Impact of local A-CDM on the operational efficiency at Mainport Schiphol

Performance analysis

Thesis

centre of excellence

knowledge & development centre
Mainport Schiphol

KDC Mainport Schiphol – Centre of Excellence
A collaboration with the Aviation Academy, Amsterdam University of Applied Sciences

Author: Roel Wouters

Date and location: 19 July 2018, Schiphol-Oost
Version: 1.0

~This page is intentionally left blank~

Impact of local A-CDM on the operational efficiency at Mainport Schiphol

Performance analysis

Thesis

Author[1]		
Name	Responsibility	
Roel Wouters	Research student KDC Mainport	
Student number	E-mail	Graduation Track
500710185	Roel.wouters@lvnl.nl	Aviation Logistics

Reviewers[2]	
Name	Responsibility

Acceptance (by client)[3]			
Name	Responsibility	Signature	Date
Evert Westerveld	Air Traffic Control the Netherlands (LVNL)		
Coen Vlasblom	KLM		
Boudewijn Lievegoed	Amsterdam Airport Schiphol		
Frenchez Pietersz	HvA		
Selma Piric	HvA Thesis Advisor		

[1] Author agrees with the content, did take notice of the review comment and applied it to his/her own insight.
[2] Reviewer declared that he reviewed the report on the basis of his expertise and provided the author with comment.
[3] The client uses or applies the result of the report, only applicable clients sign.

~This page is intentionally left blank~

Preface

The research report is written as a part of the graduation process for obtaining the Bachelor of Science degree in Aviation Operations from the Amsterdam University of Applied Sciences (AUAS). The bachelor focusses on evaluating and improving logistical processes at and around an airport from the perspective of each stakeholder (airline, airport, air traffic control and ground handler) and their relations. The research topic aims to analyse the improved cooperation and performance of the main stakeholders with capacity management as the main focus.

The research is conducted on behalf of the Knowledge Development Centre Mainport Schiphol (KDC) and its stakeholder LVNL, Amsterdam Airport Schiphol (AAS) and Royal Dutch Airlines (KLM). I would like to take each stakeholder for providing useful aviation experts who helped to conduct the research and research data. The data was obtained from Ferdinand Dijkstra who I would like to thank for his efforts and swift service. Furthermore, special thanks to the LVNL for making office space available in their headquarters for conducting the research.

During the whole research Selma Piric (AUAS thesis advisor) and Frenchez Pietersz guided me through the process. Their expertise and feedback made extra depth in the research topic available and provided a nice working environment which stimulated the research process. Special thanks to both of them for supporting me throughout the whole process.

Moreover, my thanks are in place for Alina Zelenevska for her efforts and support during the process, bi-weekly sprint reviews and the scrum sessions in particular. The scrum sessions were essential to organise the research activities and ensured that the optimal result would be achieved. Furthermore, the KDC managers from each stakeholder were also present at bi-weekly sprint reviews who provided useful feedback. I would like to thank Evert Westerveld (LVNL), Boudewijn Lievegoed (AAS) and Coen Vlasblom (KLM) for their support.

Last but not least, special thanks to my fellow students Martijn Ringelberg, Gijs Peters, Bas Broekstra, Mark Eijkens and Megan Heijke with whom I shared the office at the LVNL. We have always supported each other when necessary. They made the time at the LVNL even more pleasant.

R.Y. Wouters

Schiphol, 19 July 2018

Abstract

The purpose of the research is to assess how beneficial the implementation of local Airport-Collaborative Decision Making (A-CDM) has been for the involved stakeholders at Schiphol Airport. Local A-CDM is implemented at Schiphol Airport in November 2015. Local A-CDM focusses on main stakeholders (airlines, airport, Air Traffic Control and ground handlers) working together and making decisions based on higher quality and accurate information which should improve the operational efficiency, punctuality and predictability. The results suggest that local A-CDM has been beneficial for some aspects of the operational efficiency such as gate planning, resource and pushback planning, but mainly during days without major disruptions. Ground handlers need to update the Target Off Block Time (TOBT) which triggers the departure planning system to make a departure sequence of flights. The TOBT is updated much more often during days with disruption which causes instability of the departure sequence and causes delays. This is quantitatively analysed by calculating the on time performance (OTP), which is an overall performance indicator at an airport, has declined since the implementation of local A-CDM. The decline of the OTP is not fully related to local A-CDM, but also to the massively increased number of movements that caused congestion. Overall, the local A-CDM is not performing optimally, especially on days with major disruptions such as extreme weather conditions due to an instable departure sequence.

Table of Contents

List of Figures

List of Tables

List of Graphs

List of Abbreviations

A-CDM	Airport-CDM (see CDM)
AAS	Amsterdam Airport Schiphol
AIBT	Actual In Blocks Time
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATOT	Actual Take Off Time
AUAS	Amsterdam University of Applied Sciences, *NL: Hogeschool van Amsterdam*
CDM	Collaborative Decision Making
CODA	Central Office for Delay Analysis
CPDSP	Collaborative Pre-Departure Sequence Planning System
CTOT	Calculated Take Off Time
DPI	Departure Planning Information
EHAM	Amsterdam Schiphol Airport
EIBT	Estimated In Blocks Time
ELDT	Estimated Landing Time
EOBT	Estimated Off Blocks Time
EXIT	Estimated Taxi In Time
EXOT	Estimated Taxi Out Time
GH	Ground Handler
HCC	Hub Control Centre
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
KDC	Knowledge & Development Centre Mainport Schiphol
KLM	KLM Royal Dutch Airlines
KNMI	Dutch Meteorological Institute, *NL: Koninklijk Nederlands Meteorologisch Instituut*
KPI	Key Performance Indicator
LVNL	Air Traffic Control the Netherlands, *NL: Luchtverkeersleiding Nederland*
NABO	Narrowbody
NM	Network Manager
NMOC	Network Manager Operations Centre
RWY	Runway
SIBT	Scheduled In Blocks Time
SOBT	Scheduled Off Blocks Time
TOBT	Target Off Blocks Time
TSAT	Target Start up Approval Time
TTOT	Target Take Off Time
TXW	Taxiway
WIBO	Widebody
WTC	Wake Turbulence Category

Definitions of terms

Airport Collaborative Decision Making (A-CDM)
A-CDM is a collaboration between stakeholders aiming to improve the operational efficiency of all airport operators by reducing delays, increasing predictability of events during the progress of a flight and optimizing allocation of resources.

Actual Off-Block Time (AOBT
The actual time that the aircraft went off-blocks, meaning the aircraft started-up and the pushback process started.

Estimated Off-Block Time (EOBT)
The estimated time for the aircraft to be taken off-blocks, meaning the aircraft is ready for start-up and pushback.

Network Manager Operations Centre (NMOC)
Formerly known as CFMU, NMOC is the organization appointed to regulate and control the fair use of available airspace capacity.

Target Off-Block Time (TOBT)
The target time for completion of ground handling process.

Target Start-up Approval Time (TSAT)
The target time for start-up and pushback, to depart from the runway in time. TSAT window: $TSAT_{-5\ min}$ – $TSAT_{+5\ min}$.

Target Take-Off Time (TTOT)
The target time for take-off from the runway.

Summary

The purpose of the research is to assess how beneficial the implementation of local Airport-Collaborative Decision Making (A-CDM) has been for the involved stakeholders at Schiphol Airport. The stakeholders involved A-CDM have been working on the implementation of total A-CDM for 8-10 years at Schiphol Airport. Local A-CDM is implemented at Schiphol Airport in November 2015. Local A-CDM focusses on that the main stakeholders (airlines, airport, Air Traffic Control and ground handlers) work together and make decisions based on higher quality and accurate information which should improve the operational efficiency. Total A-CDM has supported and improved the performance of the main stakeholders at several major European airports. However, it was unknown if local A-CDM had the same positive impact on the operational efficiency at Schiphol Airport for each involved stakeholder, if not than the research can provide the industry with solution to improve the performance of local A-CDM.

The objective of the research is researching how local A-CDM has impacted the operational efficiency for each involved local A-CDM stakeholder at Schiphol Airport. Eventually the benefits of local A-CDM are analysed and calculated, if applicable, for each involved local A-CDM stakeholder. Therefore, the main research question used to achieve the objective is:

- How has local Airport – Collaborative Decision Making exactly impacted the operational efficiency for each involved local A-CDM stakeholder at Mainport Schiphol?

The impact of local A-CDM on the operational efficiency is evaluated by a qualitative and quantitative analysis. The qualitative analysis consisted of desk research and interviews. The desk research focussed on gathering information about the operation and benefits of total A-CDM which formed the basis knowledge for the interviews. The interview focussed on obtaining information about the operational changes and potential impact of local A-CDM on each stakeholder's operational efficiency. Interviews are held with several A-CDM experts working at the stakeholders and A-CDM implementation company.

The quantitative analysis was focussed on calculating the on time performance (OTP). The OTP was calculated for four seasonal periods Winter, Spring, Summer and Summer July months over the year 2015, 2016 and 2017 to analyse the trend of the OTP before the implementation of local A-CDM and the years after the implementation of local A-CDM. The dataset existed of over 165,000 departing flights. A flight did not depart on time if it left the gate more than 15 minutes after the initial estimated pushback time which is the standard according IATA.

The following results were drawn from the analyses. The operational efficiency is impacted differently for each stakeholder. The Air Traffic Control (ATC) has benefitted from the implementation of local A-CDM. It has decreased the workload of the ATC staff by having a departure planning system which makes the departure sequence of all flights. The ground handlers benefit from local A-CDM by making their resource planning and pushback planning in particular more efficient by increasing the predictability. However, the efficiency improvement is gained on days without major disruptions. The gate planning department of the airport also benefitted from local A-CDM by basing the planning on more accurate A-CDM information. Furthermore, the OTP as overall performance indicator has declined over the past years even with the implementation of local A-CDM which is partly caused by increasing congestion and airspace regulations. The stakeholders have been trying to implement total as fast as possible and have postponed the improvements that local A-CDM needed to provide the stakeholders with the expected operational efficiency benefits.

The conclusions point out that the positive impact of local A-CDM is suppressed by the stakeholders, departure planning system and other factors such as congestion. The following three recommendations are stated to support the local A-CDM's performance at Schiphol Airport:

1. Improve the outbound planning system to decrease the impact of late TOBT updates on the TSAT
2. Increase knowledge about the TOBT update system and its consequences for the whole flight operation for especially the TOBT updating staff
3. Implement feedback loops to analyse what can be improved to increase the performance of local A-CDM

~This page is intentionally left blank~

1 Introduction

More and more airports in the world are facing congestion issues due to the continuous growth of air traffic (Airbus, 2017). Some of which have the capability to expand their landside and airside infrastructure to accommodate the increasing number of movements, passengers and cargo. This is not the case for Amsterdam Schiphol Airport (AAS). AAS is reaching its capacity limits and is searching for alternative solutions to increase its capacity at Schiphol Airport or at other locations (e.g. Lelystad Airport). These solutions are hot topics in today's political debates. However, AAS is also changing the way of operation by implementing Airport – Collaborative Decision Making on a local basis at first and has just started to connect its system to the European network. A-CDM should make it possible for AAS to increase the utilization and efficiency of the existing resources which supports the decrease of current capacity constraints (Eurocontrol, 2016).

Amsterdam Airport Schiphol (AAS), KLM Royal Dutch Airlines (KLM) and Air Traffic Control the Netherlands (LVNL) form a collaboration, the Knowledge Development Centre Mainport Schiphol (KDC). KDC aims to clarify the current capacity problems at Mainport Schiphol and consequently find valuable and innovative solutions to provide Mainport Schiphol with a sustainable future development. In this field of research, the KDC focusses on the ever-growing capacity constraints. These constraints will continue to grow, since the demand for air traffic will also continue to grow each year (Airbus, 2017). Capacity related research is necessary to prevent Schiphol from becoming too congested.

Schiphol Airport has started 8-10 years ago with implementing A-CDM as well to improve the airport operations. They have finished implementing local A-CDM in November 2015 which allows them to share information and make the operation more predictable. However, they did not have implemented total A-CDM yet at that time (see paragraph 1.1). All stakeholders are required to participate and share the required data on time. Research shows that total A-CDM has been beneficial for other airports, however there are still uncertainties at Schiphol Airports which need to be resolved such as the exact performance of local A-CDM and what how beneficial it has been for the involved stakeholders.

1.1 Problem statement

AAS is at the final stage of having total A-CDM implemented. A-CDM is a platform that the five main stakeholders at an airport use to exchange information. The stakeholders work together to improve the decision making process which is based on more accurate and high quality information. AAS has currently implemented local A-CDM which means that the Network Manager (NM) is not yet connected. The airport, airlines, ground handlers and Air Traffic Control (ATC) are the stakeholders who are involved in local A-CDM. Departure Planning Information (DPI) messages have to be send to the European Network manager (Amsterdam Airport Schiphol, 2015). These DPI messages are send by the CDM Airport notifying the European Network Manager with the Target Take Off Time (TTOT). The TTOT is the time when an aircraft is expecting and able to take off from the designated runway. The TTOT is calculated by adding up the taxi time from the gate to the runway with the Target Off Block Time (TOBT). The TOBT is the time when the ground handler and airline are done with their operations at the gate and the aircraft is ready for push back. The TOBT is send to the Air Traffic Control (ATC). A departure sequence system uses the TOBT to calculate the TTOT. The TTOT is send to the European Network manager between the time that the ATC runs the sequences and the Actual Take Off Time (ATOT). The ATOT is the time that an aircraft has exactly departed from the runway (Eurocontrol, 2017). The link with the NM improves the whole European Air Traffic Management (ATM) network by improving en-route and sectoral planning (Eurocontrol, 2017). In Europe 26 airports are connected to the NM so far (Eurocontrol, 2017). The network manager is not taken into account in the research, because it is not yet implemented at Schiphol Airport. Further research could be done to analyse the benefits of the NM for Schiphol Airport.

The four other main stakeholders (Airport operator, Aircraft operator, ATC and ground handlers) are considered in the research. Local A-CDM should improve airport operations and efficiency. This can differ for each stakeholder and airport, because there are many factors which have an impact on the operation such as runway layout, weather influences, culture, etc. It is still uncertain how much all involved stakeholders have benefited from the implementation of local A-CDM at Schiphol Airport. Especially, LVNL, KLM and AAS want to know what the exact benefits are and how much they have been beneficial. The second part of the problem is that it is still not specified how involved each local A-CDM stakeholder is in the A-CDM operation. The level of involvement is analysed for each involved stakeholder and also further specified for companies itself. It will explain if the involvement of each stakeholder influences the performance of local A-CDM. In this case involvement means how much the values and opinion from each stakeholder are taken into consideration for the decision making.

1.2 Research objectives

The main aim of the research is researching how local A-CDM has exactly improved the operational efficiency for each involved A-CDM stakeholder at Mainport Schiphol until now, and what the exact benefits are. Research objectives are created to further elaborate the research's aim. The following objectives are applicable for this A-CDM research:

- To elaborate the operational characteristics of local A-CDM at Mainport Schiphol.
- To evaluate and quantify the current benefits of local A-CDM to the operation's efficiency for each involved stakeholder at Mainport Schiphol.
- To conclude how local A-CDM has improved the operation's efficiency of involved A-CDM stakeholders at Mainport Schiphol and what further improvement opportunities are.

The research is a quantitative and qualitative research, hence the fact that data is analysed to quantify the efficiency benefits of local A-CDM at AAS. However, a part of the research is based upon qualitative research. This part will focus on the link between the experts' experiences of local A-CDM and the results of the data analysis (quantitative research).

1.3 Research relevance/significance

The research is applicable for each stakeholder that is involved in the local A-CDM operation at AAS. The involved stakeholders are the Airport Operator, Aircraft Operator, ATC, Ground Handler and ATC. In this the stakeholders are AAS, KLM, LVNL and possible ground handlers. Implementing A-CDM at an airport should provide all stakeholders and the operation with cost savings and an improved efficiency. However, the stakeholders at AAS do not know if these improvements are also realised at AAS. It is essential to know for all stakeholders to know how much they have benefited and what parts of the operation could contain even further improvements.

The research will be the benchmark for further research when the connection with the European Network manager is made and total A-CDM is implemented (see paragraph 7.3). The research will analyse the performance difference between the period before the implementation of local A-CDM and the period after the implementation of local A-CDM. The period after the implementation of total A-CDM is not relevant for the research.

1.4 Research Questions

1.4.1 Main Research Question

The main research question for the research is:

- How has local Airport – Collaborative Decision Making exactly impacted the operational efficiency for each involved A-CDM stakeholder at Schiphol Airport?

1.4.2 Sub-Research Questions

The following sub questions are applicable for answering the main research question:

- What are the operational procedure changes stimulated by local A-CDM for each involved stakeholder at Schiphol Airport?
- How are the operational procedure changes stimulated by local A-CDM affecting the operational efficiency for each involved stakeholder at Schiphol Airport?
- What are the exact operational benefits gained through local A-CDM according to data analysis for each involved local A-CDM stakeholder at Schiphol Airport?

1.4.3 Background Questions

The background questions for the research are:

- What are the based principles of local A-CDM?
- Who are the stakeholders involved in local A-CDM?
- What is the difference between local A-CDM and total A-CDM?
- Why is local A-CDM being implemented at Schiphol Airport?
- What is operational efficiency?

1.5 Research objectives

The main aim of the research is researching how local A-CDM has exactly improved the operation's efficiency for each involved A-CDM stakeholder at Mainport Schiphol until now, and what the exact benefits are. Research objectives are created to further elaborate the research's aim. The following objectives are applicable for this A-CDM research:

- To elaborate the operational characteristics of local A-CDM at Schiphol Airport.
- To evaluate the current benefits of local A-CDM to the operation's efficiency for each involved stakeholder at Schiphol Airport.
- To analyse available data in order to quantify the operation's efficiency improvements thanks to local A-CDM for each involved stakeholder at Schiphol Airport.
- To choose the appropriate research methodologies for the scope of this research which takes the timeframe and data available in consideration.
- To conclude how local A-CDM has improved the operation's efficiency of involved A-CDM stakeholders at Schiphol Airport and what further improvement opportunities is.

1.6 Research scope

General scope

The research focusses on the capacity management of Amsterdam Airport Schiphol (AAS). AAS is approaching its capacity limitations due to the Alderstafel regulations (Alders, 2013). The use of its existing resources and operational efficiency is essential for accommodating the increasing number of movement and passengers. AAS and its main stakeholders have, therefore, implemented local A-CDM. It has stimulated several procedural changes for each involved stakeholder. The research's main focus is to analyse and quantify the exact operational efficiency gains for the involved stakeholders.

Stakeholder scope

Five main stakeholders have to participate for A-CDM to improve the operational efficiency. The following stakeholders are operating with A-CDM (Eurocontrol, 2017):

- Airport Operator (AAS)
- Aircraft Operator (KLM)
- Air Traffic Controller (LVNL)
- Ground Handler (GH)
- Network Management Operations Centre (NMOC)

These five stakeholders are applicable for total A-CDM. However, AAS has only implemented local A-CDM so far which means that the NMOC is not yet linked at AAS. The link with Network Manager includes sending DPI messages to European NM. Sending DPI messages is done by each CDM airport. However, the TOBT given by the GH need to be more accurate to provide the NM with usable DPI messages. The DPI messages contain the TTOT on which the sectoral and en-route planning of the network is based (Eurocontrol, 2017). The planning is improved by increasing the predictability of the aircraft. The improved planning can have an influence on the airport operations as well (Zellweger & Donohue, 2001). The increased predictability supports the stakeholders to plan their own operation and resources more efficient. However, the NMOC is not yet implemented and therefore not included in the research. There will not be any data available to analyse. There is data available for the other four stakeholders which means that for all of these the operational performance is analysed. However, the ground handler stakeholder will also not be analysed in depth due to time limitations. An analysis of the Airport Operator, Aircraft Operator and ATC requires the available time to be in depth enough and to find proper results.

Operational efficiency scope
Local A-CDM should provide the stakeholders' operation with multiple efficiency gains. Each stakeholder measures its performance differently hence the fact that each stakeholders has a different task to fulfil. The efficiency gains which are analysed are mainly calculated from data which came from the A-CDM portal. The scope for the efficiency gains is bound to the A-CDM, but each efficiency gain is required to be applicable for AAS, KLM and/or LVNL. is depending on the data made available by AAS, KLM and LVNL.
It is essential that the optimal reference data is chosen for each efficiency gain. The reference data form the data which is used to compare the current performance with. The difference between the reference data and current data will provide the research with a result. The reference point will depend on the implementation period of the specific procedures which influence the operation's efficiency. Knowing what the implementation data or period is, is required to assure the optimal comparison is made and factors other than local A-CDM are minimised.

1.7 Assumptions, Limitations, and Delimitations

Eurocontrol has conducted several researches in order to validate the performance of A-CDM at European CDM airports. Each research concluded that A-CDM had been beneficial for all involved A-CDM stakeholders (Eurocontrol, 2016) (Eurocontrol, 2011). It becomes easy to assume that the researches from Eurocontrol are also applicable for Schiphol Airport, however, making such an assumption could create a limitation for the research. Schiphol had only implemented local A-CDM at the time of the research which meant that it was not completely comparable with other A-CDM airport. The research becomes less objective when assuming that local A-CDM should improve the operational performance at Schiphol Airport. It is essential that the assumption was not made in order to ensure an objective analysis.

A limitation to the research is the time available to conduct it. There are five months planned to conduct the whole research in which a preliminary research, research plan, literature review, data analysis and thesis is done. All these steps require a variable amount of time that depends on several factors, such as available data, scoping and how much work it takes to complete. At first, the research needed to be scoped because local A-CDM has impact on five stakeholders and are all impacted differently hence the fact that they all have a different role in the operation. There is much more time required to prove and quantify all operational improvements for each stakeholder. A set of potential improvements need to be chosen which are influenced by local A-CDM. It was not certain if they were positively or negatively influenced.

