delay 87 is a diverse category which includes all kinds of problems. Two kinds of causes are identified within delay code 87. The first category is a category of unfortunate events causing a delay. These are breakdowns of equipment such as an unserviceable Departure Control System / gate reader, baggage system failures, unserviceable Aerobridges, electrical system failures or lighting. These events are difficult to predict or steer on by a turnaround coordinator, which places them outside the scope of this research.

The second category of delays is within the scope of the study. These are delays due to capacity problems, such as late / lack of passenger transport, apron congestion, parking stands not available, congestion at crew screening and no push-back clearance. Based on the Brussels Airlines data the late and lack of passenger transport is identified as a frequent cause of delay when it comes to infrastructure. Transporting passengers by bus between the aircraft and the gate places a bottleneck on the boarding process. By analyzing the comments made by turnaround coordinators, multiple ways in which buses delay the turnaround are identified:

- The boarding process depends on the availability of the buses and drivers. On several occasions turnaround coordinators placed a comment that the bus operator did not supply enough drivers/buses for a flight. 40% of bus delays reported at Brussels airlines are made by flights with an STD between 9:00 and 10:00. One post ops remark noted that the bus operator had 36 task in between 09:00 and 09:30 for only 22 drivers, which emphasizes the driver shortage during this peak hour.
- The buses have to drive over the apron, which can cause delays due to congestion airside.
- When passengers are brought to the aircraft by bus, the last bus has to wait for the last passenger(s). This means the last passenger(s) determines the arrival time of a much larger group of passengers at the aircraft, increasing the boarding time considerably.

The Ryanair flight to Rome (FR2983) is a good example of a flight which suffers from this last problem. FR2983 is part of the large majority (80 percent) of Ryanair flights who conduct their turnaround at walk-to-stands (WTS) 126, 134, 136 and 138 (see figure B.2 in appendix B). As the name already shows, these are remote stands where passengers can walk over a pathway between the gates under the A-pier and the aircraft (see figure 3.3). The Ryanair flight to Rome reports delays due to airport facilities on 13% of its flights. At all these occasions the flight was not on one of the WTS but on the remote stand 122, right next to WTS 126 (most right stand in figure 3.3). Stand 122 requires passengers to be transported by bus. With Ryanair's short turnaround of 25 minutes this bus boarding causes a delay for this flight.

Figure 3.3: Walk-to stands 126, 134, 136 and 138 and bus boarding stand 122 (source: Google Earth)

The short Ryanair turnaround also causes other airport facility related delays. Table B.4 in appendix B shows that three Ryanair flights to Dublin account for over 21% of all delay code 87 reports. Due to their non-schengen destination, the three Dublin flights don't depart from the walk-to-stands but from gates at the B-pier. At the B-pier the Ryanair flight use contact stands where passengers board via an aerobridge (as shown on the left in figure 3.3. For other airlines at the B-pier this is a service to their customers and no operational problem. But, as can be seen in figure B.1 in appendix B, these other airlines have on average 60 minutes turnaround time scheduled, while Ryanair schedules the same 25 minutes as on a WTS. Ryanair often can't conduct this quick turnaround at these contact stands because the boarding capacity of an aerobridge is lower than those of two stairs at a WTS. The airport infrastructure is therefore reported as the cause of the delay. By scheduling the absolute minimal turnaround of 25 minutes for these Dublin flights, the airline sets a difficult target for ground handling. When the aircraft is in block and the initial TOBT is set to AIBT + 25 min, the analyzed historic data shows that this TOBT will almost definitely require another update because it can not be met. Since boarding is the last process, this TOBT update is likely to take place in the last 10 minutes, causing disruptions.

The analysis of delay code 87 has shown that there are several uncontrollable and unpredictable events which can delay a turnaround. Besides these uncontrollable events, boarding by bus is identified as a cause of delay when preforming a turnaround. The analysis of the Ryanair flight has shown that airline policies can create unrealistic schedules which result in last minute TOBT updates.

3.1.5. Delay 85: Mandatory security

Strict procedures apply at the airport in order to safeguard flights from unlawful interference. These procedures can cause aircraft delays in a multitude of ways. Security related delays are therefore not concentrated to a specific set of flights: over 280 different flights reported security related delays in the three months analyzed.

The BRU sub codes on delay 85 did not provide a complete insight into the causes of delay since most reports were made only on the main category. By using the different airline delay code systems and the BRU delay codes the different causes in table 3.3 were identified. Even though most flights are still reported on the general level the main cause of delay is identified as baggage reconciliation. Baggage reconciliation procedures state that airlines can't transport baggage of passengers who are not on board of the aircraft[32]. This means that when the flight is nearing its scheduled departure time, missing passengers need to be identified from the passenger records to check if they have checked-in baggage. When this is the case and the airline does not want to wait, the ground handlers have to offload the bag(s) from the aircraft before it is allowed to depart.

Table 3.3: Causes for delay involving security (retrieved from data sample)

Delay cause	Reported	Percentage
Mandatory security (general)	367	67%
Baggage identification / unloading due to missing pax	113	21%
Congestion at security checkpoint	46	8%
Special security inspections	24	4%

The process of finding and offloading baggage is unpredictable. It for example depends on how the baggage is loaded (by piece or by ULD), how far the loading is completed when searching starts and the location of the baggage in the hold. On average the identification and unloading of baggage caused a delay of 14 minutes, but a standard deviation of 11 minutes shows that this is not a stable number. The comments made by turnaround coordinators show that the baggage identification and unloading can sometimes takes so much time that in the meantime the missing passenger is located and the process is stopped. Figure B.3 in appendix B shows that baggage identification and unloading often occurs during the morning hours between 9:00 and 11:00. These are peak departure hours at BRU, as is shown in figure A.3 and figure A.4 in appendix A. Flights departing in this time window often have large amounts of connecting passengers which have arrived in the early morning. The comments made by turnaround coordinators also show that in most cases the missing passengers are not local but transferring at BRU.

Although many flights only report security delay on the main delay code, baggage reconciliation has been identified as a common cause of delay in the turnaround. Missing passengers, mostly transfer passengers, naturally arise late in the turnaround and trigger a unpredictable process of identifying baggage which is already loaded on the aircraft. The timing and unpredictable duration of this process makes it a cause for last minute TOBT updates.

3.1.6. Delay 19: Boarding/deboarding passenger with reduced mobility

Passenger with reduced mobility (known as PRMs) have the right to special assistance at the airport. The majority of PRMs are in a wheelchair and therefore require some level of assistance. In general there are three levels of assistance: assistance to the aircraft for passengers with a walking disability (WCHR), assistance to the aircraft door for passengers with a severe walking disability (WCHS) and assistance to the aircraft seat for passenger who are unable to walk (WCHC). Each class requires its own set of special equipment to board and deboard an aircraft. Brussels Airport is responsible for offering this service and has outsources the operation to Axxicom Airport Caddy. PRMs need to apply for assistance 48 hours before their flight via their airline and indicate the required assistance. This means the airline, turnaround coordinator and Axxicom all know in advance who the PRMs are on board of a flight and what kind of assistance they require.

PRMs occur on every flight, over 188 different flights reported PRM boarding problems. The BRU delay code 19 does not have any sub codes which can give a better insight into the root causes of PRM delays. Several airlines do use their own sub codes, which give some insights. Half (45.2%) of the reports could not be interpreted using an airline sub code, as can be seen in table 3.4. Table 3.4 shows that both the boarding and deboarding of a PRM often takes more time than expected. When there are groups of PRM this logically takes even more time. But the main identified cause of delay is the late arrival of PRM staff to deboard/board the PRM. Comments show that gate agents often call Axxicom dispatch to get an update off PRMs staff for their flight but this communication is often troublesome.

Table 3.4: Causes of delay involving PRM (retrieved from data sample)

Delay cause	Reported	Percentage
PRM (General)	189	46.2%
Slow deboarding	40	9.8%
Slow boarding	37	9%
Late / lack off PRM staff	98	24%
Difficulty in handling / PRM group	41	10.02%
Breakdown / lack of ambulift	3	0.73%

PRM handling is a process which requires high care. This is often difficult to combine with the limited time available in the turnaround. The handling time of PRMs is difficult to standardize, making it an uncertain process. Combining this with an external handling party creates an uncertain environment for a turnaround coordinator to assess the progress.

3.1.7. Delay 86: Immigration,customs and health

Although the definition of delay code 86 includes customs and health, the main focus is on immigration. Both health (sub code 86X) and customs (86Y) have less than a hand full of reports contributing to the statistics in table 3.2. At BRU, Non-schengen flights arriving and are located at gates in the B-pier while the Schengen flights are handled in the A-pier. An overview of the terminal is shown in appendix A. The third pier, the T-pier, is a special case. It is not really a third pier but part of the A-pier which, in the morning, is swept clean and used as a non-schengen area for several flights to Africa. The rest of the day the T-pier is part of the Schengen zone A-pier. This means there are two immigration checkpoints at BRU: at the entrance / exit of the B-pier and between the A-pier and T-pier when it is in use. Of the 400 reports of passengers being delayed by immigration, 40% is caused by congestion at the T-pier entrance, 40% by the entrance of the B-pier and 20% by congestion for leaving the B-pier towards the A-pier.

Brussels Airlines suffers the most from delays caused by congestion at the immigration checkpoints. This is logical since it also operates the largest amount of non-schengen flights at BRU. 10 Brussels airlines flights together account for 47% of the delay 86 reports (see Table B.7 in appendix B. The top 6 flights (based on percentage of flights) delayed flights are flights to Africa which departing from the T-pier. With immigration congestion reported by these flights on 60 out of the analyzed 92 days, immigration at the T-pier is a serious cause of delay on the Africa flights. Two Paris flights are often delayed by transferring passengers as well. These passengers arrived at the B-pier and were held up at immigration when trying to transfer between the B-pier and the A-pier. When looking at comments made in the delay code reports and the airport time table, it is concluded that a part of these transfer passengers are from the troubled Africa flights. Comments at several flights mentioned that the Paris flights had to wait for passengers from Africa flights SN204, SN372 and SN358. Passengers from these flight deboard the aircraft at the B-pier after which the aircraft is towed to the T-pier for boarding as SN205, SN371 and SN359.

On several occasions (+/- 20 flights) Brussels Airlines delayed an Africa flight by 30 minutes in advance to anticipate on immigration congestion. This delay is always set with 30 minutes and after these 30 minutes passengers are often still not at the gate. This indicates that these delay settings are not based on continuous monitoring of the immigration process. The only option gate agents have for monitoring the progress at immigration is by physically going to the checkpoints to observe it. Ground handlers also report several occasions when they were missing passengers which turned out to be held by the federal police. Not sharing this information caused additional delay.

This analysis show that immigration, especially at the T pier crossing, is a serious cause of delay and that it is currently difficult to anticipate on this by a turnaround coordinator since information is not shared/available in a standardized way.

3.1.8. Ground handler responsibility

For all the filed delay codes, BAC has determined which actor carries responsibility. This results in the overview in table 3.5. The table shows that airlines are responsible for most delays. This is mainly since airlines are responsible for late inbound flights (delay code 93), which is an often occurring delay. The ground handlers only cause a fraction of the delays at BRU. The turnaround coordinator standing next to the aircraft can only have a direct sight on most of these ground handling delays. The other delays, as also mentioned in the previous subsections, happen outside of his direct surroundings: inside the terminal, in the air, in the tower or at a control centre. This again emphasizes the difficult task of the turnaround coordinator: manage a precise TOBT while most of the causes of a possible delay happen outside your direct line of sight and control.

Table 3.5: Minutes delay and reported delays allocated to responsible actor (retrieved from data sample)

Actor	Minutes delay	Delays
Airline	40057	1786
Brussels Airport Customer and passenger services	21141	1281
Belgocontrol ATC	16286	2426
Brussels Airport security	6635	478
Handler	3299	330
Air Traffic Flow Management	2462	156
Brussels Airport stand and gate allocation	744	56
Brussels Airport ICT	464	43
Brussels Airport infrastructure and real estate	371	27
Brussels Airport airside inspection	301	28

3.1.9. Conclusions from the analysis of delay codes

This analysis used a data sample of all reported delays at BRU in the months August, September and October 2017 to gain insight into the complexity of the turnaround and the different elements which can cause a delay. The analysis conducted has shown that a lot can set a turnaround of schedule, causing TOBT updates. Main causes of disruption in the turnaround which were identified are: Passenger transport to/from the aircraft by bus, unrealistic airline policies, the identification of bags due to a missing passengers, handling of passengers with reduced mobility and congestion at immigration. Most of these causes happen outside of the turnaround coordinator's direct line of sight and control and pop up late in the turnaround. This makes communication with other stakeholders important.

3.2. Field study: TOBT management on the ground

After having identified several processes as causes for last minute TOBT updates, this second part analyzes how a turnaround coordinator establishes a TOBT update. This is done with a descriptive field study of turnaround coordination at BRU. Currently there are two ground handling companies active at BRU (excluding ground handling companies who only handle cargo flights): Aviapartner and Swissport. Swissport provides services to Brussels Airlines (the largest carrier at Zaventem) and 30 other airlines including United and Lufthansa. Aviapartner services 27 airlines including Ryanair, British Airways and TUI Fly [2].

3.2.1. Structure of the field observations

At both ground handlers a turnaround coordinator at the aircraft decides when the TOBT needs to be updated. When a turnaround coordinator wants to update the TOBT he calls the flight watcher at the operations center, who then enters the update into the CDM system. Observations were conducted at both ground handler companies to get a complete view on TOBT management at BRU. At both companies the flight watchers and the turnaround coordinators were observed. This setup was chosen since it provides a mix of both quantity and quality.

At flight watch the TOBT management of flights was observed via flight information systems and camera displays. This resulted in a high number of observations, but on a high level. 8 turnarounds were observed in detail by following turnaround coordinators during the turnaround. These observations occurred at a detailed level, focusing on the tasks of the turnaround coordinator, the information which they use and how they establish the TOBT update. The environment of each observation is different: observations were done at flights of 6 different airlines with 6 different turnaround coordinators. By having this changing environments a broader range of behaviour was observed which helps in identifying common practices. Extensive reports on the field observations can be found in appendix C.

During the observations at flight watch 80 turnarounds were observed. These 80 turnarounds resulted in 36 observed TOBT updates. Another 11 TOBT updates where observed during the detailed observations. Observations were made on the moments when turnaround coordinators updated the TOBT and the magnitude of the update. Figure 3.4 shows when the observed updates were conducted on the X-axis. The number of minutes by which the TOBT was updated is shown on the Y-axis. Figure 3.4 shows that most observed updates (40%, orange) were conducted in the last 10 minutes before the TOBT and 20% (red) of the observed updates were conducted at TOBT. These observed TOBT updates confirm the trend shown in figure 1.4 in the introduction. 28% (dark red) of the updates were conducted after the TOBT had expired. This is even worse then a last minute update since this definitely caused losses in efficiency. TOBT updates are also kept rather small: in 46% of the observations the TOBT was updated by only 5 minutes.

During the observations, the reason for the update (if given), the communication in the turnaround and the communication between the turnaround coordinator and flight watcher were observed. Using this information, the rest of this section will highlight several important observation made on TOBT management in practice.

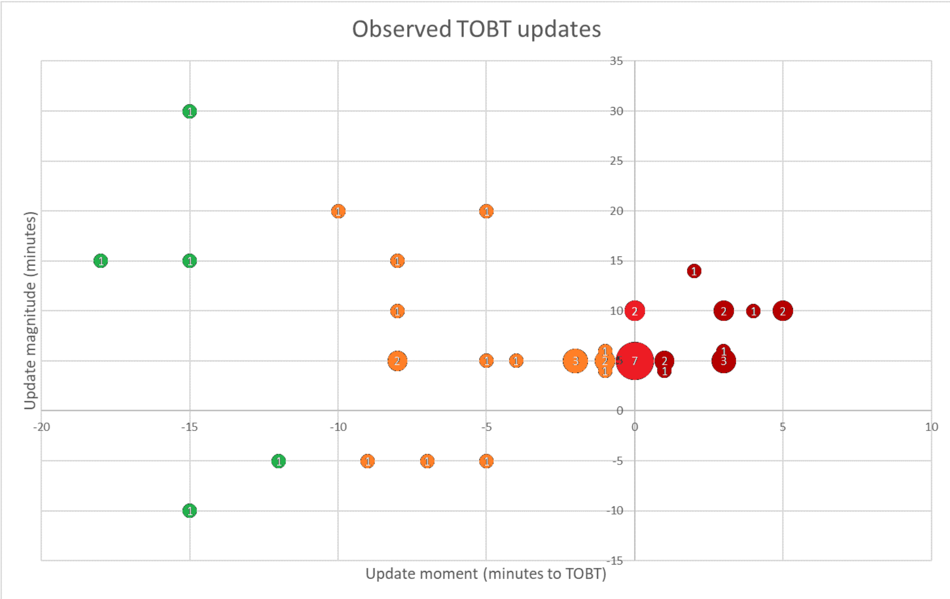


Figure 3.4: Amount of TOBT updates observed set out on time and magnitude

3.2.2. TOBT management is one of many tasks

TOBT management is perceived by the turnaround coordinators as only a small task within turnaround coordination. When introduced to the research, one turnaround coordinator was surprised by the focus area. He stated: *"TOBT updating is only 5% of my job"*. Although not measured precisely, it was observed that turnaround coordinators for the majority of the turnaround are conducting other tasks instead of managing the TOBT. After having positioned the passenger boarding bridge (if applicable) the turnaround coordinator's primary focus is on the load sheet. This task involves checking the load sheet, providing the loaders with instructions, checking their work and delivering the final load sheet to the captain. This is an important task with regard to safety and is therefore conducted with highest priority and precision. The load sheet and several other tasks require the turnaround coordinator to almost constantly move between the aircraft, the apron and his office.

While moving around, TOBT management is often conducted on the side by observing the progress of the turnaround on a high level. This high level observation is mainly conducted by observing the ground service equipment surrounding the aircraft. The presence of this equipment gives an indication of tasks which are being conducted. When no abnormality is identified, this high level observation can continue for the whole turnaround. This allows the turnaround coordinator to carry out other functions in parallel, such as checking the load sheet. However, this high level observation does cause turnaround coordinators to identify delays later.

Measuring workload is an extensive undertaking. First of all, there is the issue of definition, what is workload? Some definitions of workload only consider workload as something physical while other definitions focus more on mental activity or time pressure. There are several techniques for measuring the workload of an operator, such as performance measures, indirect measures, subjective measures and physiological measures [11]. However, these techniques are not applied easily. Measuring the workload of the turnaround coordinator was not a goal when the observations were set up. Therefore, the workload of the turnaround coordinators was not measured using a formal technique. However, by following the turnaround coordinators step by step and by conducting multiple turnarounds on one day, the observations have developed a general insight into the workload of turnaround coordinators. Based on these observations, the workload of the turnaround coordinators is assessed as high. This workload is high due to the combination of physical workload (moving between aircraft, apron and office), the mental activity (working out the load sheet, assessing turnaround progress and more) and the constant time pressure of the airline schedule.

3.2.3. Information has to be pulled and processed

During a rotation, there are a variety of actors working in and around the aircraft, such as: Pilots, cabin crew, airline representatives, gate agents, fuel suppliers, cleaners, PRM handlers, baggage/cargo handlers and a push back driver. However, these teams of actors don't form a single team in the turnaround. Each team performs the tasks they are contracted for by the airline and then depart. The turnaround coordinator works as an individual in the turnaround. He prepares the flight by himself, drives to the apron and conducts his tasks by himself. When conducted according to planning, most processes can be carried out without the turnaround coordinator interacting with the involved actors. Interaction between the turnaround coordinator and the catering crew and fuel supplier was for example never observed since they did not cause a delay. However, when there is a delay it is up to the turnaround coordinator to identify this delay. During the detailed observations it was observed that for example gate agents do not call the turnaround coordinator with the number of passengers which still need to board or a cleaner does not inform the turnaround coordinator of his progress. The turnaround coordinator has to actively pull this information out of the turnaround.

The turnaround coordinator also does not actively involve other parties into his coordinating task. It was observed that when turnaround coordinators pull information from the turnaround they never ask the other actors in the turnaround for their estimated time needed. Turnaround coordinators observe or ask what these actors still need to do (how much bagsto be loaded, pax to be boarded) and then make the estimation on time needed for himself. In calculating these times, turnaround coordinators do not have a document of clear process times per turnaround process as a reference. They work based on their own planning for the turnaround, which they have developed based on experience. Some flight are for example notorious for having slow boarding passengers, which causes the boarding time to be estimated higher than standard by the turnaround coordinator.

3.2.4. The interaction between turnaround coordinators and flight watchers

TOBT management is conducted by the turnaround coordinator located at the aircraft and a flight watcher located at the airport operations center. The flight watcher sets the initial TOBT in the CDM system when the aircraft arrives, using the standard turnaround time. During the turnaround the flight watcher gets the TOBT update from the turnaround coordinator via the radio and after validating it he enters it into the CDM system. During the observation of flight watchers it was observed that this additional person monitoring the turnaround is a safeguard in the system. At multiple occasions flight watchers pro actively called the turnaround coordinator to ask for an update on the TOBT. These calls do not necessarily prevent last minute updates but they did prevent the TOBT from expiring. However, flight watchers monitor multiple flight at the same time and also conduct a multitude of other tasks. With three vocal communication channels and a multitude of interfaces to observe flight watchers often give lowest priority to the incoming TOBT updates. This means the safeguard in the system is not always available

Besides calling the turnaround coordinators for a TOBT update, flight watchers also conduct updates themselves. The flight watcher have a camera display to monitor the process of most turnarounds. When observing at flight watch, 25% of the observed TOBT updates were conducted by flight watchers themselves. At some of the updates the flight watcher tried to call a turnaround coordinator which did not reply. At others moment the flight watcher didn't call at all. Bottom line is that at non of these occasions the flight watcher actively informed the turnaround coordinator of the conducted update. At two of the observed turnarounds it was observed that the TOBT was updated without the turnaround coordinators approval. This annoyed the turnaround coordinators since it had a direct effect on their planning and current tasks.

3.2.5. A culture of last minute updating

Finally, it was observed how last minute TOBT updates are part of the culture at BRU. A turnaround coordinator, again during the introduction of the research, stated: *"TOBT updating? That's only something for the last part of the turnaround"*. This statement is validated by the observations: during both the detailed and high level observations the majority of observed TOBT updates were conducted within the last 10 minutes prior to the current TOBT. During the field study several aspect which contribute to this culture were identified.

At flights of Brussels Airlines, TOBT management is only conducted in the last part of the turnaround due to the airline's policy. An airline and a ground handler sign a Service Level Agreement (SLA) in which they agree which services should be provided and what level of quality is expected against what price. The SLA between Brussels Airlines and Swissport does not require a turnaround coordinator to be at the aircraft for the full turnaround but only for the first and last part of the turnaround. If the turnaround coordinator is only at the aircraft during the last part of the turnaround, TOBT updates will only take place in the last part of the turnaround.

At other airlines the turnaround coordinators are present for the entire turnaround. But even when the turnaround coordinator is at the stand for the entire time, TOBT updating is something for the last part of the turnaround. A comment made by a turnaround coordinator gives one explanation for this behaviour: *"When you update the TOBT early to a later time, the push back truck comes later, but when you update the TOBT again to an earlier moment the push doesn't always come earlier. So better to leave the TOBT as it is and update later."*. Two Turnaround coordinators and a flight watcher stated that they preferred to update the TOBT in small steps. They argued, based on experience, that the chance of getting a slot is lower when you update the TOBT 3 times by 5 minutes instead of 1 time by 15 minutes. This assumption on slots is not true at all. The idea has developed over time and has become an informal rule for turnaround coordinators. The result of these two practices were seen in figure 3.4.

On several occasions it was observed that TOBT updating was avoided completely. These flights were not ready on TOBT, but no update was filed. When called by the flight watchers, the turnaround coordinators stated that they were going to use the TSAT window. When TSAT is equal to TOBT this means that the captain has until TOBT + 5 minutes to call ready. Eventually most of these flights did leave inside their TSAT window, causing no problems to the system. But on one occasion the captain called ready outside his window, requiring a TOBT update while the TOBT was already expired for 5 minutes.

A common aspect in these observations is the influence of the expected costs/benefits of over/underestimation of the TOBT on the new TOBT value. Costs and benefits in this context does not necessarily mean money, but factors such as effort and reputation. Based on the observations and additional conversations it is concluded that the costs for overestimation are generally assessed by the turnaround coordinators as being high. Updating the TOBT to an earlier moment after having overestimated it can cause a start-up delay when the TSAT stays as it was or when the push back truck is not available. The turnaround coordinator then has to explain to the captain that he caused a delay. The costs for underestimation are considered much lower: it only requires an additional TOBT update. Underestimation also has benefits: when the push back is already at the stand it won't go away as long as the TOBT is set short. This trade-off of factors leads to a multitude of small updates.

3.2.6. Conclusions from the field study

During the field study, 47 TOBT updates were observed at a high or a low level. A large majority of these updates were conducted just before TOBT, at TOBT or even after the TOBT had already expired. A combination of causes were identified:

- Turnaround coordinators are responsible for keeping the TOBT up to date. But besides TOBT management a turnaround coordinator has a large variety of other tasks. These tasks require him to almost constantly be on the move, conducting multiple tasks, creating a high workload.
- The other actors in the turnaround further add to the workload of the turnaround coordinator since they don't actively inform him. The turnaround coordinator has to actively pull information out of the turnaround process and make his assessment.
- In processing information, the turnaround coordinator has to rely on his own experience since he does not have clear information on process times to rely on.
- Flight watchers provide an useful additional set of eyes in TOBT management but due to their workload this safeguard is not always available.
- Unstructured communication between the turnaround coordinator and the flight watcher causes TOBT updates to not be communicated effectively.

Besides the information position and the workload, the culture of the turnaround coordinators causes them to report small and last minute TOBT updates instead of larger and earlier updates. Based on the observations it is expected that an improvement of the information position is likely not to change this issue since it is a cultural problem. It is recommended to first measure this behaviour by well defined KPIs and then bring it to the attention of the involved actors to try to change their behaviour, with or without an incentive. Although the development of such KPIs and enforcement schemes is a interesting and valuable contribution to the functioning of A-CDM, it is not within the scope of this study. Besides making the recommendation, the development of KPIs and enforcement schemes will not be pursued further in this research.

3.3. Conclusion on the current practice of TOBT management

The goal of this first part was to get an insight into what processes in the turnaround are the main causes for TOBT updates and into how a turnaround coordinator establishes a TOBT update. The analysis of delay codes showed that the turnaround of an aircraft is a complex process with a lot of different elements which can cause a delay, and therefore a TOBT update. The main causes of disruption in the turnaround which were identified involved the passenger process. Passenger transport to/from the aircraft by bus, the identification of bags due to missing passengers, handling of passengers with reduced mobility and congestion at the immigration checkpoints happen outside of the turnaround coordinator's direct line of sight and control and pop up late in the turnaround. This emphasizes the difficult task of the turnaround coordinator: manage a precise TOBT while most of the causes of a possible delay happen outside your direct line of sight and control. Besides the passenger process, airline policies can create unrealistic schedules which result in last minute TOBT updates.

The field study has shown that there are several factors which further complicate a turnaround coordinators ability to manage the TOBT. Turnaround coordinators have a variety of tasks which create a high workload. The other actors in the turnaround further add to the workload of the turnaround coordinator since they don't actively inform him. Because these actors don't inform the turnaround coordinator, he has to actively pull information out of the turnaround process and make his assessment. In making this assessment, the turnaround coordinator does not have clear information on process times to rely on as a reference. Additional to these problems the culture of the turnaround coordinators also causes them to report small and last minute TOBT updates instead of larger and earlier updates.

Based on this analysis of the current situations it is concluded that there is a need for improvement in the information position of turnaround coordinators regarding TOBT management. Current information channels are not formalized and tasks are allocated to operators who are already experiencing a high workload. The cognitive work analysis in the next chapter will dive deeper into the cognitive processes of TOBT management. The CWA proposes a new division of work and provides the foundation for the design of new information tool.