1.8 Thesis structure

The study is laid out to a set of 6 chapters, each with its own purpose to create a well-ordered research report. Each chapter is divided into paragraphs which are written in the table of contents.

- The first chapter is called introduction and illustrates an overview of the report. It provides the reason for performing this research and details the research questions, aim and objectives that once achieved will bring success to this research. Finally, it describes the scope and structure of the research.
- The next chapter reviews the research methodology used for the research. This means that the design and approach of the research is reviewed which ultimately leads to a clear description of the path taken to get all the reliable data necessary. It describes how and what data is used to gain enough knowledge for the literature review and to perform the data analysis.
- The methodology chapter is followed by the literature review which concentrates on analysing secondary data to provide answers to objectives mentioned in the first chapter. The literature review forms the base of knowledge used to perform the data analysis.
- The fourth chapter contains the data analysis in which the operational improvements stimulated by local A-CDM are described. Each choice made to calculate or find the operational improvement is elaborated which eventually lead to the result which is described in the next chapter. The data analysis is structured according the importance of the operational efficiency improvement.
- The next chapter is called research findings and is completely related to the previous chapter. The data analysis process is described previously and this chapter visualises

and explains the results of the analysis. The chapter is structured similarly to the data analysis chapter.

- The last chapter puts all result and findings together to detail the answers to all research questions which lead to the conclusion and discussion of the research. The conclusions are meant to provide the reader with a short and clear overview of the data analysis results combined with the literature. The discussion elaborates what could have been done differently and which results are influenced by factors not applicable for local A-CDM.

~This page is intentionally left blank~

2 Methodology

A set of research methods are used for each research to conduct. The methodology of the research is mainly structured according to the Research 'Onion" (see Figure 1). The 'Onion' contains several layers in which a part of the methodology is described. The methodology chapter answers the question: "How can the research best be done?". Each paragraph provides a part of the answer to this question. The chapter with the research design paragraph in which the philosophy, approach, strategy and choices are described (2.1). The following paragraph elaborates the research methodology applied to answer each sub-research question (2.2) The next paragraph is called research hypotheses and evaluates the hypotheses which was stated at the start of the research (2.3). The research instruments paragraph explains the how the hypotheses is tested, validated or disproved (2.4). The set of samples need to be chosen in order to use the instruments mentioned previously. The choices made for the samples used are described in this paragraph (2.5). The last two paragraphs explain how the data is collected, its specifications and how it is analysed in order to find the results (2.6-2.7).

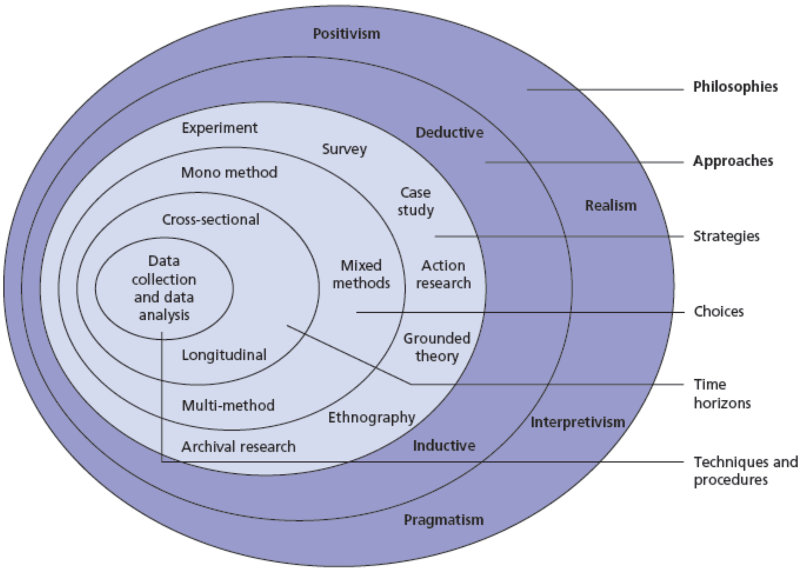


Figure 1 – The Research 'Onion' source: (Saunders, Lewis, & Thornhill, 2016)

2.1 Research Design

The research design paragraph describes the type of research and the main methods used to perform the research. As mentioned above the research design paragraph starts with a description of the philosophy, approach, choices and strategy which is linked to upcoming paragraphs (hypotheses and instruments)

2.1.1 Research philosophy

The research philosophy is the outer layer of the research 'onion' (see Figure 1). For that reason, the philosophy is chosen at the start of the study. The philosophy has an influence on the development of the whole study. The researches needs to choose a philosophy which fits the research strategy and primary data collection methods. The meaning of the philosophy is founded in the gathering and use of knowledge (Dudovskiy, 2016). During the research, new knowledge needs to be obtained to provide answers to the objectives (see paragraph 2.1.2). This is called the creation of new knowledge (Saunders, Lewis, & Thornhill, 2009). The chosen research philosophy is required to be in line with the rest of the research methodology and with the researcher's beliefs and assumptions. In business studies, there four main research philosophies used, which are shown in the outer layer of the research 'onion' (see Figure 1). The choice of philosophy is made by using Table 1. According to this table the pragmatism philosophy is applicable for the research, because a deductive approach is used (see 2.1.2) and both qualitative and quantitative data (see 2.1.3). This philosophy provides the researcher with research strategy flexibility (Dudovskiy, 2016).

	Research Approach	Research Strategy
Positivism	Deductive	Quantitative
Realism	-	Quantitative or qualitative
Interpretivism	Inductive	Qualitative
Pragmatism	Deductive/ Inductive	Qualitative and/or quantitative

Table 1 – Research Philosophy characteristics source: (Dudovskiy, 2016).

2.1.2 Research approach

The second aspect of the research that needs to be set is the research approach (see Figure 1). There are two different research approaches, inductive and deductive (see Figure 2). The research approach applied for the research is deductive (Easterby-Smith, Thorpe, Jackson, & Lowe, 2008). A deductive approach means that a theory is set at the start of the research which is confirmed by collecting and analysing data (Dudovskiy, 2016). A-CDM is considered as an effective method to improve the operational efficiency at airport according to Eurocontrol (Eurocontrol, 2016). This theory is applicable for all airports which have implemented A-CDM and are experiencing a positive result. However, it is unsure if this is also the case for Schiphol Airport.

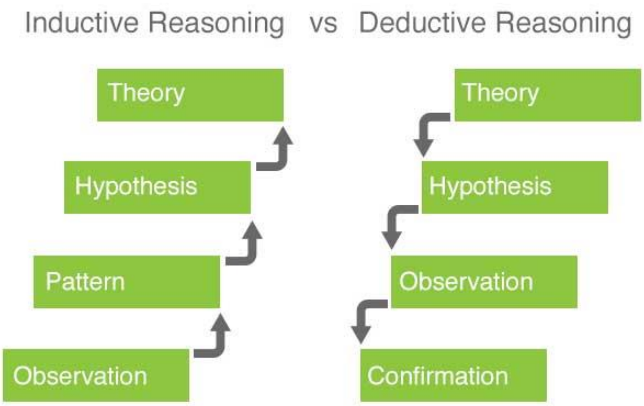


Figure 2 – Inductive reasoning approach (left) and Deductive reasoning approach (right) source: (Elmansy, 2016).

2.1.3 Research strategy and choices

An essential part of the Research Design is the research methodology and strategy. It is an overall description of the research methods and strategies used to answer each sub-research question which lead to the answer of the main research question. An understanding of both terms qualitative and quantitative data analysis is required before choosing to use one of them or both. Qualitative data is known as non-numerical data which generates words and not numbers (Adams, Khan, & Reaside, 2014). Qualitative data is obtained by content analysis and interviews for example. On the other hand, there is quantitative data which is numerical and provides numbers and statistics. Quantitative data is obtained by questionnaires and graphs for example (Saunders, Lewis, & Thornhill, 2009).

The research will both be qualitative and quantitative at the same time, because the data used for the research is both numerical and non-numerical (Saunders, Lewis, & Thornhill, 2016). The research becomes more reliable when combining qualitative and quantitative data thanks to the fact that the results of the quantitative data is validated by the qualitative data and vice versa. The qualitative data is gathered from interviews, surveys and archival research. Experts from all KDC Mainport's stakeholders are interviewed to ensure reliable data, moreover in paragraph 2.3. The quantitative data is acquired from the A-CDM and LVNL databases.

Furthermore, the next choice is related to the strategy chosen above. There are three options:

- Mono-method: using a single data collection technique which is quantitative or qualitative.
- Mixed methods: combination of more than one data collection technique which is qualitative and quantitative data, but both can only be used parallel and/or sequential. Both types of data can never be used in combination.
- Multi-method: combination of more than one data collection technique, but restricted to quantitative or qualitative data analysis.

The mixed method option is applicable for the research because both qualitative and quantitative data is acquired and used during the research. The mixed method is chosen to ensure the quality of the research's outcome thanks to the opportunity to validate and substantiate both data forms.

2.2 Research Hypotheses

Previous research about the performance of A-CDM is mainly performed by Eurocontrol, the founder of A-CDM. There are 28 European airports which have fully implemented A-CDM to their daily operation. Eurocontrol has conducted a research to quantify the operational efficiency improvements stimulated by A-CDM for each airport. The results were positive and there were significant cost savings and an increase of operational efficiency. Factors that were improved are shown in Figure 3:

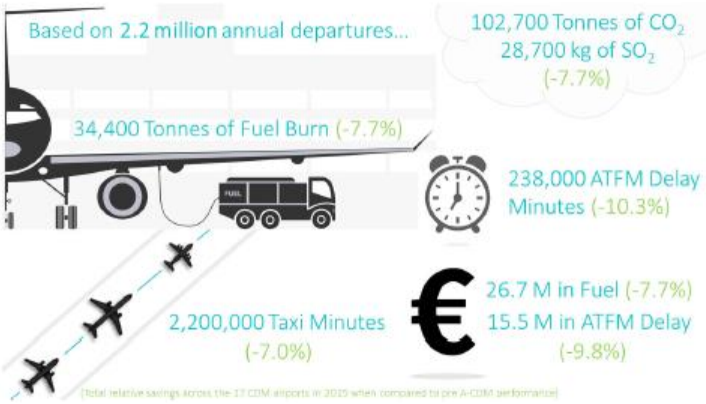
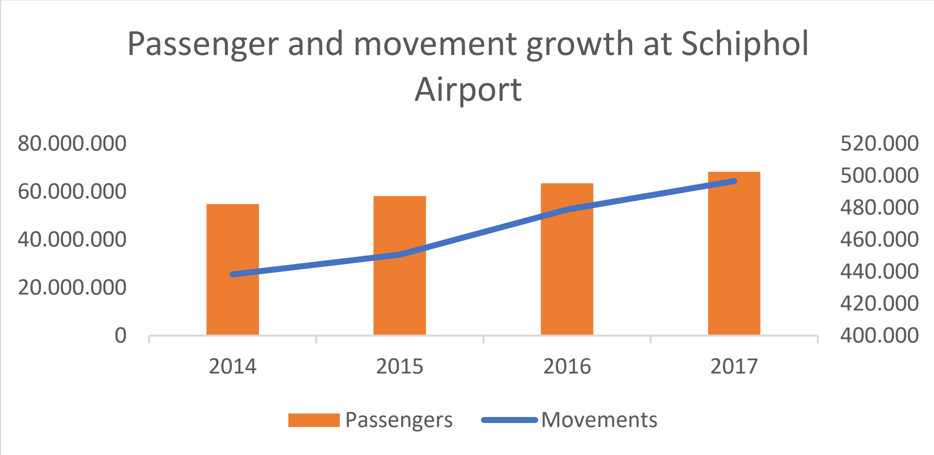


Figure 3 – Efficiency improvements stimulated by A-CDM of 17 CDM airports in 2015 source: (Eurocontrol, 2016)

These results are based on airports that have fully implemented A-CDM. The research focusses on the local A-CDM performance at Schiphol Airport. Local A-CDM means that the Network Manager is not connected, but the departure sequencer is in use and that the ground handlers and airlines are providing the system with the milestone information. The milestones are significant elements following the progress of a flight and on which the planning is made. It should improve the predictability of the operation.

Local A-CDM is implemented at Schiphol Airport in November 2015. Each new implemented will most likely not work accurately from the beginning. This is the same for local A-CDM at Schiphol Airport. The planning was to first finish the connection with the Network Manager which was done in May 2017. An improvement plan was then set in action to improve the performance of A-CDM.

It is likely that local A-CDM has been slightly beneficial for the flight operation at Schiphol Airport by improving the predictability and therefore the planning of each involved stakeholder, because A-CDM has been very beneficial for other European airports according to Eurocontrol (Eurocontrol, 2016). However, the benefits are suppressed by the fact that Schiphol is becoming more and more congested, especially the growth of the past years has affected the performance of local A-CDM (see Graph 1).



Graph 1 – Passenger and movement growth at Schiphol Airport source: (Schiphol, 2018)

2.3 Research instruments

The research instruments paragraph follows-up the research strategies in depth. Multiple research instruments are applied to answer the research questions both main and sub. The two main research instruments that are applied to prove whether local A-CDM has been beneficial for the operational efficiency of each involved stakeholder. The interviews will be held with experts who work with A-CDM and the results can validate the results from the quantitative data or will provide different insight on how to analyse the quantitative data.

All interviews will have fairly similar questions and can be found in appendix II. However, each interview in held in an unstructured way. This means that all preliminary thought of questions are not asked in same sequence in each interview to the interviewee (Sekaran & Bougie, 2016). The sequence depends on the answers given by the interviewee in order to provide the research with the most valuable information. All answers are written down in key words to be typed in full detail later.

- SQ1: What are the operational procedure changes stimulated by local A-CDM for each involved stakeholder at Schiphol Airport?

Research instruments: Desk research and interviews

Desk Research
Two methods are applied to answer the first sub-research question, desk research and interviews. The desk research is based on an articles and books analysis in which the operational changes are described in previous research. There are A-CDM manuals available that describe the A-CDM implementation process in general and for Schiphol Airport specific step-by-step. Eurocontrol has also conducted research about the performance of A-CDM at other airports in Europe. Each airport cannot not be literally compared with other, however the research can support the understanding of A-CDM changes to the airport operations and from which the operational efficiency improvements is taken. The observed changes to operation will become clear using this method and information.

Interviews
The second method is interviews. There are several A-CDM experts at the LVNL who have been working on the implementation of A-CDM at Schiphol Airport. The experts can provide the researcher with more information about the operational changes at Schiphol Airport and what the barriers were when implementing the changes. This is different from the literature and could provide topics to analyse later on in the research with the support of data analysis. Other A-CDM experts of KLM and AAS will be interviewed to attain information about their point of view towards the implementation of local A-CDM and what is changed in their daily operation. They can also provide information about how local A-CDM has been beneficial for them which is used in the following sub-research questions. The main interview questions are seen in appendix II.

- SQ2: How are the operational procedure changes stimulated by local A-CDM affecting the operational efficiency for each involved stakeholder at Schiphol Airport?

Research instruments: Desk research and interviews

Desk research
Each operational change, identified in the previous sub-research question, can affect the operational efficiency for the involved stakeholders. In this sub-research question the impact of the operational changes is analysed to find the potential performance improvements. These performance improvements are categorized based on their influence on the operational efficiency according to the literature and interviews. The most essential performance improvements are further analysed and quantified in the next sub-research question. The same research methods are used to answer the question as for the previous question, desk research and interviews with experts. There are articles available about the A-CDM's performance gains at other European airports which are made by Eurocontrol. These results support the identification of performance gains at Schiphol Airport for each involved stakeholder. Airport and operation characteristics, such as runway layout, weather and type of airport, can differ between airports and need to be taken into account. These characteristics can influence the performance of A-CDM and need to be considered when using them for Schiphol Airport. The articles combined with information attained from interviews with A-CDM experts of all parties will provide a clear overview of potential performance gains stimulated by local A-CDM at Schiphol Airport.

Interviews
Interviews are held with multiple experts from each involved local A-CDM stakeholders in order to create a clear overview of how each stakeholder is experiencing local A-CDM. The stakeholders will have a different opinion about the system and what is does to their operation. This can either be a positive effect or negative effect. The interviews lead not only to a set of operational efficiency improvements but also the downsides and perhaps even a decline of the operational efficiency. The list of benefits and downsides of local A-CDM is applied to answer SQ3.

- SQ3: What are the exact operational benefits gained through local A-CDM according to data analysis for each involved local A-CDM stakeholder at Schiphol Airport?

Research instruments: Quantitative data analysis and interviews

Quantitative data analysis
The quantitative data analysis focusses on the calculation of the on time performance at Mainport Schiphol. OTP is an essential key performance indicator (KPI) used in the aviation industry. The OTP is calculated by extracting the Estimated Off Block Time (EOBT) from the Actual Off Block Time (AOBT) (see Figure 4). The EOBT which is used for the calculation is the initial EOBT. The initial EOBT is the same as the Scheduled Off Block Time (SOBT). The difference between the SOBT and AOBT is the total delay of the flight.

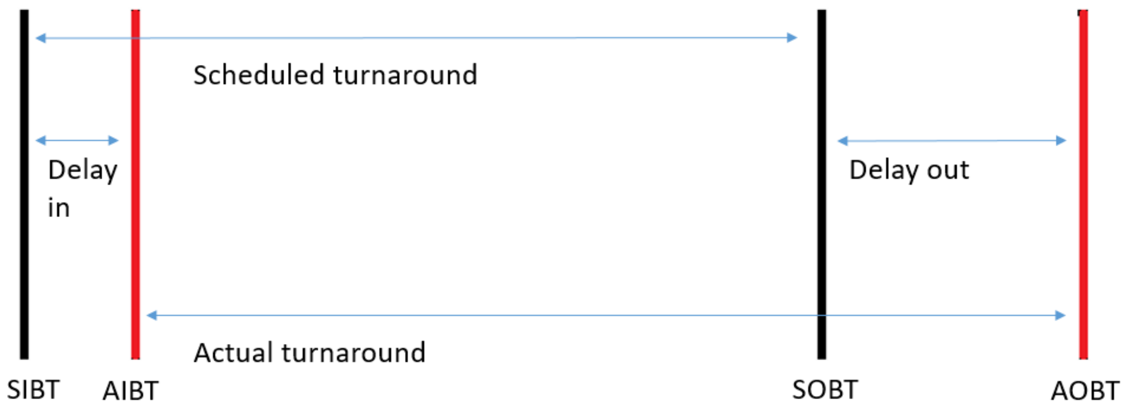


Figure 4 – Difference in scheduled and actual blocktimes including delay calculations source: (Ringelberg, 2018)

The quantitative data is derived from the A-CDM database which is updated every day. The LVNL has provided the data for the research. A specific time period needed to be set which is explained in paragraph 2.4. The data analysis program used is Microsoft Excel. The results will eventually answer the sub-research question which leads to a quantification of the performance improvements stimulated by local A-CDM. These results will be used for a comparison with the situation before local A-CDM and as a benchmark for further research after the connection is made with the network manager. An overview of the Excel datasheet is displayed in appendix IV. The datasheet contains the following categories, some of the categories are added to perform the calculation and to decrease the amount of filters (see Table 2).

Table 2 – A-CDM datasheet category titles and description

Data category	Description	Comments
Time	A-CDM timestamp	Timestamp generated by A-CDM system, same as ATD or ATA.
acid	Aircraft identification	Showing which airline operated the flight.
Reg	Aircraft registration	
Adep	Departure airport	Based on ICAO
Dest	Destination airport	Based on ICAO
Actype	Aircraft type	International standard codes
WTC	Wake turbulence category	According ICAO standard
Eobt_time	Estimated Off-Block Time	
Aobt_time	Actual Off-Block Time	
DepGnr	Departure gate number	
ArrGnr	Arrival gate number	
Arr/Dep	Arrival or Departure flight	
AOBT-EOBT	Number of delay minutes	
WIBO/NABO	Widebody or narrowbody	
RECAT-EU	Weight class category	According Eurocontrol standard

A set of predefined categorizations is applied to classify the flights in order to filter out the unnecessary rows such as business jets. The categorizations are aircraft type, arriving and departure flight and airport. There are two filters used for the aircraft type categorization, widebody or narrowbody and the wake turbulence category. The categorization is done according the NABO/WIBO and RECAT-EU categories. These categorizations are done provide the research with the results needed.

The research focusses on proving if local A-CDM has been an improvement of the operational efficiency for each local A-CDM stakeholder. The on time performance KPI shows whether all airport operations have run smoothly and according to schedule. In most cases one of the stakeholders is responsible for the delay, but it can also be weather or passenger (see paragraph 5.3-5.6). It is essential that all factors are taken into account which are different than local A-CDM. The OTP results are accompanied by interviews and literature research in order to ensure the reliability and validity.

Interviews

The data analysis forms the basis of SQ3 as mentioned before, but interviews are necessary to prove if the results are also felt in the operation itself by the different stakeholders. The interviews point out whether the stakeholders are experiencing the data analysis' result and if there is a difference in their opinion and the data, an explanation and possible improvement is searched for. Stakeholder could experience the system differently and this is also the case for the KPIs. Each stakeholder has its own opinion about the KPI results and may provide the research with new insights which are discussed with other stakeholders to combine each perspective and lead to the desired result. This is especially essential for local A-CDM factor which should improve but did not or are not experienced as improved. The interviews questions are shown in appendix II.