4

Part 2: A potential improvement in the information position

The previous chapter has shown that there is a need for improvement in the information position of turnaround coordinator when managing the TOBT. This second part will focus on what interface can be designed to improve this information position. In order to achieve this goal, a cognitive work analysis is conducted. After completion, the CWA provides the foundation for the design of new an ecological interface which can support TOBT management. Using this foundation, the second section of this chapter go through several iterations to make a first design of an ecological interface for TOBT management.

4.1. Cognitive Work Analysis of TOBT management

As already mentioned in chapter 2, Cognitive Work Analysis (CWA) is a formative approach to guide the analysis of human-information interaction in order to design new information systems [33]. Where other analysis techniques aim to describe how work is actually conducted, CWA focuses on constraints. By focusing on constraints, a model is build of how work could proceed within a given work system. This constraint based approach allows for the design of new information systems which provide the flexibility required to support workers in complex sociotechnical work systems. This analysis follows the basic templates established by Vicente in his 1999 book on CWA and additional literature by Kilgore, St-Cyr and Jamieson [34] and Naikar [36] when needed. This template was chosen since, contrary to most researchers, it contains a complete CWA and gives clear instructions on the application of the different tools.

In the remainder of this section the five steps of the CWA are applied to the turnaround coordination domain. The method of each step has been introduced in chapter 2. The formative models of the CWA are build using the data from observations in the previous part. Based on the constructed model, conclusions are drawn regarding the layer under analysis. These conclusions also determine the focus for the analysis of the next step. In order to keep the analysis feasible and relevant for this study, the focus is narrowed down in each consecutive step. This means a complete CWA is conducted in depth, but not in the complete width of the turnaround domain. After completion the CWA provides the foundation for the design of new information tool.

4.1.1. An abstraction hierarchy diagram of turnaround coordination

Several keywords which summarize turnaround coordination in job descriptions are: Safety, punctuality, quality, predictability and efficiency [7] [8]. These keywords are not a main goal of turnaround coordination but are several criteria on which can be judged if turnaround coordination achieved its purpose [36]. To get from these values and priority measures level to the higher functional purpose level, the why question is asked. Why does a turnaround need to be safe? Because safety in aviation is a permanent requirement, safety standards are laid down in the license agreement that the ground handling company signs with the airport. Why does a turnaround coordinator need to be punctual? Because that's what he has agreed with the airline in the SLA. Why does a turnaround coordinator need to be predictable? Since BRU is an A-CDM airport all parties at the airport have agreed to work within the A-CDM framework, which requires predictability. And why does a turnaround coordinator need to work efficient? Because ground handlers only have a limited set of resources available to meet the agreed service level. The answers to these why questions show that the ultimate purpose of turnaround coordination is to deliver what has been agreed upon with the airport and airline. The functional purpose of turnaround coordination is therefore formulated as: Manage a turnaround in accordance with the agreements with the airline and the airport.

With the first level and second level set, the lowest level was set in order to fill the base of the abstraction hierarchy diagram. The lowest level is the physical objects level, focusing on the man-made and natural objects in the turnaround. One could go into the smallest details of aircraft chocks, cargo manifests and catering trolleys, but this does not contribute to the usefulness of the diagram. Table 4.1 therefore presents the main categories of physical objects which are included in the abstraction hierarchy diagram and several examples of these physical objects [5] [4].

Table 4.1: Physical objects in the turnaround

Physical objects	Examples
Airline personnel	Pilots, cabin crew, gate agents (when provided by airline), representatives
Central database	Ground handlers own database, Airport BRS, Airline DCS
Ground crew	Fuelling, cleaning, PRM, baggage/cargo handlers, push back crew
Communication tools	Phone, radio, tablet, computer
Ground service equipment	Dollies, chocks, stairs, GPU, loaders, pushback/catering/fuel/water truck
Procedures and planning	Airline service agreement, turnaround planning, company procedures
Payload	Passengers, baggage, ULD's, bulk cargo, food, fuel, water
Aircraft stand	Visual Docking Guidance System, markings, aerobridge
Aircraft	Aircraft doors, cargo doors, wheels etc.
Flight documents	Fuel slip, load sheet, passenger list, flight details
Safety and security regulations	Dangerous Goods Regulation, Airside Safety, Airport security

After these three levels were set, why and how questions were asked to fill the two intermediate levels. Several iterations were made, supported by the field study and discussions with a subject matter expert [20] [28]. This produced the final abstraction hierarchy diagram, presented in figure 4.1 on the next page. The before mentioned keywords (safety, efficiency, quality, predictability and punctuality) can be found at the values and priority measures level. Within the work domain of a single turnaround, all the values and priority measures should be met to comply with the functional purpose. These values and priority measures put constraints on what can and can't be done in turnaround coordination. They also create competition between the different purpose related functions and lower levels in the small time frame of the turnaround. TOBT management is one of these processes in the complex turnaround coordination domain which has to compete with other processes for the scarcely available resources.

Multiple diagrams can be made which decompose the abstraction hierarchy into an abstraction decomposition diagram. Since this research focuses on TOBT management subsystem, this subsystem is decomposed into individual components. Figure 4.2 shows this part whole decomposition. The diagram shows how TOBT management is driven by the purpose to communicate and plan resources. Communication and resources planning are on their turn driven by the values and priority measures of punctuality, predictability and efficiency. The TOBT is a target which should be met for a punctual departure of the aircraft. When a delay occurs it is important to update the TOBT in order to remain predictable for other stakeholders. When the turnaround is ahead of schedule the TOBT should also be updated to translate this into a earlier departure.

The diagram also shows the five components of TOBT management which were identified in the field study. The turnaround needs to be monitored to gain insight into its progress. The progress of the turnaround then needs to be compared to the current TOBT to assess its validity. When the TOBT is no longer deemed valid, a new TOBT needs to be established. The TOBT update needs to comply with CDM rules and airline rules before it can be filled. Once validated, the TOBT update is filed in the central database in order to communicate the update to the other airport stakeholders. These components require interaction with many different physical objects scattered over the apron and it's surroundings.

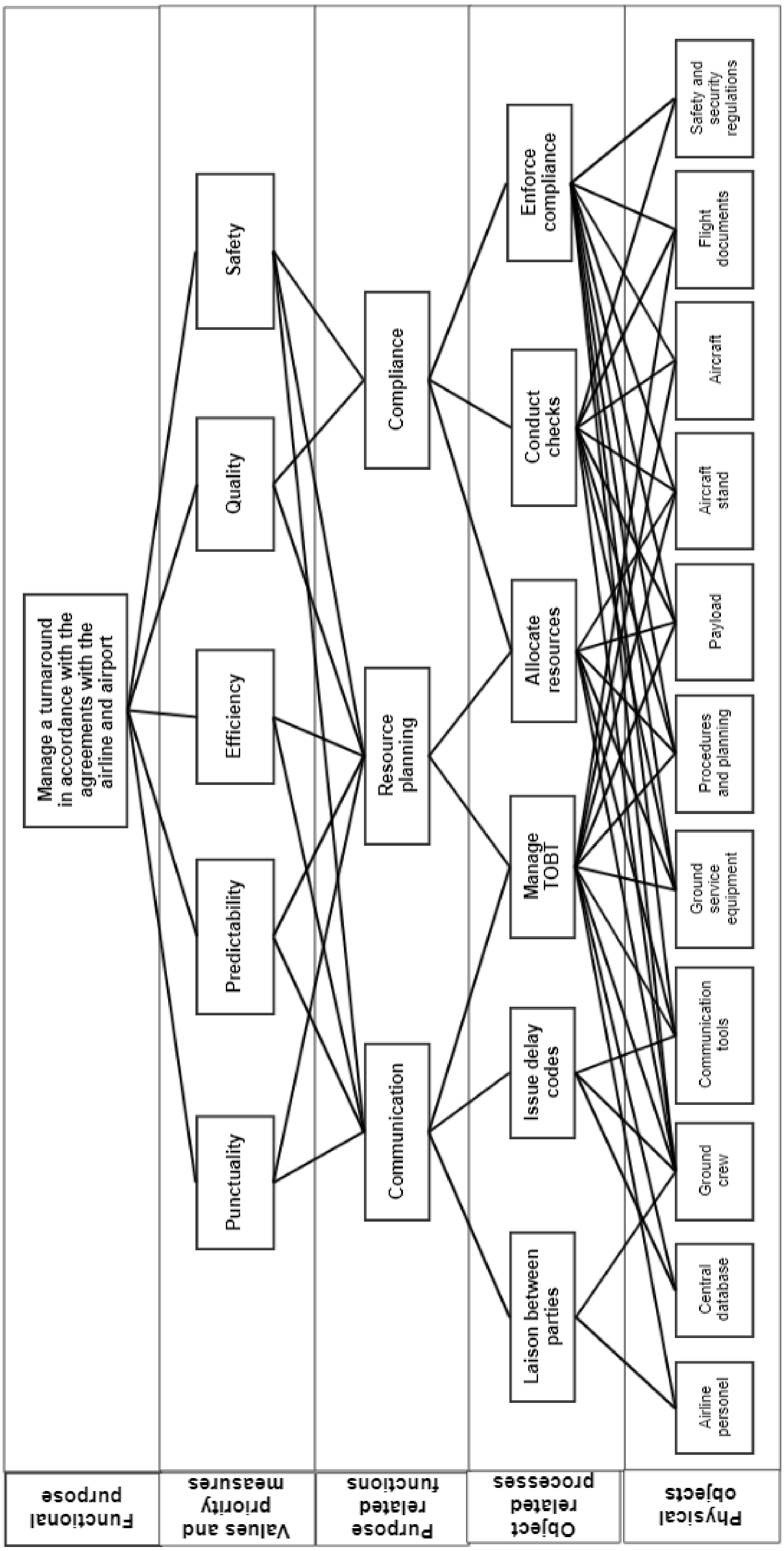


Figure 4.1: Main overview of the abstraction hierarchy of turnaround coordination.

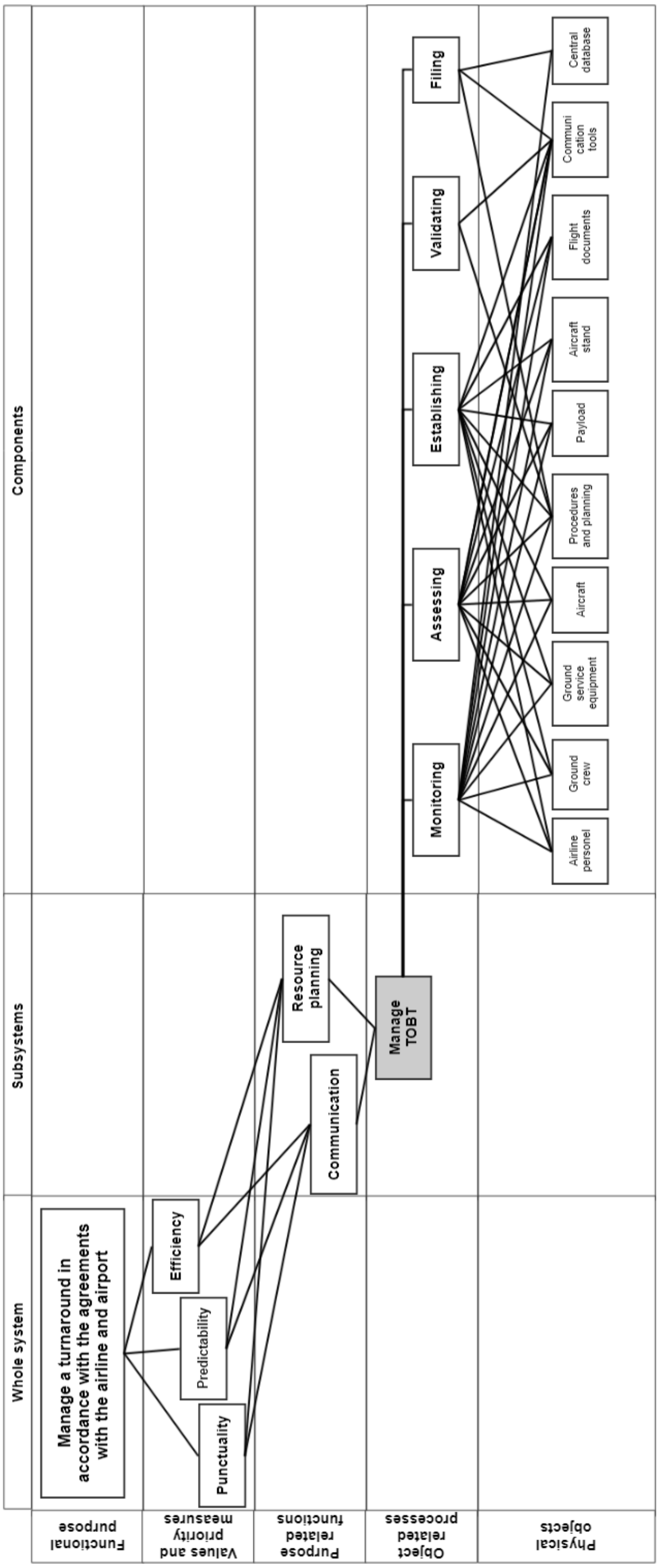


Figure 4.2: Part whole decomposition of the 'Manage TOBT' subsystem.

4.1.2. A decision Ladder of TOBT management

To achieve punctuality, predictability and efficiency, the TOBT management control task is carried out. Figure 4.3 on the next page shows a decision ladder for the TOBT management control task during the turnaround. This ladder is constructed based on the field study and the WDA. Based on the numbers in Figure 4.3, an example of how this control task can be carried out is given.

1. Upon arrival at the stand the actor observes the situation on a high level, creating knowledge on which processes are ready to start, which are being conducted and which are finished. This creates knowledge on the system state.
2. The actor must interpret this system state to determine if the TOBT is still accurate, which satisfies the performance criteria (punctuality, predictability and efficiency).
3. When the TOBT is deemed accurate, high level observation and interpretation can continue. But when a process is interpreted as delayed, this could harm the performance criteria. This creates an alert for the actor to observe this process in more detail.
4. The delayed process is observed more closely. This can be done visually, via a computer interface of by contacting another actor via telecommunication.
5. This more detailed system state is interpreted again and evaluated on the performance criteria.
6. When it is determined that the turnaround can't reach it's TOBT, a leap is made to the knowledge state that a task is required: updating the TOBT. This leap is supported by the CDM guideline that the TOBT needs to be correct at all times, creating predictability.
7. Once the actor has come to the conclusion that a TOBT update is needed, a plan must be made to update the TOBT in the CDM system.
8. To complete the TOBT management control task the actor needs to execute the formulated procedure and return to observing the turnaround.

The enumeration shows the constraint of how an actor goes from one knowledge state to another knowledge state through data processing activities. However, the enumeration does not mean that an actor simply needs to walks through the decision ladder from 1 to 8. An actor can, as observed in chapter 3, interpret the system state and come to the conclusion that the TOBT needs to be updated to an earlier moment to achieve efficiency. The actor updates immediately instead of first observing the process in more detail. An actor can also formulate a procedure which requires him to repeat a part of the decision ladder after a certain amount of time.

The control task analysis shows that TOBT management is an iterative task which requires multiple information processing activities. Even when both shortcuts are taken the control task takes 4 information processing activities: observe, interpret, formulate and execute. When multiple detailed observations need to be conducted the control task becomes even longer. The interpretation of the system state is the central data processing activity in TOBT management. This activity determines the level of the observations and triggers the formulation of a TOBT update when this is assessed as necessary. What happens inside this activity is the subject for the next step.

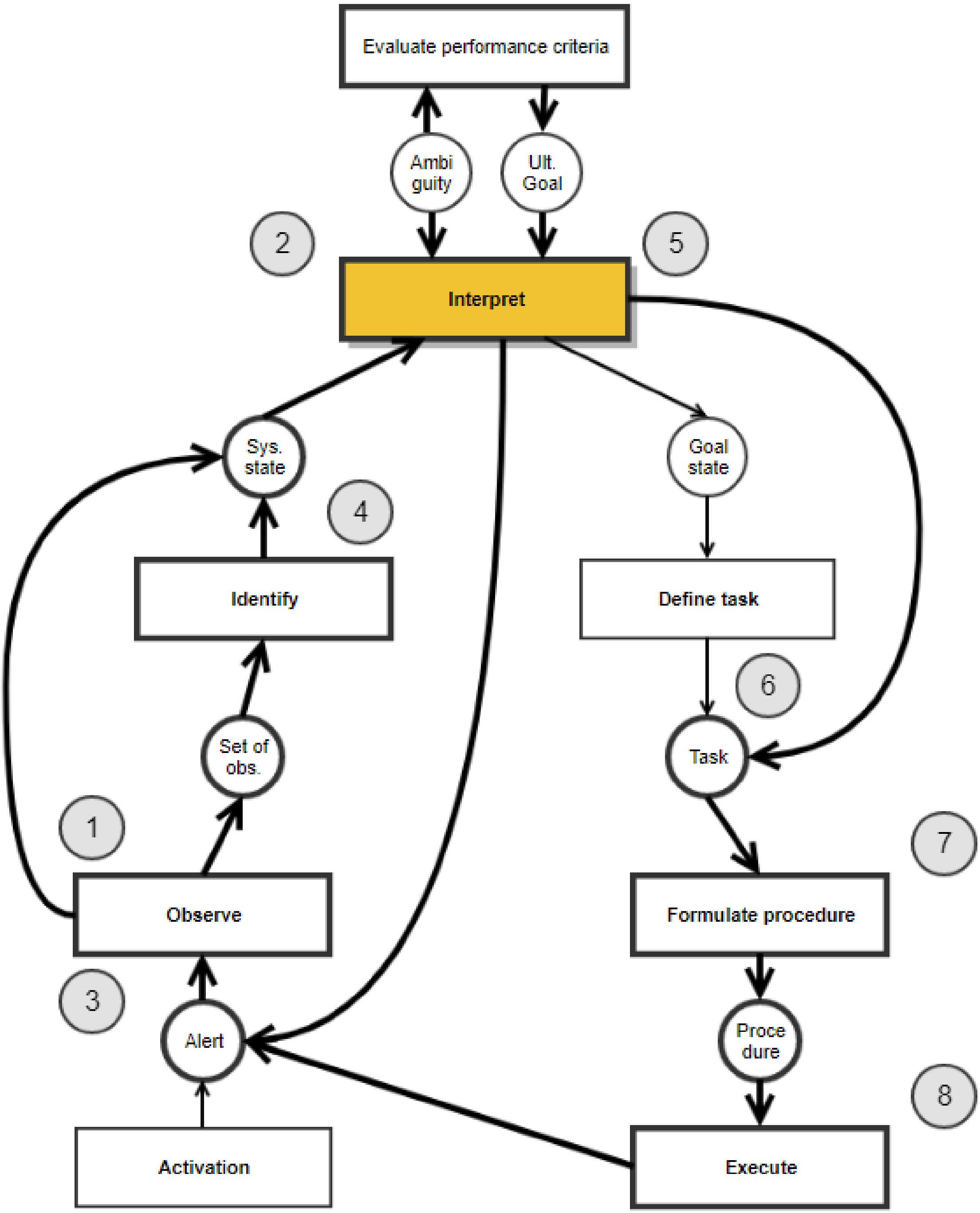


Figure 4.3: Decision ladder of TOBT management

4.1.3. Information Flow Maps of interpreting the system state

As concluded in the control task analysis the "interpret" activity is central in TOBT management. Using Information Flow Maps (IFMs) and the observation from the field study this activity is further analyzed. IFMs are not as mature as the two tools applied in the previous steps. The IFMs are therefore constructed using the work of Vicente [52] and Kilgore [34] as examples, since there is not a template or a set of rules to work with. Figure 4.4 on the next page visualizes the strategy for the interpret activity. Since this strategy takes place inside the interpret activity of figure 4.3 it has the "system state" knowledge as input (at the bottom) and "alert" and "task" knowledge states (on the right) as output. Figure 4.4 shows that there are a multitude of ways to get from the initial knowledge state to one of the final knowledge states. The activities creating these different paths in the strategy (squares in the figure) are described below.

Compare system state to standard turnaround model. Processes in the turnaround occur in a specific order to be efficient. Through experience and training a mental model is established of what should should take place when during the turnaround. With the current time, the model is turned into a checklist of processes which should have started and should have been finished at that time. By comparing the checklist to the system state, processes which are behind or ahead of schedule are identified. When no processes are off schedule this is an alert for the actor to keep observing at a high level, finishing the interpret activity. When a process is assessed as being off schedule the actor needs to determine the size of the deviation.

Adjust standard turnaround model to situation and run new turnaround model. The model of the turnaround is again needed to determine if the deviation from the schedule also affects other processes linked to it. For example: when cleaning is delayed, boarding can also not start. A library of process times, build-up based on experience, combined with experience on the specific flight is then used to determine the expected time needed. An example of combination of this knowledge: a wide body aircraft takes 30-40 minutes to board, but flights to this destination usually board slower, so 40 minutes is more certain.

Determine if enough resources for detailed observation. When the actor can't get a clear model for this estimation, he needs more information. Before starting a more detailed observations, which requires resources, the actor needs to assess if he has enough resources. This assessment is based on the time difference between the current time and the TOBT, the amount of missing information on the delayed process and the actors information position. If the resources are assessed as insufficient, the actor moves to update the TOBT. When enough resources are available the actor starts detailed observation and returns to the interpret activity with a more detailed system state to build the model on. It is also possible that a detailed system state is again not established and the actor again has to assess if there are enough resources for more detailed observation.

Assess if current TOBT is still reachable. When the actor has established a clear model and produced an estimation of the time needed he has to place this estimation next to the current TOBT to assess if this TOBT is still valid. When it is still valid, the interpret activity is over and the actor returns to high level observation. When the current TOBT is no longer valid, the actor knows that the TOBT needs updating.

Play on TSAT and assess TSAT + 5 minutes. This is a gray area of the strategy. As mentioned in the observation section, when the TSAT is equal to the TOBT this places the latest moment for the captain to call "ready" to ATC five minutes later than the TOBT. When the actor assesses that these five minutes are enough to recover the delay, he can decide to not update the TOBT. CDM guidelines are clear that the TOBT should equal the end of ground handling and the TSAT window should not be used for this purpose since missing the TSAT can cause capacity issues on the runway. It therefore depends on the attitude of the actor if this "sub-strategy" is considered. When he does not, or the TSAT window is not enough, he knows a TOBT update is needed.

Interpretation of the system state is central in the TOBT control task and is carried out multiple times during a turnaround. This strategy analysis has shown that it is a complex strategy, involving mental models which need to be compared to the actual turnaround and altered based on incoming information. These models are important for the assessment of the TOBT. These data processing activities in the interpretation of the system state are locations for possible improvements in the information position. The next step focuses on these possible improvements, by allocating the activities between human and computer.

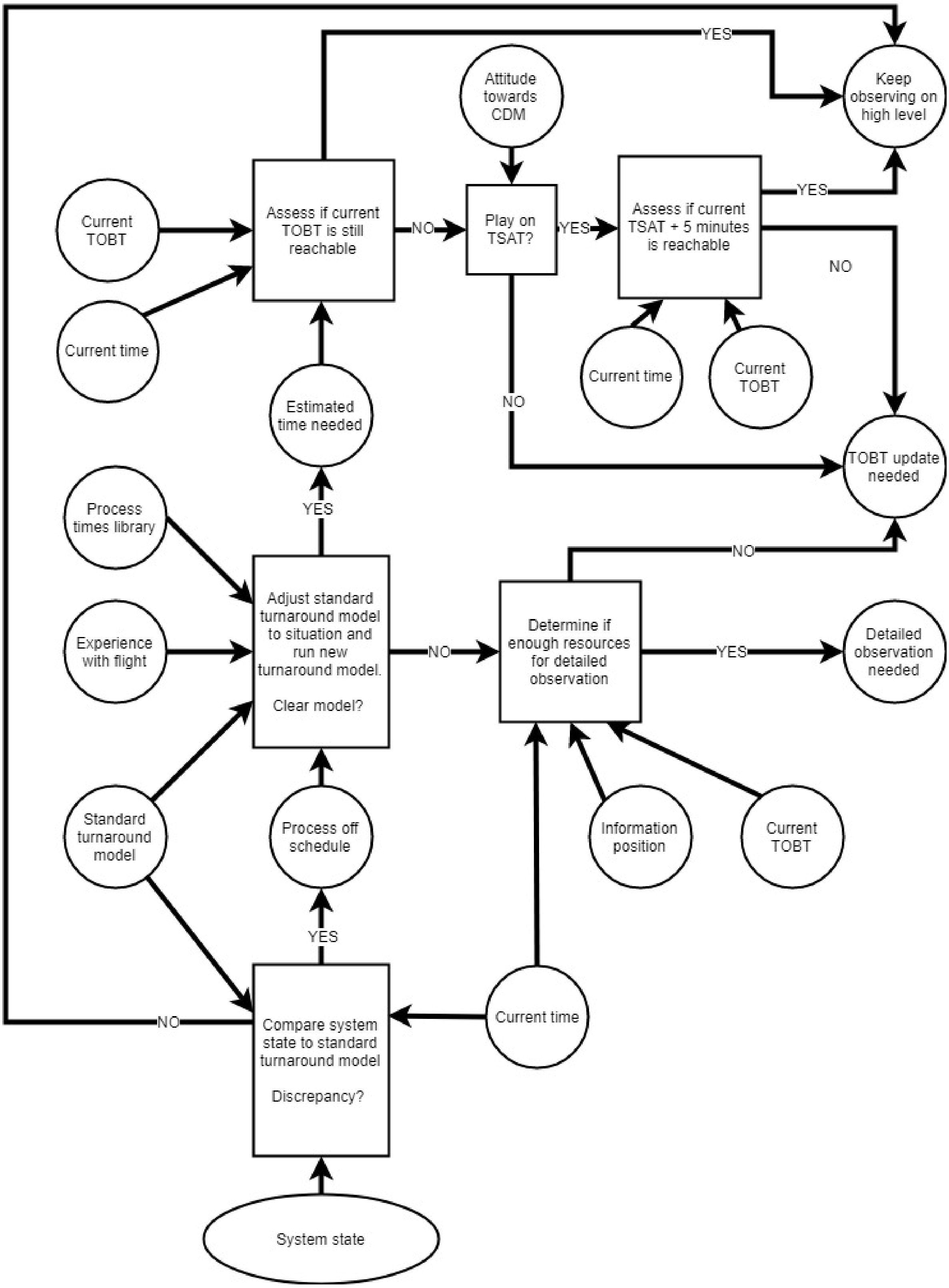


Figure 4.4: Strategy for interpreting the system state

4.1.4. Information Flow Maps allocating TOBT updating tasks

The goal of this fourth step is to determine how the social and the technical aspects of a sociotechnical system can work together to increase system performance. This is done by allocating tasks between human operators and computers. Vicente [52] referrers to 6 criteria for governing the division of work demands, which are established by Rasmussen[41]. These are criteria are:

- **Actor competency:** when work demands heterogeneous competencies, work can be allocated among actors to come to a set of more homogeneous competencies for each actor.

- **Access to information or action means:** when the access to information is not divided equally it would make sense to distribute work demands to the actors with the most immediate access to work relevant information.

- **Facilitating the communication needed for coordination:** when coordination of interdependencies is required it makes sense to allocate this to a single actor, limiting the required communication between groups.

- **Work load sharing:** work is distributed among actors because demands are too great for a single actor to cope with.

- **Safety and reliability:** redundancy is often built into a system's design to improve safety and reliability.

- **Regulation compliance:** allocation of work can be shaped by industry or corporate rules which constrain how certain tasks can be distributed.

Figure 4.5 on the next page shows the current allocation on the left side. In this situation the turnaround coordinator/flight watcher interprets the system state using his own resources. This research uses the information flow maps to visualize the allocation since it is my understanding that in these detailed visualizations the proposed allocation can be presented the clearest. Using the 6 criteria of Rasmussen, an allocation of work is proposed which is presented on the right side of figure 4.5.

The core idea of this new allocation of work is that individual service providers (such as cleaning, catering, fuelling, gate agent and loaders) and the computer take over part of the interpret activities. The service providers observe their own, small, system state for which they are responsible and communicate their expected end time with the computer. The computer system then determined if they are off schedule and if so, if the TOBT needs to be changed. When the computer determines that a TOBT update is needed, he signals the turnaround coordinator. This allocation of work tasks is based on the following assumptions on the Rasmussen criteria:

- **Actor competency:** Currently the turnaround coordinator/flight watcher requires a broad knowledge of process times since he needs to assess each turnaround process. When individual service providers observe and assess their own process this would make the set of competencies for the turnaround coordinator more homogeneous.

- **Access to information or action means:** Service providers who carry out the process on a daily basis are expected to have more direct access to information on individual process times than the turnaround coordinator. When these actors are provided with a deadline, they are in the best position to assess if this deadline can be met.

- **Facilitating the communication needed for coordination:** Each service provider in the turnaround has direct access to information on its own process. But they do not have the overview to oversee the interdependencies and constraints between the processes in the turnaround. This overview is needed to assess if the current TOBT of the flight is still reachable. Therefore all the estimates of the different service providers need to be brought together at a central actor/computer.

- **Work load sharing:** In chapter 3 it was concluded that turnaround coordinators have a high workload. By allocating a part of the workload of the interpret task and the linked observation task from the turnaround coordinator to the individual service providers and the computer, the workload for the turnaround coordinator is expected to be lowered. To prevent an information overload, a well designed interface can help channel the information to the turnaround coordinator and the flight watcher.

- **Safety and reliability:** It is a logical allocation option to bring all sub-system states together in an automated system, which then determines the TOBT and updates the TOBT in the CDM system when this is needed. This would mean that the right part of figure 4.5 no longer contains any role allocated to the turnaround coordinator and all black boxes would be white. But the CDM system heavily relies on reliability, therefore some redundancy is built into the allocation. The adjustment of the turnaround model and assessment of the current TOBT is allocated to both the computer and the human (in this case the turnaround coordinator). The computer makes this assessment based on the input from the actors. The human can decide to follow the computer instantly or make his own assessment, based on his own observations, and weigh it against the assessment of the computer. With this check, the CDM system is not affected by an individual actor updating its estimated time to an unrealistic setting. This way there are two checks in TOBT management: the turnaround coordinator checking the computer and the flight watcher checking the turnaround coordinator.

- **Regulation compliance:** It is assumed that the proposed allocation of tasks does not require a change in the existing Service Level Agreements.

Using the six criteria of Rasmussen, this step has proposed an alternative allocation of work for the interpretation of the system state. The allocation creates an important role for the human/machine interface were the computer brings together all estimates from the different service providers and assesses the current TOBT. As mentioned under the work load sharing criteria, this interface should not create an information overload. But the interface should also provide enough information to the turnaround coordinator/flight watcher to conduct his own assessments. The final step of the CWA will focus on this aspect.

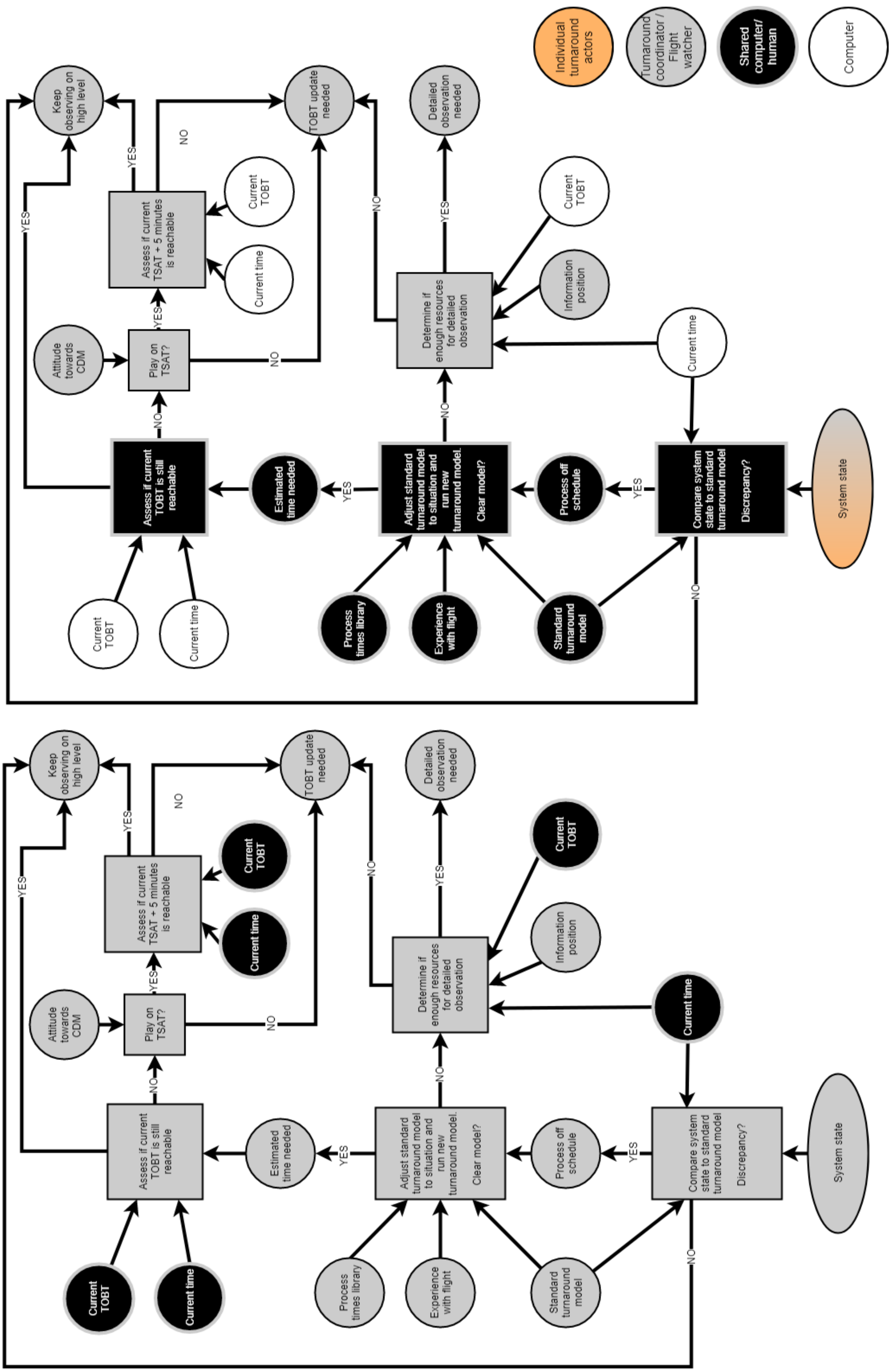


Figure 4.5: Left: Current allocation, right: proposed allocation.

4.1.5. SRK inventory of TOBT management

In this last step a SRK inventory is used to describes how an operator may carry out an information processing step using skill-, rule- or knowledge-based behaviour [34]. A full worker competencies analysis would analyze all tasks in the work domain. But in line with the continuous demarcation of this CWA, the SRK inventory is build for the "assess if current TOBT is still reachable" activity. This activity was allocated to the computer and the human, creating an interface. For each type of behaviour the way the operator might interact with the interface to assess if the current TOBT is still reachable is defined. Based on this description, design insights for the support of that type of behaviour are formulated. The result of this is presented in figure 4.6.

Type of behaviour	Interaction between operator and interface	System and interface design implications
Skill based	Directly perceive if the current TOBT is achievable or not.	The system has to use the collected time estimates and the interdependencies between the processes to calculate if the TOBT is achievable.
		The interface should only provide information in which the operator can directly identify the signals needed to trigger his actions.
		Simple point and click to manipulate the TOBT
Rule based	Use heuristics to determine whether a delay causes the TOBT to be unachievable	The interface should represents the flight specific interdependencies between the different turnaround tasks.
		The interface should highlight the critical path of the turnaround and the state of the processes.
		The interface needs to adapt the display to present the most up to date expectations on the turnaround progress.
		The interface should display the current time and the current TOBT.
Knowledge based	Reason based on mental model of the turnaround and processes if the TOBT is achievable or not.	The interface should provide all the estimated times of each turnaround actor to the operator.
		A schematic overview of the flight specific turnaround with its interdependencies should be provided as a basis for the operators mental model.
		The interface should display the current time and the current TOBT.
		As much additional information as available in the work domain on the separate turnaround processes should be provided by the interface to aid in the construction of a mental model.
		Contact information of each turnaround actor should be made available in the interface
		The operator should be allowed to change the interface based on his own reasoning

Figure 4.6: SRK inventory and design implications

The requirements formulated in the SRK provide a starting point for the design of an ecological interface. This is an interface which supports all three levels of behaviour in an efficient manner. At the skill level, only little cognitive resources from the operator are required since he only needs to perceive the alert and then preform the standard patterns to update the TOBT in the CDM system. For rule based behaviour, the interface should provide an one-to-one mapping between the turnaround system and the provided signs. These direct diagnostics on the system state allow for the worker to use more economical rule based behaviour [52]. Finally, the interface supports knowledge based behaviour of the operator by externalizing a part of the mental model. This is done by collecting information in the computer system and presenting it in the interface. Using the interface, the operator does not have to encode, store and retrieve all this information in his mind. This way the interface makes knowledge based behaviour quicker, less resource demanding and less prone to errors [52].

This last analysis has shows that the three kinds of behaviour require different types of support from the interface and the underlying computer system. A direct link between the cognitive workload of the operator and the workload for the computer is identified. On one side, skill based behaviour requires a high workload from the computer in processing the information, while the operator can rely on little cognitive resources to complete his responsibilities. On the other side, knowledge based behaviour requires the computer to only collect, store and present relevant information, while the operator has a high cognitive workload processing this information.

4.1.6. Conclusions on the Cognitive Work Analysis

The CWA has given a deeper insight into TOBT management and has provides the foundation for the design of new information tool. The Work Domain Analysis has shown that, to achieve its values of punctuality, predictability and efficiency, TOBT management requires interaction with many different physical objects scattered over the apron and it's surroundings. To achieve the values of TOBT management, iterative observations of the turnaround processes on both high and detailed levels are required. The analysis identified the interpretation of the system state as the key data processing activity in TOBT management.

In the Strategies Analysis it was found that this interpretation of the system state is a complex activity. It requires a clear mental model of the turnaround which needs to be compared to the current system state and altered to predict the consequences of deviating processes on the TOBT. These data processing activities in the interpretation of the system state were identified as locations for possible improvements in the information position. Currently, all these data processing activities are allocated to turnaround controllers and flight watchers. Using Rasmussen's six criteria for governing the division of work, an alternative allocation of tasks was proposed. In the proposed allocation, individual service providers (such as cleaning, catering, fuelling, gate agent and loaders) take over part of the observe and interpret activities by observing their own system state for which they are responsible and communicate their expected end time with the computer. The computer brings together all these estimates from the different turnaround actors in an interface.

Since the turnaround coordinator remains responsible for updating the TOBT, the human/machine interface is important in this new division of work. The last analysis of the CWA has focused on this ecological interface and has provided a set of design implications. The next section uses the insight from the CWA to come to a first design of an ecological interface for TOBT management.

4.2. Interface design

The Cognitive Work Analysis conducted in the previous section has proposed a new division of work in TOBT management. This section will focus on a first design of an ecological interface which can accommodate this new division of work. Figure 4.7 on the next page shows the starting point of this design process. The core idea established in the Social Organization and Cooperation analysis is that the service providers on the left observe their own progress for the task which they are responsible for and determine how much time they need to complete their task. In the middle of figure 4.7 the to be designed interface and underlying system are shown.

The main user of the TOBT management interface is the turnaround coordinator. The turnaround coordinators makes the decision to update the TOBT. But as seen in the field study, the flight watchers also play an important role in TOBT management since they enter the update into the CDM system. The flight watcher is therefore the second user of the to be designed TOBT management interface. Just like the turnaround coordinator the flight watcher can use the interface to monitor the turnaround and conduct TOBT updates. Through the interface he also receives the TOBT updates conducted by the turnaround coordinator which he can then approve and feed into the CDM system. The focus of this first design is on the interface for the turnaround coordinator. The interface for the flight watcher is assumed follow the design of the turnaround coordinator interface, but on a higher level to accommodate several flights in one view.

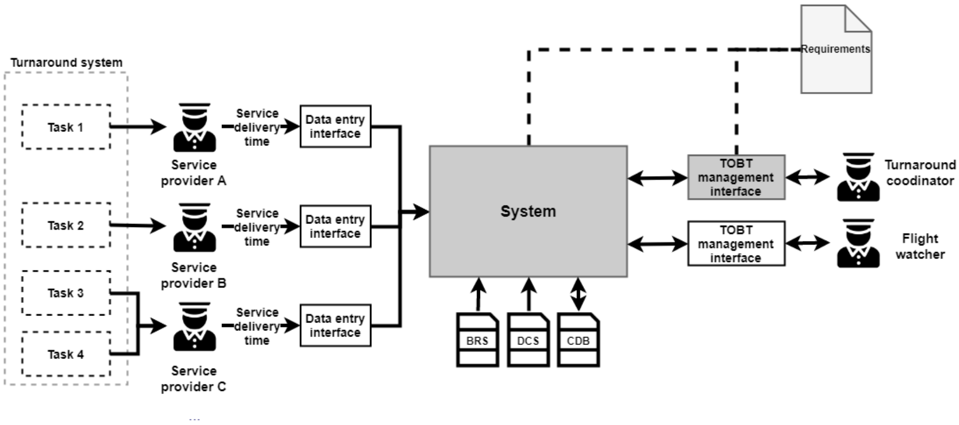


Figure 4.7: System diagram illustrating the starting point of the system design

4.2.1. Service providers in the turnaround

Table 4.2 gives an overview of the services in the turnaround and the providers who offer these services at BRU. Push back service is not included in the table since this service is not included in TOBT management. Table 4.2 shows that, besides a turnaround coordinator, a fully serviced turnaround requires 6 different operators or teams of operators. These operators can be from 4 or 5 different companies which are contracted by the airline. However, several flight at BRU are not fully serviced turnarounds. Some European flights for which BRU is the outstation usually don't require fuelling, water and toilet service since they are serviced at their base airport for a round trip. Other airlines (such as Ryanair) also don't require cleaning and catering services during the turnaround. Passenger services and baggage/cargo handling are therefore the only service providers which are always present in the turnaround.

Table 4.2: Turnaround services and service providers at Brussels Airport [14]

Service	Service providers	Type of service
Passenger services (Gate)	Aviapartner, Swissport, Brussels Airlines	Mandatory
PRM service	Axxicom Airport Caddy	Optional
fuelling	Brussels Airfuels Services, Skytanking	Optional
Catering	Newrest, LSG Skychefs	Optional
Cleaning	Mobility Masters, Swissport	Optional
Water and Toilet service	Aviapartner, Swissport	Optional
Baggage/cargo handling		Mandatory

The discussion above shows that the composition of service providers in the turnaround can differ per flight. Each of these service providers requires access to an interface to communicate their expected service delivery time. This means that each service provider would be equipped with a portable device. Another possibility is to integrate devices into the airport infrastructure, placing devices at the base of the passenger bridge and the entrance of the aircraft. The design and other considerations of this data entry interface for the service providers is however not within the scope of this research. Designing such interfaces should be done based on an analysis which is similar to what this research has conducted for the turnaround coordinator. The design of the TOBT management interface is therefore made under the assumption that the service providers provide time estimates via an interface.

4.2.2. Systems available in the turnaround

On the bottom of figure 4.7, three existing systems present in the turnaround are shown: the Baggage Reconciliation System (BRS), the Central Database (CDB) and the Departure Control System (DCS). Since these systems contain useful information and it is not the goal of this research to reinvent the wheel, they will shortly be elaborated upon.

The Baggage Reconciliation Systems is a shared system used at the airport to check if both the passenger and his checked-in baggage are on the aircraft. When a passenger has not boarded the aircraft but does have hold baggage the baggage needs to be offloaded since airlines can't transport baggage of passengers who are not on board of the aircraft [32]. The BRS help in this process by identifying the passenger and locating the baggage. Besides aiding in the offloading procedure the BRS is also useful for tracking the progress of both the passenger boarding and baggage loading process. Based on the check-in data and the scanned bar codes on baggage and boarding passes, the BRS gives real time how many bags and passengers still need to be loaded.

The Central Database is the central CDM system were the CDM stakeholders at BRU share their data. The CDB is where the flight watcher updates the TOBT, which is then shared with, for example, ATC who update the TSAT accordingly. The ground handling companies have designed their own systems (flight information systems) which are linked with the CDB. Important data in the CDB for the turnaround coordination of a flight are the Expected In Block Time (EIBT), Actual In Block Time (AIBT), Expected Off Block Time (EOBT), Target Off Block Time (TOBT), Target Startup Approval Time (TSAT) and the Actual Off Block Time (AOBT).

The Departure Control System is used by airlines to automate passenger procedures such as check-in and boarding. There are numerous systems on the market and some airlines also develop their own systems. The most common DCS at Zaventem is the Amadeus Altéa Suite, which is used by Brussels Airlines and most of its star alliance partners [43]. Just as the BRS, the DCS gives an overview of passenger progress. The DCS also provides the turnaround coordinator with useful passenger info such as if a passenger is on a transfer or is a passenger with reduced mobility.

Useful information from these three systems can be incorporated in the TOBT management interface via the underlying system. It is not the goal of this research to give a detailed description on how these different systems could provide information to the designed interface. But, since the interface is closely linked with the underlying system, the implications of the interface design on the underlying system is described later in this part. The main focus of this section is however on the design of the TOBT management interface.

4.2.3. Design methodology

The main goal of Ecological Interface Design (EID) is to support all three types of behaviour (skill, rule, knowledge based) and not to force cognitive control to a higher level than the current task requires [52]. To ensure all three level are supported by the interface, three design principles should be followed [49].First, in order to support skill-based behaviour, the representation should be isomorphic to the part whole structure and direct manipulation should be facilitated. To support rule-based behaviour a consistent one-to-one mapping between the constraints and the cues or signs should be provided. And finally, to support knowledge-based behaviour, the interface should be represented in the form of an abstraction hierarchy to serve as an externalized model of the system. These design principles are very general and do not provide a clear path for a design process. In their 2008 research, Upton and Doherty [49] have proposed a visual design methodology which is used as a guide for this design process. Figure 4.8 gives an overview of the design methodology.

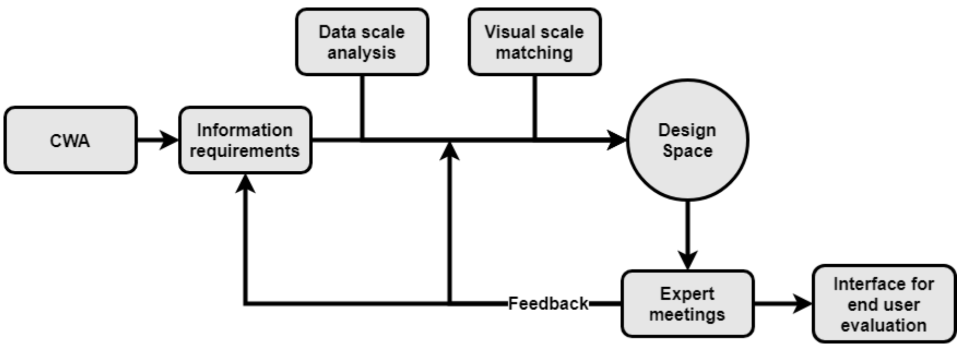


Figure 4.8: The design methodology (based on Upton and Doherty [49])

Based on the CWA a list of information requirements is constructed. This requirements list provides a description of the information requirement and the data format of the required information. Data scale analysis then uses the formal properties of the data format to categorize the requirement as nominal, ordinal, interval or ratio. These data scales are then be matched with basic elements of graphic composition. This is done with the table shown in figure 4.9. By matching the data type (on the top) with a suitable visual variable (on the left), the performance of cognitive tasks can be improved [49]. In selecting a suitable visual variable, the goal was to vary the use of visual variables as much as possible. Presenting information with different data formats with the same visual variable can cause confusion in the interpretation of the interface.

Visual Variable	Type of Perception			
	Associative	Selective	Ordered	Quantitive
Spatial X	YES	YES	YES	YES
Spatial Y	YES	YES	YES	YES
Size		YES	YES	YES
Brightness		YES	YES	
Texture	YES	YES	YES	
Colour	YES	YES		
Orientation	YES	YES		
Shape	YES			

Figure 4.9: Visual scale matching [49]

Were Upton and Doherty evaluate the design space directly with end users, this research evaluates the design space with experts during several expert meetings. Based on the feedback of these meetings, missing requirements are added and the data scales and visual scales are adjusted to optimize the design space and come to an interface for the end user evaluation. By first iterating the design several times with aviation and EID experts, a more developed interface can be evaluated with the end users. This method has been chosen since the access to the end users (the turnaround coordinators) is scarce, making an iterative process with these end users unfeasible for this research. Designing is a process which requires a large amount of design iterations and evaluations which lead to a long development time. Since this research is time constraint, three iterations were made based on feedback sessions with subject matter experts. Appendix D shows the iterative process in more detail.

4.2.4. The designed interface

The iterative process explained above created a final interface design. Figure 4.10 on the next page shows three examples of this final interface design. The top view in figure 4.10 shows the interface at the beginning of the turnaround, when the passengers are deboarding, their baggage are taken off and the refuelling has begun. The middle image shows the interface when the turnaround is 20 minutes before its TOBT. In this situation cleaning takes more time than scheduled, which delays the boarding process and results in an unfeasible TOBT. The bottom image show the interface when the turnaround coordinator has decided to update the TOBT by pressing the "update TOBT" button. The rest of this subsection will use these three examples to go into more details on the interface and the design choices.

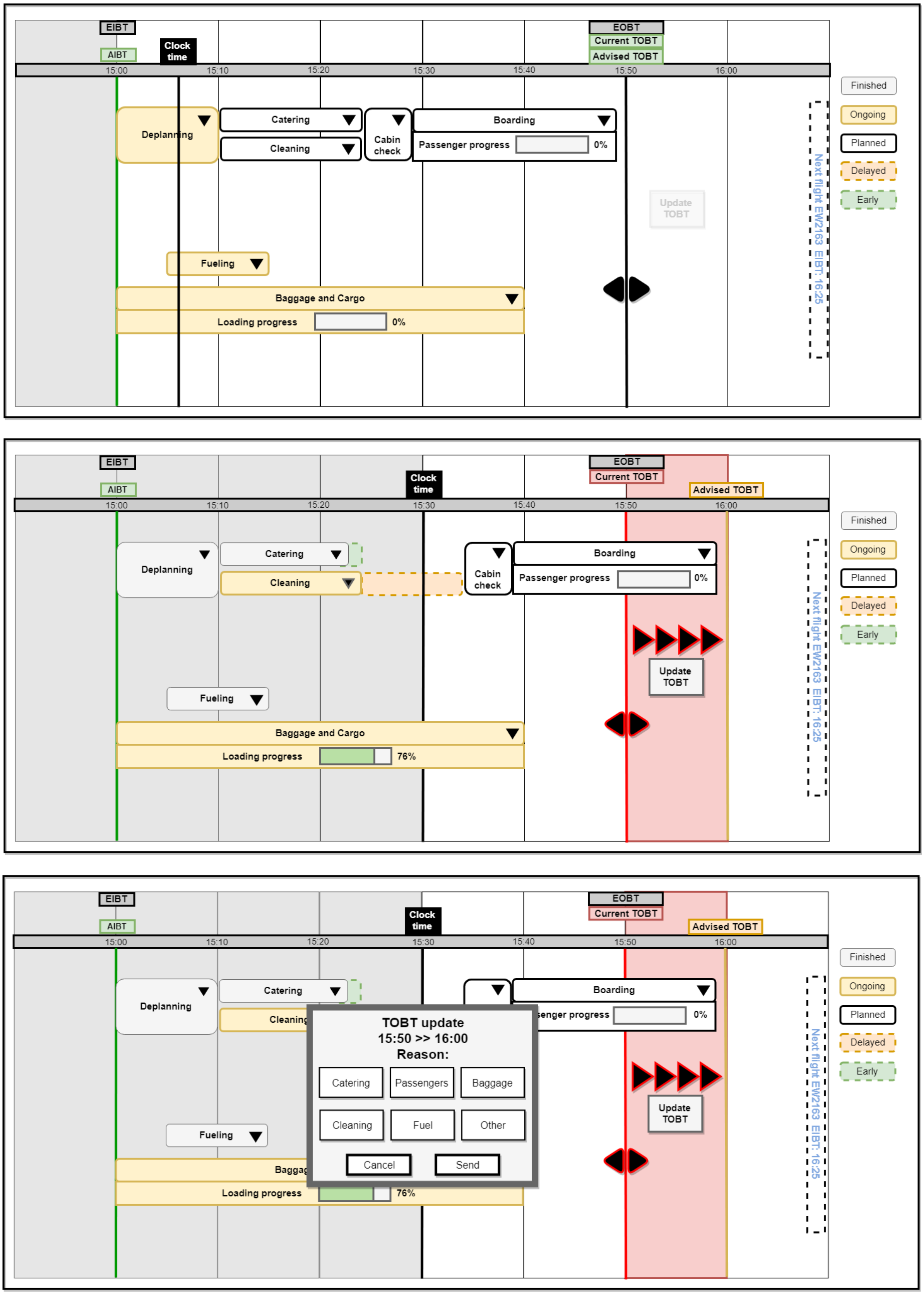


Figure 4.10: The final interface design, in three situations

Time is the main element in the turnaround work domain. The input from the service providers is a time indication and all the CDM related milestones are expressed in time as well. To accommodate these important elements, the interface displays the turnaround processes and milestones along a time line on the X-axis. Following the decision ladder, the interface first provides high level information at the top and then more detailed process information beneath. The high level information shows what time the rotation started (AIBT), the current time, at what time the aircraft is scheduled to leave (EOBT). Most important, the current TOBT and the advised TOBT are shown. The advised TOBT is calculated by the system based on the time indications from the service providers. Together these CDM milestones provide a high level overview of the turnaround. Beneath the high level information the more detailed process information is displayed. The interface provides all the process information in one sight. Each process in the turnaround is displayed along the x-axis, showing its start time, duration and end time. Processes which are directly dependent on each other are presented on the same level along the y-axis. The longest chain of dependent processes is the critical path [50]. This critical path is displayed at the top of the detailed information section, with the other non-critical processes underneath it. Using data from the BRS system, the baggage and boarding process contain a additional layer of detailed information which shows the progress off loading and boarding.

As can be seen in the top image of figure 4.10, some processes are white. This indicates that they are planned to take place during the turnaround. The start time, duration and end time of planned processes are established based on a turnaround process library. This library contains average process times of each process for each specific turnaround. Once a process is started by the service provider it is highlighted in yellow in the interface. At the same time, the start and end time are updated based on the service provider's actual start time. Once the process is finished it fades into the background. This gives the turnaround coordinator a natural focus on current and planned processes. Finished processes are however not removed completely from the interface, allowing the turnaround coordinator to review the processes after they are finished.

When the start or the end time of a process does not equal its scheduled time this is indicated by a green (early) or red (delayed) doted area. A delay of a process (such as cleaning in figure 4.10) updates the scheduled times of the processes which are dependent on it, moving them along the X-axis. This keeps the turnaround overview in the interface up to date. The end time of the last process, plus a margin for clearing all ground equipment, is taken as the advised TOBT. The middle image in figure 4.10 shows a situation in which there is a difference between the current and the advised TOBT. This difference is indicated in multiple ways. On the high level, the advised TOBT turns yellow while the current TOBT becomes red. The area between the current TOBT and the advised TOBT becomes red as well, providing a clear visual signal over the entire interface. Finally, the option to update the current TOBT to the advised TOBT becomes available. The turnaround coordinator has four options at this moment:

1. Update the TOBT immediately to the advised TOBT by clicking the update button.
2. Update the TOBT by a fraction of the advised TOBT update by using the arrows on the current TOBT line.
3. Contact the service provider responsible for the delayed process or observe the delayed process to develop better understanding of the situation.
4. Ignore the alert.