2.4 Sample

Choosing a sample that will lead to reliable results is essential for a research in order to become a success. Sampling is specific method which is applied to select members of a population that are included in the research's analysis. The main reason for sampling is that in most cases the population is too large to investigate, so a sample is taken from a population for the research to make the analysis performable. The same sample is applicable for each sub-research question.

A time period was required to be set before deriving the data from the databases. Local A-CDM was implemented in November 2015. The reference period data is taken from the months before November in 2015. The comparison data comes from the months in 2016 and 2017. Both years are chosen to provide the analysis not with a single comparison but also a trend. A trend provides the research a clearer overview of local A-CDM's performance. The four comparison that are chosen as the sample are:

1. Winter
2. Spring
3. Summer
4. Summer July

These four periods are chosen as the sample in order to calculate if the systems functions most efficient in busy periods (Summer) or less busy periods (Winter). The next step is to choose which months will form the optimal comparison. The number of movements have been increasingly rapidly the past year which is causing congestion during e.g. peak hours (see Graph 1). The months that are chosen in the Winter, Spring and Summer period come from the year 2015, 2016 and 2017. The months are selected by their number of movements and therefore are in some cases different over the years (see paragraph 4.2). Several data analysis techniques are applied to analyse the data.

The interviews which need to validate and discuss the data analysis results are held with at least 5-10 different interviewees. They are all required to work with A-CDM or have the knowledge how A-CDM works. These experts are working are at one the main local A-CDM stakeholders, but are from different companies to ensure that the results are not coming from a single company. This could influence the research's reliability negatively. The experts interviewed that are interviewed work at different departments at companies such A-CDM implementation project ground services, etc. These experts will provide the research with different insights on the operational impact of local A-CDM to their daily operation.

2.5 Data Collection

This paragraph describes how the research instruments are applied to find the answers to the sub-research questions. Furthermore, each research needs to have a certain level of reliability and validity, the issues and limitations are explained. Interviews are held to collect data and quantitative data is analysed to provide content for the research and therefore a set of ethical considerations and data confidentiality is required. The use of data collection methods is described for the overall research.

KDC Mainport Schiphol consists of the local A-CDM stakeholders at Schiphol Airport except for the ground handlers. However, KLM has its own ground services companies which can be used for the research. The data required for the research easy to collect via these KDC relations. It is easier to obtain data from parties other than the KDC stakeholders, because each stakeholders have its own relation to parties in the industry which provides more opportunities. There are several common questions asked by companies when asking for data such as what kind of data do you want and for what research purposes will it be used. Companies are always concerned about their reputation when they need to provide data. A clear overview of this information is provided to the company in order ensure a good cooperation with these stakeholders.

The data required for this research is obtained from the A-CDM portal. A-CDM records thousands or even millions rows of data each day. Each A-CDM stakeholder has infinite access to these data, because A-CDM is type of operation where information is shared in confidence. The research also honours these rules in order to prevent any negative effect on stakeholders' relations. The millions of data rows need to be filtered before use, otherwise every data analysis tool will fail and the possibility for a reliable result becomes less significant. Several months in the years 2015, 2016 and 2017 are applied in the research. In the end each stakeholder is well informed about the data purposes and the results.

The second data collection technique applied in the research is the interviews. Every interview is held with a different person who can have a different about the use of their opinion. Therefore, ethical considerations are taken into account for each interview in order to maintain a trustworthy interview strategy for every interviewee. The interviewees will maintain anonymous in the report, however the company and job title is mentioned to provide the reader with an insight of the interviewee's knowledge. The following ethical considerations are applicable for the research:

Ethical considerations
The following Ethical guidelines retrieved from nine professional social sciences research associations are applicable for the research:

1. Research participants should not be subjected to harm in any ways whatsoever.
2. Respect for the dignity of research participants should be prioritized.
3. Full consent should be obtained from the participants prior to the research.
4. The protection of the privacy of research participants has to be ensured.
5. Adequate level of confidentiality of the research data should be ensured.
6. Anonymity of individuals and organizations participating in the research has to be ensured.
7. Any deception or exaggeration about the aims and objectives of the research must be avoided.
8. Affiliations in any forms, sources of funding, as well as any possible conflicts of interests have to be declared.
9. Any type of communication in relation to the research should be done with honesty and transparency.
10. Any type of misleading information, as well as representation of primary data findings in a biased way must be avoided.

2.6 Data Analysis

The last paragraph called data analysis focusses on the techniques and tools used to analyse the qualitative and quantitative data. This will check the validity and reliability of the data and results as well. The paragraph explains the tools and techniques used for all sub-research question.

More and more tools for analysing data are being invented and are all used to finding results in a different way. Some of them are providing researches with a clear result such as Microsoft Excel. Excel is, therefore, applied to analyse the data retrieved from the A-CDM portal. Excel contains many different functions to easily filter and analyse data to improve the way of finding reliable results. The researcher always needs to consider the consequences of each filter which is used. The filter may never remove rows which are necessary for the research's result.

Excel has also functions that visualise data results. These functions are applied in the research to display the results clearly. However, there are also other programs available that use Excel data as input but can create more accurate and applicable visualisations such as Tibco Spotfire. This program is used by KLM (KDC Mainport Schiphol stakeholder) to display they performance. The visualisation makes it easy for employees to see what the performance and results are from a company. Spotfire allows the user to filter out values that are not applicable for the research's result (Tibco Spotfire, 2018). The results are easily analysed when the applicable visualisation is created and makes it possible for the researcher to find the desired conclusions produced by the data.

Desk research has also been done to create a literature background to the problem and to describe what is already known about the subject. It is essential that the sources used to create the literature background are reliable and validated. Most of the sources are retrieved from Researchgate and Mendeley which are both trustworthy and commonly used by researchers all over the world (Researchgate, 2018) (Mendeley, 2018). Eurocontrol is also an essential information source, because A-CDM is created by Eurocontrol (Eurocontrol, 2017). They have done many studies to the performance of A-CDM at other European airports and have their own implementation manual of A-CDM (Eurocontrol, 2017) (Eurocontrol, 2016). Other sources are provided by the KDC stakeholders, KLM, AAS and LVNL.

3 Review of the Literature

The literature review elaborates the local A-CDM benefits at Schiphol Airport. Local A-CDM is a current topic which requires more research, because many airports have implemented it and others are still working on the implementation implementing it. However, it is still uncertain how beneficial it is for any specific airport in particular. This is also the case for Amsterdam Airport Schiphol. The following elaborates how A-CDM operates and what its benefits are for each stakeholder provided by previous research on current A-CDM airports.

3.1 Airport – Collaborative Decision Making platform

A-CDM is a platform that the five main stakeholders (see Figure 6) at an airport use to exchange information. The stakeholders work together to improve the decision making process which is based on more accurate and high quality information. They have to provide the required information on time. The use of resources will be optimised and the predictability of the whole operation will be improved. A-CDM focusses mainly on aircraft turn-around and the pre-departure sequencing processes. Local A-CDM is currently implemented at AAS which includes the four main stakeholders (Airport operator, Aircraft operator, ATC and ground handlers), the connection with the network manager is not yet implemented. Local A-CDM should improve the stakeholders' operational efficiency by improving the predictability and decision making.

3.2 Operational changes stimulated by A-CDM

The implementation of A-CDM has usually takes several years at current European CDM Airports (Eurocontrol, 2017). This is mostly caused by the fact that A-CDM is based on data sharing which is not in the culture of all involved stakeholders. Airlines and ground handlers are less likely to share data, because they have to compete with each other and confidential information sharing will decrease their market position. However, A-CDM does not require them to share that much confidential data but still slows down the process. Data sharing is not the only change stimulated by A-CDM. There are also several operational changes which influence the daily operation of involved stakeholders.

A-CDM milestone approach

CDM Airport will operate by the milestone approach. The milestone approach is part of the A-CDM operation in which particular information is shared on specific times in the flight operation (milestones). The selected milestones (see Figure 5) represent the progress of the flight such as arrival, landing, taxi-in, turn around, taxi-out and departure (Eurocontrol, 2017). Each milestone is applicable for a change in the flight process. The milestone approach is used to further improve the common situational awareness of all partners especially in the inbound and turn around phase of the flight (Eurocontrol, 2017).

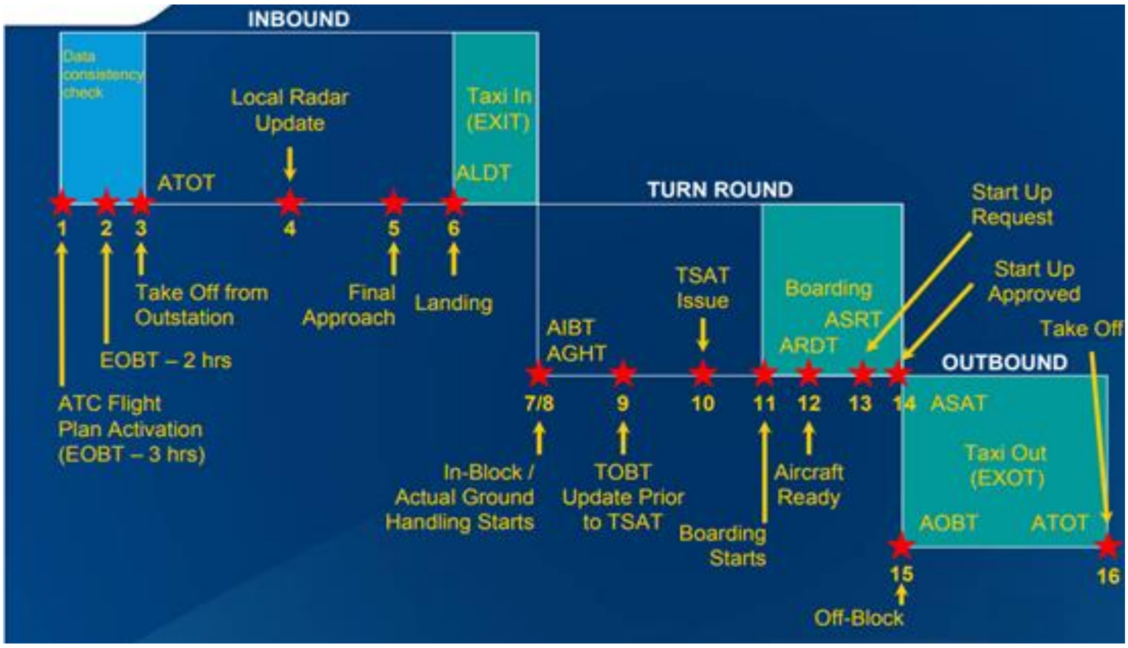


Figure 5 – A-CDM milestone approach source: (Eurocontrol, 2011)

Airports need to implement as many milestones as possible to improve the performance of A-CDM. The following milestones are implemented at Schiphol Airport (Amsterdam Airport Schiphol, 2015):

- Milestone 2, EOBT -2 hours
- Milestone 4, Local Radar Update
- Milestone 5, Final Approach
- Milestone 6, Landed
- Milestone 7, In-block
- Milestone 11, Boarding starts
- Milestone 13, Start-up requested
- Milestone 15, Off-Block
- Milestone 16, Take Off

The milestones form the basis of the A-CDM operation at Schiphol Airport. These milestone information moments were not in their operation before A-CDM. All involved stakeholders had to change their operational procedures to ensure the performance of the milestone approach. Each stakeholder has to provide the real-time information on time to the applicable receiver(s). Other requirements also need to be met to distribute the information over the stakeholders such as technical infrastructure which shares information and displays the output of milestone processes to determine the performance.

3.3 Benefits of A-CDM

Each stakeholder should experience its own set of benefits which are stimulated by A-CDM. The airport operator will be able to improve its gate usage by a reduction of late gate changes. This is possible, because data of flight arrivals and turnaround disruptions is shared which makes it possible to proactive handle the situation and preventing a late gate change (Eurocontrol, 2016). Furthermore, the taxi times will reduce and there will be fewer queues on runways which decreases congestion on the apron and taxiways (Eurocontrol, 2017). This is useful to prevent Schiphol Airport from becoming more congested (CAPA, 2017).

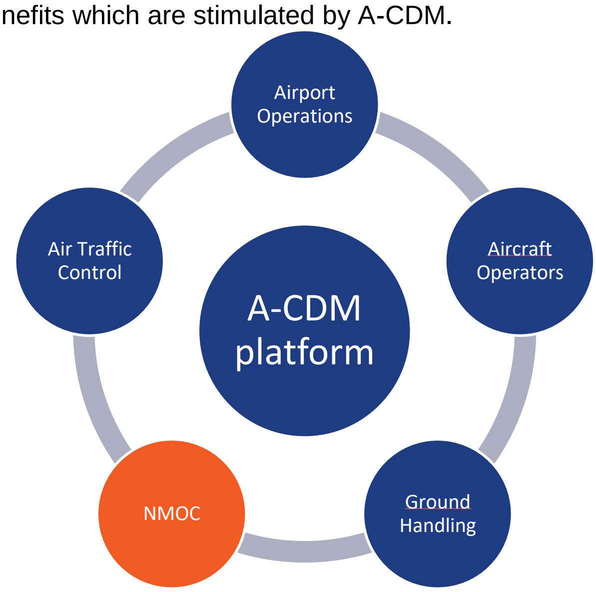


Figure 6 – Involved stakeholders in total A-CDM source: (Eurocontrol, 2016)

The second stakeholder is the aircraft operator. A-CDM is also very beneficial for this stakeholder. The aircraft operator is provided with an increase of aircraft awareness. The location and status of the aircraft will be more accurate which makes scheduling and preparing for the departure easier. The fuel burn of the aircraft will also be reduced thanks to the decrease of taxi time and runway queues (Eurocontrol, 2016). This will benefit airlines in an economic way and environmental way. The EOBT and TOBT will also be more accurate, because the NMOC automatically files a DLA message using the TOBT values in the DPI messages (Eurocontrol, 2017). This optimizes the flight operations for the airlines.

The next stakeholder is the ATC. The ATC will be able to improve the runway and capacity planning thanks to the predictability, this is especially useful at Schiphol Airport because the airport is getting increasingly congested. The ATC receives information such TOBT and ELDT earlier in the process. This increases their awareness of where aircraft are and when they will become their responsibility. They will be able to plan ahead to prevent any disruptions. (Eurocontrol, 2016). Furthermore, they can make more accurate take-off time prediction thanks to the Collaborative Pre-Departure Sequence Planning system (CPDSP) (Eurocontrol, 2016) (Amsterdam Airport Schiphol, 2015). The CPDSP (see Figure 7) is a system that uses the TOBT provided by the GH or airline in order to assign a TSAT to the aircraft at the gate (Amsterdam

Airport Schiphol, 2015). The system creates the optimal departure sequence and provides the airlines with a more accurate take-off time.

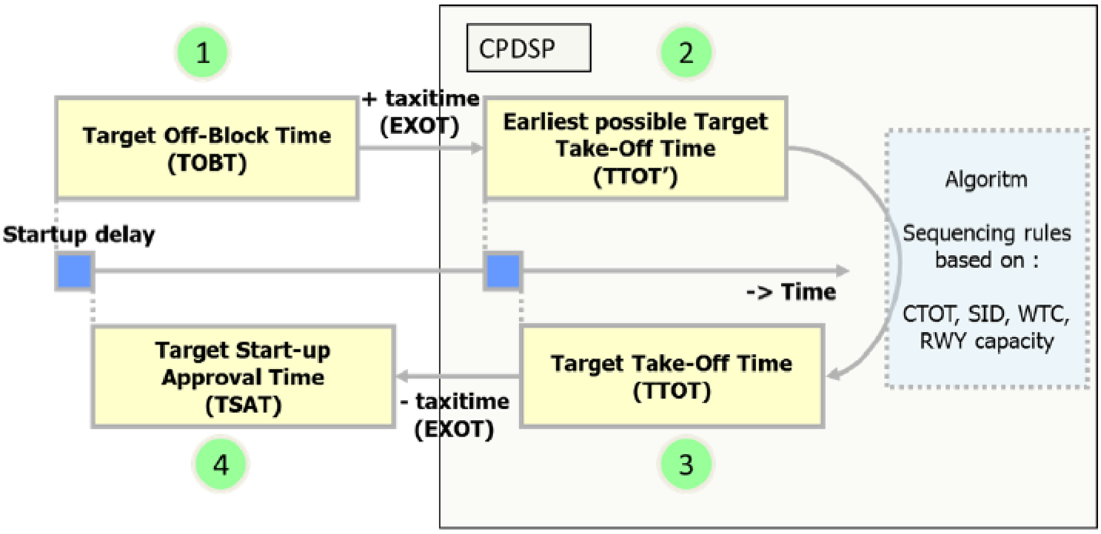


Figure 7 - Collaborative Pre-Departure Sequence Planning system (CPDSP) source: (Amsterdam Airport Schiphol, 2015)

The last main stakeholder is the ground handler. The most essential benefit for the ground handler is that the resource schedule is optimized in every situation thanks to data sharing. The accurate arrival times are communicated which allows the ground handler to schedule its resources optimally and preventing any unnecessary delays. This benefits the passengers as well (Eurocontrol, 2017).

Research has shown that the above mentioned factors improve the operation's efficiency for each involved stakeholder (Eurocontrol, 2016). However, more research needs to be done at Schiphol Airport if these benefits also are realized at Schiphol Airport.

~This page is intentionally left blank~

4 Qualitative and quantitative analysis

The analysis chapter is essential aspect of the research. Every research contains data which is collected differently and requires an analysis. The researcher is responsible for choosing the optimal research methods and analyses. The methodology is described in chapter 2. The analysis chapter focusses on how the research is conducted to find the result using several research methods. The exact application of the research methods is explained. The chapter is divided by the two types of analysis used during the research, qualitative and quantitative analysis. The qualitative analysis paragraph describes how the interviews are held and with whom, followed by the interview results. The results are structured according the local A-CDM stakeholders, ATC, ground handler, airlines and airport. The quantitative analysis is based on the on time performance calculation. Firstly, the analysis decisions and process are elaborated. The results of the quantitative analysis are evaluated in chapter 5.

4.1 Qualitative analysis

The qualitative analysis part of the research was performed by interviewing A-CDM experts working at the stakeholders of local A-CDM and consultancy company at Schiphol Airport. Each interview was planned by e-mail and took at least 30 minutes. However, in most cases 60 minutes were scheduled in the agenda to ensure there was enough time to discuss every subject necessary. The interviews started with a personal introduction, sharing work experience and explained the purpose of the research to inform the interviewee about what kind of questions he or she could expect. They were always held at the office of the interviewee to provide them with the least amount of used time. All interviewees were asked the same four main questions (see appendix II). The interviewees were all A-CDM experts working at different companies which have another role in the local A-CDM system. The following A-CDM experts were interviewed:

- A-CDM implementation consultant, at To70 (Ground Handler, Airport, Airline and ATC)
- Aviation expert, at Aviation Academy (Ground Handler, Airport, Airline and ATC)
- Duty Hub Manager, at KLM (Ground Handler and Airline)
- Data analyst, at To70(Ground Handler, Airport, Airline and ATC)
- Supervisor Operations NL, at Aviapartner (Ground Handler)
- A-CDM data analyst, at Amsterdam Airport Schiphol (Airport)

Explanation of interview questions

The following explains the purpose of each main interview question and for which research question they will provide an answer:

- How do you experience working with local A-CDM at Schiphol? How has the implementation impacted your operation?

The first essential question answering what operational changes were implemented to the stakeholders' operation contains two parts. The first part is to gather information from each stakeholder on what their opinion is about local A-CDM so far. This provides the research with an overall thought about the rest of the interview. The interviewee will provide answers according his opinion. This can either be positive, negative or neutral. The question will explain how stakeholders work with local A-CDM.

The second part of the question will provide a more detailed answer to what operational changes were implemented to the stakeholders' operation. The impact on their operation will be explained as operational changes, if not a follow-up question is asked about the operational changes. Furthermore, the impact on their operation leads to more variety of answers because impact is interpreted differently.

- What does your company do to ensure the quality of information the local A-CDM requires?

The functionality of local A-CDM is based on sharing accurate information to other stakeholders. Data sharing methods have been changed for each stakeholder thanks to local A-CDM (see paragraph 3.2). Stakeholders need to make sure that all the information they share is accurate, because other stakeholders make their planning according information from others. Providing inaccurate information will eventually influence their own operation as well, because it could delay other aircraft or provide them with a delayed TSAT. This question will explain how the stakeholders provide others with that accurate information.

The answers of the interview question form the basis of the research question and is validated by available literature. It depends per airport which A-CDM milestones are implemented and therefore the requirements for stakeholders can differ. The interviews will point out exactly what each stakeholder had to change to their operation.

- How has local A-CDM affected the operational efficiency of your company? Can you name benefits and downsides applicable to this question?

The question above is quiet to the point and asks the stakeholders if local A-CDM has been beneficial for their operational efficiency. It will provide an answer which can either be positive or negative. The stakeholders provide the research with a list of benefits and/or downsides of local A-CDM. The essential part of this question is to link the benefits and downsides to operational changes which are stimulated by local A-CDM and not to other factors that influence their performance. Each benefit and downside given by the interviewees requires an explanation in which the cause, consequence and importance. After the full description is given for each benefit and downside the next question is asked.

- What aspects of local A-CDM need to be improved to provide a more beneficial system?

The next question follows-up the previous one, because if the system has any downsides or benefits which could be improved, the interviewee shares his/her thoughts in this part of the interview. The system is not fully implemented yet, so the chances are high that are still aspects which need to be improved. Each stakeholder will give their insights on those improvement aspects. This provides the research with a better understanding on how the stakeholders see the system working at this moment and how they would like to see it working in the future. The answer to this interview questions also supports the recommendations of the whole research.

The following part of the chapter describes the information gathered during the interviews. The information is structured according the four main stakeholder operating the local A-CDM system (ATC, Ground Handler, Airline and Airport).