For action three, the drop down menu of each process (indicated by the triangle) provides the operator with the contact details of the service provider. The drop down menu also provides the turnaround coordinator the possibility to alter the process time of the process manually based on his own assessment. This can be useful when a service provider enters an extreme value into the system. The turnaround coordinator can then identify the process and apply his knowledge based behaviour and log the outcome in the interface for later usage.

Finally, when the turnaround coordinator decides to update the TOBT (completely or by a portion) a confirmation screen pops up where the turnaround coordinator has to confirm the TOBT update. This pop-up screen also allows the turnaround coordinator to give a first indication of the cause of the delay, choosing between passengers, catering, cleaning, fuelling, baggage or other. This way the interface supports other processes in the work domain, in this case the issuing of delay codes. This information can be used to improve the delay code mechanism, which weaknesses were discussed in part 1.

The layout of the interface support all three types of behaviour (skill, rule, knowledge based) and does not force cognitive control to a higher level than needed. When using skill based behaviour, the turnaround coordinator can manage the TOBT by pressing the button once the system calculates that a TOBT update is required. For rule based behaviour the turnaround coordinator can use the colours and magnitudes to backtrack the advised TOBT update to the process or processes causing the delay. In order to allow the turnaround coordinator to apply knowledge based behaviour the interface provides an overview of the interdependencies between the processes, data from the BRS and the possibility to alter process times himself.

4.2.5. Implications for the underlying system

As mentioned in the system setup section, this subsection will shortly elaborate on the implications of an interface design on the underlying system. An important part of the underlying system is the before mentioned turnaround process library which contains average process times for each turnaround. Based on this library it is determined when processes should start and how long they should take. The idea behind this library is that it is self learning. First, initial process times are defined for a turnaround. All process times of the turnaround are saved in a database. The system updates the average process times in the library when a flight has conducted a turnaround without a large delay. This way the interface provides scheduled process times based on a flight's specific history. The designed ecological interface uses data from two existing systems at BRU: the BRS and the CDB. The BRS is used to display the progress made in loading baggage and boarding passengers. The CDB system provides the information on the milestones to the system and the interface. The other way around, after the flight watcher has confirmed the TOBT update, the system sends the new TOBT to the CDB.

4.2.6. Benefits for the A-CDM system and stakeholders

In the literature overview the key challenges for implementing A-CDM which were identified by Corrigan were discussed. One of the key challenges identified was that all actors need to be able to understand and quantify the benefits of A-CDM for their own organization to get them motivated. For the expansion of A-CDM which is proposed in this part, this key challenge is also of importance. Table 4.3 therefore identifies the a first set of potential benefits for the existing CDM stakeholders (airlines, airport, ground handler, ATC and NMOC) and the service providers.

Table 4.3: Benefits per stakeholder

Benefits of the interface and the underlying system	Stakeholders benefiting
Support in turnaround coordination.	Ground handler
Earlier and more stable TOBT updates	Airline, Airport, ATC
Easier and more reliable delay code setting.	Airline, Airport, Ground handlers
Better insight into service provider performance	Airline, Airport
Better planning and dispatching or resources.	Airport, Airline, Ground handlers, Service providers
Faster recovery after lightning procedures	Airport, Airline, Ground handlers, Service providers
Increased predictability of flights departing from BRU.	Airport, ATC, NMOC

Table 4.3 shows that the interface first of all benefits the entire A-CDM system since it allows for earlier and more stable TOBT updates which increases predictability on different levels. But as Corrigan also identified, imbalance in rewards and efforts between stakeholders occurs in CDM. In the current form of A-CDM, the airport operator and the airlines are the largest beneficiary, while ATC and the ground handlers benefit less [24]. Table 4.3 shows that the service providers, which provide the main input for the interface, are not the largest beneficiaries of the interface. Since the service providers are in the same corner of A-CDM as the ground handlers, their benefits are mostly in better planning and dispatching. The ground handlers will further benefit from the interface since it supports their work. The main beneficiaries of the interface will be the current beneficiaries of A-CDM, the airlines and the airport operator.

4.2.7. Conclusions on the interface design

This section used the outcomes of the CWA in an iterative design process to come to a first design of an ecological interface for TOBT management. The interface presents the turnaround processes and milestones along a time line. Using the input from the service providers, an advised TOBT is calculated and compared to the current TOBT. The interface provides visual signals, high level information and detailed process information in one sight to support the turnaround coordinator in each level of cognitive control. Besides supporting the ground handlers the interface also creates benefits for the airline and the airport, such as reliable delay code setting.

4.3. Conclusion on a potential improvement in the information position

The goal of this part was to to explore what interface can be designed to improve the information position of the turnaround coordinator. The CWA identified that TOBT management requires iterative observations of many different physical objects scattered over the apron and it's surroundings, on both high and detailed levels. With these observations an image of the current system state is created. The interpretation of this system state is a complex activity which requires a clear mental model of the turnaround which needs to be compared to the current system state and altered to predict the consequences of deviating processes on the TOBT. This complex activity, which is currently conducted by the turnaround coordinator was identified as a location for possible improvements in the information position. Using Rasmussen's six criteria for governing the division of work, an alternative allocation of tasks for the interpretation of the system state was proposed. This allocation proposes an interface which brings together the expected process times which are communicated by the individual service providers. In order to facilitate different types of operator behaviour this ecological interface should both present highly processed as well as raw information.

Based on the CWA a list of information requirements is constructed and after several iterations a first design of an ecological interface was made which is shown in figure 4.10. This designed interface presents the turnaround processes and milestones along a time line. Using the input from the service providers and the BRS, the interface is altered to the current situation of the turnaround. Based on this current situation, an advised TOBT is calculated and compared to the current TOBT. The interface provides visual signals, high level information and detailed process information in one sight to support the turnaround coordinator in each level of cognitive control. The interface was designed using experts and not the end users. In the next, and final, part of this research the interface is therefore presented to the turnaround coordinators for evaluation. This evaluation will assess the usability of the additional information presented in the TOBT management interface during the turnaround.

5
Part 3: Evaluation with end users

The previous part has created a first design of an ecological interface for TOBT management. In this final part, the interface is presented to the turnaround coordinators for evaluation. This evaluation assesses the usability and acceptance of the additional information presented in the TOBT management interface. The results of this evaluation will show to what extend the information position of the turnaround coordinators can be improved with relevant information.

5.1. Evaluation setup

Figure 5.1 shows the structure of the evaluation. Since the production of a working prototype is beyond the scope of this research, a paper prototype was used during the evaluation with the turnaround coordinators. The evaluations were conducted at both Aviapartner and Swissport with turnaround coordinators who were either on a brake or were conducting desk work. Since the evaluation was conducted while turnaround coordinators were in between tasks, time to conduct the evaluation was often limited. In total, 10 turnaround coordinators completed the evaluation. This is not a large sample size, but sufficient for this research since it focuses on the evaluation of a first design of an interface. The goal is therefore to make logical generalizations to a theoretical understanding instead of probabilistic generalization to a population. The evaluation is comprised of three parts: an introduction, a simulation part and an evaluation part. In the introduction, a basic scenario of the turnaround is shown to explain how the interface works and what the options are in managing the TOBT. The introduction can be found in appendix E. After the interface is introduced the simulation and evaluation parts were explained.

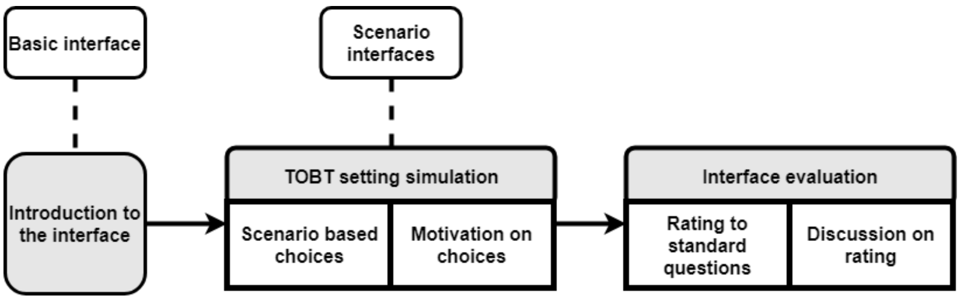


Figure 5.1: The followed evaluation structure

In the simulation part the turnaround coordinators used the interface to manage the TOBT. The turnaround coordinators are introduced to a hypothetical airline, Exotic Airlines (Callsign: XX). A hypothetical airline was used to cancel out any possible background knowledge which might influence a decision. All turnaround coordinators from both companies therefore knew just as much on the characteristics of the turnaround. In the simulation they were presented with five different scenario's of different Exotic Airlines flights. During the observations it was observed that Lufthansa already provides the turnaround coordinators with a tablet. It was therefore chosen to present these scenario's on a tablet as well. This gave the turnaround coordinators a more realistic view on how they might be using the interface in the future. Table 5.1 gives a short overview of the 5 scenarios used in the simulation. For each turnaround coordinator the same scenario's are used, creating substantial experimental control to conduct descriptive statistical analysis.

Table 5.1: The 5 scenario's used for the simulation

Scenario	Time to TOBT	Advised TOBT update	Short description
Scenario 1	40 minutes	+ 5 minutes	Slow deplaning
Scenario 2	20 minutes	+ 10 minutes	Late inbound and slow cleaning
Scenario 3	20 minutes	- 7 minutes	Quick catering and deboarding
Scenario 4	10 minutes	+ 15 minutes	Slow deplaning, late cleaning and late transfer passengers
Scenario 5	0 minutes	+ 15 minutes	Two bag search and offload

In each scenario the turnaround coordinators are given a short introduction on the turnaround and are presented with an illustration of the interface on a tablet. The illustration of each scenario can be found in appendix E. Based on the information on the tablet, the turnaround coordinators have to choose how to react to the situation from a set of standard answers:

1. Update the TOBT immediately to the advised TOBT by clicking the update button.
2. Update the TOBT by a fraction of the advised TOBT update by using the arrows on the current TOBT line.
3. Contact the service provider or observe the delayed process to develop better understanding of the situation.
4. Ignore the alert.
5. A different option (open answer)

Besides choosing one of the above options the turnaround coordinators are asked to motivate their decisions and explain how they used the interface in their decision making.

In the evaluation part, turnaround coordinators are given a set of statements on the usability and acceptance of the additional information provided by the display. These statements are constructed using the Unified Theory of Acceptance and use of Technology (UTAUT)[51]. UTAUT is a theory developed through the consolidation of multiple models on information systems usage behaviour. UTAUT specifies several key constructs of usage behavior. This research uses these key constructs as a guideline for formulating the statements. These key constructs are: performance expectancy (question 1 and 2), effort expectancy (question 3 and 4), social influence (question 5), facilitating conditions (question 6) and intention to use the system (question 7) [51]. These statements are first responded to via a standardized 5 point Likert scale ranging from completely disagree to strongly agree. Based on the response on the statement, the focus of the open questions will again be on the motivation behind these answers. The complete structure of the whole evaluation can be found in appendix E.

Table 5.2: Statements used for evaluation

Statement	Statement
1: Usefulness	I expect that the interface is useful for managing the TOBT
2: Workload	I expect that the interface will lower my workload with regard to TOBT management
3: Overview	The interface provides me with a quick and clear overview of the turnaround
4: Interaction	I would be able to easily work with the interface
5: Stakeholders	I expect that the involved stakeholders at the airport encourage the usage of such a system
6: Trusted aid	I would trust this system as an aid in managing the TOBT
7: Use intention	When the interface comes available, I expect to use it in each turnaround

The simulation and evaluation both result in standardized answers to each question and a motivation. For the analysis of the simulation and evaluation part the standardized answers are first combined to provide an overview on how the turnaround coordinators responded. Using these statistics, notable responses are further analyzed using the motivations of the turnaround coordinators.

5.2. Results of the simulation part

Table 5.3 gives an overview on how the turnaround coordinators reacted in the different scenario's. The full answers and motivation of the turnaround coordinators can be found in appendix E. Overall, turnaround coordinators were quick to decide on how they would respond. This shows that they could quickly retrieve the information from the interface and that they acted based on their existing strategies. The overview shows that of the total of 50 choices made by turnaround coordinators, only 10% of those choices involved updating the TOBT immediately. In the other 90% of the choices, the turnaround coordinators observed the information but chose not to follow the advise presented by the interface directly but to react in a different way. In most of the scenarios the majority of the turnaround coordinator chose to update the TOBT with a value of their own (40% of the total choices). In all cases this value was lower than the advised TOBT update presented on the interface.

Table 5.3: Answers of the turnaround coordinators on the presented scenario's

	Update Directly	Update to own value	Contact service provider	Ignore	Other
Scenario 1	0	0	0	**10**	0
Scenario 2	2	**6**	0	1	1
Scenario 3	0	0	0	4	**6**
Scenario 4	0	**7**	2	0	1
Scenario 5	3	**7**	0	0	0
Total	10%	40%	4%	30%	16%

In the first scenario, were a 5 minute delay occurred 40 minutes before TOBT, all the turnaround coordinators chose to ignore the alert and not take any action. They all motivated their answer along the same line: it is still early in the turnaround and 5 minutes can be dealt with. In the second scenario the reaction of turnaround coordinators was more divided. Six turnaround coordinators chose to update the TOBT by 5 minutes instead of the advised 10 minutes. They argued that they did compensate for the late inbound of the flight, but not for the slow cleaning. Two turnaround coordinators did follow the advice of the interface and updated directly. These two turnaround coordinators, together with a third one, stated that they would start pre-boarding. This means they start the boarding process at the gate but passengers can not enter the aircraft yet. This is a common mitigation measure to mitigate small delays. It is therefore interesting that pre-boarding is applied in combination with a full update of 10 minutes.

In scenario's 4 and 5, a 15 minutes update was advised at 10 minutes before TOBT (4) and at TOBT (5). Scenario 4 involved late transfer passengers. Two turnaround coordinators responded that they would contact the involved service provider (in this case the gate agent) for additional information on the passengers and after that contact the captain. One turnaround coordinator stated that he would contact the captain, without contacting the gate agent first. These turnaround coordinators stated that it is up to the captain to decide if they are going to wait for the passengers. In scenario 5, bags needed to be offloaded. Three turnaround coordinators did follow the advise on the interface, arguing that they believed offloading bags can indeed take that long. In both scenario's seven turnaround coordinators chose to update only by 10 minutes or 5 minutes instead of the advised 15 minutes. In their motivation, two turnaround coordinators explicitly stated that they would use the TSAT window if, after their update of 10 minutes, more time was needed. Two other turnaround coordinators explicitly stated that after their 5 minute update, they would keep adding 5 minutes until ready. These choices and motivations show that the culture of last minute TOBT updating, which was discussed earlier in this research, is not changed by the introduction of the interface. With an improved information position the turnaround coordinators still prefer to underestimate the TOBT.

The setup of scenario 3 differed from the others since a TOBT update to an earlier instead of a later moment was advised. This also resulted in different answers. When turnaround coordinators were advised to bring the TOBT forward, four respondents ignored this advice. The main reason given by the turnaround coordinators was that boarding had just started and that they would check after 10 minutes, when boarding was further. The other six turnaround coordinators responded with a non standard answer. They answered that, when they were ready to update the TOBT, they would check with the captain and the pushback driver to see if they were ready as well. This reaction highlights a missing piece of information in the interface. The definition of the TOBT is: the time at which the aircraft is estimated to be ready, with all doors closed and boarding bridges removed. Following this definition, the pushback driver was not included in the interface since it was the assumption that this service was not considered in TOBT management. It was assumed that since the pushback drivers are scheduled using the TOBT, this makes them a reaction on the TOBT and not an input factor for determining the TOBT. The response to scenario 3 however shows that this assumption is incorrect under specific circumstances. The feedback from the turnaround coordinators has shown that when the TOBT needs to be brought forward, information on the pushback driver is considered in TOBT management. The same goes for the captain. To further complete the interface, these two actors should be included.

5.3. Results of the evaluation part

Table 5.4 gives an overview of how the turnaround coordinators responded on the statements. The complete response to these statements and the motivation of the turnaround coordinators can be found in appendix E. It was noted during the evaluation that the turnaround coordinators did not answer the evaluation questions as quickly as the simulation questions. After consideration, their answer to the statements often included some condition under which they would (dis)agree with the statement. These conditions can be found in appendix E under the motivations. Due to the limited time available for the evaluation it was not possible to ask follow-up questions on the answers, but many motivations were clear on themselves.

Table 5.4: Answers of the turnaround coordinators on the presented statements

Statement	Completely disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
Statement 1: Usefulness	0	1	2	**6**	1
Statement 2: Workload	0	**5**	3	2	0
Statement 3: Overview	0	0	0	2	**8**
Statement 4: Interaction	0	0	1	4	**5**
Statement 5: Stakeholders	0	**5**	3	2	0
Statement 6: Trusted aid	0	0	1	**7**	2
Statement 7: Use intention	0	1	0	3	**6**

Overall, the turnaround coordinators were positive on the interface. The majority of respondents found the interface to be useful as an aid for managing the TOBT since it provides them a clear overview of the turnaround. The design of the interface was well received by turnaround coordinators, answering statement 3 and 4 positively. Most turnaround coordinators stated that the layout and the usage of colours made the interface clear and easy to read and to work with. This indicates that the goals of the ecological interface design have been achieved. Almost all turnaround coordinators acknowledged that they would trust this system as an aid in managing the TOBT and expected to use it in every turnaround once it is available.

But besides this positive feedback there are also several points of attention. Table 5.4 shows that most of the turnaround coordinators disagreed or were neutral on the statement regarding workload (statement 2). Most turnaround coordinators expect that due to the interface they might have to make less calls or walk around a bit less, but they still felt the need to check everything themselves. This also comes back in the comments on statement 6: turnaround coordinators really see the interface as an aid, the TOBT update remains their estimation. This is further supported by the observed choices in the simulation, where turnaround coordinators updated the TOBT to their own chosen value.

Turnaround coordinators also answered skeptical on whether the involved stakeholders at the airport would encourage the usage of the system (statement 5). The interface requires an effort of a large group of stakeholders who are not yet included in CDM. Turnaround coordinators not only questioned how the implementation costs would be divided but more importantly, whether the involved parties would all be willing to work with the system. 9 out of the 10 turnaround coordinators identified this, in their own words, as a key condition for the system to work: every service provider in the turnaround has to work with the system in a truthful manner. With this turnaround coordinators identified a potentially large challenge. Currently, when a flight is delayed, the responsible service providers often deny responsibility and place the blame on another party. This 'blame game' has already been addressed shortly during the analysis of the delay code data. Since the system behind the interface logs all the process times it can be used to identify the source of a delay more precisely. The turnaround coordinators expect that because of this, service providers who are currently playing the blame game in their favour might resist against the implementation of the system or won't use it truthfully after implementation.

Finally, although the turnaround coordinators responded positive on statement 4, there were several notes (also in response to other questions) on how easy turnaround coordinators would be able to work with the interface. The introduction of the interface would add an additional information system to turnaround coordination. During the evaluation the interface was shown on a tablet. Several turnaround coordinators stated that they would use it on a tablet, but only if that tablet also gave them access to the other systems they are currently using. One coordinator did not find it feasible to carry a tablet around while conducting a turnaround and two coordinators preferred to have the interface on their smart phone. These different preferences show that the platform on which the interface is available is an important factor which should be considered when adding a new interface to the work environment. In this consideration the already available interfaces should be taken into account as well to prevent an overflow of devices in the turnaround.

5.4. Conclusion on the end user evaluation

The evaluation has shown that the designed interface provides the turnaround coordinators with a clear overview of the turnaround progress. It allows them to get a direct view of how the turnaround is currently going, and how the turnaround has gone so far. Almost all turnaround coordinators expected that they would trust this system as an aid in managing the TOBT and that they would use it in every turnaround once it is available. The evaluation showed that in the further development of the interface the pushback driver and captain, which are currently not included in the interface, should be included as well. Attention should also be paid to the platform on which the interface becomes available, since this has an impact on how often the turnaround coordinators will use the interface.

Implementation of the interface is expected to be an organizational challenge. The interface requires an effort of a group of stakeholders who are not yet included in CDM. Implementation of the system can have negative side effects for several stakeholders since it can be used to identify the source of a delay more precisely. Because of this, service providers might not want to use the system or won't use it truthfully. If not all service providers use the system in the correct fashion this will undermine the idea of the interface and therefore its usability. This is a large risk in the implementation of the interface.

Turnaround coordinators find the interface useful but the simulation and evaluation showed that the turnaround coordinators only consider the interface to be an aid. The interface does not replace the tasks which are currently part of TOBT management, such as observing and assessing the system state. It therefore does not change their workload much. The choices made by the turnaround coordinators and their motivation has show that with the interface as an aid there were no notable differences in how the TOBT updates were conducted. Since the additional information presented in the interface does not change the culture, the turnaround coordinators still prefer to update late and underestimate the TOBT.

6
Conclusions and recommendations

This thesis has researched how ground handlers at Brussels Airport Zaventem update the TOBT and it has explored how the information position of ground handlers managing the TOBT can be improved. This chapter will conclude the research by addressing main research questions. After concluding the research, several techniques applied in this research are discussed and recommendations for both the industry and the scientific community are presented.

6.1. Conclusions

The main question which guided this research was formulated as: **to what extend can the information position of the turnaround coordinator in TOBT management be improved with relevant information?** To answer the main research question, a case study was conducted at Brussels Airport Zaventem (BRU). In short, it can be concluded that the information position of the turnaround coordinator can be improved with a lot of relevant information for TOBT management. The feasibility and the impact of this improvement in the information position however strongly depends on the stakeholders at the airport.

In the literature overview, a stakeholder was quoted saying: A-CDM is 10% technology and 90% people, process and culture [16]. The conclusion of this research is in line with this quote.

6.1.1. 10% Technology

The analysis of TOBT management at BRU showed that the turnaround of an aircraft is complex, with a multitude of processes which can cause a delay and therefore a TOBT update. Most causes are related to passengers and happen outside of the turnaround coordinators direct line of sight and pop up late in the turnaround. This makes managing the TOBT a difficult task for the turnaround coordinator. This task is further complicated since the turnaround coordinator has to actively pull information out of the turnaround process to make an assessment on the TOBT. In making this assessment, the turnaround coordinator does not have clear information on process times to rely on as a reference. This showed that there is a need for improvement in the information position of turnaround coordinators regarding TOBT management.

Cognitive work analysis was used to provide a foundation for the design of a new information tool. The analysis identified the interpretation of the turnaround system state as a location for possible improvements in the information position. The interpretation of the turnaround system state is a complex activity which requires the turnaround coordinator to have a clear mental model of the turnaround which he needs to compare to the current system state and alter to predict the consequences of deviating processes on the TOBT. In the CWA it was proposed that individual service providers (such as cleaning, catering, fueling, gate agent and loaders) take over part of the work of the turnaround coordinator. They do this by observing their own system state for which they are responsible and communicate their expected end time with the turnaround coordinator via an interface.

Through several iterations, an ecological interface was designed to support in TOBT management. The designed interface does not require a technological breakthrough of some sort. It is based on a system which collects information from the service providers in the turnaround and from existing systems at the airport. This information is combines in an up-to-date schedule of the turnaround. The interface therefore presents the turnaround processes and milestones along a time line, as can be seen in figure 6.1. The interface provides high level information, detailed process information and visual signals in one overview to support the turnaround coordinator in each level of cognitive control during TOBT management.

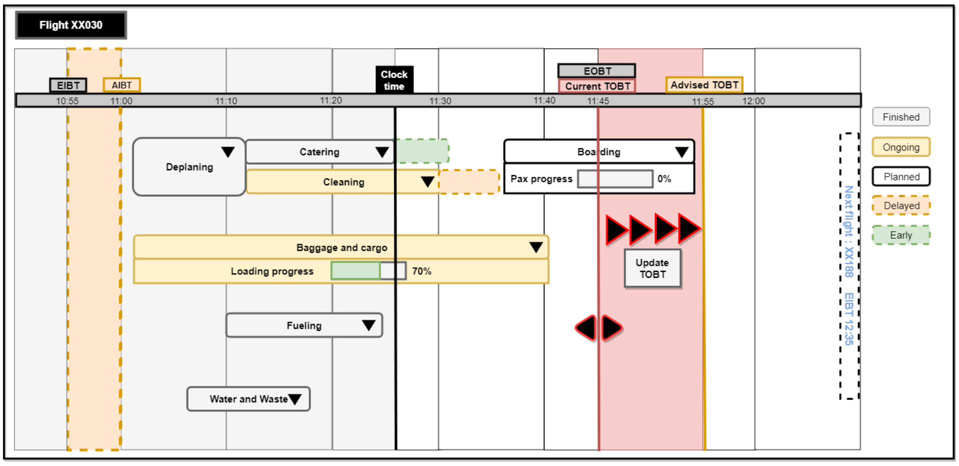


Figure 6.1: The designed interface

The evaluation of the interface with turnaround coordinators showed that the goals of the ecological interface design have been achieved. The turnaround coordinators found that the designed interface provided them with a clear overview due to its layout and usage of colours. Although preferences on devices differed, the turnaround coordinators found the interface easy to work with during the turnaround. Most turnaround coordinators expected that they would use this system as an aid in managing the TOBT in every turnaround once it is available. With these results, the research has shown that an interface can be designed which improves the turnaround coordinators information position in managing the TOBT.

6.1.2. 90% people, process and culture

But, technology such as the designed interface only plays a facilitating role in A-CDM. The biggest challenges to achieve this improvement in the information position and in TOBT management are related to people, process and culture. These challenges can be found at both the input and the output side of the interface.

At the input side, the interface requires an effort of the service providers in the turnaround. These service providers are not yet included in A-CDM. They therefore have to be introduced into A-CDM, which requires them to understand and believe in the benefits of A-CDM and change their working methods accordingly. Although the system as a whole benefits from the shared information and the interface, the biggest beneficiaries remain the airport operator and the airlines. Improving the information position can also have negative side effects for the service providers. The collected data can be used to identify the source of a delay more accurately. This excludes the blame game which some service providers are currently playing to avoid penalties. Because of this, service providers might not want to use the system or won't use it truthfully. And if not all service providers use the system in the correct manner this will undermine the idea of the interface.

At the output side of the interface, the turnaround coordinators pose a challenge as well. The abstraction hierarchy diagram showed that for a well executed turnaround the values of safety, efficiency, quality, predictability and punctuality should be met. But where safety, efficiency, quality and punctuality are strictly enforced by stakeholders at the airport, predictability is not enforced. TOBT management is mainly driven by this value of predictability. When the turnaround coordinator makes a decision on the TOBT, predictability has to compete with other values such as punctuality. Keeping these values in mind, turnaround coordinators assess the costs of overestimating and underestimating the TOBT. The costs for overestimation are generally assessed by the turnaround coordinators as being high since overestimation can harm a flights punctuality. The cost of underestimating is assessed as low, since predictability is not enforced. This trade-off leads to a culture in which TOBT updates are small and last minute.

With introduction of the interface, updating the TOBT remains the responsibility of the turnaround coordinator. During the observations of TOBT management, 88% of the observed TOBT updates were conducted in the last 10 minutes and 46% of the updates were only by 5 minutes. In the evaluation of the interface it was noted that the majority of turnaround coordinators did not follow the advised TOBT updates. They still preferred to wait until a later moment in the turnaround or decided to update the TOBT only by a fraction of the advised TOBT. This shows that the culture of last minute and small updates remains present, keeping its influence on the way the TOBT is managed. Without a change in this culture, an improvement in the information position will not create a more reliable TOBT. Besides strengthening the information position of the turnaround coordinator, the measurement and enforcement of predictability is therefore the key in improving TOBT management.

6.2. Discussion

This research has applied several techniques to reach the aforementioned conclusions. After these conclusions, this discussion will elaborate on some of the limitations of this research.

6.2.1. Brussels Airport as a single case study

This research used Brussels Airport Zaventem as a case study for several pragmatic reasons. The case study has given a thorough insight into turnaround coordination at BRU. But since it was a single case study no research has been conducted at other airports. In the introduction it was assumed that generalization of the outcomes is possible because airport systems and procedures are similar due to international standard and recommended practices. Looking at an airport from a purely technical perspective, this assumption is logical. But with the conclusion that the researched problem is 90% people, process and culture, this technical perspective can not be uphold. While this research focused on turnaround coordinators at Brussels Airport, turnaround coordinators at airports in Germany or the United Kingdom might have developed a different culture and procedures among their own. It can therefore not be stated with full confidence that the identified technological and organizational aspects will be directly applicable to other A-CDM airports.

6.2.2. Data analysis and field observations

This research used data from the delay code system to identify which processes in the turnaround frequently caused TOBT updates. Questions can be raised on the accuracy of the delay code data. In order to hide their own mistakes, operators are know to be use the wrong delay codes. Some checks are applied at BRU to prevent this, but it can be expected that there is still some questionable delay code data in the used sample. Since this research did not have the tools to check this, and the effects of it was estimated to be small in such a large database, the data was used. Even though the data analysis provided a clear overview, the lack of sub codes also meant that the data analysis could not always go into as much detail on some delays as desired.

TOBT management was not captured by the A-CDM database in the way that would have made a data analysis possible. Therefore field observations of TOBT updates were conducted. This did mean that the number of analyzed TOBT updates was limited. This is the result of carrying out research in the live environment of the turnaround: not every observed flight had a TOBT update. The observations however also gave detailed insight into turnaround coordination which would not have been possible using data analysis. If this research would have only focused on the data of A-CDM, the valuable conclusion on the importance of people, process and culture could probably not have been made.

6.2.3. Designing for the turnaround coordinator

Several aspects had to be placed out of scope in the design process in order to keep the research feasible and to the point. The design process focused on a first design. Therefore a limited number of iterations were made and the process did not deliver a working prototype. For the purpose of this study this was sufficient, but for further development and research on the interface a working prototype should be developed. The TOBT management interface was also designed under the assumption that the service providers would provide time estimates via their own interface. This placed the service providers outside the scope of this research. Focusing on the turnaround coordinators made this research one sided, while the conclusion shows how important the other side is as well. And maybe there are even other sides in this multi-stakeholders environment which this research has not shed a light on. The conclusion therefore does not provide a complete view on the expansion of A-CDM with these service providers.

6.3. Recommendations

The conclusion and discussion provide starting points for new questions and research directions. In this section, recommendations are made to A-CDM stakeholders and the scientific community to further work towards this improved A-CDM operation.

6.3.1. Comparing ground operations of A-CDM airports

A-CDM is 90% people, process and culture. But as stated in the discussion, turnaround coordinators at airports in Germany or the United Kingdom might have developed a different culture on their own. They might conduct processes or communicate differently within the framework of A-CDM. It is therefore recommended that future academic research focuses more on these aspects by comparing the ground operations of different A-CDM airports. This research can be comparable to the field study conducted in this research: focusing on the role of the turnaround coordinator, the communication in the turnaround and the moment, magnitude and reasons of a TOBT update.

By comparing the operation at multiple airports, it can be determined how comparable the ground operations at different A-CDM airports are, which is useful for the generalization of other scientific research (such as this research). Through the comparison, best practices can be defined which can benefit the whole sector. When the operations are not deemed comparable, causes for these differences should be investigated further. Investigating these causes can be useful for high level organizations such as Eurocontrol in developing new EU wide concepts which incorporate these differences.

6.3.2. Measuring TOBT management behaviour with KPIs

As stated in the conclusion, the measurement and enforcement of predictability is key in improving TOBT management. The graph on TOBT updates in the introduction only gives a high level indication that TOBTs are updated last minute. The observations gave an important insight into how the TOBT was actually updated. For an airport it is however impossible to constantly observe how the TOBT is managed in all turnarounds at the airport. It is therefore recommended to measure TOBT management behaviour by defining and implementing new KPIs. In its A-CDM manual, Eurocontrol does not provide a set of KPIs which can capture TOBT management behaviour. It presents KPIs which focus on the difference between milestones, such as the difference between the AOBT and TOBT. The TOBT is at the hart of the A-CDM system and should therefore be monitored in as much detail as possible.

Brussels Airport Company should therefore focus on developing these KPIs which could help to monitor and improve TOBT management. Examples of possible KPI's include the number of TOBT updates per turnaround and the update moment in reference to the current TOBT at the moment of updating. These KPIs are facilitators, they allow the A-CDM stakeholders to have more informed discussions. In theses discussions, stakeholders can address behaviour which is not in line with the A-CDM guidelines and monitor if a stakeholder is improving after being confronted with his behaviour. In defining these KPIs, the observations of this research can be used as a starting point since they show what can happen on the ground. With these observations the airport should look at the A-CDM database structure and determine what data can be combined to come to these KPIs.

6.3.3. Researching enforcement schemes in A-CDM

Besides measuring, enforcement is also needed. So besides defining KPIs, research should also focus on the enforcement of predictability. Most of the identified values of turnaround coordination are enforced by a stakeholder with a fining system. But predictability, the value of A-CDM, is not enforced. Corrigan and others already noticed that the leader in A-CDM (often the airport operator) usually does not have the tools to actively enforce the proper use of A-CDM on a stakeholder since it is not laid down in detailed contracts. Scientific researchers should investigate how different airport currently enforce A-CDM. What enforcement mechanisms are currently used? How do these mechanisms relate to contractual agreements (such as airport concessions and Service Level Agreements) between the different stakeholders? What is the impact of these mechanisms? And what are the risks involved in implementing such enforcement schemes? Besides focusing on A-CDM airports, research can also be widened to include collaborative frameworks in other industries.

6.3.4. Investigating the integration of service providers in A-CDM

This research has worked under the assumption that the service providers provided time estimates via their own interface. The introduction of these different parties however requires more research. A cost benefit analysis should be carried out to determine the added value of introducing the service providers into A-CDM. On the cost side estimations have to be made for the implementation costs of the system and the interface, together with its maintenance. Where the costs side is a more basic estimation for an IT project, the benefits side requires much more research. What is the change in predictability going to be? How does this affect the efficiency of the different resources at the airport? Besides the focus on the overall costs and the benefits for the system, attention should also be given to the distribution of these costs and benefits. This research already gave a first indication that the benefits will not be equally divided over the different stakeholders.

Practical aspects of the integration of service provider in A-CDM should also be investigated. Similar to this research, the work domain of each service provider should be analyzed to determine how they can best be connected to the A-CDM system and what changes in their work procedures are required. If the analysis comes to positive conclusions, the design proposed by this research can be further developed into a first working prototype. In the development of this prototype, care should be given to how the prototype is placed in the work environment. Trialling of the system in a small number of turnarounds, with all involved stakeholders, is expected to provide valuable information on how to develop the system further and get more benefits from it.

7 Reflection

The Discussion in chapter 6 already reflected on the applied techniques in this research. After completing this research, I would like to shortly reflect in this chapter on the personal experience i had in the past last year with my thesis.

I started this report by stating my gratitude to Brussels Airport Company for providing me with a case study. At the end of this report, I again would like mention that I'm very thankful for the opportunity that was given to me by Brussels Airport Company to conduct my research at their airport. With ten months, this research has taken considerably longer then the average thesis for the master of Transport, Infrastructure and Logistics at the TU Delft. This 10 months can be split up in four months of research setup and six months of actually conducting the research with BRU as a case. I believe it is important to reflect on the encounters I had in setting up this research since it shows some of the difficulties for conducting research in a multi-stakeholder environment.

Before arriving at Brussels Airport, several other options were discovered with other market parties. The parties will not be mentioned by name, since that does not contribute to the point I'm trying to make in this reflection. I have spoken with an airport operator, a large airline and a ground handling company. On a high level, all these meetings followed the same structure. After having introduced the research the conversations quickly went into serious details on the research. At the end of the meeting, all market parties were positive on the research and they would come back to me after having discussed it internally. These positive first meeting however were not followed op. The airline did not respond to my follow-up email or calls for unclear reasons. The ground handler had to cancel its contribution to the research do to internal restructuring. The contact at the airport operator remained positive for almost three weeks but then canceled the collaboration to the research after having discussed it internally.

Although collaboration and data sharing is the core of A-CDM, my experience showed that when it comes to research this is not always the case. This is unfortunate and not good for the development of the A-CDM and TAM concepts. I believe that research done by outside parties, who are not an A-CDM stakeholder, is off large value for the development of the A-CDM and TAM concepts. Outside parties are not driven by the specific interest of one stakeholder. This open minded view allows for objective research which, according to my believe, benefits the overall system instead of a specific stakeholder.

With concepts such as Total Airport Management and the Airport Operations Plan on the horizon I hope that in the future more research can be conducted by graduating students in this multi-stakeholder environment. I would like to advise future graduates to look further then just analyzing data. At the beginning of my research I strongly focused on data analysis as a technique. There is so much data in A-CDM and data analysis always feels like a strong scientific technique. This research however has shown me how interesting and valuable it is to actually observe how work is conducted on the ground and analyze it in dept with a technique such as cognitive work analysis.

In this research I have applied multiple techniques which are of use in my career after graduation. Besides applying these hard skills, the way I carried out the research has also further strengthened my soft skills. Developing a project proposal, writing to-the-point summaries and adjusting them quickly to a client/stakeholders needs has brought me valuable insight which are of great use in my future career. The experience of the operation of a live airport has further strengthened my passion for aviation, its constant time pressure and it increasing complexity. I therefore look forward to start my career at to70 after graduating, focusing on the current and future challenges of the aviation sector.

Bibliography

[1] Airbus. *Airbus A319 aircraft characteristics airport and maintenance planning*, jul 01/95 edition, 2017.

[2] Brussels Airport. Luchtvaartmaatschappijen. `https://www.brusselsairport.be/nl/contact/airls`, 2017.

[3] *CDM-AMS operational manual v1*. Amsterdam Airport Schiphol, 2015.

[4] International Air Traffic Association. *IATA Ground Operations Manual*, 30th edition, 2010.

[5] International Air Transport Association. *Airport Development Reference Manual*. International Air Transport Association, 10 edition, 2017.

[6] J.A.D. Atkin, G. De Maere, EK Burke, and J.S. Greenwood. Addressing the pushback time allocation problem at heathrow airport. *Transportation Science*, 47(4):584–602, 2012.

[7] ESMA aviation academy. Turnaround coordinator job description. `http://www.esma.fr/en/training/ground-staff/turnaround-coordinator/turnaround-coordinator-job-description/`, 2017.

[8] All Air Jobs aviation board. Airlines - ground staf - turnaround coordinator. `http://allairjobs.com/j10379/Lufthansa-jobs-Turnaround-Coordinator`, 2017.

[9] R. Bohme, D.and Brucherseifer and L. Christoffels. Coordinated arrival departure management. In *7th USA/Europe ATM 2007 R&D Seminar.—2007*, 2007.

[10] D. Booth and D. Huet. A-cdm impact assessment final report. Technical report, Eurocontrol, 2016.

[11] S. M. Casner and B. F. Gore. Measuring and evaluating workload: A primer. *NASA Technical Memorandum*, 216395:2010, 2010.

[12] Brussels Airport Company. Visie 2040 2d plannen. `https://www.brusselsairport2040.be/nl/visie-2040/63/2d-plannen`, 2016.

[13] Brussels Airport Company. Brussels airport breekt drie absolute records in 2017. `https://www.brusselsairport.be/pressroom/nl-be/brussels-airport-breekt-drie-absolute-records-in-2017/`, 2018.

[14] Brussels Airport Company. Service providers at brussels airport. Email correspondence, April 2018.

[15] Brussels Airport Company. Monthly traffic figures. `https://www.brusselsairport.be/en/corporate/statistics/monthly-traffic-figures`, nd.

[16] S. Corrigan, L. Mårtensson, A. Kay, S. Okwir, P. Ulfvengren, and N. McDonald. Preparing for airport collaborative decision making (a-cdm) implementation: an evaluation and recommendations. *Cognition, Technology & Work*, 17(2):207–218, 2015.

[17] K. de Bolle. Airport collaborative decision making (a-cdm) concept elements: Setting milestones. `https://newairportinsider.com/airport-collaborative-decision-making-a-cdm-concept-elements-setting-milestones/`, 2013.

[18] B. De Reyck. Apoc business process re engineering big data study. Technical report, UCL School of Management, University of Virginia and Heathrow Airport, 2016.

[19] D. Elbers, K.and Kemper and M. Tielrooij. Feedback session with K. Elbers, ground handling expert at to70 and M. Tielrooij, aviation consultant and EID expert, 2017.

[20] K. Elbers. unstructured interviews with K. Elbers, ground handling expert at to70, 2017.

[21] V. Eleftheriou. Moving towards timely and succesful a-cdm 2.0 implementation. *International Airport Review*, pages 32–34, September 2017.

[22] *Airport CDM Implementation Manual*. Eurocontrol, 5 edition, 2017.

[23] Eurocontrol. Airport collaborative decision making. `http://www.eurocontrol.int/articles/airport-collaborative-decision-making-cdm`, 2018.

[24] Eurocontrol. Airport cdm: Steps to boost efficiency. `https://www.schiphol.nl/nl/.../6wGWW70OqQi8kEIYyUye4Q.pdf`, nd.

[25] Guillermet F. Towards total airport management. `http://www.airport-business.com/2017/06/towards-total-airport-management/`, June 2017.

[26] M. Groppe, R. Pagliari, and D. Harris. Applying cognitive work analysis to study airport collaborative decision making design. In *Proceedings of the ENRI International Workshop on ATM/CNS*, pages 77–88, 2009.

[27] M. Groppe, R. Pagliari, and D. Harris. Monitoring the airport-cdm runaround process: applying a qualitative confinitive model based on field observations. In *27th international congress of the aeronautical sciences*, pages 52–64, 2010.

[28] P. Groskamp. unstructured interviews with P. Groskamp, Senior Aviation Consultant at to70, 2017.

[29] Y. Günther, A. Inard, B. Werther, M. Bonnier, G. Spies, A. Marsden, M. Temme, D. Böhme, R. Lane, and H. Niederstraßer. *Total Airport Management (Operational Concept and Logical Architectur)*. PhD thesis, DLR, 2006.

[30] IATA. Iata forecast passenger demand to duible over 20 years. `http://www.iata.org/pressroom/pr/Pages/2016-10-18-02.aspx`, October 2016.

[31] New Airport Insider. Airport collaborative decision making in europe. `https://newairportinsider.com/airport-collaborative-decision-making-in-europe/`, 2013.

[32] *Security. Safeguarding International Civil Aviation Against Acts of Unlawful Interference*. International Civil Aviation Organization, eighth edition edition, April 2006.

[33] SESAR joint undertaking. Cognitive work analysis (cwa). `https://ext.eurocontrol.int/ehp/?q=node/1615`, 2012.

[34] R Kilgore, O. St-Cyr, and G. Jamieson. From work domains to worker competencies: a five-phase cwa. *Applications of cognitive work analysis*, pages 15–48, 2008.

[35] W. Malik, G. Gupta, and Y. Jung. Managing departure aircraft release for efficient airport surface operations. In *AIAA Guidance, Navigation, and Control Conference*, page 7696, 2010.

[36] N. Naikar, R. Hopcroft, and A. Moylan. Work domain analysis: Theoretical concepts and methodology. Technical report, DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION VICTORIA (AUSTRALIA) AIR OPERATIONS DIV, 2005.

[37] S. Okwir, P. Ulfvengren, J. Angelis, F. Ruiz, and Y. Guerrero. Managing turnaround performance through collaborative decision making. *Journal of Air Transport Management*, 58:183–196, 2017.

[38] A. Papenfuss and Y. Günther. Feasibility of traffic prognosis for an airport operation centre. *Results of an initial Field Study, ICRAT, Istanbul, Türkei (accepted paper)*, 2008.

[39] M. Pierobon. A-cdm: the route to efficiency. *Passenger terminal world*, pages 64–68, June 2017.

[40] J. Rasmussen. Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE transactions on systems, man, and cybernetics*, pages 257–266, 1983.

[41] J. Rasmussen, A. Pejtersen, and L. Goodstein. Cognitive systems engineering. 1994.

[42] International Airport Review. News: Brussels airport plans major runway renovation works, 2016.

[43] Amadeus IT Group SA. Altea suite. http://www.amadeus.com/web/amadeus/en_1A-corporate/Airlines/Airline-Systems/Airline-Core-Systems/Alt%C3%A9a-Suite/1400000039525-Categorizable_P-AMAD_SuiteDetailPpal-1319637765587?industrySegment=1259068355670, 2017.

[44] M. Schaper and I. Gerdes. Trajectory based ground movements and their coordination with departure management. In *Digital Avionics Systems Conference (DASC), 2013 IEEE/AIAA 32nd*, pages 1B4–1. IEEE, 2013.

[45] M. Schaper, G. Tsoukala, R. Stavrati, and N. Papadopoulos. Departure flow control through takeoff sequence optimisation: Setup and results of trials at athens airport. In *Digital Avionics Systems Conference (DASC), 2011 IEEE/AIAA 30th*, pages 2B2–1. IEEE, 2011.

[46] P. Swanborn. *Case study research: What, why and how?* Sage, 2010.

[47] U. Tancredi, D. Accardo, G. Fasano, A. Renga, G. Rufino, and G. Maresca. An algorithm for managing aircraft movement on an airport surface. *Algorithms*, 6(3):494–511, 2013.

[48] M. Tielrooij and H. Huang. Feedback session with M. Tielrooij, aviation consultant and EID expert and H. Huang, aviation consultant, 2017.

[49] C. Upton and G. Doherty. Extending ecological interface design principles: A manufacturing case study. *International Journal of Human-Computer Studies*, 66(4):271–286, 2008.

[50] W. B. van Blokland, R. Huijser, R. Stahls, and S. A. Santema. Future airport turnaround ground handling processes. In *Conference proceedings of 10th TRAIL Congress, TRAIL Research School, Delft (The Netherlands)*, 2008.

[51] V. Venkatesh, M. Morris, G. Davis, and F. Davis. User acceptance of information technology: Toward a unified view. *MIS quarterly*, pages 425–478, 2003.

[52] K. J. Vicente. *Cognitive work analysis: Toward safe, productive, and healthy computer-based work.* CRC Press, 1999.

A

Appendix A: Overview of Brussels Airport Zaventem

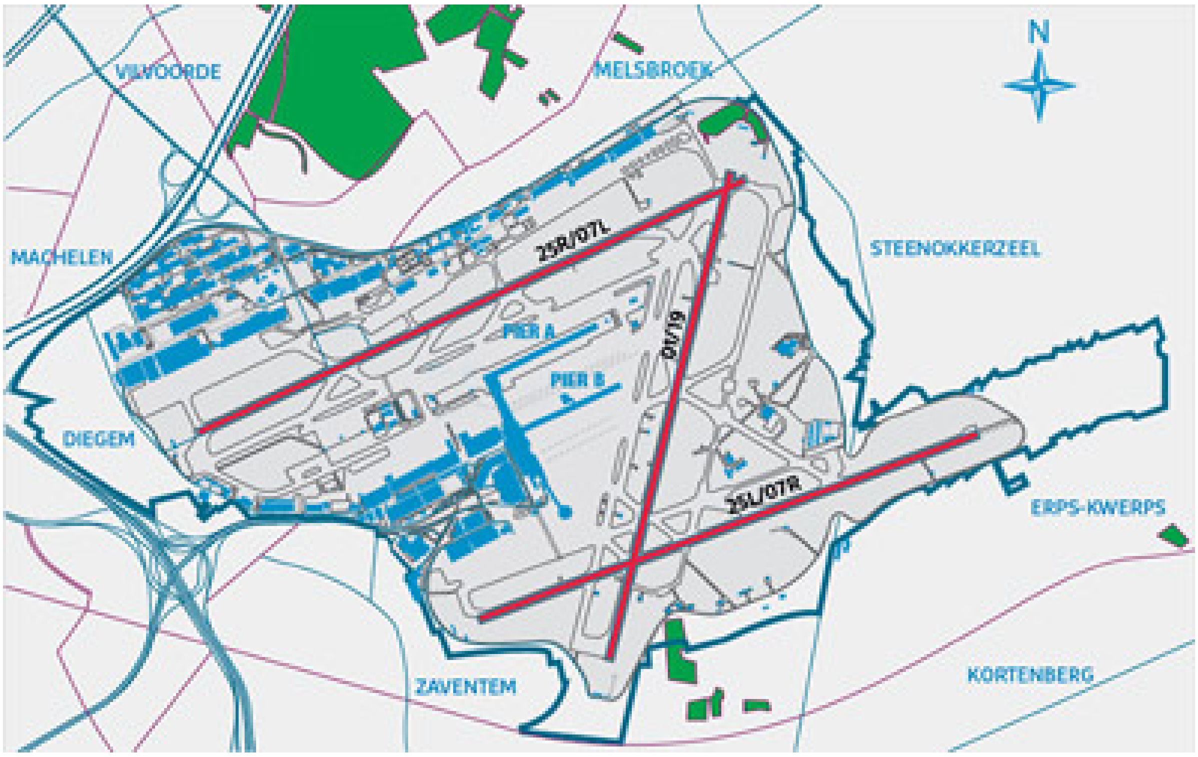


Figure A.1: Overview of Brussels Airport Zaventem airport ground [42]

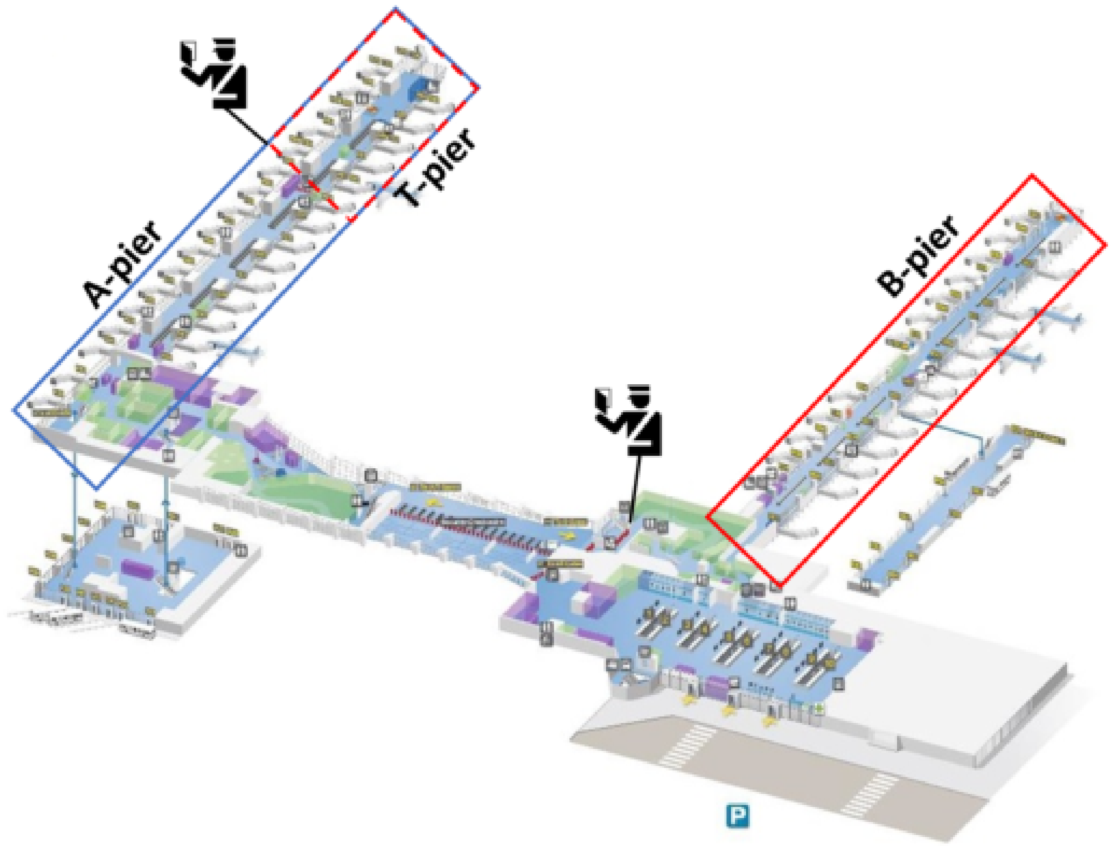


Figure A.2: Overview of piers and immigration points

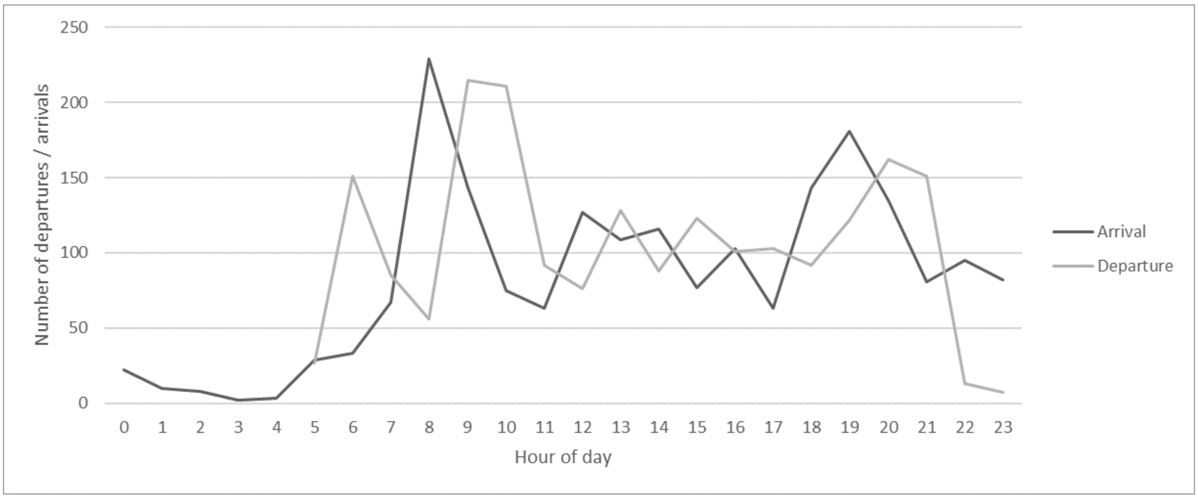


Figure A.3: Arrival and departure pattern at Zaventem based on 1 week traffic (4000 flights)

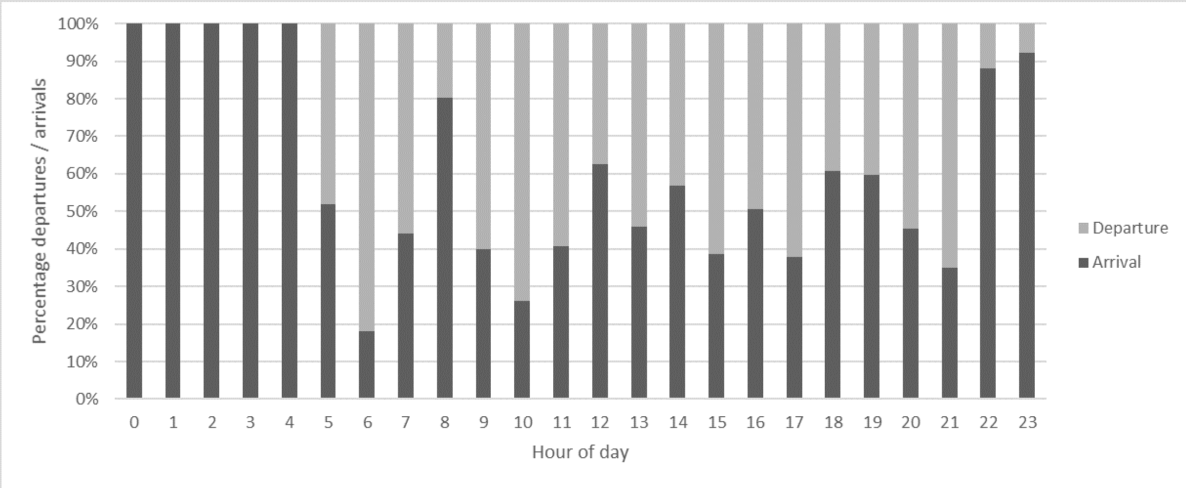


Figure A.4: Arrival and departure pattern in percentages at Zaventem based on 1 week traffic (4000 flights)