4.1.1 Air Traffic Control (LVNL)

The ATC is one of the stakeholders which really needed to change their work method for local A-CDM. They did not have to change their whole operation, but a part of it. The departure sequence was made by people instead of a machine before local A-CDM. An outbound departure planning system was implemented thanks to local A-CDM, called Collaborative Pre-Departure Sequence Planning system (CPDSP) (see paragraph 3.3). This had an impact on how the outbound worked, because he did not have to make the whole departure sequence anymore, the ground handlers and airlines provided most of the information required for the system to create the optimal departure sequence. However, the outbound planner could adjust the departure sequence if necessary. A reason could be that a flights needs to get prioritised over other flights and the reasoning behind the prioritisation is not implemented is the algorithm of the system. The outbound planner's daily task is changed from making the outbound planning to operating and controlling the CPDSP and providing the pushback and runway details to the cockpit crew.

Local A-CDM has had an effect on the operations of the ATC. The ATC only has to communicate with the cockpit crew of a flight according the planning made by the CPDSP. The ATC had contact with flights more often before local A-CDM this increases the workload. Therefore, the workload of the ATC decreases thank to the fact that the TOBT updates go to the outbound planner and directly into the local A-CDM system. The system does the work for the ATC by providing a departure sequence according several input variables (see paragraph 3.3). However, the workload of the outbound planner itself is not significantly decreased, because the produced departure sequence needs to be monitored at all times and adjustments are made when necessary. The CPDSP must be monitored more closely on days with major disruptions, because other stakeholders experience significant TSAT changes when they update their TOBT which is not desirable (see paragraph 4.1.2).

The ATC experience a small reduction in taxi times as well. Aircraft are held at the gate till there is a runway almost directly available for take-off, hence the fact that otherwise aircraft will have to wait on taxiways which will block them. Blocking taxiways can cause a traffic jam or delays to other aircraft that have to wait. The CPDSP produces the TSAT for flights is such a way that there is minimal waiting time for runways or that will not be another aircraft delayed due to the waiting aircraft. However, the reduction is small because the ATC was already using Start-Up control before local A-CDM which also keeps aircraft at the gate will there is a runway available. The Start-Up control was, on the other hand, not always the system which was used, because it was more an indication and the departure sequencer which produces TSAT times sets the time for pilots which they will have to follow.

4.1.2 Ground Handler

The ground handler provides essential information to the ATC. The information provided is the TOBT. The TOBT is the input for the CPDSP and based on that TOBT a TSAT is produced for each flight. The ground handlers did not have to provide the ATC with a TOBT before local A-CDM. They only had to contact the ATC when they were ready for pushback on which the ATC decided the departure sequence at that moment. The difference between the situation before and after the implementation of local A-CDM is that the ground handler has to provide a TOBT as soon as possible to improve the predictability of the system. They have to update the TOBT, whenever the ground handler is not going to be ready for pushback on its TOBT. Providing and updating the TOBT is the new operational task for the ground handlers and is essential for local A-CDM to work. The ground handlers have educated the platform supervisors with knowledge about how local A-CDM operates including the TOBT and TSAT. The supervisors need to make sure that the TOBT is provided and updated on time.

Local A-CDM increases the predictability of the airport operations. The ground handlers experience that their resource planning and their pushback planning in particular is improved thanks to local A-CDM. However, they experience the improvement mostly on days without major disruption such as extreme weather conditions. The TSAT provided by the CPDSP is much more stable on non-disrupted days than on days with disruptions. The TSAT instability is caused by a combination of factors. The ground handlers and airlines update the TOBT more often on disrupted days and in most cases in the last 15 minutes before the previous TOBT. The late updates lead to changes in the TSAT which can be shifted must further in future due to the CPDSP depending on the calculation input of each flight. the TSAT will shift constantly, if several flights update their TOBT more often in the last 15 minutes. A shift of the TSAT further away from the TOBT leads to delays which are undesirable. The consequence of the shifting TSAT is that the ground handlers have to change their pushback planning constantly as well as having staff and equipment waiting at gates due to an occupied gate caused by a shifted TSAT. The cause of the shifting is partly due to the late TOBT updates and outbound planner algorithm which is very sensitive for TOBT updates. The system produces a whole new departure sequence whenever a TOBT is updated which in some cases does not change many TSATs and sometimes it does.

Furthermore, the platform supervisors of ground handler are educated to have the knowledge about what the TOBT is and what an update of the TOBT has a consequence. However, the platform staff is not aware of the possible consequences late TOBT updates can have. The platform staff have to focus on their turn around tasks in order to provide the airline with a quick and reliable turn around. The workload of platform staff would increase if they would also have to focus on updating the TOBT or not. The late updates can cause TSAT instability and efficiency gains could decline or disappear as mentioned above.

4.1.3 Airlines (KLM) and Airport (AAS)

Providing and updating the TOBT is the task of the ground handler. However, the airline has to update the TOBT whenever it causes a delay which influences the TOBT. The TSAT is produced by the CPDSP which is based on the TOBT given by the ground handler or airline. The TSAT is normally shown on a display in front of the aircraft. The cockpit crew have to ask the ATC what their TSAT when there is not a display with the TSAT available and have to provide an update if they will not be able to be ready in time for their TSAT. They will be provided with an updated TSAT. An essential part of local A-CDM is that the airline is responsible for the performance of

the ground handler and has the task to monitor its performance of TOBT updates. The quality of the TOBT information is, therefore, ensured by the airlines.
The airport is an essential stakeholder in local A-CDM, because it provides the infrastructure and gates for the other stakeholders. However, not much has changed for the airport operationally by implementing local A-CDM. It only had an impact on the gate planning. The gate planning department now uses more accurate and predictable in block times and off block times for assigning the aircraft to gates such as Estimated In Block Time (EIBT) and Estimated Off Block Time (EOBT). Their system is updated to use these milestones times. AAS conducts research on how the airlines are performing by analysing the TOBT stability and adherence. Those results indicate if airlines are providing accurate TOBT on which they can really leave the gate (adherence) and whether they provide the ATC with many late TOBT updates or not (stability). Both results are published to the airlines and ground handlers in order to improve local A-CDM performance.

Local A-CDM does not have direct benefits for the airlines, but can benefit from a well-functioning local A-CDM system. Airline schedule their flights with a certain buffer which differs per airline. Local A-CDM makes the flight operation more predictable, therefore, buffer schedules can become more compact which leads to a higher aircraft utilisation. The airlines should reach a higher on-time performance (OTP) (see chapter 5). Local A-CDM has limited benefits for the airlines, however, total A-CDM should have more impact on the airlines' operational efficiency.

Local A-CDM has a positive impact on the airport operations of AAS, especially the gate planning. The gate planning is based on more accurate information thanks to local A-CDM milestones. EIBT and EOBT form the basis of the gate planning. These milestones provide the gate planning system with the required data further before the actual arrival time. The predictability is increased which supports the gate planning process. A benefit is that the waiting times for gates is decreased when there are enough gates available. However, the gate capacity at Schiphol is not always sufficient during peak hours. The gate planning is in that case influenced by other factors than local A-CDM, but local A-CDM provide the gate planning department with the predictability to know earlier in the process that there are not enough gates available at certain point of the day. The gate planning is the only process on which local A-CDM has a significant impact on for the airport.

4.2 Quantitative analysis

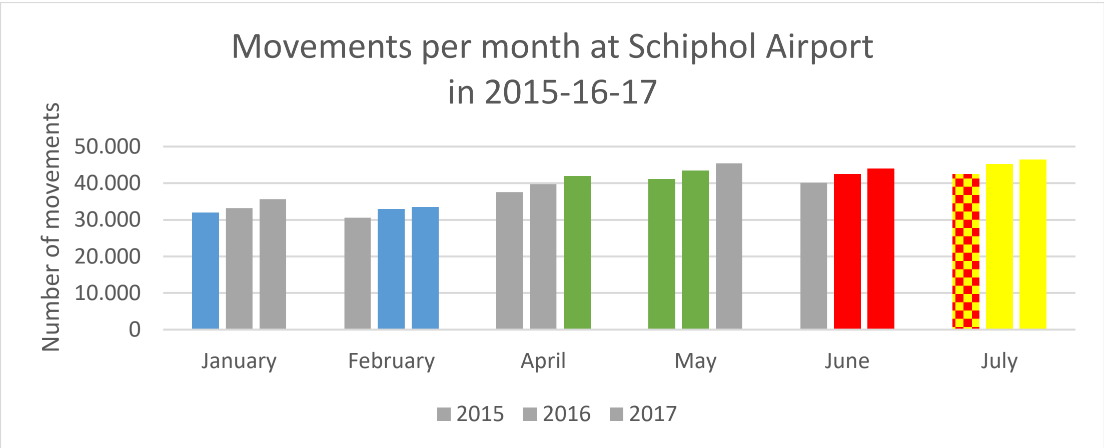
In the qualitative analysis the operational changes stimulated by local A-CDM and the potential operational benefits are analysed. The next step is to prove whether these potential improvements are actually realised and are supported by local A-CDM. The A-CDM system generates many rows of data every day which contain the flight information (registration, flight number, etc.) and milestone information (EOBT, TOBT, TSAT, etc.). The A-CDM data is used to calculate the OTP which is an essential KPI for ground handlers and airlines is on-time performance. The cause of the OTP result is connected to local A-CDM and other factors that influence the operation in order to validate the results. Factors that influence the OTP are delays. Each delay has a different cause and are based on IATA delay codes (see appendix VI). The further link to the delays is elaborated at the end of the paragraph. The following explains what steps are taken and which decisions are made to calculate the OTP.

Several choices were made to calculated the OTP. The first step was choosing the most selected sample (see paragraph 2.4). Local A-CDM was implemented in November 2015 and therefore the months before November in 2015 are the reference point for the research. The other two comparison months are in 2016 and 2017 (see Table 3Table 3 – OTP comparison periods, selected by monthly movements source: (Schiphol, 2018)). Both years are chosen in order to find a progressive, digressive or stable trend. Comparing just two periods from the past will only show an improvement or decline, however a trend shows how the system is performing over a longer period of time. It is always possible that a new system starts with negative results just after implementation. A trend shows how the OTP is changed over the years at Schiphol Airport.

Table 3 – OTP comparison periods, selected by monthly movements source: (Schiphol, 2018)

Comparison period	Months	Monthly movements
Winter	January 2015 February 2016 February 2017	32.032 32.959 33.400
Spring	May 2015 May 2016 April 2017	41.072 43.419 41.873
Summer	July 2015 June 2016 June 2017	42.494 42.418 44.012
Summer July	July 2015 July 2016 July 2017	42.494 45.260 46.496

The months are chosen based upon the number of movements. The impact of the congestion factor which is influencing the performance of stakeholders at Schiphol Airport is reduced by choosing the months with the most similar number of movements (see Graph 2). The last comparison called Summer July focusses on the system's performance during a busy period and by reducing the influence of other factors such as holidays and weather because they fluctuate less in the same months each year. So, the first three seasonal comparisons (see Graph 2) focus on the Winter (blue), Spring (green) and Summer (red). The month analysed can differ slightly within in a comparison in order to decrease the influence of the increased number of movements which causes congestion and delays. The Summer July (yellow) comparison is not focussed on decreasing the impact of the congestion, but focusses more on the performance of the system in the exact same month and climate each year.



Graph 2 – Monthly number of movements at Schiphol airport in 2015-16-17 coloured by comparison period source: (Schiphol, 2018)

The selected data was obtained after deciding which periods will form the basis of the data analysis. A-CDM data retrieved from the A-CDM portal which is afterwards processed to filter out the unnecessary periods and data columns. The initial data included arrival and departure flights. The arrival flights are not applicable for calculating the OTP and filtered out of the data sheet. The OTP calculation is based upon the departure of flights. Arrival flights are only applicable for delays caused by late arrival flights, but they are further evaluated by analysing delay statistics.

The data sheet contains the two essential columns are the EOBT (initial) and AOBT. The Excel data sheet columns are in appendix IV. The AOBT is chosen as the moment of departure instead of choosing the ATOT. The taxi times would be included as a variable when choosing the ATOT. However, Schiphol Airport was using start-up control before the implementation of local A-CDM. Start-up control means that aircraft are kept at the gates if there is not a runway available yet for an aircraft to depart from. Normally this method is used by airports when A-CDM is implemented thanks to the departure sequencer. The AOBT is, therefore, the moment of departure in the research. The minutes of delay per flight is calculated by subtracting the EOBT from the AOBT. In Table 4 is shown what the outcome of the sum means for the result.

Table 4 – Description of AOBT-EOBT outcomes

AOBT - EOBT	Description
Positive	Delayed
Neutral	Exactly on-time
Negative	Early

An aircraft has departed from the gate later than planned when the outcome is positive as shown Table 4. For example: a flight had as the initial EOBT a time of 10:00 AM and an AOBT of 10:10 AM. The following calculation is done:

$$10:10 - 10:00 = 0:10$$

The result is positive which means that the aircraft departed 10 minutes later dan initially planned according the EOBT, this results in a delay of 10 minutes. However, this does not directly mean that an aircraft did not depart on time according to IATA standards (Bureau of Transportation Statistics, 2018). The IATA standards acknowledge that an aircraft is delayed when it leaves the gate more than 15 minutes after EOBT. This standard is implemented in the analysis of the OTP in the research. In the calculation of the OTP all values are counted which are lower or equal to 15 and divided by the total number of values. This calculation is made for each month that is included in the research. An overview is made in which the results for each month and trend periods are compared.

The OTP is directly linked to the delay minutes and the cause of the delay. Analysing the causes of each delay longer than 15 minutes support the validation of the data analysis. This done by interviewing experts and delay results provided by previous researches.

The result of the OTP calculation is visualised in several graphs (see paragraph 5.6). Each of them requires a different analysis technique. The first step is to analyse and compare the OTP averages for each month and trends. The averages provide a quick overview of how the OTP developed the past years. The next step is to link these results to the delays and causes of the increased or decreased OTP as mentioned above. Other graphs are made in order to further analyse the changes in OTP. The changes are further analysed by comparing the Summer July period months on a daily scale. The daily OTP results are sequenced from high to low. There are initially three different outcomes possible for the increase or decrease of the OTP. The following figures show what the normal situation and other possibilities are.

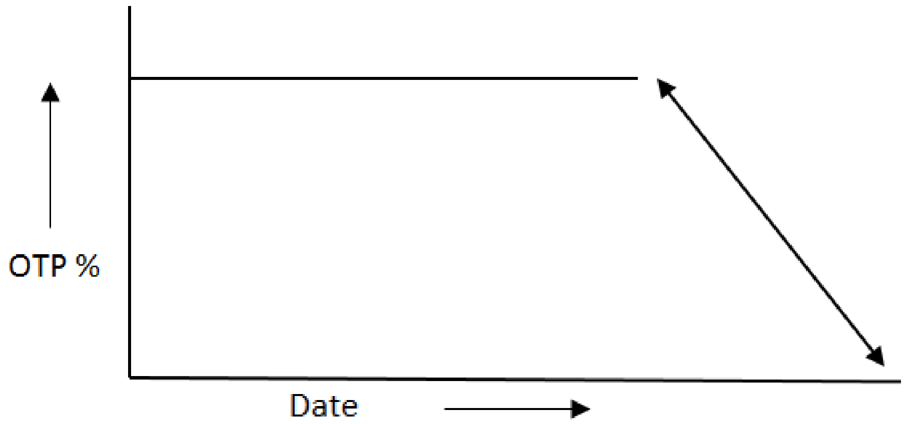


Figure 8 – Schematic drawing of the OTP per date of a single month

The normal OTP situation in month is shown in Figure 8. The y-axis is the OTP in percentage and the x-axis shows each date which is applicable for the OTP percentage result. The upper horizontal line is the overall OTP on which the airport wants to perform. The horizontal line will move upwards when the OTP increases and vice versa. Furthermore, the arrow shows the disrupted days in that particular month which differ significantly from the OTP goal. The upper part of the arrow can move from left to right and moves up and down according the OTP goal. The lower part on the other hand can only move up and down. This is depending on the lowest

OTP value of that month. The next figures explain the possible outcome situation when analysing the OTP.

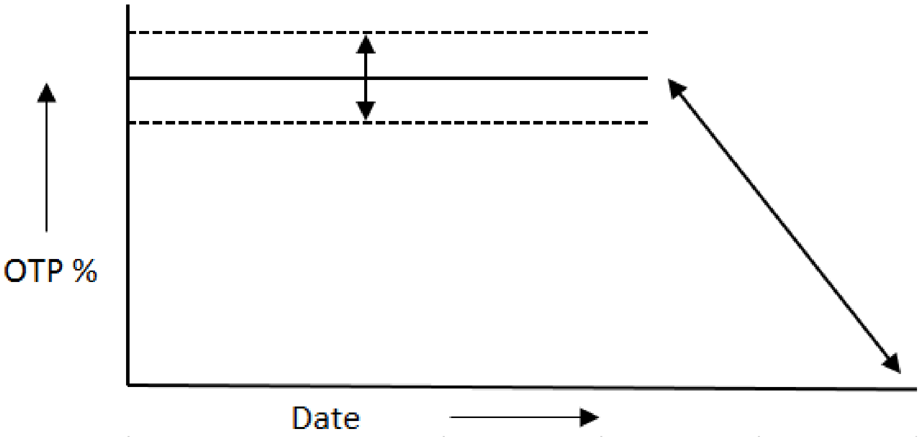


Figure 9 – Schematic drawing of the OTP goal changes in a single month

The OTP goal line can move up and down according the performance in that month (see Figure 9. The past years the OTP has been impacted at Schiphol Airport, however it is unknown if the impact is positive or negative. Local A-CDM is one of the possible factors. The first change is overall OTP is increased or decreased. An overall OTP change is a significant improvement to the local A-CDM stakeholders' operation if the OTP change is positive. A shift of the overall OTP has a large impact on the whole operation and if the OTP change is negative further research is required to analyse the cause and potential solutions.

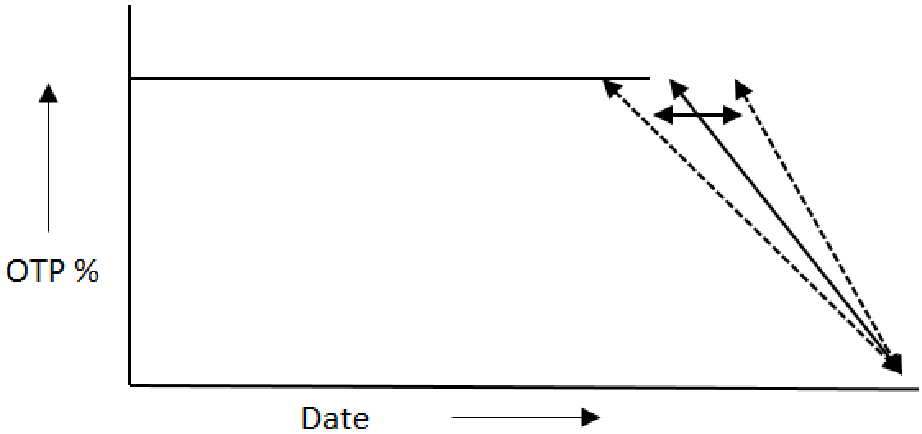


Figure 10 – Schematic drawing of the OTP on the number of disrupted days in a single month

The second possibility (see Figure 10) is that the number of disrupted days has increased or decreased when comparing it to other years. Upper part of the arrow moves left when more days have an OTP value which is lower than the OTP goal and vice versa. The number of disrupted days differs each month and is influence by many other factors such as weather. However, local A-CDM could also influence the number of disrupted days. The number of disrupted days will decrease when local A-CDM works optimal and will increase when there are days on which the system is not operating as it should.

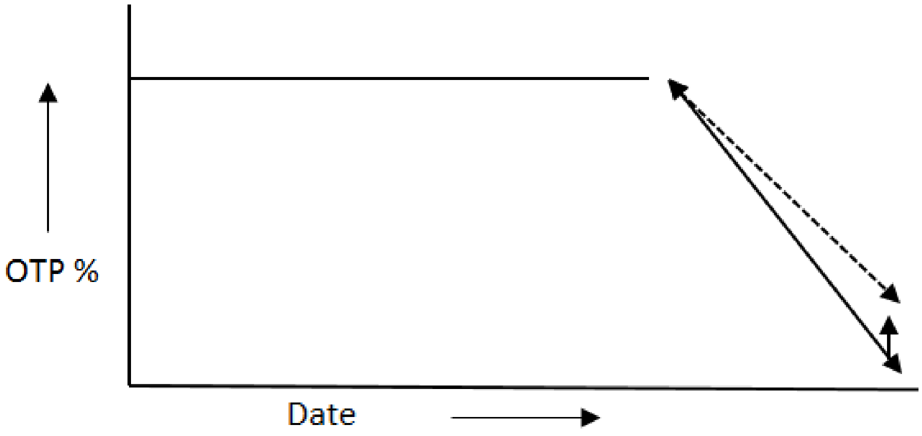


Figure 11 – Schematic drawing of the OTP values of disrupted days in a single month

The last possible influence is also an impact on the disrupted days. However, it is not an impact on the number of days but the OTP result of each disrupted day (see Figure 11. Local A-CDM has an impact on the performance when a disruption occurs. The system increases the predictability and therefore should improve the OTP on non-disrupted days as well as disrupted days. However, experts experience that local A-CDM has a negative impact on the OTP (see paragraph 4.1). The data will show whether this is the case or not.

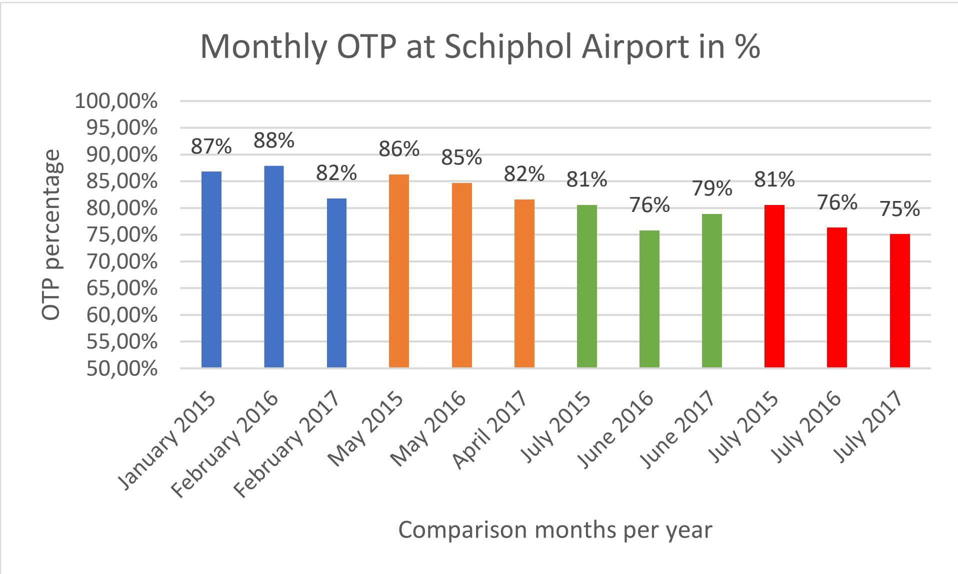
These possibilities show which part of the OTP has changed and with how much. The severity depends on which part of the OTP has changed. The result is explained in paragraph 5.6.

5 On Time Performance Research Findings

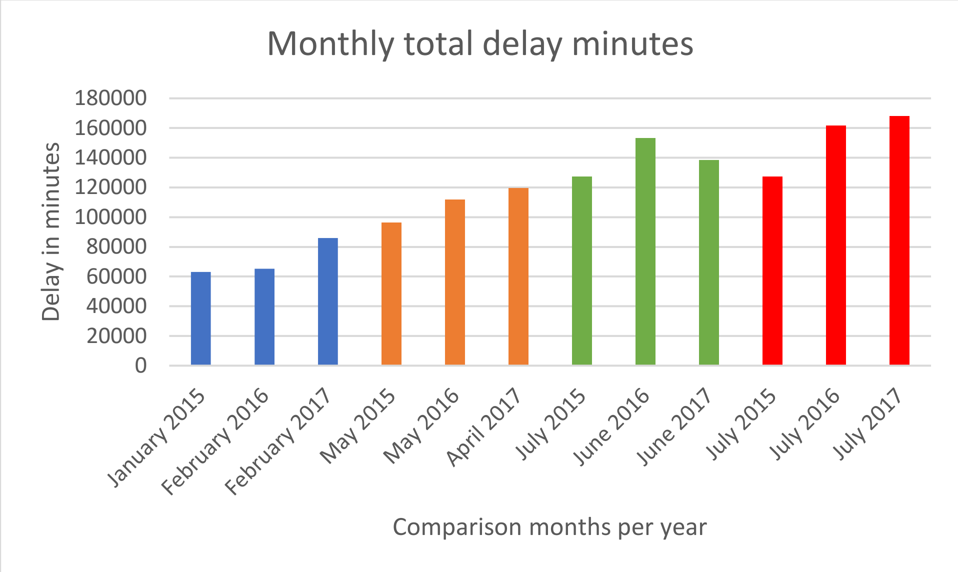
The on time performance research findings chapter is connected to the quantitative analysis explained in the previous chapter. The analysis has described how the OTP is calculated. The research findings chapter focusses on presenting the results of the quantitative data analysis objectively. The presentation of results is supported by graphs and tables. Furthermore, the chapter is organized by the data analysis of the on time performance (OTP). Firstly, the average OTP for each month is compared, followed by the results of the distribution. The seasonal comparisons results are explained next by describing what caused the OTP changes. Finally, the daily OTP results are compared for the July month of 2015, 2016 and 2017 to analyse the shift of the overall OTP line.

5.1 Monthly average on time performance results

The on time performance is calculated by a data analysis and evaluated by the delay causes. The OTP is analysed per seasonal period (see paragraph 4.2). The OTP results are shown in Graph 3. The graph shows that the OTP is declined during the past three years. Each month has its own total minutes of delay which are shown in Graph 4. In most cases the total delay minutes increase whenever the OTP declines as expected. However, in February 2016 the OTP has increased by 1% but the total delay minutes have increased slightly (see Graph 4). This is explained by the fact that more aircraft have departed on time but the delayed flights have experienced longer delays.



Graph 3 – Monthly OTP at Schiphol Airport in percentage for each season comparison

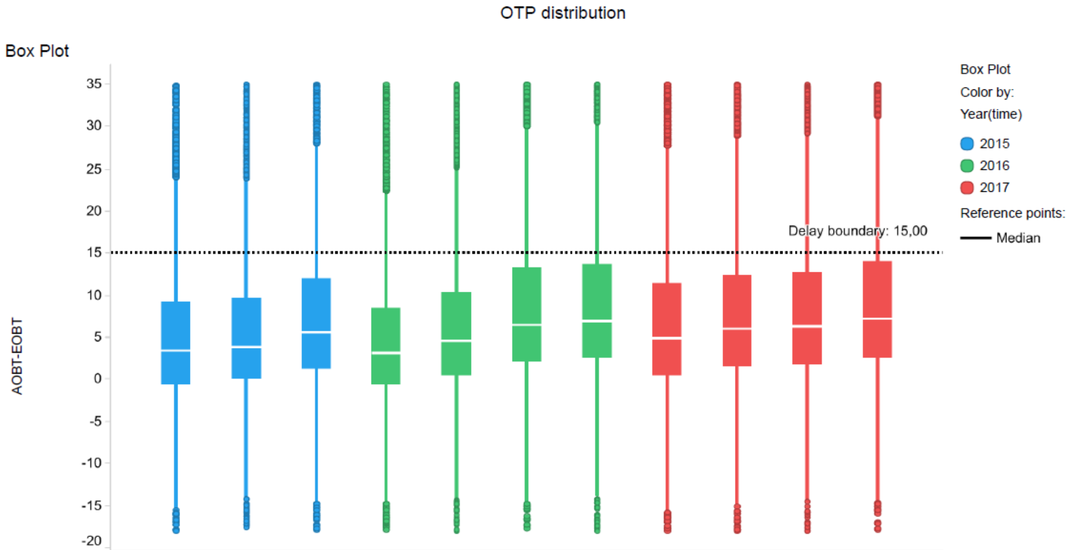


Graph 4 – Monthly total delay minutes per comparison per year

5.2 On time performance distribution

The distribution of the OTP for each month and year is shown in Graph 5. The graph shows that there are a significant number of departures above the delay boundary line which is the AOBT +15 minutes. The box plot squares which contain 50% of all flights are coming closer to the delay boundary line each year. This means that the OTP is declining which is accompanied by a declining OTP trend. The results of the OTP need to be linked to the delays and interview results in order to explain why the OTP is decreasing and what the link is to local A-CDM. The following explains the OTP results per comparison period.

There is another aspect to the distribution which stands out. The median is not significantly changing over the years (the white stripes in Graph 5). The median is value that is in the exact middle of all values. The OTP has changed significantly in most cases over the year when analysing each comparison (see Graph 3). Another part of the boxplot has changed in order to validate the declining OTP. The upper rectangle (above the median) is increasing in size which means that those 25% of all values are more spread out. There is an increasing number of flights which have a slightly longer delay than before. A consequence of this is that the bottom of the upper 25% (de line between the box and dots) in getting higher and more flights rise above the delay boundary line. The OTP trend is therefore in comparisons negative as seen in Graph 3.



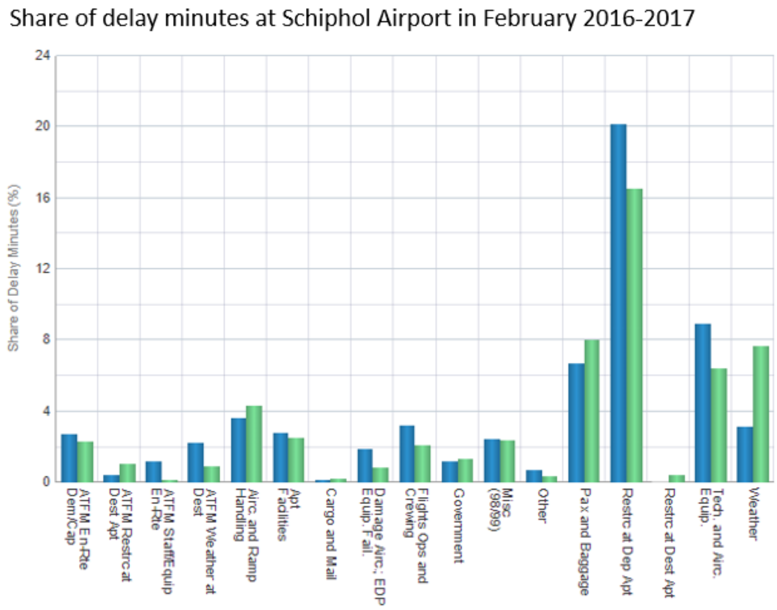
	2015			2016				2017			
	jan	mei	jul	feb	mei	jun	jul	feb	apr	jun	jul
Count	11146	15343	14919	12585	15985	14583	16056	11571	15178	15314	15902
Avg	4,92715	5,4118	7,20916	4,57376	6,10595	8,30643	8,62841	6,54176	7,39153	7,78831	8,87472
StdDev	8,25504	7,93991	8,46154	7,9135	8,11224	8,75392	8,58295	8,65914	8,29218	8,40087	8,64593

Year(time) Month(time)

Graph 5 – OTP distribution for each month and year source: (Tibco Spotfire, 2018)

5.3 Winter

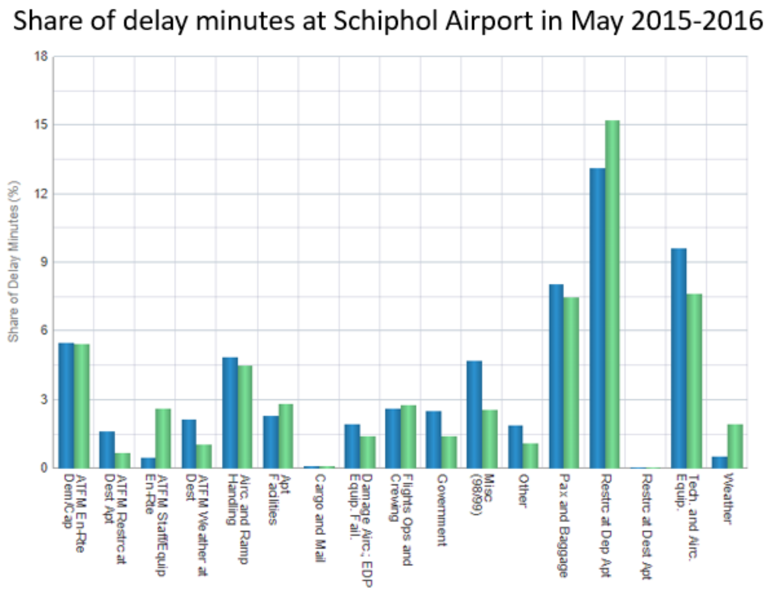
The OTP results are shown in Graph 3. The graph shows that the OTP is declined during the past three years. The Winter period which is January 2015, February 2016 and February 2017 experienced a growth of one percent during the first after the implementation of local A-CDM. However, this was declined by six percent the next year. The share of delays for those months in both years explain why the OTP has declined. Graph 6 shows that weather has played a role in the performance of the airport. More delays were caused by weather conditions. The weather factor can be linked to several interview results. The experts from Aviapartner and KLM stated that the local A-CDM is not performing as it should in disrupted situations due to TSAT instability (see paragraph 4.1.1-4.1.3). The ground handlers have to update the TOBT whenever they are expecting to miss it. Each time the TOBT is updated the sequencer has to renew the departure sequence which causes new TSATs for each flight (see paragraph 3.3). The TOBT is updated more frequently during disrupted situations which leads to TSAT fluctuations. A TSAT which is pushed further in the future causes an aircraft to get a delay. This is caused by the weather conditions and many TOBT updates. The OTP decline in the Winter period is in this case linked to the weather conditions.



Graph 6 – Share of delay minutes at Schiphol Airport in February 2016-2017 source: (Eurocontrol, 2018)

5.4 Spring

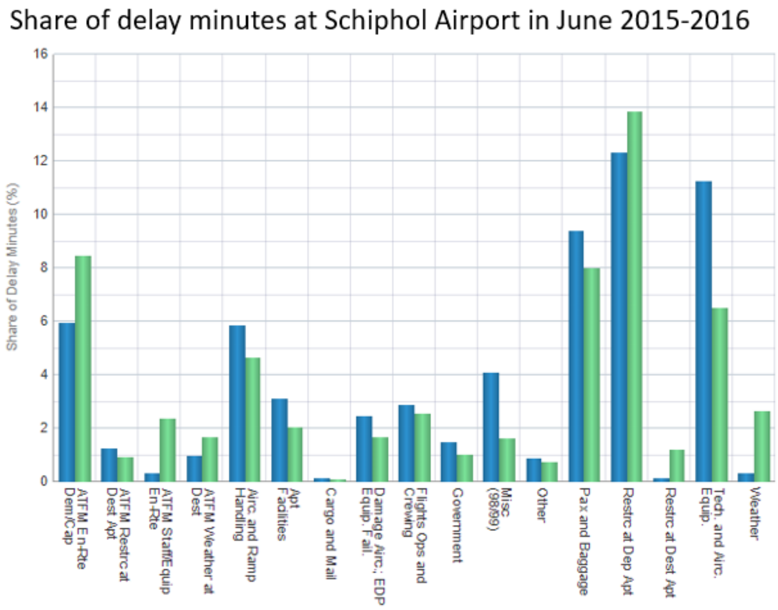
The spring comparison contains the smallest decline of OTP compared to the other three. These months contain the least amount of weather influence and therefore less disrupted situations (see Graph 7). The only aspect which has caused the delays are restrictions at the departure airport. This means that the infrastructure was not sufficient for the number of movements at Schiphol Airport in those months.



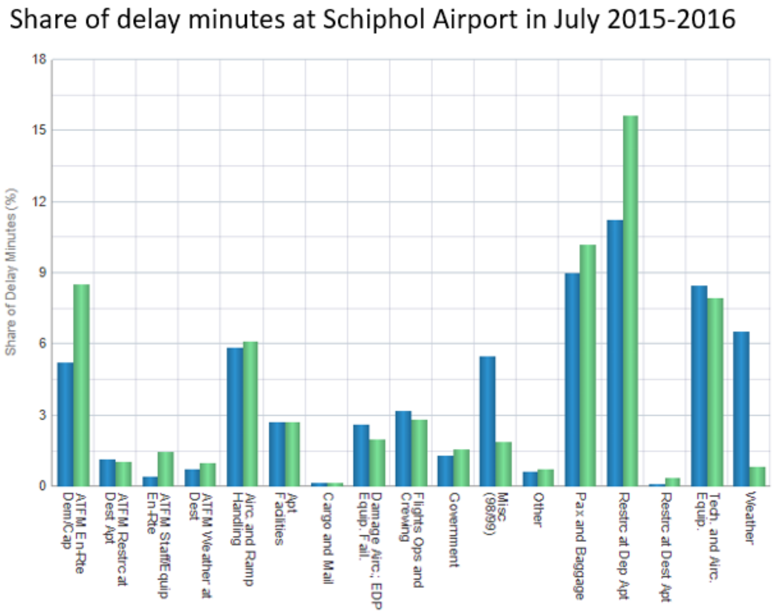
Graph 7 – Share of delay minutes at Schiphol Airport in May 2015-2016 source: (Eurocontrol, 2018)

5.5 Summer

The most obvious difference in the summer comparison which compares the OTP of the months July 2015, June 2016 and June 2017 is between 2015 and 2016. The month July 2015 has around 42,5 thousand movements and June 2016 has around 42,4 thousand movements. The number of movements in those months are more or less the same, however the OTP has decreased from 81% to 76% which is significant. The share of delays are shown in Graph 8 and Graph 9. In Graph 8 the green part of the diagram (June 2016) is and the blue part (July 2015) is used from Graph 9. The most significant difference is found in the delay share of the weather. In the month July 2015 extreme weather conditions were experienced such as tropical heath temperatures and heavy rain (KNMI, 2015), however, the weather conditions did not influence the OTP significantly. A difference in the restrictions at the departure airport is registered and has influenced the OTP at Schiphol Airport significantly negative.



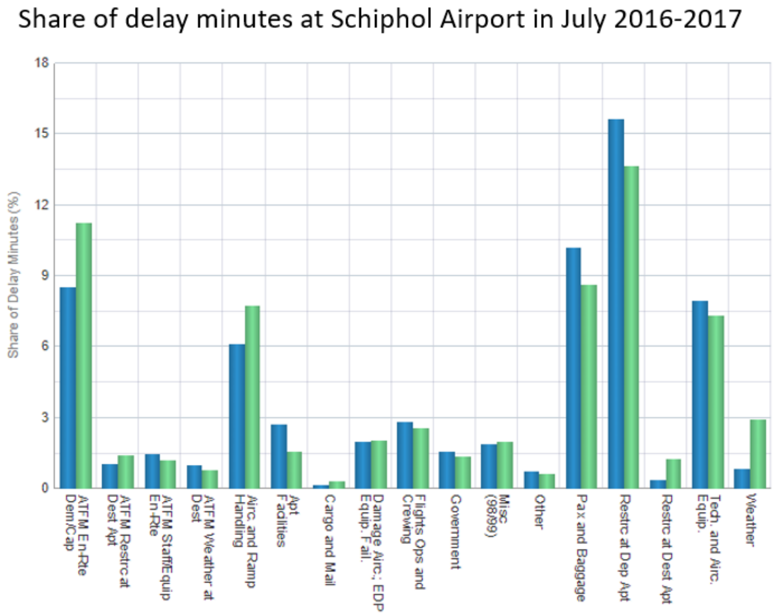
Graph 8 – Share of delay minutes at Schiphol Airport in June 2015-2016 source: (Eurocontrol, 2018)



Graph 9 – Share of delay minutes at Schiphol Airport in July 2015-2016 source: (Eurocontrol, 2018)

5.6 Summer July

The reason for the OTP drop in July 2015 and 2016 is much more obvious, because the share of delays caused by restrictions at the departure airport is around 10-15% (see Graph 9). This caused the OTP to decline in combination with an increase of ATFM en-route delays. These delays occur when the capacity or a particular part of the airspace is reached at a certain point in time and aircraft are hold at an airport till there is space available in the airspace. ATFM en-route delays occur more often during the Summer season, because there are more flights being executed and the airspace will get too full which if not regulated becomes a safety hazard for the aircraft in that particular area.