B

Appendix B: Supporting output for delay code analysis

Overall data

Table B.1: Top 10 delay codes based on frequency with the average delay per delay code (retrieved from sample)

Delay code	Average time per delay (minutes)	Stdev (minutes)
89	7	5
93	26	36
87	14	11
85	14	13
19	12	9
86	24	14
16	9	8
81	16	11
91	18	15
35	8	5

Table B.2: Top 10 delay keys, retrieved from data sample

Delay key	Delay key reported	% flights flights
89	1035	25.1
93+89	629	15.3
87	269	6.5
85	262	6.4
86	255	6.2
19	145	3.5
93+87	102	2.5
93+19	101	2.4
93+85	68	1.6
16+89	45	1.1

Delay code 87: Airport facilities

Table B.3: Delay code 87 subcodes reported by Brussels Airlines (retrieved from data sample)

Delay code	Cause	Flights reported	Percentage
87	Airport facilities (general description)	39	18.2%
87L	Departure control system (DCS) / Gate reader unserviceable	40	18.7%
87D	Late / lack of passenger transport	39	18%
87V	Baggage System Failure	35	16.4%
87T	Aerobridge unserviceable	13	6.1%
87Y	Apron congestion	11	5.1%
87R	Electrical system failure	11	5.1%
87W	Gate limitation/no gate available	8	3.7%
87X	Lighting and buildings	6	2.8%
87Z	Parking stands limitation/no parking stands available	5	2.3%
87E	Congestion crew screening	5	2.3%
87G	Other	2	1%

Table B.4: Top 9 flights reporting airport facilities as a cause of delay, retrieved from data sample

Flight	Destination	Flights delayed	% of flights
FR1457	Dublin	65	82.3%
FR1453	Dublin	40	43.47%
FR1455	Dublin	30	76.9%
BT602	Riga	15	19%
EI631	Dublin	14	17.3%
FR2983	Rome	12	13%
BM1102	Newcastle	9	16.4%
JU301	Belgrade	9	34.6%
SN3289	Tel Aviv	9	10%

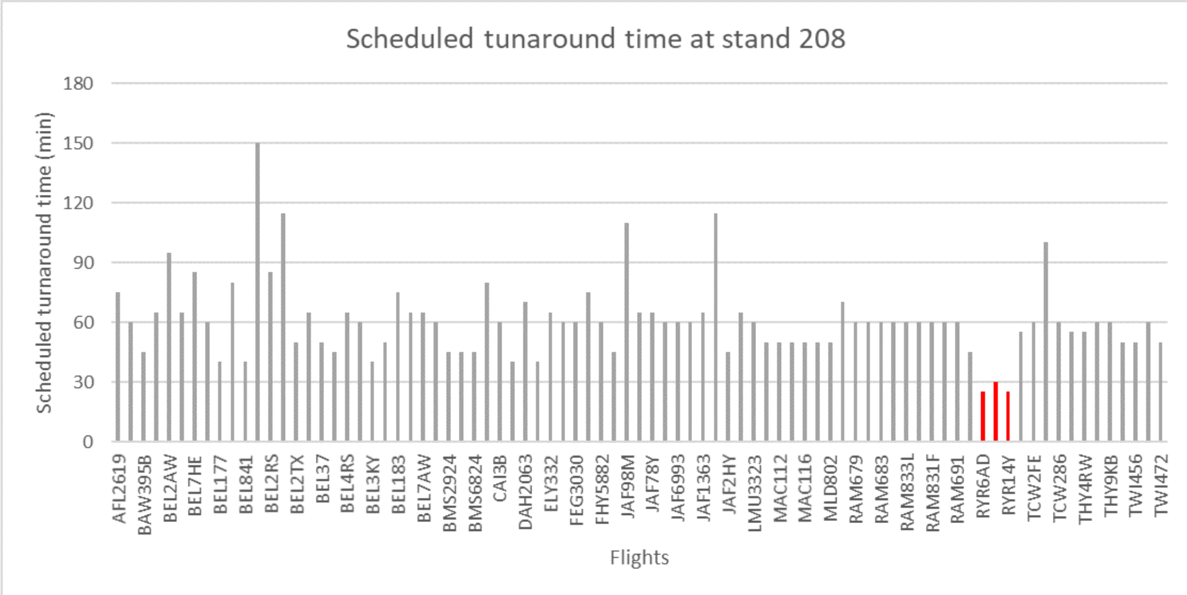
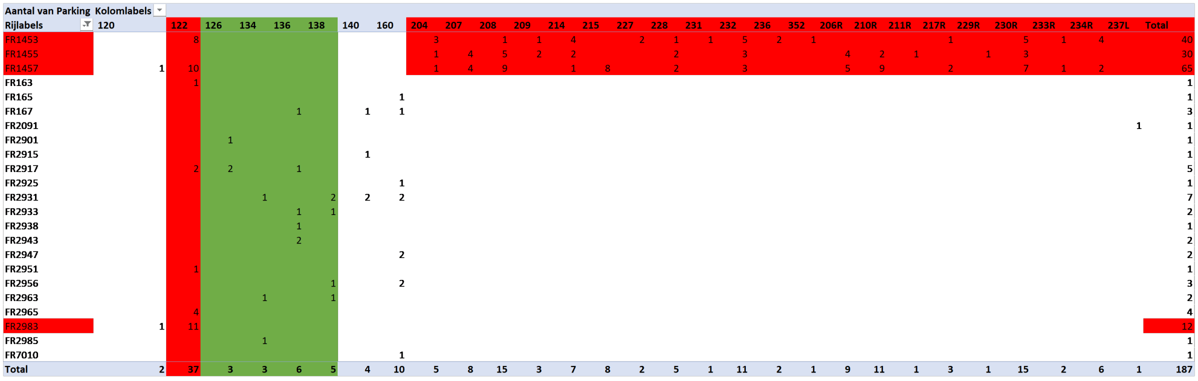


Figure B.1: Scheduled turnaround time of flights at stand 208 in august and september 2017



Aantal van Parking	Kolomlabels																													
Rijlabels	120	122	126	134	136	138	140	160	204	207	208	209	214	215	227	228	231	232	236	352	206R	210R	211R	217R	229R	230R	233R	234R	237L	Total
FR1453		8							3		1	1	4		2	1	1	5	2	1				1		5	1	4		40
FR1455									1	4	5	2	2			2		3			4	2	1		1	3				30
FR1457	1	10							1	4	9		1	8		2		3			5	9		2		7	1	2		65
FR163		1																												1
FR165								1																						1
FR167					1		1	1																						3
FR2091																													1	1
FR2901			1																											1
FR2915							1																							1
FR2917		2	2		1																									5
FR2925								1																						1
FR2931				1		2	2	2																						7
FR2933					1	1																								2
FR2938					1																									1
FR2943					2																									2
FR2947								2																						2
FR2951		1																												1
FR2956						1		2																						3
FR2963				1		1																								2
FR2965		4																												4
FR2983	1	11																												12
FR2985				1																										1
FR7010								1																						1
Total	2	37	3	3	6	5	4	10	5	8	15	3	7	8	2	5	1	11	2	1	9	11	1	3	1	15	2	6	1	187

Figure B.2: Overview of delayed Ryanair flights per gate, 80% of flights take place at the 4 green stands

Delay code 85: Security

Table B.5: Top 9 flights reporting mandatory security as a cause of delay, retrieved from data sample

Flight	Destination	Flights delayed
FR1453	Dublin	11
PS146	Kiev	10
SN3633	Paris	8
EI631	Dublin	7
SN3587	Lisbon	7
SN3631	Paris	7
WW463	Reykjavik	7
LH2283	Munich	6
TB217	Miami	6

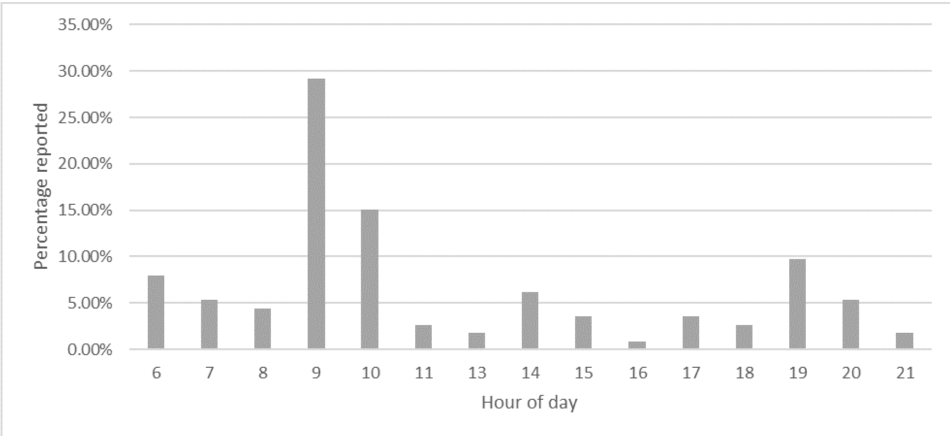


Figure B.3: Spread of reported baggage identification / unloading over the day (retrieved from data sample)

Delay code 19: PRM

Table B.6: Top 7 flights reporting PRM as a cause of delay, retrieved from data sample

Flight	Destination	Flights delayed
VY1333	Alicante	16
TK1940	Istanbul	10
TK1944	Istanbul	10
3O114	Tanger	8
TK1938	Istanbul	8
TK1942	Istanbul	8
VY8993	Barcelona	7

Delay code 86: Immigration

Table B.7: Top 10 flights reporting immigration as a cause of delay, retrieved from data sample

Flight	Destination	Flights delayed	Percentage of flights
SN359	Luanda / Kinshasa	28	70%
SN285	Abidjan / Cotonou	26	63%
SN205	Dakar / Conakry	21	53%
SN469	Kigali	14	35%
SN371	Douala / Yaoundé	26	33%
SN277	Accra / Lomé	16	31%
SN2835	Moscow	18	20%
SN(2)173	Manchester	13	14%
SN3633	Paris	13	14%
SN3631	Paris	12	13%

C
Appendix C: Field observations of TOBT management

This appendix contains information gathered during the field observations at BRU. Table C.1 gives an overview of the conducted field observations. Each section contains schemes, tables and notes which were made during the observations.

Table C.1: Overview of field observations at BRU

Date	Time	Location	Actor	Observation goal
21-02-2018	13:30 - 20:45	Flight Watch	Aviapartner	General overview of TOBT updating
27-02-2018	14:00 - 21:30	Flight Watch	Swissport	General overview of TOBT updating
28-02-2018	09:00 - 16:30	Apron	Aviapartner	Detailed observation of TOBT updating
20-03-2018	08:00 - 16:00	Apron	Swissport	Detailed observation of TOBT updating

C.1. Observation 1: Flight Watch Aviapartner

Conditions during observation: Off-peak hours, clear weather, alternate mode runway usage (01 landing, 07R take-off) creating some inbound delay. Total of 45 flights monitored during observation.

Observations on the position of Flight Watch (FW) in TOBT updating:

- The main task allocation in TOBT management: Turnaround Coordinator (TC) decides on a TOBT update, FW carries out the update in the Flight Information System of Aviapartner.
- FW reminds the TC in general when TOBT is expired by 5 minutes.
- FW conducts small TOBT updates themselves when a flight is in blocks late, or the EOBT is changed by the airline.
- In general, the TC is the only actor during the turnaround who communicates with FW. TC only communicates with AP personnel around the stand, communications with other actors goes through FW (see figure C.1).
- Besides TOBT updating, FW has many other tasks. This causes their workload to be high in peak moments, meaning they have to prioritize.

Information sources FW (see figure C.2):

- Phones: communication with BAC, Belgocontrol, Dispatch Axxicom, Busses etc.
- Radio (VHF): communication with flight crews.
- Trunk: communication with turnaround coordinators.
- Display with other camera's: wide array of options (roads towards the airport, terminal, runways).
- Display with turnaround coordinator schedules: used to identify the turnaround coordinator of a flight and its trunk number (read only).
- Display with Flight Information System: used to conduct updates (Block time, TOBT, flight details), check progress inbound flights, and communication (flight information displays to pax, fuel to fuellers).
- E-Mail: Telex messages on flight changes, usually for planning purposes.
- Eurocontrol portal: Check inbound flights, expected ATC delay.
- ACARS: Messages send when aircraft brake is off, used for logging the off-block time.
- Display with stand camera's: used to visually check turnaround progress.

Observations on information usage:

- When it comes to voice communication there is a clear priority on which channel is answered first: radio (crews) -> Phones (can be anybody) -> Trunk (own AP people).
- The FIS needs to be manually updated. Operators also seem to be unable to have 1 screen with arrivals next to 1 screen with departures. This requires constant switching between the two.
- The available cameras in the terminal are not used by FW to check for congestion. BAC sends automatic messages when there is congestion in the terminal but these messages usually arrive late.
- Stands 120-138 are not equipped with camera's, causing FW to be 'blind' on these stands.

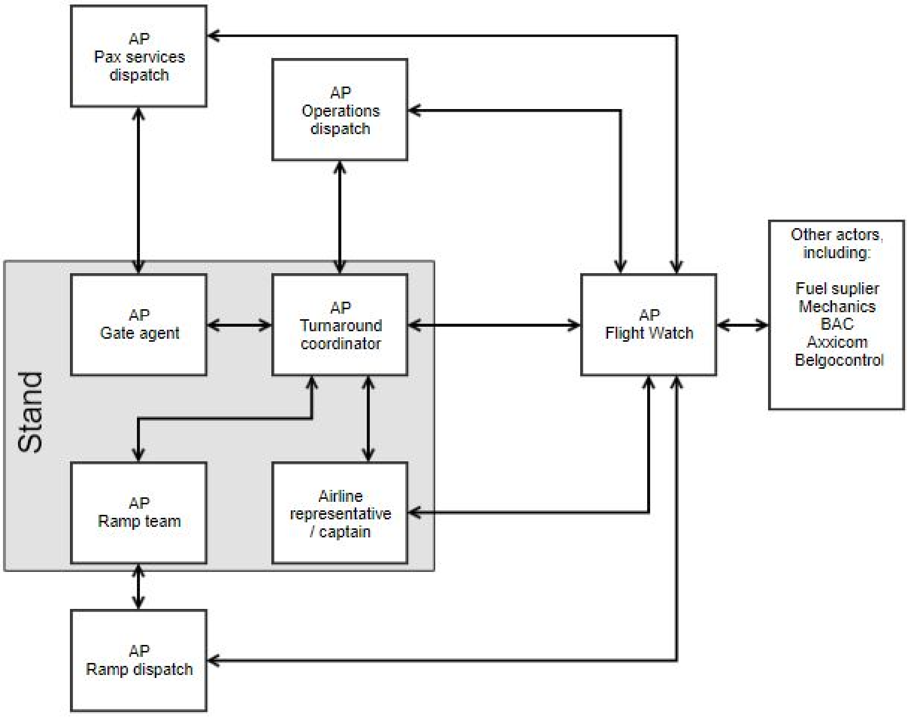


Figure C.1: Position of flight watch within AP)

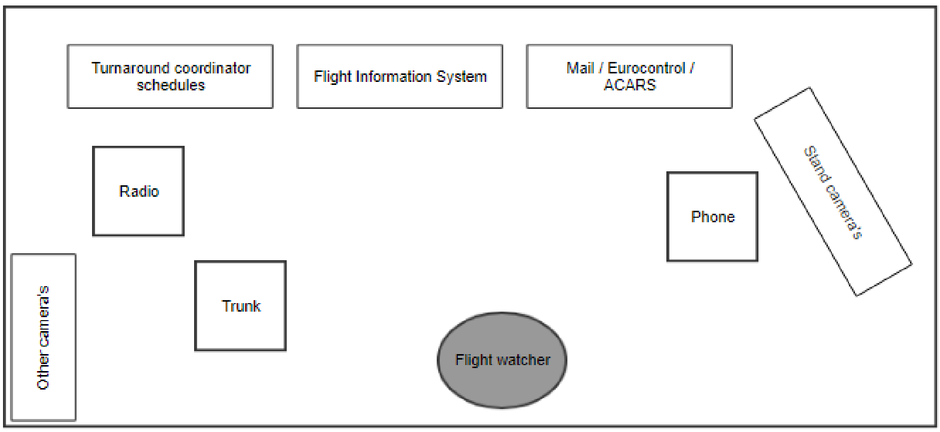


Figure C.2: Overview of Flight Watch setup at AP (shown for one operator)

Observations on TOBT updates

- Of the +/- 45 departing flights in time window 13 flights with TOBT updates were observed (see table C.2.
- All observed TOBT updates were observed in the last 10 minutes before TOBT or after the TOBT already expired.
- All communication via trunk, in rare cases via bridge phone.
- TC's are not very specific on the reasons for a TOBT update. Some don't even communicate clearly that a TOBT update is required.
- 5 minutes seems to be the norm when it comes to TOBT updating, comes back in all kinds of settings.
- TOBT's are often rounded of to 5 minutes.

- FW emphasises: 1 update of +20 minutes is better than 4 updates of +5 minutes. Only the experienced TC's do these larger updates when they think it's necessary. Newer TC's usually stick to a 5 minutes strategy, afraid of kicking the TSAT back to much and create a start-up delay, or even a slot.
- Besides experience, strategy also strongly depends on the cause of the delay.
- Flightwatch often offers the 5 minute strategy themselves: "shall I update the TOBT by 5 minutes?".
- TSAT window is also sometimes used as buffer instead of updating the TOBT.
- Airlines also have a say in TOBT management. They often manage their EOBT themselves, and EOBT and TOBT should stay within 15 min of each other.

Table C.2: Observed TOBT updates and remarks between at flight watch Aviapartner

FLTNR	STD	TOBT updates and remark
TB3723	13:05	Late inbound TOBT initially on 1415 EOBT update by airline on captain request to 1440, TOBT followed. Called TC @ 1412, 1440 was doable GH done @ 1435, TC wants TOBT update to 1435 but captain wanted to leave it (probably not ready)
AT833	16:40	At TOBT update by 10 min (1650) due to delayed loading. TC had to check TOBT update with the airline rep Off-block at 1650, but airline rep decided 0 delay min to declare
KL1732	17:55	TOBT update at 1753, 1755 ->1800, 1800 still busy, no update, 1805 again +5 min, (system removed the +5 update, had to be refiled again)
A54317	18:00	TOBT update at 1800, 1800 ->1810 TOBT update at 1813, 1810 ->1815
BA399	18:15	1814 no update, called, TOBT 1815 ->1820 1819 FW own update, TOBT 1819 ->1824 1825 LC called, set TOBT to 1825, FW: impossible, TOBT 18:24 -> 18:28
A3623	18:20	1820 no update 1823 bridge removed Used TSAT window, no TOBT update
IB3205	18:45	1837 called for FID +5, so FW also updated TOBT +5 FW added +5 due to late inbound Eventually TOBT at 1924?
LY332	18:45	CTOT 1912, TSAT 1854 Aimed for TSAT instead of TOBT Airline rep called to set TOBT on TSAT
TP613	18:50	TOBT update 1850 ->1900 due to hand luggage 1900 FW updated to 1905
FR2963	18:55	TOBT set to 1909 1909 TC called to set TOBT to 1910, impossible
FR2923	19:20	EOBT update to 1930 TOBT update +5
FR1457	19:45	1946 TOBT update 1945 ->1950 1953 TOBT update 1950 ->1955 Off block @ 1959 Early arrival, late departure (2 X MTT)
SK2906	20:10	EOBT set to 2030 2018 TC called to bring TOBT back from 2030 to 2025 Eventually off block was still 2030

C.2. Observation 2: Flight Watch Swissport

Conditions during observation: Off-peak hours, clear weather, alternate mode (01, 07R). Total of 35 flights monitored. Observed one out of two flight watchers who handled all flights except for Brussels Airlines flights. Brussels airlines has vague agreements with Swissport on TOBT setting, causing both parties to manage the TOBT. Swissport's redcaps are also not in charge of the full turnaround, only of the load sheet and the loading process.

Observations on the position of Flight Watch (FW) in TOBT updating:

- Main task allocation in TOBT management: TC decides on TOBT update, FW carries out the update.
- FW conducts updates of flight plans to keep the TOBT and EOBT within 15 minutes. For some airlines the FWer has full authority to do this while at other airlines he needs to consult the airline representative for this.
- In general, the TC is the only actor during the turnaround who communicates with FW, but FW can also contact each individual actor in the turnaround.
- FW also focuses on day +1 (and weekends) planning.

Information sources FW (see figure C.4:

- Phones: BAC, Belgocontrol, Dispatch Axxicom, airline rep
- Radio (VHF): flight crews
- Trunk: Turnaround coordinators and each actor in the turnaround
- Special trunk and phone for de-icing operation (out of scope)
- Display with Flight Information System: used to conduct updates (Block time, TOBT, flight plan, flight details), check progress inbound flights, check overal system state and communication (flight information displays to pax, fuel to fuellers).
- Amadues Departure Control System: shows pax scans at boarding and access control and missing pax per flight.
- Mail: Telex messages on flight changes, usually for planning purposes.
- ACARS: Messages send when aircraft brake is off, used for logging the off-block time.
- Hub control: Swissport internal system. Shows the different tasks per turnaround with a status (see figure C.3). The system also shows passenger info (total number, connecting passengers, medical conditions) and baggage numbers.
- Stand camera's: used to visually check turnaround progress.

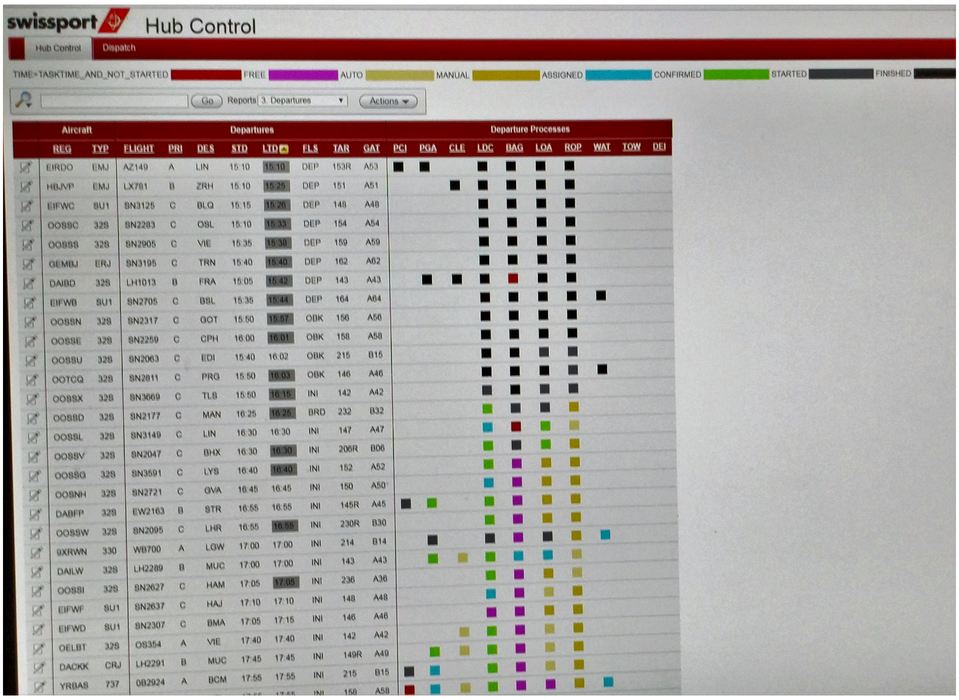


Figure C.3: Overview of Swissport's Hub control interface showing the different turnaround tasks)

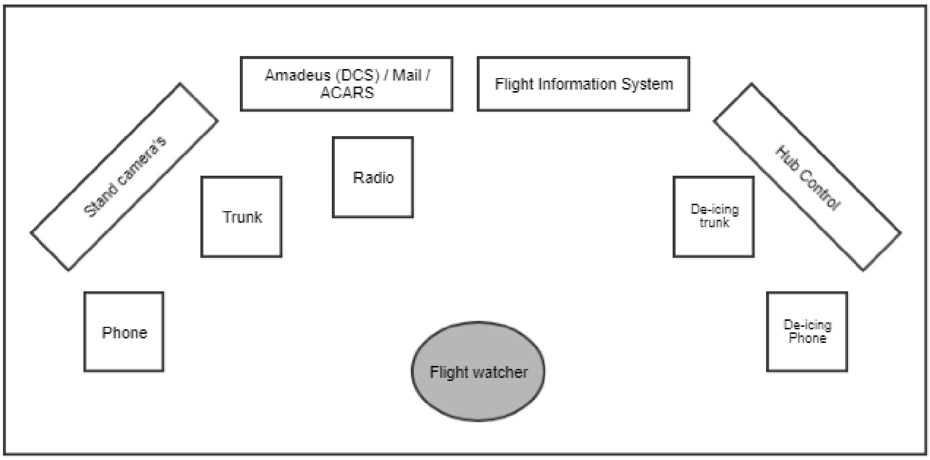


Figure C.4: Overview of Flight Watch setup at Swissport (shown for one operator)

Observations on information usage:

- When it comes to voice communication there is a clear priority: radio (crews) -> Phones (can be anybody) -> Trunk (own people).
- Images from the terminal are not used by FW to check for signs of congestion.
- The system state in FIS is not always reliable. Flight can call ready to ATC when not ready at all. When scanning FIS on a higher level this creates a misleading image for the flight watcher.
- Actors often forget to start their task in the hub control system. Actors who are assigned a task mainly focus on conducting that task as efficient as possible, often forgetting the need for clear communication. This makes the system unreliable for the flight watcher to act upon.

Observations on TOBT updates

- All communication via trunk, in rare cases via bridge phone.
- Most updates were in the last 10 minutes or even after TOBT. Very few pro active TOBT setting observed
- When the fligth watcher updates the TOBT of a late inbound flight he often updates by MTT and then subtracts 5 minutes, arguing that they can always save time somewhere.
- TC not very specific on the reasons for a TOBT update. FW: don't really care for the reason, can explain it later.
- Future developments at Swissport: Redcap conducts TOBT on its own via PDA into the Swissport hub-control system which communicates with FIS to the CDM system at BRU.
- Benefits of flight watch according to FW: checking, communicating. Redcap also has interfaces in his office but is on the move a lot, which makes calling with FW easier. Example: Where are the bags? FW checks hub control, on its way!
- Just as at AP, 5 minutes seems to be the norm, comes back in all kinds of settings and TOBT's are often rounded of to 5 minutes
- Strategy on TOBT management strongly depends on the TC, some never call.
- TSAT window is often used as buffer instead of updating the TOBT.
- When flight has a CTOT, the focus in on that instead of TOBT.
- Strategies for TOBT strongly influenced by CTOT, TSAT, Minimal Turnaround Time (MTT) and MTT tolerance set by the airline.
- TC often have little knowledge of the exact MTT because there are so many different MTT's.