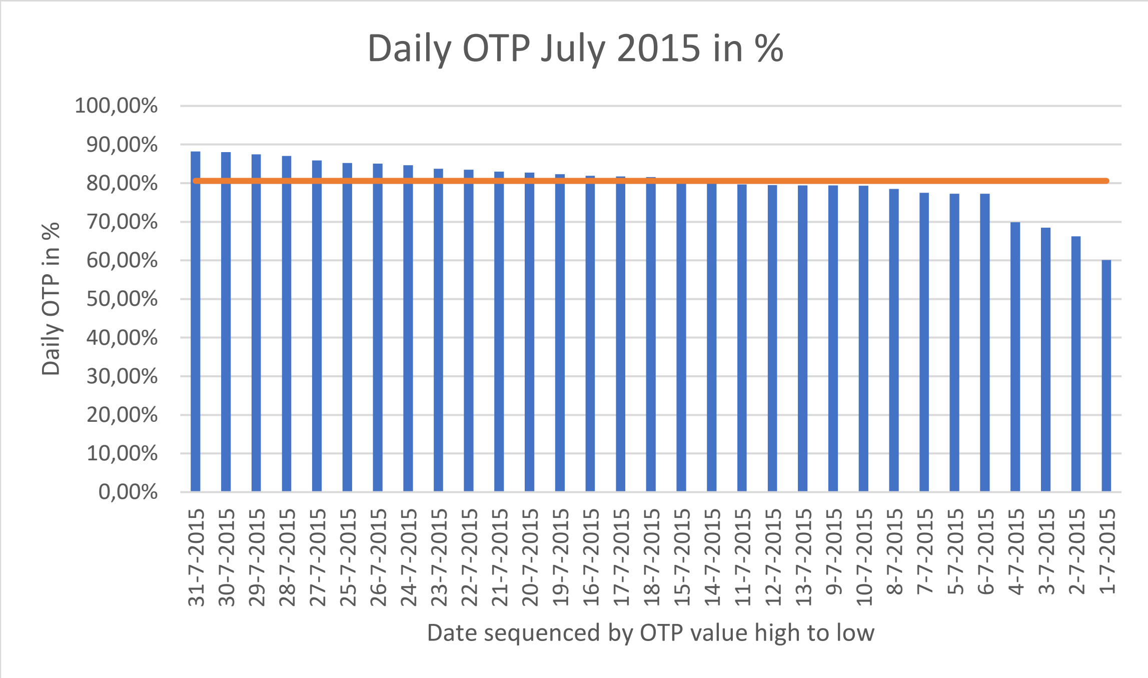


Graph 10 – Share of delay minutes at Schiphol Airport in July 2016-2017 source: (Eurocontrol, 2018)

5.6.1 Shift of the daily on time performance over the month July

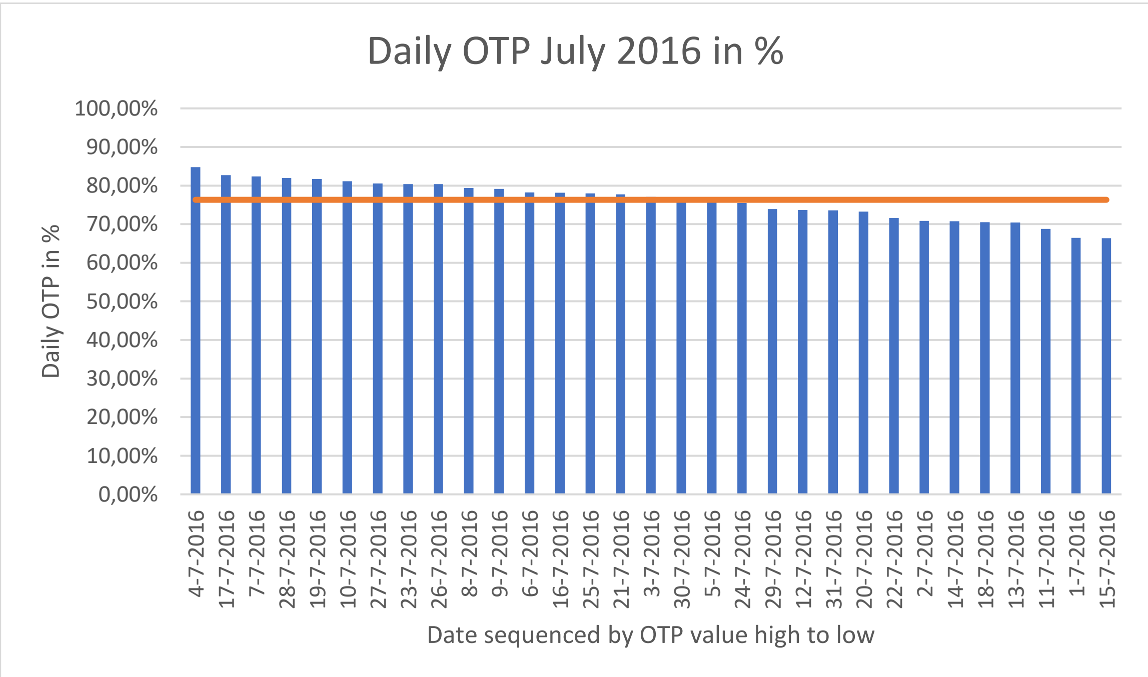
A second OTP analysis is performed for the Summer July comparison which contains the years 2015, 2016 and 2017 (see paragraph 4.2). The analysis focusses on explaining how the daily OTP is developing in the Summer month July over the years. The first aspect of July 2015 which stands out is that there are four values significantly less than the rest. The OTP was between 60% and 70% in the first four days of July which is almost 10% lower than the worst day of the months' remaining days. Weather had large impact on the operation in July 2015 according the delay share of weather (see Graph 9). A tropical heatwave struck the Netherlands from 30 June 2015 which had an influence on the flight operation at Schiphol. The runway temperature climbed above the maximum boundary, therefore, Schiphol was required to cool the asphalt down by spraying water over the runways to prevent damage and cracks from coming in the runways (Het Parool, 2015). Cooling the runways meant that the runways were part of the days unusable and caused delays which is validated by the delay share of weather seen in Graph 9. The first week of July causes the OTP to be lower. The fact that these significantly low OTP days are present means that the stakeholders handled the situation too late in order to minimize the potential delays caused by the severe weather conditions. Operating in this type of weather conditions is possible, because in several airports in the world the temperature rises even much above the temperature measured in the first week of July 2015 in the Netherlands.

Another aspect which stands out is the fact that the OTP results are sequenced from the highest value to the lowest value and that the x-axis represents the day of the month and is almost completely in the sequence from 31st of July till the 1st of July. The OTP improved during the whole month July 2015. The recovery of the heatwave is a reason for the improving OTP. The airlines operate with a tight schedule during the Summer season and so does the airport with its gate planning. The next step is to analyse the daily OTP results of July 2016 and 2017 to see what the impact was of implementing local A-CDM.



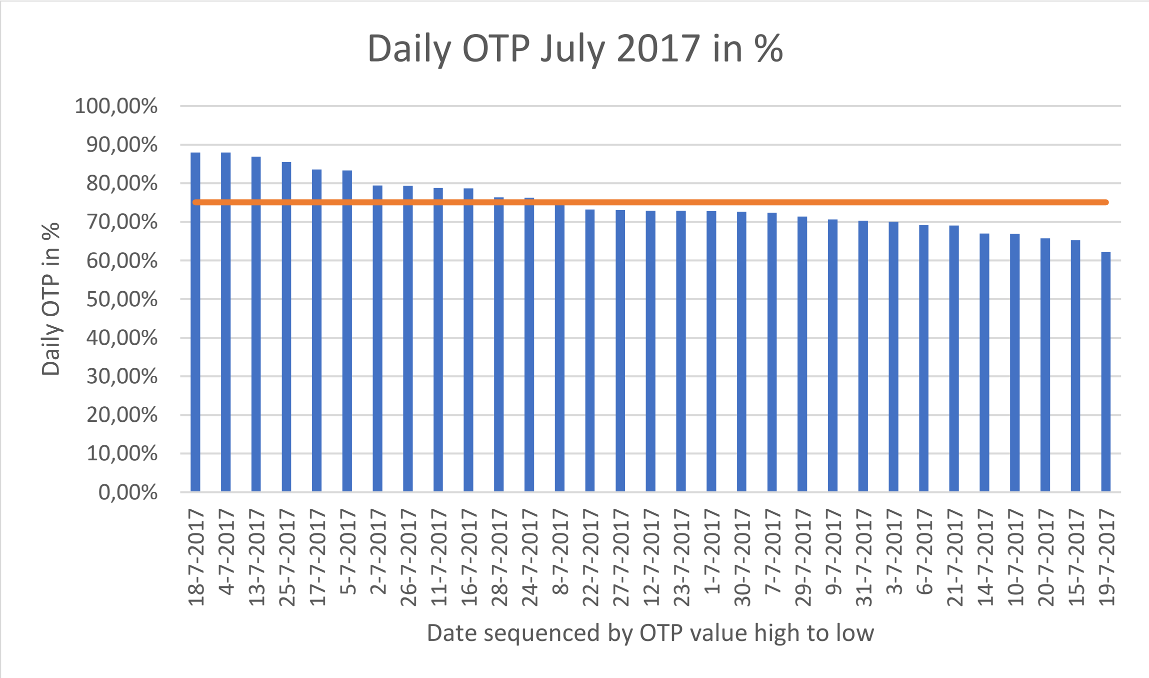
Graph 11 – Daily OTP results for the month July 2015 in percentage

The first possibility shown in Figure 9 is that the overall OTP is increased or decreased. The orange line in the graph is the weighted average which is the overall OTP for that particular month. The weighted average has dropped 4% when comparing July 2015 and 2016. There is only a 1% difference between July 2016 and 2017. The overall OTP is therefore declined, but it is also essential to analyse the variation of the values. A very wide spread of values was experienced in July 2015 which vary from 60% till 88%. However, in July 2016 the variety of values is much less. The total variety is in 2016 only 18% which is 10% less than in 2015 (see Graph 11 and Graph 12). The daily OTP results show that in July 2016 not a single day was above 85% in contrast with 7 days in July 2015. This is explained by the fact that the number of movement increased with 6,5% which is around 3000 movements. The increased amount of movements caused extra delays according the delay shares (see Graph 9). Furthermore, especially the lowest values in the month July 2015 cause a wide variety of values and is explained previously. An improvement in variety is seen between July 2015 and July 2016, but the overall OTP was declined.



Graph 12 – Daily OTP results for the month July 2016 in percentage

The variety of OTP values had increased again from 18% till 26% when comparing July 2016 with July 2017 which is seen in Graph 12 and Graph 13. The difference is found in the upper and lower values in July 2017. There are five days that have an OTP above 85% in contrast with none in July 2016. July 2017 also contains seven value below 70% which cause the 1% decline of overall OTP. This was caused by an increase of ATFM en-route delays and handling delays (see Graph 10). The increased number of movements is a reason both delays. It seemed that the OTP variety had improved from 2015 to 2016, but in 2017 it worsened again. In paragraph 4.2 several possibilities of OTP changes were described and shown (see Figure 9, Figure 10 and Figure 11). The result show that the OTP goal line has moved down over the years which means a decrease in OTP. The number of disrupted days has decreased from July 2015 to July 2016, but has increased again to July 2017. The last possibility was that the OTP of disrupted days would be suppressed by local A-CDM. This was the case for July 2016, because the variety of OTP values was much lower. However, in July 2017 the high variety returned even with local A-CDM.



Graph 13 – Daily OTP results for the month July 2017 in percentage

6 Conclusions

The stakeholders involved in Airport-Collaborative Decision Making (A-CDM) have been working on the implementation of A-CDM for 8-10 years at Schiphol Airport. The first step was to implement local A-CDM which is operating the milestone approach and using a departure planning system based on those milestones. Local A-CDM is implemented in November 2015. A-CDM has supported and improved the performance of several major European airports. However, it was unknown if local A-CDM had the same positive impact on the operation at Schiphol Airport for each involved stakeholder. The research question is, therefore:

- How has local Airport – Collaborative Decision Making exactly improved the operational efficiency for each involved A-CDM stakeholder at Mainport Schiphol?

6.1 Operational changes stimulated by local A-CDM

The first sub-research question analyses the changes stakeholder had to implement to their operation. The research question is answered by literature research and interviews with aviation experts from the key stakeholders. Both types of information gathering are used to validate the results.

Each stakeholder is impacted by local A-CDM differently, because all stakeholders had to implement a different operational change thanks to local A-CDM. The ATC and ground handlers' daily operation was impacted the most. The ATC had to implement a departure planning system called CDPSD. The system produced a departure sequence of all flights according several input data of which the Target Off Block Time (TOBT) was the most important. The ground handlers provide the system with the TOBT whenever they think the aircraft will be ready for pushback. The airline can update the TOBT as well, but is only done when the airline causes a delay. The cockpit crew has to know how local A-CDM in order to provide the system with the milestone data during the flight and on the ground. The airport has to change less to its operation. The airport had to some adjustments to the input data of the gate planning system. The gate planning system is now based on local A-CDM milestone information such as the Estimated In Block Time (EIBT) and the Estimated Off Block Time (EOBT). The current data used by the gate planning system is more accurate.

6.2 Effect of operational changes on the operational efficiency

The second sub-research question focusses on what the effect is of the operational changes to the operational efficiency of each involved stakeholder of local A-CDM. The same research methods are applied to answer this research question.

The operational efficiency is impacted differently for each stakeholder. The Air Traffic Control (ATC) has benefitted from the implementation of local A-CDM. It has decreased the workload of the ATC staff by having a departure planning system which makes the departure sequence of all flights. The ground handlers benefit from local A-CDM by making their resource planning and pushback planning in particular more efficient by increasing the predictability. However, the efficiency improvement is gained on days without major disruptions. The system does not provide the same benefits on disrupted days such as extreme weather due to TSAT instability. The TSAT instability is caused by late TOBT updates. The platform staff is not aware of the possible consequences late TOBT updates can have, because they are not as well as educated with the local A-CDM as the platform supervisors. Furthermore, the airline does not have direct clear benefits from local A-CDM but should get them from total A-CDM which contains the connection with the Network Manager (see paragraph 7.1). Airlines have implemented buffers in their flight schedule which can be become more compact to increase the aircraft utilisation. The buffers should only become more compact as the on time performance is already high enough (see paragraph 7.3). Local A-CDM is beneficial for the gate planning department of the airport. The gate planning is based on more accurate data retrieved from local A-CDM which improves the predictability and reliability of the gate planning.

6.3 Exact operational benefits gained to local A-CDM

The last sub-research question is a deeper analysis of the operational efficiency improvements. The operational efficiency change is analysed by a data analysis of A-CDM. The results are the validation of the interviews and literature research of the other sub-research questions.

The on time performance (OTP) is calculated for four seasonal periods and over three years:

- Before the implementation of local A-CDM
- The year after the implementation of local A-CDM
- Two years after the implementation of local A-CDM

The three years show a trend of the OTP development. In each seasonal period it is clear that the OTP is decreasing and when analysing the daily OTP of a single month of a seasonal period, it becomes clear that the overall OTP is decreasing. The decrease of the OTP is partly caused by other factors than local A-CDM such as airport infrastructure congestion, weather and airspace regulations which limits the number of aircraft in particular part of the airspace. However, it is partly caused by local A-CDM, because the system has been implemented very quick without already trying to improve it. The improvements of the system were planned after the implementation of total A-CDM (see chapter 8).

6.4 Overall conclusion

The following main research question is answered by the answers of paragraph 6.1-6.3:

- How has local Airport – Collaborative Decision Making exactly impacted the operational efficiency for each involved A-CDM stakeholder at Schiphol Airport?

When analysing the answered provided above, it becomes clear that implementing local A-CDM was successful decision, because it was the step between a normal airport and a total A-CDM airport, when combining the conclusions of each sub-research question. Local A-CDM has not been as beneficial as hoped, but brought light to the problems which the stakeholders are facing at Schiphol Airport. The performance of the system will improve when the system is fully implemented. The following factors need to be controlled to ensure an optimal performance of local A-CDM. It is shown in a Ishikawa diagram (see Figure 12). Several factors influence the performance and need to be managed (see chapter 8). All in all, the system is supporting the operations at Schiphol Airport, but needs improvements to be beneficial in every situation for each involved stakeholder.

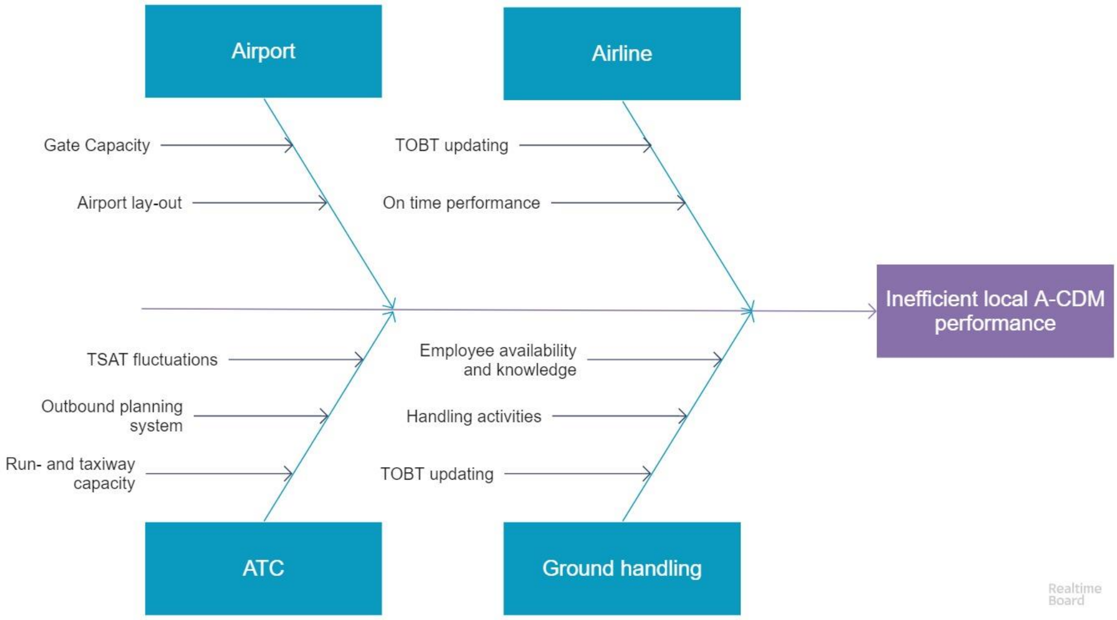


Figure 12 – Ishikawa diagram of the influences on local A-CDM performance source: (Realtime Board, 2018)

7 Discussion

The conclusion is a concise overview of the research's outcome. The discussion of the research, on the other hand, is a more in-depth analysis of the results, limitations and further research opportunities. The chapter is divided into three paragraphs:

- Interpretation of results
- Limitations of the research
- Further research opportunities

7.1 Interpretation of results

The research analysed the benefits which local A-CDM has had for the four involved stakeholders. The research was designed by firstly analysing the potential benefits of total A-CDM by performing a literature research. There is difference between total A-CDM and local A-CDM. The connection with the European Network Manager is still missing when using local A-CDM. Both quantitative and qualitative research was conducted to find answers to the sub-research questions and main research question. Interviews were held with several A-CDM experts working at each local A-CDM stakeholder. The interviews pointed out what the potential operational efficiency were stimulated by local A-CDM on which a data analysis was possible. The literature review is the base of the research which is further analysed by the interviews and validated by the data analysis.

The results pointed out that benefits realised by total A-CDM were much more significant than with local A-CDM. The connection with the network manager has brought several significant benefits to other European airports according Eurocontrol's research. Total A-CDM has had the following significant benefits for the European airports (Eurocontrol, 2016):

- Decrease of fuel (-7.7%)
- Decrease of taxi minutes
- ATFM delay time reduction (-10.3%)
- Reduction of emissions (-7.7%)

These benefits are yet realised by local A-CDM because the connection with the Network Manager is essential to provide these benefits for the airport. There are several other factors which are influenced positively by total A-CDM, but those are the most significant and measurable which was not the case with several other factors influenced by local A-CDM (see paragraph 7.2). Operational efficiency performance measurements which are influenced by local A-CDM are the on time performance, gate planning, workload ATC, airline buffer schedules, resource and pushback planning of ground handlers.

Furthermore, the results of Eurocontrol's research has led to positive expectations of local A-CDM's impact on the operational efficiency. The positive expectations were even more stimulated by interviewing A-CDM experts working at To70, LVNL and AAS. However, airlines and ground handlers were slightly less positive about the performance of local A-CDM so far. The ground handlers and airlines experienced TSAT instability during days with major disruptions which were not felt by the other stakeholders. The varying opinions were an indication of the potential outcomes of the data analysis and results. However, the introduction, motivation, theoretical framework, hypothesis and research questions were more based on a positive outcome of local A-CDM's performance at Schiphol Airport. It was already known that total A-CDM has been beneficial before starting the research, but it was not clear how beneficial local A-CDM has been for Schiphol Airport's stakeholders. Along the way of the research, it became clear that local A-CDM has not yet been as beneficial as expected. The statement is based on the outcome of the literature review combined with the quantitative and qualitative analysis.

The literature review focussed on the operational efficiency benefits stimulated by total A-CDM as mentioned above. The interviews, on the other hand, were focussed on the benefits provided by local A-CDM, because that is applicable for the research. Each interview contained four main questions and was further specified depending on the answers given by the stakeholders. The experts of each stakeholder provided their opinion and thought about the impact of local A-CDM on their daily operation. They experienced the benefits of local A-CDM mostly during days without major disruption and a slightly negative impact of local A-CDM on days with a major disruption.

A major disruption could be extreme weather conditions, runway maintenance, etc. These factors also have an influence on the on time performance (see paragraph 7.2). The OTP, therefore, was declined over the past years.

The hypothesis was based on already existing knowledge and partly preliminary research derived from Eurocontrol. The outcome of the research is matching with the part of the hypothesis that is based on already existing knowledge and not corresponding with the results of the Eurocontrol. The preliminary research pointed out that especially total A-CDM should be beneficial for the stakeholder, but that local A-CDM is also improving the operational efficiency thanks to the A-CDM milestones and departure planning system (Eurocontrol, 2016). However, the research did not take into account several other factors that can influence the performance of local A-CDM and airport operations such as congestion which is currently a problem at several airports in the world (International Airport Review, 2018).

There is one more factor which has supressed the benefits of local A-CDM. It was essential that Schiphol Airport was connected to the Network Manager as soon as possible after implementing local A-CDM. The performance of local A-CDM was not analysed thoroughly for that reason in order to improve the new system, before connecting to the Network Manager. A new system will most likely have aspects which need to be improved to have a well-functioning system. However, the improvements were of local A-CDM were planned after the connection was made with the Network Manager. This also explains why the performance of local A-CDM is not experienced as optimal which meets the results of the quantitative and qualitative analysis.

7.2 Limitations to the research

The on time performance is measured over several periods before and after the implementation of local A-CDM to analyse whether the overall performance is improved. The OTP is key performance indicator which shows the performance of the whole flight operation at the airport. However, the OTP is influenced by several factors some of which are not local A-CDM such as congestion, weather and airspace regulations. The results made clear that the overall OTP is declined during each seasonal comparison over the years 2015, 2016 and 2017. In chapter 4 the quantitative analysis is explained. A limitation to the quantitative analysis of the OTP is that the OTP is also negatively influenced by the factors mentioned above. These factors make it harder to connect the OTP results to local A-CDM as the cause for the negative result. It seems that since local A-CDM the OTP is declined, but the decline could also be mainly caused by the increased number of movements. Furthermore, the number of movements has been massively increasing the past years and caused more and more congestion at the airport. This leads to an increased amount of delays that were less applicable a couple years earlier. The limitation to the analysis is that the result is slightly affected by factors which are not related to local A-CDM. However, it is not measurable what the overall OTP would have been if local A-CDM was not implemented. The result of the OTP calculation could even have been much worse when local A-CDM was not implemented.

The interviews also pointed out that other local A-CDM benefits were not really measureable by a quantitative analysis such as gate planning, resource planning and workload ATC during the time frame of the research. Especially a calculation for the gate planning and workload ATC improved was not provable by data calculations. These benefits are acknowledged by several experts from the stakeholders, but a data calculation could have validated their opinion. The reliability of the result would have been increased.

7.3 Further research

In paragraph 1.3 research relevance is stated that the research will be the benchmark for further research before the connection with the European Network manager is made and total A-CDM is implemented. The research will analyse the performance difference between the period before the implementation of local A-CDM and the period after the implementation of local A-CDM. The period after the implementation of total A-CDM is not relevant for the research. However, the further research which analyses the operational efficiency benefits after the implementation of total A-CDM including the connection with the Network Manager. The results of that research can be compared with this research to analyse what the exact improvements have been by implementing total A-CDM in comparison with the situation before and after the implementation of local A-CDM. Several other aspects of the operational efficiency are influenced by total A-

CDM which are not influenced by local A-CDM and are also interesting to analyse such as ATFM delay time, emissions and fuel burn. These results cannot be compared with this research, but will complete the results of the further research.

The quantitative analysis part of the research contained an analysis of the on time performance before the implementation of local A-CDM compared with the OTP after the implementation of local-A-CDM. Other operational efficiency factors are influenced which are mentioned in the elaboration of the interviews in chapter 4, especially the resource and pushback planning cost savings can be calculated in further research by gathering the data from ground handlers. The result of the data analysis can validate the interview results whether the resource and pushback planning is improved. It will improve the benchmark reliability for the further research after the implementation of total A-CDM mentioned above.

~This page is intentionally left blank~

8 Recommendations

The results and conclusions of the research lead a set of recommendations which can be used by the involved local A-CDM stakeholders. Local A-CDM is not living up to its full potential and all the stakeholders can together improve the system which will lead to more benefits for each of them. The following recommendations are applicable for the optimisation of local A-CDM performance:

1. Improve the outbound planning system to decrease the impact of late TOBT updates on the TSAT
2. Increase knowledge about the TOBT update system and its consequences for the whole flight operation for especially the TOBT updating staff
3. Implement feedback loops to analyse what can be improved to increase the performance of local A-CDM

The ATC uses a departure planning system called CPDSP. The CPDSP is influence by several factors such as the TOBT. The TOBT is updated by the ground handler or airline. Each update of a TOBT triggers the CPDSP to run again and create a completely new departure sequence. The CPDSP provides TSATs to the flights and they can change negatively when the system is run again. The TOBT is updated must more often during disrupted days which influences the TSATs negatively for many flights. The algorithm behind the system needs to change in order to be less influenced by these TOBT updates. The benefits of the change are a decrease of the ATC workload and an increase of the TSAT stability.

Many TOBT updates are performed during days with a disruption which influence the TSATs as mentioned above. The platform staff is not learned what the TOBT exactly is and what especially late TOBT updates can have as a consequence. The platform supervisors are aware of the consequences of the TOBT updates. The platform staff should be learned how local A-CDM exactly works and also what consequences late TOBT updates can have. There will be less unnecessary TOBT updates when the staff is aware of these consequences. The workload of the staff will increase, but it will become a daily task which limits the impact on their workload.

Last but not least, the involved local A-CDM stakeholders should implement a feedback loop in which the performance of good days and bad days are discussed and learned from. Analysing what went wrong on disrupted days with the local A-CDM system, will support system improvement. The stakeholders will experience a better functioning system when they know what is going wrong and what causes even more disruptions. Furthermore, it is also essential to analyse days on which the system was work properly. The stakeholders need to know why the system was working as good as it did in order to find solutions for days with a bad local A-CDM performance.

List of References

Abhijeet. (2011, 1 03). *How to prepare the analysis chapter of a dissertation*. Retrieved from Dissertation deal: http://www.dissertationdeal.com/publications/how-to-prepare-the-analysis-chapter-of-a-dissertation?page_subcat=advice&page_cat=advice/analysis

Adams, J., Khan, H., & Reaside, R. (2014). *Research Methods for Business and Social Science Students.* SAGE Publications: New Delhi.

Airbus. (2017). *Global Market Forecast Growing Horizons 2017/2036.* Blagnac Cedex: Airbus S.A.S.

Alders, H. (2013, 10 8). *Eindadvies Alderstafel Schiphol.* Retrieved from Rijksoverheid: https://www.rijksoverheid.nl/documenten/brieven/2013/10/08/eindadvies-alderstafel-schiphol

Amsterdam Airport Schiphol. (2015). *Amsterdam Airport Airport Collaborative Decision Making Operations manual.* Schiphol: Amsterdam Airport Schiphol.

Bureau of Transportation Statistics. (2018, 03). *Airline On-Time Statistics and Delay Causes*. Retrieved from Bureau of Transportation Statistics - United States Department of Transportation: https://www.transtats.bts.gov/ot_delay/ot_delaycause1.asp

CAPA. (2017). *Amsterdam Airport Schiphol - schedule analysis*. Retrieved from CAPA: https://centreforaviation.com/data/profiles/airports/amsterdam-schiphol-airport-ams/schedules-analysis

Corrigan, S., Kay, A. M., Martensson, L., & Okwir, S. (2014). *Preparing for Airport Collaborative Decision Making (A-CDM) implementation: an evaluation and recommendations.* London: Springer-Verlag.

Dudovskiy, J. (2016). *The Ultimate Guide to Writing a Dissertation in Business Studies: A Step-by-Step Assistance.* Research Methodology.

Easterby-Smith, M., Thorpe, R., Jackson, P., & Lowe, A. (2008). *Management Research* (3rd ed.). London: Sage.

Elmansy, R. (2016). *Using Inductive Reasoning in User Experience Research*. Retrieved from Designorate: http://www.designorate.com/inductive-reasoning-in-user-experience-research/

Eurocontrol. (2011, 3 30). *Airport Collaborative Decision Making Eurodays 2011 Madrid.* Retrieved from Eurocontrol: https://www.eurocontrol.int/sites/default/files/event/files/airport_cdm_presentation_madrid-30-03-2011.pdf

Eurocontrol. (2015, July 15). *RECAT-EU European Wake Turbulence Categorisation and Separation Minima on Approach and Departure.* Retrieved April 10, 2018, from eurocontrol.int: https://www.eurocontrol.int/sites/default/files/content/documents/sesar/recat-eu-released-september-2015.pdf

Eurocontrol. (2016, 04 18). *Airport Collaborative Decision making (A-CDM) Impact Assessment*. Retrieved from Eurocontrol: http://www.eurocontrol.int/publications/a-cdm-impact-assessment

Eurocontrol. (2017, 04 07). *Airport CDM Implementation Manual*. Retrieved from Eurocontrol: http://www.eurocontrol.int/articles/airport-collaborative-decision-making-cdm

Eurocontrol. (2017). *Airport Collaborative Decision Making (A-CDM)*. Retrieved from Eurocontrol: http://www.eurocontrol.int/articles/airport-collaborative-decision-making-cdm

Eurocontrol. (2018, 06 14). *CODA delay report Airport*. Retrieved from Eurocontrol Network Business Intelligence: https://ext.eurocontrol.int/analytics/saw.dll?Dashboard

Het Parool. (2015, 07 01). *Schiphol koelt start- en landingsbanen*. Retrieved from Het Parool: https://www.parool.nl/amsterdam/schiphol-koelt-start-en-landingsbanen~a4092390/

IATA. (2018, 06 13). *Standard IATA Delay Codes (AHM730)*. Retrieved from IATA: https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/facts-and-figures/coda-reports/standard-iata-delay-codes-ahm730.pdf

International Airport Review. (2018, 06 19). *EUROCONTROL study: European aviation faces serious capacity challenges*. Retrieved from International Airport Review: https://www.internationalairportreview.com/news/70700/eurocontrol-capacity-challenges/?utm_medium=email&utm_campaign=IAR%20-%20Newsletter%2025%202018%20-%20Fraport%20-%20Members&utm_content=IAR%20-%20Newsletter%2025%202018%20-%20Fraport%20-%20Members+CID_

KNMI. (2015, 08 04). *Juli 2015*. Retrieved from KNMI: https://www.knmi.nl/nederland-nu/klimatologie/maand-en-seizoensoverzichten/2015/juli

KNMI. (2015, 09 01). *Zomer 2015 (juni, juli, augustus)*. Retrieved from KNMI: https://www.knmi.nl/nederland-nu/klimatologie/maand-en-seizoensoverzichten/2015/zomer

KNMI. (2016, 08 01). *Juli 2016*. Retrieved from KNMI: https://www.knmi.nl/nederland-nu/klimatologie/maand-en-seizoensoverzichten/2016/juli

KNMI. (2017, 08 07). *Juli 2017*. Retrieved from KNMI: https://www.knmi.nl/nederland-nu/klimatologie/maand-en-seizoensoverzichten/2017/juli

Mendeley. (2018). *Mendeley - homepage*. Retrieved from Mendeley: https://www.mendeley.com/

Okwir, S., Ulfvengren, P., Angelis, J., Ruiz, F., & Guerrero, Y. M. (2016). *Managing turnaround performance through Collaborative Decision .* Amsterdam: Elsevier Ltd.

Realtime Board. (2018). *Fishbone diagram local A-CDM performance*. Retrieved from Realtime Board: https://realtimeboard.com/app/board/o9J_kzG12zk=/

Researchgate. (2018). *Researchgate - homepage*. Retrieved from Researchgate: https://www.researchgate.net/

Ringelberg, M. (2018). Schiphol-Oost: KDC Mainport Schiphol.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students - fifth edition.* Harlow: Pearson Education Limited.

Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research methods for business students* (7th ed.). Harlow: Pearson Education Limited.

Schiphol. (2018). *Annual Traffic Reviews*. Retrieved from Amsterdam Airport Schiphol: https://www.schiphol.nl/en/schiphol-group/page/traffic-review/

Sekaran, U., & Bougie, R. (2016). *Research Methods for Business.* Chichester: John Wiley & Sons Ltd.

Spring, M., Selviaridis, K., & Zografos, K. (2016). *Coordination in service supply networks: insights from “Airport Collaborative Decision Making".* Lancaster: Lancaster University.

Tibco Spotfire. (2018). *Tibco Spotfire - homepage*. Retrieved from Tibco Spotfire: https://spotfire.tibco.com/

Zellweger, A., & Donohue, G. (2001). *Assessing the benefits of collaborative decision making in air traffic management.* Reston: American Institute of Aeronautics and Astronautics.

~This page is intentionally left blank~

Appendix I – Reflection

The research report is written as a part of the graduation process for obtaining the Bachelor of Science degree in Aviation Operations. A set of skills and competences is necessary to make the research a success to fulfil the requirements of the degree. A reflection is written to elaborate the development of primary and secondary research skills, improvement of time-management skills and increase the level of self-confidence. The following set of skills and competences are set by the Amsterdam University of Applied Sciences (AUAS) that are required to have:

- Solve an industry issue or problem based on solutions which are in the context of the issue and makes use of the most recent developments in the industry.
- Apply relevant industry insight and/or research methods, concepts and theories to solve the issue.
- Propose a solution which is in the context of the problem with a visible link between relevant theories and research.
- Provide a solution of which the client is satisfied and willing to implement.

The reflection on these topics is structured according the STARR-method. The STARR-method provides a reflection on behaviour from the past which gives a good indication from the behaviour of a person in the future. STARR stands for: Situation, Task, Actions, Result and Reflection. The STARR-method is used to reflect on the primary, secondary research skills and Scrum/sprint review.

Primary and secondary research skills

Three different primary and secondary research skills are applied to achieve the desired result for the Aviation Operations degree according AUAS's requirements. A quantitative data analysis and interviews are held to form the primary research aspect and desk research is performed as the secondary research aspect. The following explains the reflection on these skills according the STARR-method as mentioned above.

Situation

The initial plan for the quantitative analysis was to calculate several operational efficiency impacts of local A-CDM on the stakeholders' operation. The potential operational efficiency impacts were identified by desk research and several interviews with A-CDM experts of stakeholders. However, it was obvious that calculating several impacts would not be possible during the research period. The on time performance was chosen as the major factor influenced by local A-CDM. A-CDM data was used to analyse the on time performance before and after the implementation of local A-CDM. At first, only one period before the implementation of local A-CDM was compared with a period after the implementation, but it seemed more useful when two periods after the implementation were measured to analyse the OTP development over several years.

Task

Interviews

The qualitative research was mostly performed before the quantitative analysis. The interviews in combination with the literature have led to a list of potential benefits which are caused by local A-CDM. The experts provided me with a fairly similar list even when they were from different stakeholders. It was essential during the interviews that I maintained as objective as possible, because some stakeholders tried to convince me to continue on their way of thinking. This was new for me.

Quantitative analysis

In the current curriculum of Aviation Operations, the focus is not completely on processing large amounts of data which was essential for the quantitative analysis, hence there were several hundreds of thousands rows at the start of the analysis. The analysis is performed in Excel on which attention is dedicated during the study. However, the analysis and filters were applied by formulas and Excel functions which cost more time than writing a code in VBA when able to write an applicable VBA code. My main goal for the analysis was to become faster and more efficient in filtering, analysing and visualising large amounts of data in Excel, because it has been a very commonly used program in companies for analysing data. There were other programs possible to analyse the data, however I was unfamiliar with each offered program and would cost too much to learn to work with during the research.

Action

Interviews

The first step was to determine which A-CDM experts would be applicable for my research. There is an A-CDM implementation department at the LVNL which was approached first to gather the basic information about local A-CDM in general and what their thoughts were about it. The other interviewees were recommended by the KDC managers which were present at the sprint reviews (see next STARR-method application). All interviewees had to be approached professionally to ensure a reaction and hopefully a meeting.

Quantitative analysis

I already had some of the basic Excel skills before starting the quantitative analysis. However, this was not yet sufficient for the large amount of data for the OTP calculations. Martijn Ringelberg, another graduation student at the KDC, used the same A-CDM data as I did. We worked together especially in the beginning to improve our Excel skills and understand the data. This supported us, especially me to analyse and visualise the data efficiently. The analysis took a bit longer than expected and that is when I realised that performing data analysis for several local A-CDM impacts was not possible.

Result

Interviews

The professional approach had worked and several A-CDM experts were very enthusiastic to have a meeting with me. They provided me with lots of information about the subject matter and also provided detailed example. Some of which included their data analysis about local A-CDM performance. The interviews really completed the story opinion about local A-CDM by providing me with their knowledge, analyses and system experience.

Quantitative analysis

The collaboration with Martijn has saved me lots of time which I have used to further analyse the OTP and the rest of the research such as interviews. The quantitative analysis provided me with better understanding of the overall performance at Schiphol Airport and also the performance of local A-CDM. This helped me significantly during the thesis writing period and interviews.

Reflection

I look back at my time at LVNL as a very enjoyable and learning experience thanks to the fact that the KDC provided me with lots of information, methods and contacts to broaden my knowledge and view of the aviation industry. The quantitative analysis skills to faster process data is improved in particular and also the visualisation of the results in order to make them more comprehensible for myself and others. Moreover, the interviews and conversations with experts were very interesting and provided me with new insights in the current aviation industry. This is especially the case for the different opinions stakeholders can have about a system such as local A-CDM. I had a bit of knowledge about A-CDM before the research started, but that is much more improved during the research.

Scrum method and sprint reviews

The scrum method and sprint reviews were introduced at the start of the research to ensure an organised working approach and our progress. The scrum-method has as main function to organise al the activities required to achieve the desired result. The sprint reviews had as main purpose that the KDC managers and other experts could follow our progress and could give advice about what we did so far and could do in the following weeks.

Situation

The KDC uses a process management method called scrum. Scrum is normally used by programming project groups to improve the efficiency of the team. The scrum method uses a poster or whiteboard, on which post-its are attached to.

The poster contains four different columns, the user story, to do, doing and done. There is one category added for this research, waiting, because when making appointments with experts or when waiting for specific files it will not be efficient to place them at to do again. Therefore, the column waiting will be the location where post-its containing the appointment and file information are placed. Each Tuesday and Thursday a consult with the client is held to discuss the scrum board, the research's progress and current issues. The following describes what the function is of each column. The user story explains the team members, in this case the researcher, what the overall end product will be. The to do sections contains what needs to be done in the next two weeks. The other three categories are what the names are stating. The to do column contains all post-its of all assignments which need to be done in two weeks. These post-its are moved to the doing column whenever the researcher starts with them. There can only be one post-it in the doing column to ensure the researcher's focus. When an assignment is done it will be moved to the done column.

Every two weeks there will be a so called sprint review in which the researcher presents to KDC management what is done and what the next steps will be in a short pitch presentation. Other experts from one the KDC stakeholders were present at several sprint reviews to provide even more feedback.

The scrum-method is not only used to ensure the researcher always has a clear overview of what is done and needs to be done but also lets the researcher think about what the exact goal of the research is when presenting the pitch each two weeks. The researcher and the management team will always know the progress of the project and if it is still on track as expected.

Task
I never worked with scrum before. In the beginning I really had to focus on using the method, because it was essential that my scrum board was always up-to-date with the activities I had to do at that particular time. Every two weeks I needed to check whether I finished all my previous tasks and provide feedback to myself why I did not finish every task or how it was possible that I was done early. The tasks for upcoming two weeks needed to be set and written on a post-it. One post-it needed to be in the to do section which I sometimes forgot in the beginning, but improved

The task for each sprint review was to make a short presentation in which the progress and results of the activities done in the past two weeks were described. Each two weeks the presentation would change, because new information and data was gathered. The more essential information was presented; the more usable feedback was provided by the management.

Action
The scrum board was discussed two times a week as mentioned above which stimulated me to keep it even more up-to-date, because the more I could discuss of what I was working on, the more information was provided to me. This kept me motivated to work actively with the scrum board especially in the beginning of the research process, because than lots of different activities needed to be done such as contacting experts, research plan, literature research, data gathering and so on.

We have been at the KDC with six graduation students and every two weeks we all had a sprint review. We practised our presentations together and provided each other with feedback to improve our presentations and information we would tell during the presentation. This ensured that the presentations were sufficient for each sprint review and kept us up-to-date about all our project's progress.

Result
The scrum method really helped me to stay organised throughout the whole process. I only had to look over my shoulder to see what I still needed to do and what was already finished. Another benefit I experienced was the fact that every two weeks I had to think for period of time about what the real next steps needed to be for my research process which kept me on track considering the research goal. The meetings which were two times a week provided me with useful information about current problems and also contained nice tips to improve my research.

The sprint reviews provided useful feedback about the content of the research and heading of the thesis subject. Even when the presentations were only two minutes, the feedback was very substantive and could generally be implemented in the research.

Reflection
The combination of the scrum-method and sprint reviews supported me to stay on track for my desired research goal and always provided me with useful feedback to improve and broaden my knowledge about the subject matter. I will definitely use the scrum method and sprint reviews again for my next research project to ensure achieving the desired result.

Overall reflection

I look back at my time at the KDC as very time in which I have not only learned a lot about the aviation industry, but also how to organise a research process as large as a thesis and working in an environment with lots of aviation professionals of whom information need to be obtained. I will definitely be using the skills and competences gained by the KDC in the future to reach my career goals and personal goals.

Appendix II – A-CDM interview question list

How do you experience working with local A-CDM at Schiphol? How has the implementation impacted your operation?
What does your company do to ensure the quality of information the local A-CDM requires?
How has local A-CDM affected the operational efficiency of your company? Can you name benefits and downsides applicable to this question?
What aspects of local A-CDM need to be improved to provide a more beneficial system?

Appendix III – Interview outcomes

Interview – To70 (A-CDM)

Preparation

- A-CDM benefits for the stakeholders
  - ATC
  - Airport
  - Airline
  - Ground Handler
- Difference before and after NMOC

Meeting

- General A-CDM benefits
  - Increased predictability
  - Increased transparency
- A-CDM benefits for the ATC
  - Outbound planning system
  - Workload decreases (outbound planner +- workload)
  - ATC calls aircraft according to a planning
  - Analysis delays: period March till June thanks to minimal CTOT
  - Workload registration: “Werk-Last Model”

- A-CDM benefits for the Airport
  - Gate planning
    - Sequencer plans the outbound aircraft optimally
      - Gate utilization optimised
    - More accurate EOBT → less waiting times for gates on TXW
  - Small change in taxi times due to start up control
  - Reputation improves with total A-CDM
  - Possible improvement: rules for TOBT which are set by ground handlers

- A-CDM benefits for the Airlines
  - Buffer schedules can become more compact → higher utilization of aircraft
  - Possible issue: KLM has its own TOBT system

- A-CDM benefits for the Ground Handlers
  - Resource planning optimisation
    - Cost savings

Interview – Aviation Academy

Preparation

- A-CDM benefits for the ground handler
- A-CDM influence on gate planning
    - Airlines' preferences

Meeting

- A-CDM benefits for the Ground Handlers
    - Without disruptions (weather) improved efficiency
        - Pushback planning and resource planning
    - With disruptions (bad weather) worse efficiency
        - Due to TSAT instability
    - Problems become visible thanks to A-CDM

- A-CDM influence on gate planning
    - Gate planning issues are made visible → by TSAT
    - IATA code 89 → gate occupied delay
    - Airlines have gate preferences:
        - Passenger streams are essential for transfers
        - Security (e.g. transatlantic flights to USA need specific security)
        - Cluster turnaround more resource efficient

Interview – KLM (HCC)

Preparation

- A-CDM benefits for the ground handler
- A-CDM influence on gate planning
  - Airlines' preferences

Meeting

- A-CDM benefits for the Ground Handlers
  - Without disruptions (weather) improved efficiency
    - Pushback planning and resource planning
  - With disruptions (bad weather) worse efficiency
    - Due to TSAT instability
  - Problems become visible thanks to A-CDM

- A-CDM influence on gate planning
  - Gate planning issues are made visible → by TSAT
  - IATA code 89 → gate occupied delay
  - Airlines have gate preferences:
    - Passenger streams are essential for transfers
    - Security (e.g. transatlantic flights to USA need specific security)
    - Cluster turnaround more resource efficient

Interview – To70 (data analyst)

Preparation

- Previous A-CDM data analyses
- Measurable A-CDM efficiency benefits
    - Relate OTP changes to A-CDM

Meeting

- Previous A-CDM data analyses
    - A-CDM system performance e.g.
        - Difference AOBT + ATT = ATOT?
    - Analysis for stakeholder performance not included

- Measurable efficiency benefits
    - OTP
        - Link to particular delays → which delays increased and decreased?
        - Link to number of movements
    - Gate utilization
    - Realised RWY throughput
        - Number of movements per hour
            - Same weather conditions and RWY in use required for comparison
            - Peak moments → enough traffic to achieve maximum RWY throughput

Interview – Aviapartner (supervisor operations)

Preparation

- A-CDM benefits for the Ground Handler Aviapartner
- Improvements to A-CDM and airport
- TOBT knowledge and usage

Meeting

- A-CDM benefits for Aviapartner
  - Pushback planning improved
    - Predictability increased by the use of TOBT and TSAT
    - Pushback planning are optimised when TSATs change
    - Cost savings and improved GH performance
  - Resource planning slightly improved
    - Increased predictability → EOBT more accurate

- Improvements to A-CDM and airport
  - Late TOBT updates → hard to prevent (last 10-15 minutes most changes)
    - Due to e.g. boarding issues, baggage search
      - Solutions: boarding button to calculate TOBT
      - Pre boarding areas
      - ECAS doors closed timing data
  - Gate capacity declined due to new terminal and increased number of movements
    - More waiting for and at gates
    - More buffer and remote stands used
      - Resource planning harder to manage and more travel distance for equipment and staff
    - Not enough space for all GH equipment
      - Search for usable equipment
      - Increased travel distance and cost

- TOBT knowledge and usage
  - Operational staff have the required TOBT knowledge
    - Consequences and importance
  - Platform staff less knowledge
    - Perform their own tasks to ensure safe and efficient ground handling activities

TOBT task → increase workload → A-CDM performance increase?