Table C.3: Observed TOBT updates and remarks between at flight watch Swissport

FLTNR	STD	Off-block	TOBT updates and remarks
MS726	1500	1525	1445 FW noticed on camera still ofloading bags and no boarding yet. Called Redcao, TOBT to 1515 (idea FWer) 1500 Airline Rep wants EOBT to 1515 1519 Rep and Redcap did not answer, FWer updates TOBT to 1525
WB700	1700	1702	1645 redcap calls all ready, request TOBT -10 min (TSAT did not update due to CTOT) 1650 Captain calls for TSAT update, FW: not possible
EW2163	1655	1703	1654 TOBT about to expire, FWer assesses TSAT window will be just enough (1659) 1701 Captain called outside of TSAT window (1701), so 5 minutes TOBT update (delay op ATC)
LH2289	1700	1706	1700 Redcap called, TOBT to 1705 due to loading handbagage
LH1017	1805	1809	1728 redcap called because he wanted the full MTT, not MTT – 5. So TOBT updated by 5 minutes, 1800 Boarding completed, 1809 Finished, FW: could have done it without the 5 minutes in worked a bit faster.
OS354	1740	1758	1739 No TOBT update, redcap thinks 1750 is possible (TSAT was 1747), 1743 Redcap: TOBT to 1755, 4 missing pax. FW makes it 1750 instead of 1755.
LH2291	1745	1753	1748 Redcap: CTOT is on 1801 right? FW: yes but TSAT is 1749!. No TOBT update, possibly within window.
OU4457	1815	0000	1757 Redcap: defect rotor, looking for mechanic. TOBT to 1830 1803 FW calls: keep me updated 1815 FW calls: still no mechanic found, TOBT to 1900 1830 Redcap: flight is going to be cancelled
AZ165	1825	1902	1823 Airline delayed to 1915 (MTT+20), contact with Rep needed, 1825 FWer moved TOBT to 1854, 1853 called redcap: damaged ULD's. TOBT to 1900. Redcap: don't bother me, 1855 redcap: ULD's loaded, no idea how boarding is going (turned out to be completed)
LX783	1850	1845	1836 captain already called ready
LH1019	1905	1916	1905 redcap: TOBT to 1915
AY1546	1915	1910	1908 redcap: bring TOBT 5 minutes forward, everything is ready
LO234	1925	1943	1920 Redcap: slow boarding, not during fueling. TOBT + 5 1928 Redcap: pax stil in the bridge, TOBT + 5. (but startup was already requested) 1936 FW: still pax in bridge, TOBT + 5 by FW
LX789	1955	2026	1957 Redcap: are still cleaning, TOBT to 2009 (FW: is not going to be enough, but ok) 2001 observed: boarding started 2003 observed: Start-up already approved 2012 boarding still ongoing, TOBT to 2015 2014 FW: flightplan to 2015, TOBT to 2020 (TSAT remained on 2009)
OS356	2000	2007	2002 Redcap: Still some baggage and cleaning was slow. No TOBT update (uses TSAT window)
FB408	2020	2028	2018 Redcap: full flight in and out, TOBT to 2025 (+5)
LH2293	2040	2055	2035 Redcap: not going to make it, TOBT to 2055 (+20)
EW8103	2040	2049	2036 Start-up already requested, 2039 called: TOBT + 5 minutes

C.3. Observation 3: Turnaround coordination Aviapartner

During the Observation window three flights were observed, following three different TCers. figure C.5, figure C.6 and figure C.7 show the observation sheets filled out during the observation moments on site.

General observations turnaround coordination:

- A TC'er conducts around 3 to 4 turnarounds during a shift in the off-season.
- Between turnarounds the workload is low: delay codes for the previous flight are declared and the documents for the upcoming flight are checked and the TC'er waits.
- During the turnaround the workload is extremely high. TC'ers seem to prefer face-to-face communication and observation, which causes them to constantly move between the flight deck, the apron, the boarding bridge and the small TC office located under the boaridng bridge. With the gate most communication is via the radio until boarding starts.
- Since the TC is moving around all the time, the interfaces which are available in his office are not accessed much.

Issues which occur early in the turnaround are observed by the TC but often do not trigger him to actually conduct the TOBT update. Multiple reasons for this were observed:

- **Optimism**: FR2985 was missing 1 baggage handler, which was known at the beginning of the turnaround. Instead of updating the TOBT right away since slower baggage loading could be expected the TC waited, tried to fix the problem herself by assisting with loading, and eventually updated the TOBT only at the last minute.
- **Uncertainty**: When an issue arises with an uncertain delay time, such as a technical issue, TC'ers keep their updates small and last minute. They do this because they are afraid that when they put the TOBT further away and then eventually want to bring it forward again the TSAT won't move forward, leaving the aircraft with a start-up delay.
- **Strategic**: TC'ers only care about their own turnaround, for which they are responsible. When the push back truck is already at the stand, TC'ers tend to keep their updates small and last minute to avoid the push back truck to go to another aircraft first.

General flight information							
FLTNR	FR 2985	Stand	138	STD	11:00	ACGH	10:33
Airline	Ryanair	Des	Valencia	Off-block:	11:05	AEGH	11:04

Additional flight information
Walk To Stand
Typical short turnaround (MTT 25 minutes)
1 PRM (WHCS) both in and out

TOBT update 1			
Time:	11:00	Update:	11:05 (+5)
Last peaces of of baggage to be loaded (WCH and +/- 90 pieces of carry on baggage)			
Turnaround coordinator was working on the baggage herself since bag team was one person down (3 instead of 4).			

TOBT update 2			
Time:		Update:	

TOBT update 3			
Time:		Update:	

Comments
No information at stand, all porto
Timeline:
1022 Arrived at stand
1023 called gate to check on outbound PRM, which was already at the gate
1025 called axxicom dispatch to check PRM
1026 called FW to check expected time of arrival (1035)
1035 first pax deboarding
1040 called to check number of checked in baggage
1042 called gate to let passengers start walking towards the plane and check axxicom
1043 all passengers deboarded
1044-1059 focus on collecting handbaggage for loading
1049 called gatem, 10 missing pax with no bags -> offloaded
1052 about 100 pieces of baggage to be loaded
1054 all pax on board
1057 pushback truck ready
1102 all doors closed
Turnaround coordinator had to fill out loadsheets while at the stand. Checking crosstables and filling out forms. Which takes a lot of time

Figure C.5: Observation sheet flight FR2985 to Valencia

General flight information							
FLTNR	TB301	Stand	228	STD	15:55	ACGH	15:03
Airline	TUI	Des	Santo Dom	Off-block:	16:20	AEGH	16:15

Additional flight information
Late inbound, original STD 13:25 due to no ETOP (longer flight)
Flight often troubled (old plane, slow pax)
4 WCHR and 1 WCHS

TOBT update 1			
Time:	15:47	Update:	16:10 (+15)
Cleaning still busy, moving slowly			
No boarding yet			

TOBT update 2			
Time:	16:02	Update:	16:15 (+5)
Boarding started at 15:53			
Bridge full of passengers			

TOBT update 3			
Time:	?	Update:	16:20 (+5)
Updated by FW, no communication			

Comments
Timeline:
1503 cleaning arrived, catering already there, no power
1525 boarding should have started, but still cleaning
1532 pre boarding started, still cleaning
1541 ULD needs to be checked due to damage, supervisor needs to come and look
1545 pushback arrived
1602 gate closed
1610 VGDS still displays TOBT 1605, called FW to check and it changed
Comment on TOBT: when you update the TOBT early to a later time, the push commes later. When you update the TOBT to a earlier moment the push doesn't come earlier. So prefer to leave the TOBT alone
Only your own flight counts

Figure C.6: Observation sheet flight TB301 to Santo Domingo

General flight information							
FLTNR	TB 303	Stand	228	STD	13:10	ACGH	12:10
Airline	TUI Fly	Des	Punta cana	Off-block:	14:01	AEGH	13:43

Additional flight information
Load controler at AP airside office
airline rep assisting
inbound conducted earlier / so only departure part of turnaround observed
265 pax

TOBT update 1			
Time:	13:00	Update:	13:30 (+20)
Cargo door had to be reopend to check ULD number			
Boarding had not started yet			
Due to technical reasons additional fuel might be needed			
Strategy: boarding +/- 30 minutes, rounding of to 13:30			

TOBT update 2			
Time:	1326	Update:	13:35 (+5)
Boarding system: still +/- 50 pax need to be boarded			
TC: put it on 35, we will see			

TOBT update 3			
Time:	13:33	Update:	13:40 (+5)
still pax missing, might need to offload			

Comments
Timeline:
1208 arrived at gate
1218 checked for catering (done), still no crew
1220 checked situation at gate
1230 still no crew, boarding delayed
1235 crew briefed
1245 still no boarding
1246 checking ULD numbers
1250 called to start pre boarding
1253 back to AP to collect loadsheet since printer at stand was broken
1307 first pax on board
1319 captain said he wanted to de-ice
1324 80 pax to board
1331 13 pax to board
1333 - 1338 recounted boarding passes, boarding complete
1341 doors closed

Figure C.7: Observation sheet flight TB303 to Punta Cana

C.4. Observation 4: Turnaround coordination Swissport

During the observation window five flights were observed, following three different TCers. Figures figure C.8, figure C.9, figure C.10, figure C.11 and figure C.12 show the observation sheets filled out during the observation moments on site.

Observations on TOBT management:

- When stating that I researched TOBT management, one turnaround coordinator stated: "that's only something for the last 15 minutes of the turnaround".
- Another turnaround coordinator stated: "TOBT management is only 5% of my work".
- A turnaround coordinator acts on what has been agreed upon in the SLA. All airlines at BRU except for Brussels airlines require a TC'er to be present during the entire turnaround. At Brussels airlines the agreement only requests a turnaround coordinator to be present in the last +/-15 minutes of the turnaround. This means that delays often go unnoticed until the TC'er arrives and notices the delay. When a TOBT update is then done, this is very likely last minute.
- A turnaround coordinator is not consulted or notified when Flight Watch / airline decide to update the EOBT and therefore the TOBT.
- Besides the TC'er and FW'er and in some cases the airline representative no other turnaround actors are involved in the management of the TOBT. TC'ers in general don't consult how long actors think they need to complete their task, they observe, calculate and make their own judgment.

Observations on interfaces:

- The amount of different systems used by TC'ers is high.
- It seems that system interfaces are not expanded with functions but instead additional systems and therefore additional interfaces are added in parallel.
- Although TC'ers find the information presented on their PDA's useful, they do not carry it with them when walking around in the turnaround. Most heard argument is that they need their hands free to handle other documents and the portophone.

Chain is as strong as the weakest link

General flight information							
FLTNR	LH1005	Stand	147	STD	09:05	ACGH	08:22
Airline	Lufthansa	Des	Frankfurt	Off-block:	09:15	AEGH	09:14

Additional flight information
Late inbound, FW set EOBT/TOBT on 09:15
1 deportee
Complete turnaround

TOBT update 1			
Time:	X	Update:	X

TOBT update 2			
Time:	X	Update:	X

TOBT update 3			
Time:	X	Update:	X

Comments
0830 on-block
0832 cleaning arrived
0835 redcap helps with ULD's
0840 redcap briefs loaders
0841 redcap checks ULD's
0844 redcap checks time, assesses that TOBT is reachable based on check of FCCLB (Fuel, catering, cleaning, loading, boarding)
0850 called to start boarding
0904 checks BRS, al bags loaded
0905 gate closed
0909 all pax boarded
0914 off-block
Redcap uses LH own tablet based system
Tablet is portable, but in combination with other tasks hands get full very quickly
Tablet replaces some systems but systems like BRS and DCS still need to be used on the computer in the redcap office
Redcap has handheld on which dispatch assigns him tasks
Handheld can also be used to find contact details of other turnaround actors
Handheld is not carried arround during turnaround, usualy stays in the car

Figure C.8: Observation sheet flight LH1005 to Frankfurt

General flight information							
FLTNR	SN205	Stand	165	STD	11:00	ACGH	10:15
Airline	Brussels	Des	Dakar/Conakry	Off-block:	11:26	AEGH	11:20

Additional flight information
Afrika flight (often troubled)
half turnaround, inbound conducted at B-pier
Redcap arrived late on stand due to earlier delay
SLA with Brussels Airlines gives GH limited authority on TOBT

TOBT update 1			
Time:	10:52	Update:	11:10 (+10)
redcap: no idea who and why, was not consulted on this			
Probably SP FW or Brussels Airlines directly			
System does not create an allert when TOBT is updated			

TOBT update 2			
Time:	11:13	Update:	11:20 (+10)
still loading last pieces of baggage which just showed up			
boarding completed			
FW placed TOBT on 1115 against request of redcap			
Caused a TSAT for 1126, redcap assesses that if TOBT was placed on 1120 there would have been no start-up delay			

TOBT update 3			
Time:		Update:	

Comments
1025-1035 Checking ULD documents
1035 Boarding already started, gate agent is SN, so they decide on their own and don't need approval of the redcap
1042 redcap assesses that TOBT is critical since almost all ULD's still need loading
Wait until 45 with update, first need to finish loadsheet and take a better look, also have not started up the systems yet
1052 since TOBT is already updated, now time for other tasks such as loadsheet
1055 pushback arrived
1100 loadsheet finalised. TOBT assessed as achievable in terms of cargo, but no idea on pax
1102 32 bags (1 ULD) missing, short connection Berlin
1105 also 3 passengers missing, contact SN station manager, he has to decide
1109 Berlin bags arrive, stil 2 missing
1113 last pax arrive, gate closed
1120 doors closed, 2 bags remained missing
Redcap: each actor should give a indication of the progress of their work. But the high pressure and low wages make people very unmotivated, so they often only do what is strictly needed. If they like you, they might work a bit harder

Figure C.9: Observation sheet flight SN205 to Dakar

General flight information							
FLTNR	FI555	Stand	149	STD	12:50	ACGH	11:48
Airline	Iceland air	Des	Reykjavik	Off-block:	12:48	AEGH	12:41

Additional flight information
aircraft (757) only has bulk load
Odd sized cargo (7 m long)

TOBT update 1			
Time:	12:41	Update:	12:45 (-5)
everything is ready			
could have placed it on 12:42 but pushback driver also has to make his round			

TOBT update 2			
Time:		Update:	

TOBT update 3			
Time:		Update:	

Comments
1152 start offloading
1155 pax deboarding
1211 cargo manifests missing, requires extensive contact with load coordinator off site
1223 ready to board
1238 push arrived
1240 all pax boarded
1241 all done
Redcap did not often do the FI555, so checked staff pages to see what the agreements were for the turnaround (who does what?)
Redcap: don't have interface to see if a fligth has a CTOT
PDA is good for communication with other actors in the turnaround, but cant take the PDA with me all the time since hands are ussualy already full with papers
Observed no interaction of redcap with fuellers or cleaners, only with the loaders

Figure C.10: Observation sheet flight FI555 to Reykjavik

General flight information							
FLTNR	SN2587	Stand	140	STD	13:25	ACGH	13:05
Airline	Brussels	Des	Berlin	Off-block:	14:24	AEGH	13:16

Additional flight information
SN only pays for Redcap to be on the stand in the last 15 minutes to check loadsheet and control the bridge

TOBT update 1			
Time:	X	Update:	X

TOBT update 2			
Time:		Update:	

TOBT update 3			
Time:		Update:	

Comments
1305 arrived: catering already done, all bags at the stand, fuel and catering ongoing
1310 no boarding at STD - 15 minutes (boarding is done by SN)
1311 called FW, flight has a slot at 1424
1312 called SN gate agent to check on handbaggage and boarding
Gate agent informs that captain wants to delay boarding due to the slot
Redcap leaves at 13:16 since he is not going to wait at the stad for an hour
Captain agrees to radio when boarding is started so SP can send a redcap again

Figure C.11: Observation sheet flight SN2587 to Berlin

General flight information							
FLTNR	MS726	Stand	207	STD	15:00	ACGH	14:16
Airline	Egypt air	Des	Cairo	Off-block:	15:20	AEGH	15:20

Additional flight information
5 ton cargo inbound = a lot of work
Late inbound: 1415 instead of 1400 so EOBT/TOBT to 1515

TOBT update 1			
Time:	15:00	Update:	15:20 (+5)
Boarding has not started yet at STD-15 minutes, boarding call has to be made by rep			
Also updated the EOBT to cover possible additional TOBT updates			

TOBT update 2			
Time:		Update:	

TOBT update 3			
Time:		Update:	

Comments
1435 Cleaning, catering, bags and cargo all assessed as on schedule
1455 still loading cargo, pre boarding has started
1505 still loading bags, boarding started by rep
1509 gate closed
1515 last baggage from cabin moved to cargo
1518 crew is very slow in finishing up
1520 pushback
Redcap chose one of 6 cars which has the computer build into it, so he didn't have to use the small office that much.
Redcap on TOBT management: prefer to underestimate the TOBT. 3 times 5 minutes instead of 1 time 15 minutes update. It keeps the chance of a slot low. It does not say that in documents or rules, it's someting you learn on experience
Redcap on information: there is so much information, but it is very dispereced over different systems, nothing is braught together into one system

Figure C.12: Observation sheet flight MS726 to Cairo

D

Appendix D: Design iterations

This appendix shows the design iterations made to come to the ecological interface presented in chapter 4. The methodology behind these iterations was explained in chapter 4. For each iteration The information requirements are presented together with their scale and the chosen visual variable. These visual variables were presented in a visual display during an expert meeting. The feedback from these meetings is shown and taken into account in the next iteration.

D.1. Iteration 1

Using the findings of the CWA, a first set of requirements were set up. This is not an extensive list. It was mainly used to set up a first design which would provide input for a discussion in the first evaluation/brainstorm session. Based on these requirements a first attempt for a design of the ecological interface was made. The result is shown in figure D.1.

Table D.1: Information requirements for a first iteration

Information requirement	Data format	Scale	Visual variable
Current time	Time (hh:mm)	Interval	Spatial X
AIBT	Time (hh:mm)	Interval	Spatial X
Current TOBT	Time (hh:mm)	Interval	Spatial X
Advised TOBT	Time (hh:mm)	Interval	Spatial X
TOBT update needed	Yes/No	Nominal	Shape
Process lies in critical path	Yes/No	Nominal	Spatial X
Process ongoing	Yes/No	Nominal	Colour (Blue)
Process finished	Yes/No	Nominal	Colour (Green)
Scheduled process length	Minutes	Ordinal	Size
Actual process length	Minutes	Ordinal	Size
Process of schedule	Yes/No	Nominal	Colour (Red)

The design was discussed in a evaluation/brainstorm session with several aviation consultants of which one was specialized in ground handling and another in Ecological Interface Design[19]. Several comments made during the evaluation are also shown in figure D.1.

The main points of the feedback session were:

- The setup of the interface, with the processes positioned in time along the X-as, was logical and clear.
- Experts stated that they had a difficult time to find an initial focus point. The line which displays the current time does not create a clear demarcation between the past and the future. This demarcation is important since the turnaround coordinator should have his focus on the future instead of on the past.
- In order to make the interface more intuitive, the action of updating the TOBT should be offered at the same place were the problem occurs. The current pop-up box at the top creates a distance between the action and the problem, which is visualized lower in the display.
- Only processes with clear additional attributes should have attributes, otherwise the attributes create an information overload.
- The difference between the actual and scheduled process length (the delay) is not visualized.

- The information on 'process of schedule" is not used properly. If cleaning causes the delay, that process is of schedule. No the image is created that cabin check and boarding are also off-schedule. These processes are pushed back by cleaning, but this does not mean that they contribute to the problem.
- The critical path is not visualized clearly between deplaning and cleaning/catering.
- CDM milestones such as the EIBT and EOBT are missing, these are important for TOBT management as well.

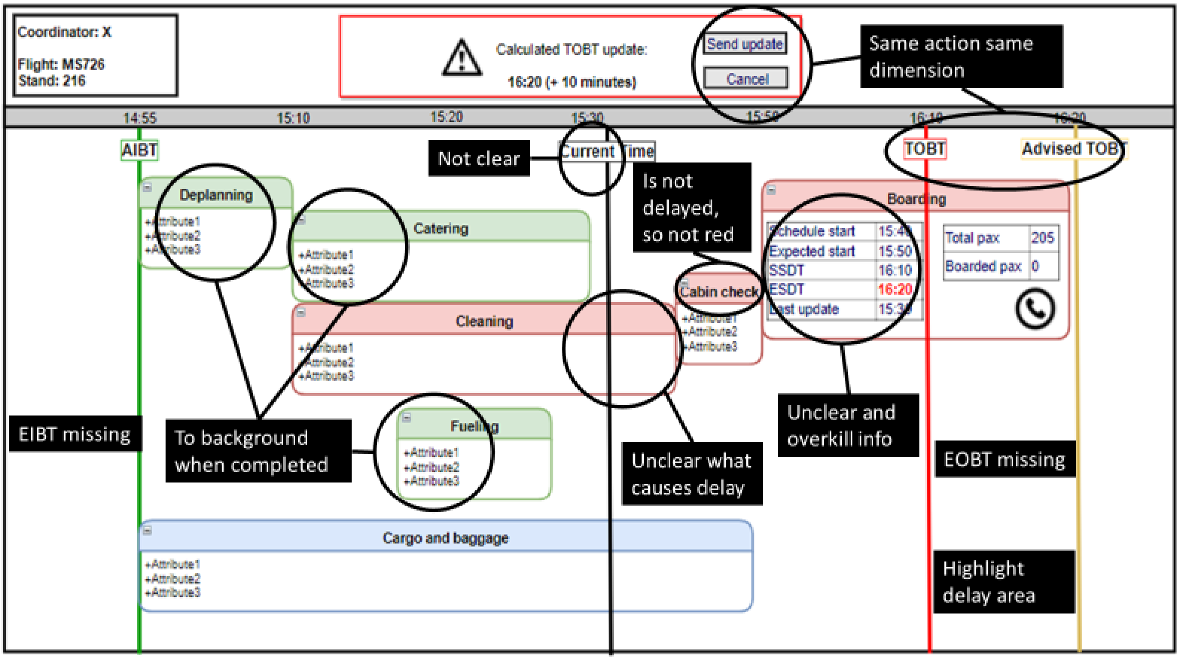


Figure D.1: A first interface design with feedback from experts

D.2. Iteration 2

The feedback from the first iteration resulted in an expansion of the number of information requirements and also changed the visual variable of several information requirements. This resulted in a new list of information requirements, shown in table D.2.

Table D.2: Information requirements for a second iteration

Information requirement	Data format	Scale	Visual variable
Global			
Abstraction level	System/subsystem/component	Ordinal	Spatial Y
Current time	Time (hh:mm)	Interval	Spatial X
History	Yes /No	Nominal	Colour (Grey)
EIBT	Time (hh:mm)	Interval	Spatial X
AIBT	Time (hh:mm)	Interval	Spatial X
EOBT	Time (hh:mm)	Interval	Spatial X
Current TOBT	Time (hh:mm)	Interval	Spatial X
Advised TOBT	Time (hh:mm)	Interval	Spatial X
Process			
Process in critical path	Yes/No	Nominal	Spatial Y
Scheduled process start	Time (hh:mm)	Interval	Spatial X
Actual process start	Time (hh:mm)	Interval	Spatial X
Process length	Minutes	Ordinal	Size
Indicators			
Process ongoing	Yes/No	Nominal	Colour (Yellow)
Process finished	Yes/No	Nominal	Brightness
Difference between EIBT and AIBT	Yes/No	Nominal	Colour
Difference between EOBT and calculated TOBT >15 minutes	Yes/No	Nominal	Colour
Difference between current and advised TOBT	Yes/No	Nominal	Colour
Difference between actual and scheduled process start	Minutes	Ordinal	Texture
Difference between actual and scheduled process length	Minutes	Ordinal	Texture
Direction of differences	Negative / Positive	Nominal	Colour (Red/Green)
Action			
Can update TOBT to advised TOBT	Yes / No	Nominal	Shape
Can update TOBT to own setting	Yes / No	Nominal	Shape

Based on this new requirement list and the comments from the feedback session, a second design of the ecological interface was made. The result is shown in figure D.2. This design was again discussed in a evaluation/brainstorm session with two aviation consultants of which one was specialized in Ecological Interface Design[48]. Several comments made during the evaluation are also shown in figure D.2.

The main points from the feedback session were:

- The next flight which the turnaround coordinator has to conduct can be included on the side of the display, showing him what his buffer is between flights.
- The graphic arrows between the current TOBT and the advised TOBT should more clearly show that by clicking on the update button the TOBT will move to the advised TOBT.
- The additional information on baggage and passengers should also be visualized.
- A confirmation screen should be showed when the TOBT is updated to prevent updating by mistake.
- To further accommodate the object related processes in the AH, a first indication on the cause of the delay can be given when confirming the TOBT update.
- When boarding is delayed this would create a red segment over a red segment, which won't be clear.

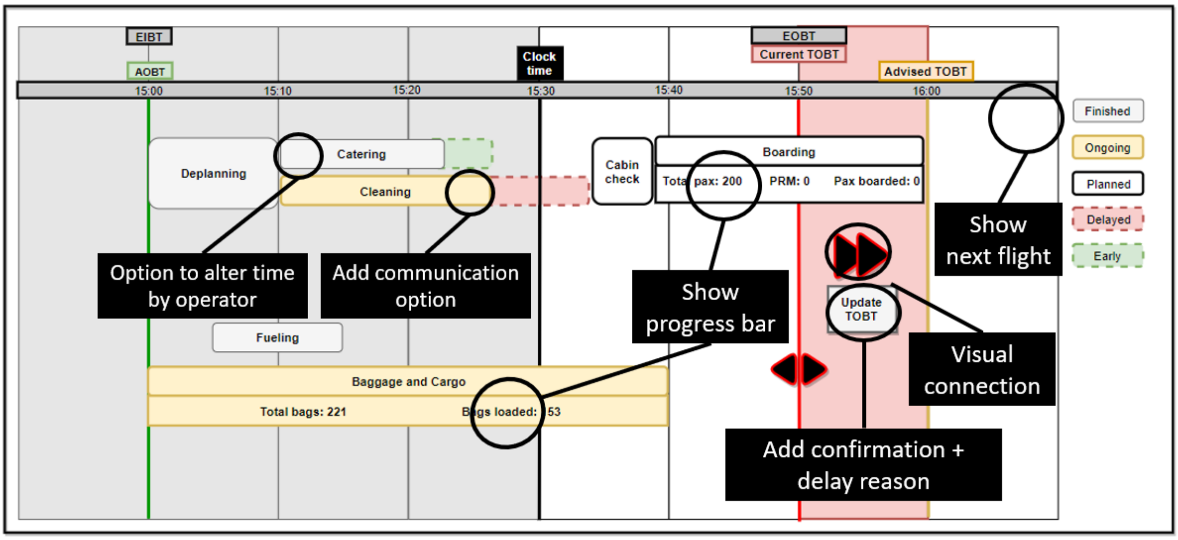


Figure D.2: The second interface design with feedback from experts

D.3. Iteration 3

The feedback from the second iteration resulted in several changes in the interface and the additional confirmation screen. This resulted in the design shown infigure D.3. This is the final interface design, which is discussed further in the main chapter and is used in the evaluation.

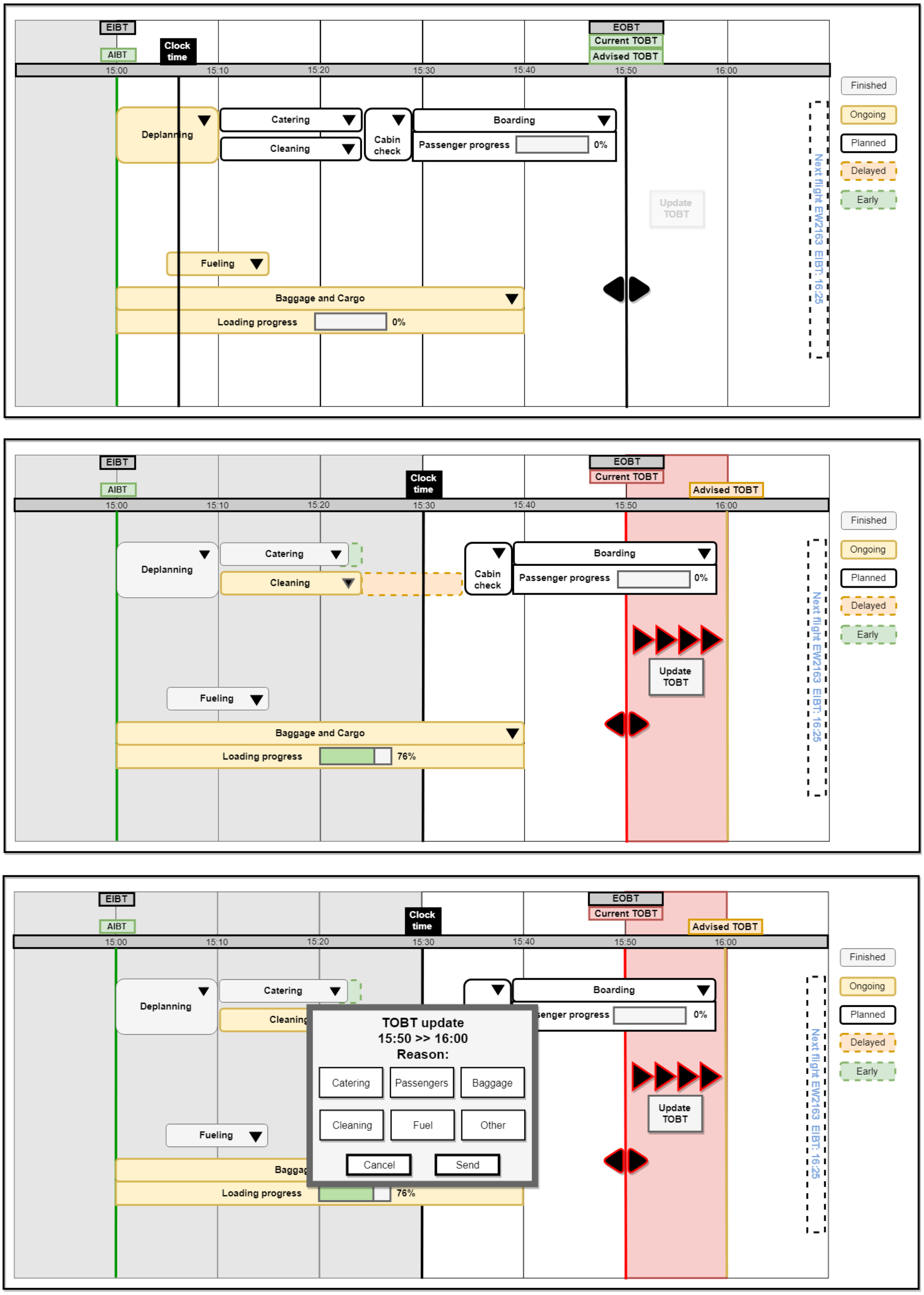


Figure D.3: The final interface design

E

Appendix E: Evaluation setup and outcome

This appendix provides the layout of different questions of the evaluation and the response of the turnaround coordinators on each question.

E.1. Evaluation setup

This evaluation focuses on a potential TOBT management interface which could support a turnaround coordinator in managing the TOBT. The goal of this evaluation is to introduce turnaround coordinators to the interface and to discuss the potential of such an interface. This evaluation consists out of three parts: an introduction of the interface, a simulation part and several evaluation questions.

E.1.1. The interface

An example of the interface is shown. The idea behind the interface is that the different service providers in the turnaround (cleaners, gate agents etc.) communicate when they start their work, when they expect to be finished and when they are actually finished. How these service providers provide information is outside the scope of this research. For this research it should be assumed that service providers have acces to a device on which they can manage their process times.

The example interface gives a graphic overview of the turnaround on 2 moments: before the aircraft arrives and after 20 minutes. The interface works as follows:

- The top of the interface shows the familiar CDM milestones which are being updated through the Central Database and a indication of the current time.
- The interface is divided in blocks of 10 minutes.
- The boxes indicate the planned duration of the different processes in the turnaround. This planned duration is based on the measured process time in earlier turnarounds of the flight.
- As mentioned earlier, the interface is updated with information cumming from the service providers. When a process is going to take or has taken, longer or shorter then planned the interface shows this and adapts the rest of the planned processes to the new situation (see lower example).
- For loading of baggage and boarding of passengers the interface shows a progress bar based on the data form the BRS.
- Based on the progress of the processes the interface presents an expected TOBT (advised TOBT). When there is a time difference between the TOBT and the advised TOBT the interface displays this and provides an alert.

The service providers are responsible for keeping their process times up to date, but the turnaround coordinator remains responsible for managing the TOBT. For managing the TOBT, 2 direct actions are possible on the interface:

- Update the TOBT directly to the advised TOBT by pressing the update button. This provides the flight watcher with a signal to update the TOBT to the advised TOBT.
- Update the TOBT to a self chosen value using the arrows. This provides the flight watcher with a signal to update the TOBT to this value.

There are also other possibilities:

- Observe the process yourself or contact the service provider. You can adjust the duration of a process by yourself based on your own estimation (using the arrows at the process box).
- You can naturally also ignore the alert.

E.1.2. Setup of the evaluation

The simulation part of the evaluation focuses on the hypothetical airline Exotic Airlines (IATA: XX). Exotic conducts flights from BRU to destinations around the Mediterranean with multiple A320-200 aircraft. At BRU, the aircraft of Exotic make a full rotation, with an MTT of 50 minutes.

During the evaluation, screenshots of the interface are shown of 5 different Exotic flights. Besides the screenshot a small description of the turnaround until that time is given. In each scenario the idea is that you use the available information presented on the interface and make a decision on how to react:

- Update the TOBT directly to the advised TOBT
- Update the TOBT to a self chosen value
- Observe the process yourself or contact service provider
- Ignore
- Other (own option)

In each scenario I would like to hear how you got to the decision.
After the scenario I will ask several evaluation questions on the interface.

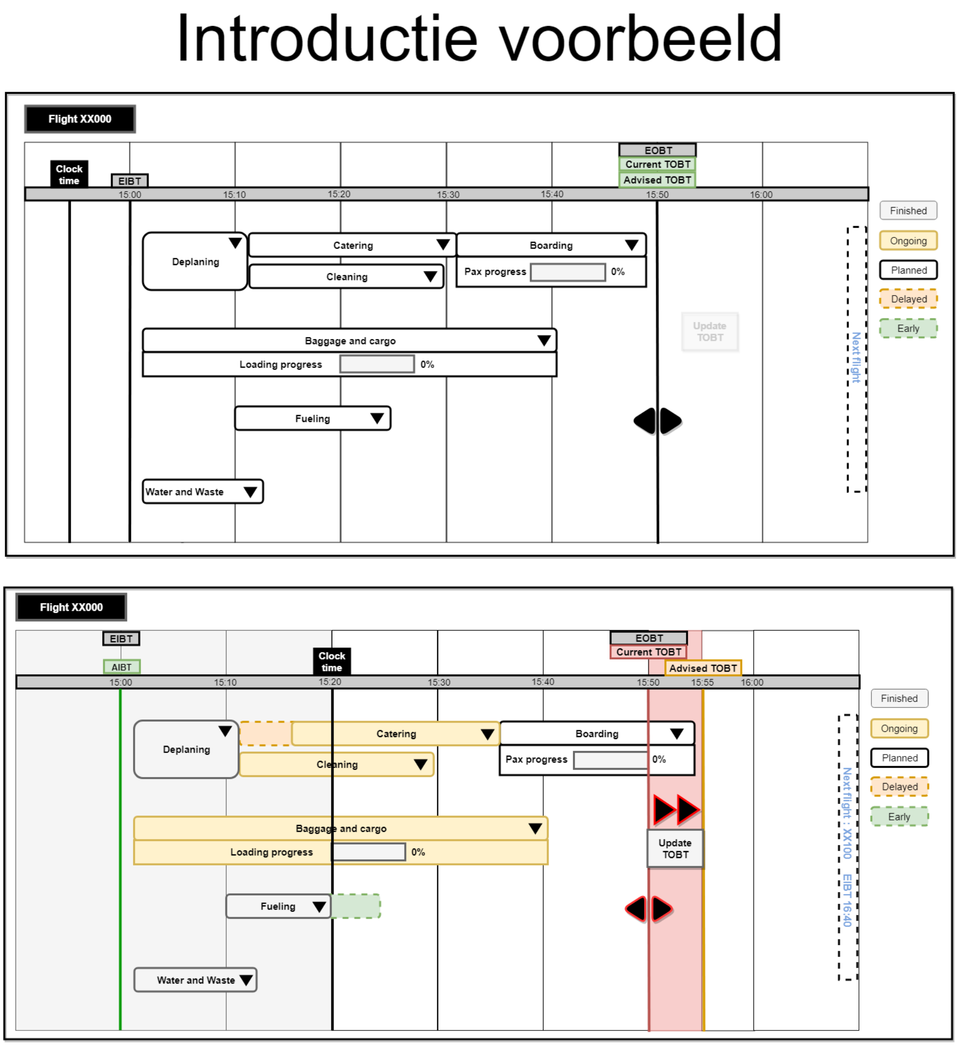


Figure E.1: The interface as shown during the introduction

E.2. Simulation

Scenario 1

- You're 10 minutes in the turnaround
- Flight XX020 has arrived on schedule
- After connecting the bridge you're now on the tarmac checking outgoing cargo
- You receive an alert and the following overview

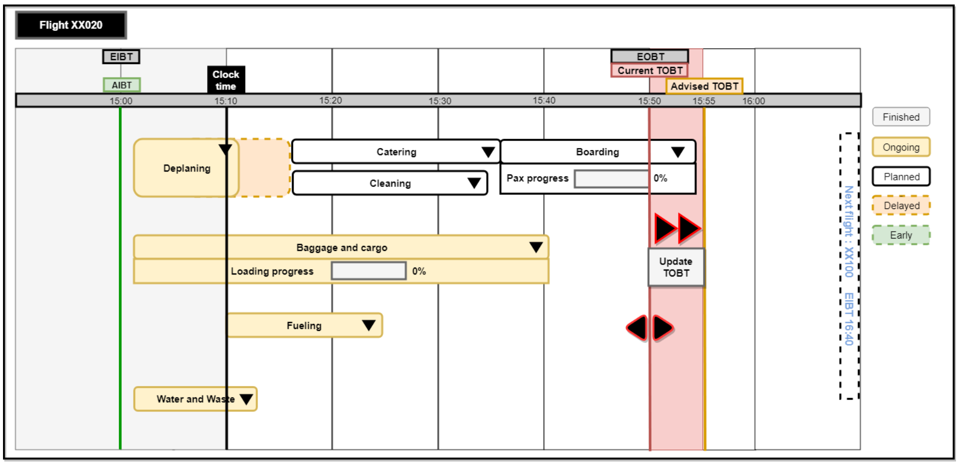


Figure E.2: The interface as shown during scenario 1

Reaction:

- Update the TOBT directly
- Update to own value
- Contact service provider / observe process
- Ignore
- Other (own answer)

Table E.1: Response to scenario 1

Res	Answer	Motivation
1	Ignore	Wait until boarding has started with updating the TOBT
2	Ignore	To early in the turnaround
3	Ignore	Can catch up, with preboarding for example
4	Ignore	Can probably catch up somewhere
5	Ignore	It is still early in the turnaround
6	Ignore	No need to update that early
7	Ignore	Is only 5 minutes, which can be compensated
8	Ignore	Still early
9	Ignore	Way to early, can easily be dealt with
10	Ignore	I never update that early

Scenario 2

- The rotation is 25 minutes in
- Flight XX030 has arrived on blocks 5 minutes late
- Until now everything has gone according to planning
- You're in your office working on the load sheet
- You receive an alert and the following overview

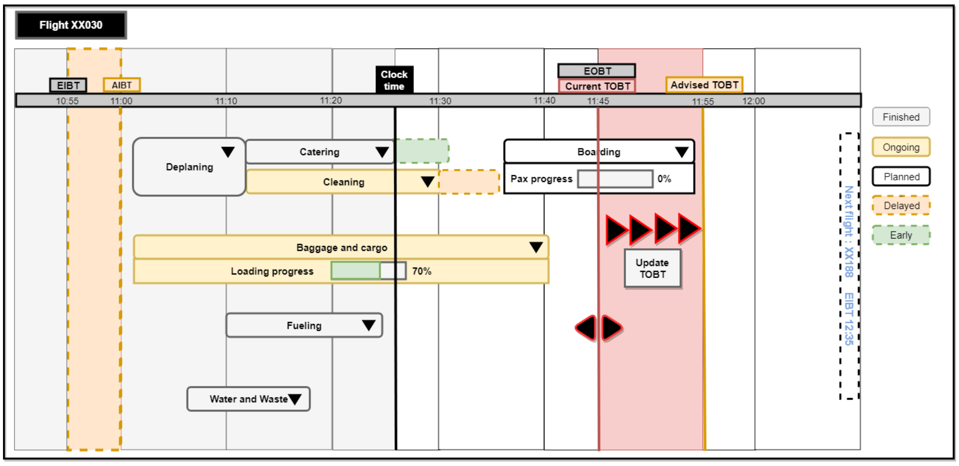


Figure E.3: The interface as shown during scenario 2

Reaction:

- Update the TOBT directly
- Update to own value
- Contact service provider / observe process
- Ignore
- Other (own answer)

Table E.2: Response to scenario 2

Res	Answer	Motivation
1	Update to own value	TOBT on +5 instead of +10. update because of late inbound, check for update again after 10 minutes, miracles can happen.
2	Update directly	Update and start pre boarding
3	Update to own value	TOBT +5 instead of +10 to compensate for late inbound. Would start pre-boarding.
4	Update to own value	Update +5 minutes for late inbound, cleaning can be caught up
5	Start pre-boarding	would not update but start pre-boarding
6	Update directly	Update and start pre boarding
7	Update to own value	Update with 5 minutes, but would really depend on which airline it is
8	Ignore	Boarding can sometimes go really fast, so will see once boarding has started
9	Update to own value	Would update with 5 minutes for the late inbound, boarding can often go faster when started late.
10	Update to own value	Update 5 min for late inbound, would keep cleaning in my head for other updates.

Scenario 3

- Flight XX080 has arrived on blocks accurding to planning
- The rotation is 30 minutes in and until now nothing special has happened
- You just informed the gate that boarding can be started
- You receive an alert and the following overview

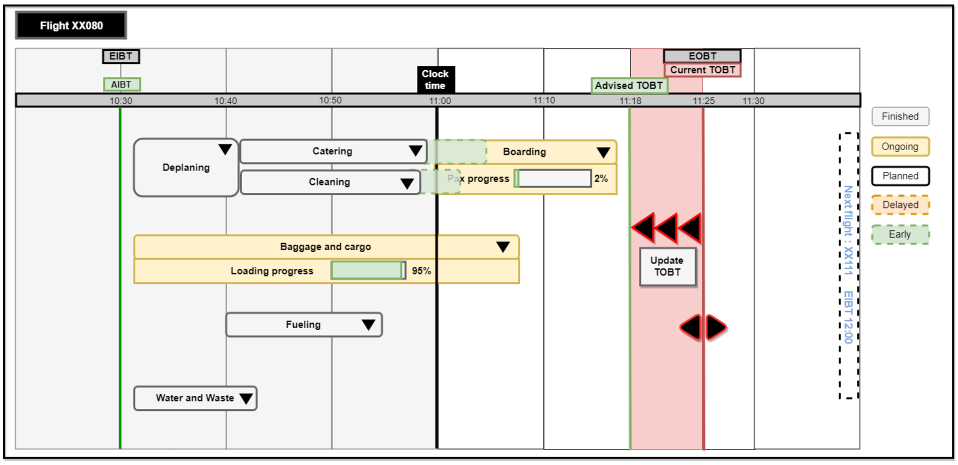


Figure E.4: The interface as shown during scenario 3

Reaction:

- Update the TOBT directly
- Update to own value
- Contact service provider / observe process
- Ignore
- Other (own answer)

Table E.3: Response to scenario 3

Res	Answer	Motivation
1	Check push and captain	I would keep it in mind and probably update after 10 minutes, once i have checked with the push and the captain.
2	Check push and captain	Would want to update but have to check first if everyone is ready
3	Check push	If push is available i would update TOBT - 5
4	Check push	Would only update is push ready and doors closed
5	Ignore	Boarding can be delayed as well
6	Ignore	Would check after 10 minutes
7	Ignore	Boarding is difficult to predict, will check after boarding is further
8	Check push and captain	Can't place the TOBT earlier if the other actors are not ready
9	Ignore	TOBT still far away, would check again after 10 minutes
10	Check push and captain	Wait until 11:10 and then update if push and captain are ready

Scenario 4

- Flight XX150 had some small issues with deplaning of a PRM and the cleaning crew which did not arrive on time
- Apart from that everything has gone according to planning
- On the apron everything is ready and boarding has started
- Flight XX150 has a lot of passengers with a short connection
- The TSAT has just been given
- You just walked out of the cockpit where you delivered some last documents
- You receive an alert and the following overview

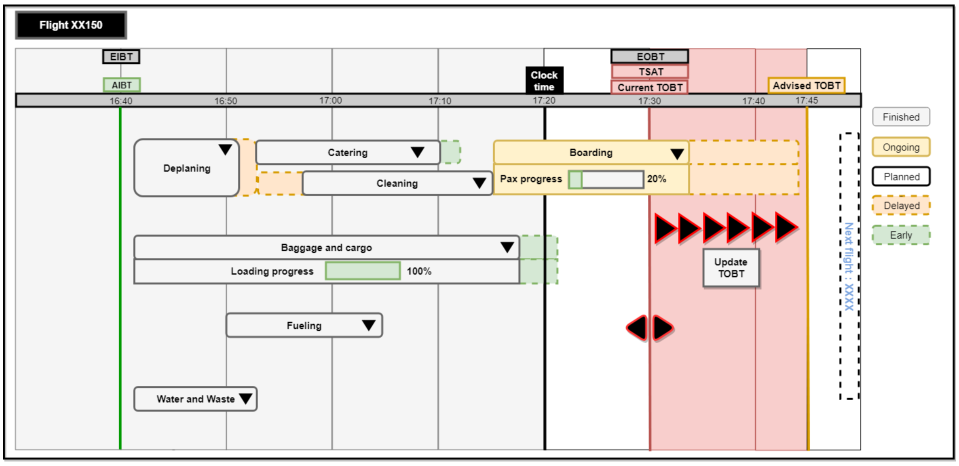


Figure E.5: The interface as shown during scenario 4

Reaction:

- Update the TOBT directly
- Update to own value
- Contact service provider / observe process
- Ignore
- Other (own answer)

Table E.4: Response to scenario 4

Res	Answer	Motivation
1	Check captain	I would check this with the captain, it is the airlines call to wait or not wait.
2	Update to own value	Would compensate for the earlier delay, but wait to see how the rest develops.
3	Update to own value	Would update +10 instead of +15
4	Update to own value	Update by 5 minutes, passengers can suddenly arrive quickly
5	Update to own value	update +5 minutes
6	Update to own value	update by 10 minutes, rest in TSAT window
7	Contact service provider	Would ask gate agent which passengers, from which connecting flights etc. and check with captain if he want's to wait.
8	Update to own value	Add 5 minutes and then 5 minutes again if needed
9	Contact service provider	Would ask gate agent were pax have to come from and check with captain if he want's to wait.
10	Update to own value	Update by 10 minutes and check progress at gate

Scenario 5

- The rotation of flight XX204 has gone without any issues
- You are in the terminal at the gate which just has been closed
- There are two missing passengers and it has been decided to offload their bags
- They just started searching for the bags
- You receive an alert and the following overview

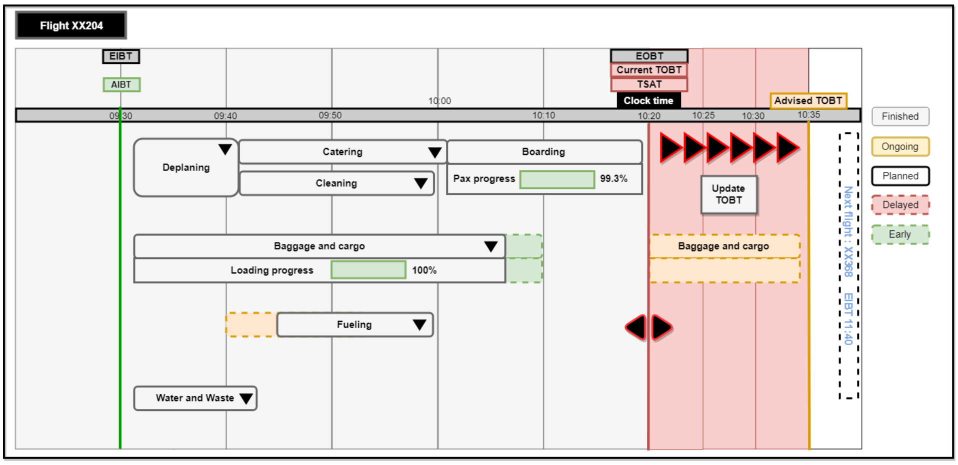


Figure E.6: The interface as shown during scenario 5

Reaction:

- Update the TOBT directly
- Update to own value
- Contact service provider / observe process
- Ignore
- Other (own answer)

Table E.5: Response to scenario 5

Res	Answer	Motivation
1	Update to own value	Would make +10 of it instead of +15, last work can be done under TSAT if needed.
2	Update directly	I think i have to at this stage
3	Update to own value	Update + 10, offloading is very unpredictable so will see after 10 minutes
4	Update to own value	Update by 5 minutes at a time, the loaders also can't estimate this well
5	Update to own value	first +10, after that evaluate
6	Update directly	Can take long
7	Update directly	15 minutes is about average for a bag search and offload
8	Update to own value	Add 5 minutes and then 5 minutes again if needed
9	Update to own value	Update by 10 min, should not over estimate. Loaders often don't know how long it is going to take as well.
10	Update to own value	Update by 10 min, 15 minutes is a lot

E.3. Evaluation questions

Statement 1: I expect that the interface is useful for managing the TOBT

Table E.6: Response to statement 1

Res	Answer	Motivation
1	Agree	The interface provides a better overview of the processes, because of this I expect to update the TOBT earlier then now. I think the interface will also be useful for the flightwatchers that work on a distance
2	Strongly agree	I believe it will definitely be useful. But only when all the parties are actually going to use it. If one party doesn't, it loses its value
3	Agree	It will be useful but I don't think it will ever be 100%
4	Disagree	It doesn't provide a prediction of what is going to happen. I therefore think it provides a late overview of the turnaround, which is not very useful
5	Agree	Will be useful, if everybody participates
6	Agree	I think it will be useful as an aid, it will not replace any tasks
7	Agree	I can look back when I'm later at the stand and I have to call less service providers since they actively provide information
8	Neutral	Has it's pros (such as overview) and cons (everybody has to contribute, carry around). I also think it is more useful for Flight watchers who work on a distance, I'm in the turnaround so i can see for myself.
9	Agree	The interface gives a good overview of what already took place. This can be useful when you arrive later at the stand (always the case at SN).
10	Neutral	Really depends on the service providers in the turnaround. Sometimes their input will be useful, sometimes it won't

Statement 2: I expect that the interface will lower my workload with regard to TOBT management

Table E.7: Response to statement 2

Res	Answer	Motivation
1	Neutral	Could be. I do expect I would have to walk less and make less calls. But it really depends on the weakest link in the process
2	Neutral	I might have to make less calls, but apart from that i don't expect so
3	Agree	It provides me with a good overview, i would probably have to make less calls and have to walk around less
4	Disagree	Would have to keep checking progress as i do now
5	Agree	It provides me with a clear overview without having to observe myself
6	Disagree	As I said, it does not replace work. The only think that might change is that i have to walk a little less
7	Neutral	Would probably make it a bit easier but not less. I still have to check everything
8	Disagree	I would hope so, but i don't expect that it will
9	Disagree	Have to keep checking everything myself since I remain responsible for the TOBT
10	Disagree	I still have to check the progress myself. Maybe even more then now when people are using the system wrong

Statement 3: The interface provides me with a quick and clear overview of the turnaround

Table E.8: Response to statement 3

Res	Answer	Motivation
1	Strongly agree	The red bar indicating that a TOBT update is needed is a good global indicator for the whole turnaround. I don't have any points for improvement
2	Strongly agree	The colours and the processes are very clear. The time indication on the top is also clear.
3	Strongly agree	Everything is there, the time indications and process times are clear
4	Strongly agree	It provides a good overview of how the turnaround has gone until now. Will also be good for post-ops evaluation (delay codes)
5	Agree	The interface clearly shows which processes happen at the same time and which processes follow each other. The use of colours is also clear
6	Agree	Clear overview with the used colours. Maybe include an option that service providers can give short reasons for their delays?
7	Strongly agree	The scheme is very clear as well as the colours used
8	Strongly agree	It shows everything that i currently do in my head
9	Strongly agree	The colours immediately pop out and are easy to understand. Only the use of the doted lines were not directly clear
10	Strongly agree	It is clear, nothing to add or change

Statement 4: I would be able to easily work with the interface

Table E.9: Response to statement 4

Res	Answer	Motivation
1	Strongly agree	Would be easy. If the interface is accessible via internet i could use it on my own phone. Maybe the alerts should have an audio option which reads the advised TOBT to you.
2	Strongly agree	I could definitely work with the system. But only if other programs i use will also become available on the same device!
3	Agree	Would be very easy to work with. Personally i prefer to adjust the TOBT time by typing in a new time instead of using a slider
4	Strongly agree	I would be able to work with the system. It is another additional system, so should look at integrating it with other systems.
5	Strongly agree	X
6	Neutral	The interface itself is probably easy to work with. But I can't walk around with a tablet all the time during the turnaround
7	Strongly agree	For the young it would be easy to work with, I'm not so sure about the older staff
8	Agree	Yes, is not that difficult
9	Agree	Only if i can be used on the same tablet which I currently use for Lufthansa flights. I am not going to walk around with 3 different devices (2 tablets and 1 pda)
10	Agree	Just point and click, would prefer it on a smart phone instead of a tablet

Statement 5: I expect that the involved stakeholders at the airport encourage the usage of such a system

Table E.10: Response to statement 5

Res	Answer	Motivation
1	Disagree	The benefits are only for us (the turnaround coordinators) and not for the other parties. Who is going to supervise that the service providers actually start their time? Maybe the purser should indicate when the processes in the cabin have started.
2	Agree	I think the willingness is there with the stakeholders. But it is going to take a long time before it is implemented.
3	Neutral	For us redcaps this system will be useful, but for others it probably won't have positive effects. With this system they can no longer cheat in the delay code setting since times are measured. Since everybody has to contribute for the system to work, this might be difficult to achieve.
4	Neutral	Don't know
5	Disagree	It is a large investment to implement this system. Also I have noticed that my older colleagues who do this work for a long time are not really open to change
6	Disagree	Costs a lot of money and also requires effort from all the involved parties
7	Disagree	If this system becomes available it will change the blame game which is currently going on. This will create disadvantages for parties such as cleaning, which will probably resist against the implementation then.
8	Agree	If the companies make it mandatory, it will be used
9	Disagree	Costs a lot of money, who is going to pay for it? Several parties (not mentioning any) will not be able to play the blame game anymore, which could lead to resistance.
10	Neutral	Don't know

Statement 6: I would trust this system as an aid in managing the TOBT

Table E.11: Response to statement 6

Res	Answer	Motivation
1	Strongly agree	Yes, but really as a aid. The TOBT update remains my estimation of the situation
2	Strongly agree	Yes i would, but only if all involved parties stick to it as well! The delay blame game is probably going to prevent actors from using the system truthfully.
3	Agree	As a aid, it remains my own estimation in the end
4	Agree	Yes, but only as an aid.
5	Agree	The interface itself provides a clear overview. But my trust in the system strongly depends on if everybody is going to use it.
6	Agree	I would, but only as an aid and when everyone agrees and actually does work with it
7	Agree	As an aid
8	Agree	I think its more something for flight watch. As a flight watcher i would use it as an aid
9	Agree	As an aid i would, to quickly see what i should focus on. Not to directly update the TOBT
10	Neutral	As mentioned before, it depends on the service providers on the other side of the system. \\Some won't use it honestly, just as the delay code system now\end{tabular}

Statement 7: When the interface comes available, I expect to use it in each turnaround

Table E.12: Response to statement 7

Res	Answer	Motivation
1	Strongly agree	Maybe not on the very short ryanair turnarounds. But apart from those flights i would always use the interface.
2	Strongly agree	I would if, as I mentioned before, all the other program's are also available on the device. If they are not, this device will be just another device and will probably stay in the office while i am outside.
3	Strongly agree	Yes i would, but only if everyone works with the system
4	Strongly agree	I would probably use it as an aid in each turnaround, to set global deadlines for myself
5	Strongly agree	When it is available and when the company demands it I will use it. But then multiple systems should be integrated on the same device.
6	Strongly agree	Yes i would probably use it at least once every turnaround
7	Agree	I probably use it in all rotations, except for the very short ones
8	Disagree	I would not, since i do most of this in my head instead of on a computer. For flightwatch it would be useful.
9	Agree	Would probably look at it a couple of times, if it is on a tablet with the other program's
10	Agree	Probably, but depends on the turnaround and the service providers in the turnaround

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