Interview – Amsterdam Schiphol Airport (A-CDM)

Preparation

- A-CDM benefits for the airport
- Current A-CDM problems
- A-CDM performance measurements

Meeting

- A-CDM benefits for the airport and current problems
  - Overview and insight in outbound planning and turnaround process
  - Increased predictability
    - Gate planning
    - Bus planning
    - Decrease of ATC workload → measurable with survey
  - LVNL and GH most beneficial
    - GH lack of knowledge → improvement for A-CDM performance
    - Resource planning improved
    - Little improvement to taxi times → start up control
    - Disruption days → TOBT and TSAT instability
- A-CDM performance measurements
  - TOBT stability
  - TOBT adherence
  - TSAT adherence
    - Results stimulate airlines and GHs to improve

Appendix IV – Excel OTP datasheet example

The table below is a part of the Excel datasheet from which the OTP and delay minutes are calculated. The total sheet contains 165.722 rows which stand for departure flights in several months in 2015, 2016 and 2017.

time	acid	reg	adep	dest	actype	wtc	eobt_time	aobt_time	depGnr	arrGnr	Arr/Dep	AOBT-EOBT	WIBO/NABO	RECAT-EU
1-1-2015 05:14	TFL071P	PHOYI	EHAM	EPWA	B763	H	1-1-2015 05:00	1-1-2015 05:02	G08		Departure	2,667	Wide	C
1-1-2015 06:31	TRA5753	PHHZE	EHAM	GMMX	B738	M	1-1-2015 06:15	1-1-2015 06:21	D16		Departure	6,017	Narrow	D
1-1-2015 06:59	TRA6901	PHHSJ	EHAM	OMDB	B738	M	1-1-2015 06:35	1-1-2015 06:51	D51		Departure	16,783	Narrow	D
1-1-2015 06:47	KLM1721	PHKZI	EHAM	EBBR	F70	M	1-1-2015 06:45	1-1-2015 06:40	B16		Departure	-4,467	Narrow	E
1-1-2015 06:46	KLM1597	PHBCA	EHAM	LIRF	B738	M	1-1-2015 06:50	1-1-2015 06:38	C11		Departure	-11,417	Narrow	D
1-1-2015 06:56	TRA6331	PHHZW	EHAM	LEVC	B738	M	1-1-2015 06:50	1-1-2015 06:48	D53		Departure	-1,383	Narrow	D
1-1-2015 07:08	KLM23P	PHBXB	EHAM	LFPG	B738	M	1-1-2015 06:55	1-1-2015 07:00	C09		Departure	5,550	Narrow	D
1-1-2015 06:58	TRA61F	PHHSF	EHAM	LEMG	B738	M	1-1-2015 06:55	1-1-2015 06:49	C08		Departure	-5,150	Narrow	D
1-1-2015 07:05	SWR737	HBIJM	EHAM	LSZH	A320	M	1-1-2015 07:00	1-1-2015 06:59	B17		Departure	-0,800	Narrow	D
1-1-2015 07:16	UAE9982	A6EFO	EHAM	HECA	B77L	H	1-1-2015 07:00	1-1-2015 07:07	S82		Departure	7,433	Wide	B
1-1-2015 07:41	DLH2A	DAIZR	EHAM	EDDF	A320	M	1-1-2015 07:05	1-1-2015 07:33	B23		Departure	28,350	Narrow	D
1-1-2015 07:07	TRA2Y	PHHSI	EHAM	LOWI	B738	M	1-1-2015 07:05	1-1-2015 07:00	D47		Departure	-4,600	Narrow	D
1-1-2015 07:25	KLM1001	PHBXW	EHAM	EGLL	B738	M	1-1-2015 07:15	1-1-2015 07:17	D31		Departure	2,433	Narrow	D
1-1-2015 07:40	TRA131R	PHHZL	EHAM	LEBL	B738	M	1-1-2015 07:35	1-1-2015 07:32	D12		Departure	-2,600	Narrow	D
1-1-2015 07:42	IBS3721	ECLYM	EHAM	LEMD	A320	M	1-1-2015 07:40	1-1-2015 07:35	B15		Departure	-4,750	Narrow	D
1-1-2015 07:55	BAW423	GEUYR	EHAM	EGLL	A320	M	1-1-2015 07:45	1-1-2015 07:43	D28		Departure	-1,217	Narrow	D
1-1-2015 07:52	KLM1351	PHKZS	EHAM	LKPR	F70	M	1-1-2015 07:45	1-1-2015 07:45	B32		Departure	0,233	Narrow	E
1-1-2015 07:56	KLM45C	PHEZB	EHAM	EDDM	E190	M	1-1-2015 07:45	1-1-2015 07:48	B55		Departure	3,733	Narrow	E
1-1-2015 07:57	KLM1153	PHEZR	EHAM	ESGG	E190	M	1-1-2015 07:55	1-1-2015 07:50	B28		Departure	-4,667	Narrow	E
1-1-2015 08:13	KLM1821	PHEZP	EHAM	EDDT	E190	M	1-1-2015 08:00	1-1-2015 08:00	B54		Departure	0,500	Narrow	E
1-1-2015 08:08	KLM33G	PHKZN	EHAM	EGPD	F70	M	1-1-2015 08:00	1-1-2015 08:02	B74		Departure	2,700	Narrow	E
1-1-2015 08:28	KLM37P	PHBXS	EHAM	LFPG	B739	M	1-1-2015 08:00	1-1-2015 08:20	C07		Departure	20,250	Narrow	D
1-1-2015 08:11	KLM1107	PHBXH	EHAM	ESSA	B738	M	1-1-2015 08:05	1-1-2015 08:01	C06		Departure	-3,133	Narrow	D
1-1-2015 08:10	KLM85J	PHBGB	EHAM	LEBL	B738	M	1-1-2015 08:05	1-1-2015 07:59	D05		Departure	-5,117	Narrow	D
1-1-2015 08:23	KLM1073	PHBXA	EHAM	EGCC	B738	M	1-1-2015 08:15	1-1-2015 08:16	D16		Departure	1,250	Narrow	D
1-1-2015 08:14	KLM1763	PHKZL	EHAM	EDDF	F70	M	1-1-2015 08:15	1-1-2015 08:05	B24		Departure	-9,650	Narrow	E
1-1-2015 08:32	KLM21S	PHEZN	EHAM	EGNT	E190	M	1-1-2015 08:20	1-1-2015 08:26	B93		Departure	6,750	Narrow	E
1-1-2015 08:45	KLM83F	PHBXU	EHAM	EGBB	B738	M	1-1-2015 08:25	1-1-2015 08:35	D29		Departure	10,717	Narrow	D
1-1-2015 08:44	KLM1341	PHEXD	EHAM	EKBI	E190	M	1-1-2015 08:35	1-1-2015 08:38	B91		Departure	3,433	Narrow	E
1-1-2015 08:47	KLM1619	PHBXY	EHAM	LIML	B738	M	1-1-2015 08:45	1-1-2015 08:37	C16		Departure	-7,433	Narrow	D
1-1-2015 08:59	DWT255	HBACB	EHAM	EDDP	AT72	M	1-1-2015 08:55	1-1-2015 08:52	B95		Departure	-2,067	Narrow	E
1-1-2015 09:04	EZY17NC	GEZWP	EHAM	EGKK	A320	M	1-1-2015 08:55	1-1-2015 08:51	H02		Departure	-3,517	Narrow	D
1-1-2015 09:21	CSN479	B2081	EHAM	ZUCK	B772	H	1-1-2015 09:00	1-1-2015 09:09	R81		Departure	9,367	Wide	B
1-1-2015 09:34	TRA6845	PHHSG	EHAM	GVAC	B738	M	1-1-2015 09:10	1-1-2015 09:27	D41		Departure	17,083	Narrow	D
1-1-2015 09:23	UAL877	N647UA	EHAM	KEWR	B763	H	1-1-2015 09:15	1-1-2015 09:11	D08		Departure	-3,017	Wide	C
1-1-2015 09:28	KLM1723	PHEZL	EHAM	EBBR	E190	M	1-1-2015 09:20	1-1-2015 09:20	A46		Departure	0,983	Narrow	E
1-1-2015 09:25	KLM27G	PHKZF	EHAM	EDDV	F70	M	1-1-2015 09:20	1-1-2015 09:19	B75		Departure	-0,267	Narrow	E

Appendix V – Wake turbulence categorisation according RECAT-EU

Table 5 – Aircraft types assigned to RECAT-EU categories (Eurocontrol, 2015).

'Super Heavy'	'Upper Heavy'	'Lower Heavy'	'Upper Medium'	'Lower Medium'	'Light'
'CAT-A'	'CAT-B'	'CAT-C'	'CAT-D'	'CAT-E'	'CAT-F'
A388	A332	A306	A318	AT43	FA10
A124	A333	A30B	A319	AT45	FA20
(…)	A343	A310	A320	AT72	D328
	A345	B703	A321	B712	E120
	A346	B752	AN12	B732	BE40
	A359	B753	B736	B733	BE45
	B744	B762	B737	B734	H25B
	B748	B763	B738	B735	JS32
	B772	B764	B739	CL60	JS41
	B773	B783	C130	CRJ1	LJ35
	B77L	C135	IL18	CRJ2	LJ60
	B77W	DC10	MD81	CRJ7	SF34
	B788	DC85	MD82	CRJ9	P180
	B789	IL76	MD83	DH8D	C650
	IL96	MD11	MD87	E135	C525
	(…)	TU22	MD88	E145	C180
		TU95	MD90	E170	C152
		(…)	T204	E175	(…)
			TU16	E190	
			(…)	E195	
				F70	
				F100	
				GLF4	
				RJ85	
				RJ1H	
				(…)	

Table 6 – RECAT-EU separation minima on approach and departure (Eurocontrol, 2015).

RECAT-EU scheme		"Super Heavy"	"Upper Heavy"	"Lower Heavy"	"Upper Medium"	"Lower Medium"	"Light"
Leader / Follower		"A"	"B"	"C"	"D"	"E"	"F"
"Super Heavy"	"A"	**3 NM**	**4 NM**	**5 NM**	**5 NM**	**6 NM**	**8 NM**
"Upper Heavy"	"B"		**3 NM**	**4 NM**	**4 NM**	**5 NM**	**7 NM**
"Lower Heavy"	"C"		**(*)**	**3 NM**	**3 NM**	**4 NM**	**6 NM**
"Upper Medium"	"D"						**5 NM**
"Lower Medium"	"E"						**4 NM**
"Light"	"F"						**3 NM**

The different types of aircraft are categorized according the wake turbulence category and if they narrow or wide body aircraft:

Aircraft mix		
Aircraft	**NABO/WIBO**	**EU categorisation**
A20N	Narrow	D
A318	Narrow	D
A319	Narrow	D
A320	Narrow	D
A321	Narrow	D
AT72	Narrow	E
AT75	Narrow	E
B733	Narrow	E
B734	Narrow	E
B735	Narrow	E
B736	Narrow	D
B737	Narrow	D
B738	Narrow	D
B739	Narrow	D
B752	Narrow	C
B753	Narrow	C
BCS1	Narrow	D
BCS3	Narrow	D
CRJ2	Narrow	E
CRJ7	Narrow	E
CRJ9	Narrow	E
CRJX	Narrow	E
D228	Narrow	F
D328	Narrow	F
DH8D	Narrow	E
E120	Narrow	F
E145	Narrow	E
E170	Narrow	E
E175	Narrow	E
E190	Narrow	E
E195	Narrow	E
E75L	Narrow	E
F70	Narrow	E
F100	Narrow	E
J328	Narrow	F
MD83	Narrow	D
MD87	Narrow	D
RJ85	Narrow	E
RJ1H	Narrow	E
SB20	Narrow	E

SU95	Narrow	E
A306	Wide	C
A310	Wide	C
A332	Wide	B
A333	Wide	B
A343	Wide	B
A345	Wide	B
A346	Wide	B
A359	Wide	B
A388	Wide	A
B744	Wide	B
B748	Wide	B
B763	Wide	C
B764	Wide	C
B772	Wide	B
B773	Wide	B
B77L	Wide	B
B77W	Wide	B
B788	Wide	B
B789	Wide	B

Appendix VI – IATA delay codes

The figures below show all delay codes set up by IATA for stakeholders at an airport to assign a delay to a cause source: (IATA, 2018).

A. Standard IATA Delay Codes (AHM730)

Others

00-05 AIRLINE INTERNAL CODES
06 (OA) NO GATE/STAND AVAILABILITY DUE TO OWN AIRLINE ACTIVITY
09 (SG) SCHEDULED GROUND TIME LESS THAN DECLARED MINIMUM GROUND TIME

Passenger and Baggage

11 (PD) LATE CHECK-IN, acceptance after deadline
12 (PL) LATE CHECK-IN, congestions in check-in area
13 (PE) CHECK-IN ERROR, passenger and baggage
14 (PO) OVERSALES, booking errors
15 (PH) BOARDING, discrepancies and paging, missing checked-in passenger
16 (PS) COMMERCIAL PUBLICITY/PASSENGER CONVENIENCE, VIP, press, ground meals and missing personal items
17 (PC) CATERING ORDER, late or incorrect order given to supplier
18 (PB) BAGGAGE PROCESSING, sorting etc.
19 (PW) REDUCED MOBILITY, boarding / deboarding of passengers with reduced mobility.

Cargo and Mail

21 (CD) DOCUMENTATION, errors etc.
22 (CP) LATE POSITIONING
23 (CC) LATE ACCEPTANCE
24 (CI) INADEQUATE PACKING
25 (CO) OVERSALES, booking errors
26 (CU) LATE PREPARATION IN WAREHOUSE
27 (CE) DOCUMENTATION, PACKING etc *(Mail Only)*
28 (CL) LATE POSITIONING *(Mail Only)*
29 (CA) LATE ACCEPTANCE *(Mail Only)*

Aircraft and Ramp Handling

31 (GD) AIRCRAFT DOCUMENTATION LATE/INACCURATE, weight and balance, general declaration, pax manifest, etc.
32 (GL) LOADING/UNLOADING, bulky, special load, cabin load, lack of loading staff
33 (GE) LOADING EQUIPMENT, lack of or breakdown, e.g. container pallet loader, lack of staff
34 (GS) SERVICING EQUIPMENT, lack of or breakdown, lack of staff, e.g. steps
35 (GC) AIRCRAFT CLEANING
36 (GF) FUELLING/DEFUELLING, fuel supplier
37 (GB) CATERING, late delivery or loading
38 (GU) ULD, lack of or serviceability
39 (GT) TECHNICAL EQUIPMENT, lack of or breakdown, lack of staff, e.g. pushback

Technical and Aircraft Equipment

41 (TD) AIRCRAFT DEFECTS.
42 (TM) SCHEDULED MAINTENANCE, late release.
43 (TN) NON-SCHEDULED MAINTENANCE, special checks and/or additional works beyond normal maintenance schedule.
44 (TS) SPARES AND MAINTENANCE EQUIPMENT, lack of or breakdown.
45 (TA) AOG SPARES, to be carried to another station.
46 (TC) AIRCRAFT CHANGE, for technical reasons.
47 (TL) STAND-BY AIRCRAFT, lack of planned stand-by aircraft for technical reasons.
48 (TV) SCHEDULED CABIN CONFIGURATION/VERSION ADJUSTMENTS.

Damage to Aircraft & EDP/Automated Equipment Failure

51 (DF) DAMAGE DURING FLIGHT OPERATIONS, bird or lightning strike, turbulence, heavy or overweight landing, collision during taxiing
52 (DG) DAMAGE DURING GROUND OPERATIONS, collisions (other than during taxiing), loading/off-loading damage, contamination, towing, extreme weather conditions
55 (ED) DEPARTURE CONTROL
56 (EC) CARGO PREPARATION/DOCUMENTATION
57 (EF) FLIGHT PLANS
58 (EO) OTHER AUTOMATED SYSTEM

Digest – Delays to Air Transport in Europe

Flight Operations and Crewing

61 (FP) FLIGHT PLAN, late completion or change of, flight documentation
62 (FF) OPERATIONAL REQUIREMENTS, fuel, load alteration
63 (FT) LATE CREW BOARDING OR DEPARTURE PROCEDURES, other than connection and standby (flight deck or entire crew)
64 (FS) FLIGHT DECK CREW SHORTAGE, sickness, awaiting standby, flight time limitations, crew meals, valid visa, health documents, etc.
65 (FR) FLIGHT DECK CREW SPECIAL REQUEST, not within operational requirements
66 (FL) LATE CABIN CREW BOARDING OR DEPARTURE PROCEDURES, other than connection and standby
67 (FC) CABIN CREW SHORTAGE, sickness, awaiting standby, flight time limitations, crew meals, valid visa, health documents, etc.
68 (FA) CABIN CREW ERROR OR SPECIAL REQUEST, not within operational requirements
69 (FB) CAPTAIN REQUEST FOR SECURITY CHECK, extraordinary

Weather

71 (WO) DEPARTURE STATION
72 (WT) DESTINATION STATION
73 (WR) EN ROUTE OR ALTERNATE
75 (WI) DE-ICING OF AIRCRAFT, removal of ice and/or snow, frost prevention excluding unserviceability of equipment
76 (WS) REMOVAL OF SNOW, ICE, WATER AND SAND FROM AIRPORT
77 (WG) GROUND HANDLING IMPAIRED BY ADVERSE WEATHER CONDITIONS

ATFM + AIRPORT + GOVERNMENTAL AUTHORITIES

AIR TRAFFIC FLOW MANAGEMENT RESTRICTIONS

81 (AT) ATFM due to ATC EN-ROUTE DEMAND/CAPACITY, standard demand/capacity problems
82 (AX) ATFM due to ATC STAFF/EQUIPMENT EN-ROUTE, reduced capacity caused by industrial action or staff shortage, equipment failure, military exercise or extraordinary demand due to capacity reduction in neighbouring area
83 (AE) ATFM due to RESTRICTION AT DESTINATION AIRPORT, airport and/or runway closed due to obstruction, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
84 (AW) ATFM due to WEATHER AT DESTINATION

AIRPORT AND GOVERNMENTAL AUTHORITIES

85 (AS) MANDATORY SECURITY
86 (AG) IMMIGRATION, CUSTOMS, HEALTH
87 (AF) AIRPORT FACILITIES, parking stands, ramp congestion, lighting, buildings, gate limitations, etc.
88 (AD) RESTRICTIONS AT AIRPORT OF DESTINATION, airport and/or runway closed due to obstruction, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
89 (AM) RESTRICTIONS AT AIRPORT OF DEPARTURE WITH OR WITHOUT ATFM RESTRICTIONS, including Air Traffic Services, start-up and pushback, airport and/or runway closed due to obstruction or weather[1], industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights

Reactionary

91 (RL) LOAD CONNECTION, awaiting load from another flight
92 (RT) THROUGH CHECK-IN ERROR, passenger and baggage
93 (RA) AIRCRAFT ROTATION, late arrival of aircraft from another flight or previous sector
94 (RS) CABIN CREW ROTATION, awaiting cabin crew from another flight
95 (RC) CREW ROTATION, awaiting crew from another flight (flight deck or entire crew)
96 (RO) OPERATIONS CONTROL, re-routing, diversion, consolidation, aircraft change for reasons other than technical

Miscellaneous

97 (MI) INDUSTRIAL ACTION WITH OWN AIRLINE
98 (MO) INDUSTRIAL ACTION OUTSIDE OWN AIRLINE, excluding ATS
99 (MX) OTHER REASON, not matching any code above

SOURCE: *IATA – Airport Handling Manual (730 & 731)*

[1] Restriction due to weather in case of ATFM regulation only, else refer to code 71 (WO)