Operational benefits since the connection of Amsterdam Airport Schiphol with the Network Manager

Impact analysis

Thesis

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Preface

This thesis focused on the operational benefits related to the implementation of A-CDM at Schiphol has been written as part of the Aviation Operations track at the Aviation Academy in Amsterdam. I was engaged in researching and writing this thesis from September 2018 to March 2019. The research was commissioned by the Knowledge Development Centre – Mainport Schiphol which fosters the collaboration between sector parties at Schiphol and universities such as the Amsterdam University of Applied Sciences.

The combination of the multi-stakeholder research subject of A-CDM and the multi-stakeholder research setting in which business and academic objectives converged proved to be challenging. Looking back, being triggered to deal with and solve the challenging aspects first-hand were actually the most rewarding.

First of all, my appreciation goes out to Frenchez Pietersz. His guidance allowed me to think outside of the box and to stay curious throughout the research while maintaining focus on creating and communicating relevant and understandable results. I would like to thank Alina Zelenevska for her guidance and support in bringing focus and relevance to each of the many research design iterations by means of the SCRUM sessions. The time-constraints of the SCRUM sessions and bi-weekly sprint reviews were challenging but I want to thank you for showing directorship and in maintaining consistency in available time among all team members.

Incorporating the main driver of ATC the Netherlands ('Enabling aviation together') was personally experienced to be relevant in solving the challenging aspects of the research related to A-CDM. At ATC the Netherlands, I would like to thank David Zwaaf, Huib de Jong, Stefan Knijnenburg and Timo Noortman for sharing expert knowledge while discussing A-CDM and for constructive feedback. The visit to MUAC and data analysis were supported by Ferdinand Dijkstra who motivated me to go more in-depth in qualitative and quantitative research activities.

At Amsterdam Airport Schiphol, my appreciation goes out to Boudewijn Lievegoed for being supportive in relation to the personal research-challenge of finding common ground among the A-CDM stakeholders in relation to the research design. Also, his efforts in supporting the KDC CoE students to form a team and optimistic though goal-oriented working style were highly appreciated. Also, I would like to thank Jeffrey Schäfer and Yiannis Alexopoulos for making the time in providing and explaining expert-level insight into A-CDM in an objective way and for access to the A-CDM dashboard.

At KLM, I would like to thank Coen Vlasblom, Duty Hub Manager Edwin Okèl, Flight Dispatchers and Flow Controllers Alexis and Rob Arnhem for their hospitality in visiting the Hub Control Centre and Operations Control Centre and openness in sharing the operational challenges related to A-CDM from the perspective of an Aircraft Operator. From the perspective of the ground handler, former colleague Bertus Snelting (DNATA) has been able to bring light to what is regarded as one of the main sources of decreased effectiveness in CDM. This proved to helpful in relativizing the results of the research. Last but not least, I would like to thank the CDM partners at the EUROCONTROL Airport Unit and MUAC. Your hospitality and openness were very motivating and enabled the research to gain value by providing the interesting network-perspective for CDM partners and to Schiphol.

In general, I would like to thank those present at the bi-weekly sprint reviews for your feedback. Coen Vlasblom, David Zwaaf, Ilse Megens, Evert Westerveld, Yoram Obbens, Alina Zelenevska, Ferdinand Dijkstra, Frenchez Pieters and Leo Hoogerbrugge. The research challenges were more easily dealt with by means of discussing experiences with fellow KDC CoE students Casper Moll, Marc Riebeek and Tessa Rietema. I think we managed to create a diverse research setting allowing serious discussions in combination with a healthy dose of humor. I wish you all the best in your future career paths which I hope to come across with. Finally, I want to thank the KDC main stakeholders for their efforts in providing a very educative graduation setting. I hope this research contributes to ongoing A-CDM development at Schiphol, other airports already running A-CDM and those still to be connected to the EUROCONTROL network.

Marc Voogt

Abstract

In European Air Traffic Flow and Capacity Management, various operational partners exchange timely, accurate and stable flows of operational planning information (such as take-off time predictions) to enable its effectiveness. This process is part of Collaborative Decision Making. Since May 2018, Schiphol runs the version of Airport-CDM (A-CDM). This means that it shares operational planning information with high accuracy and is regarded as 'the connection with the Network Manager'. Before this connection, less accurate operational planning information was shared by Schiphol with the Network Manager. This version of CDM is called local-CDM.

Research is carried out into the operational benefits related to the connection of Schiphol with the Network Manager. In doing so, it analyses changes made in procedures, human factors and operational performance since the connection to determine A-CDM effectiveness in relation to local-CDM. In determining A-CDM effectiveness, it considers take-off time predictability and non-compliance of Schiphol to take-off slots imposed by the Network Manager as the two primary KPIs. KPIs associated to take-off time predictability are considered as well, although secondary.

The research identifies A-CDM to be more effective in relation to local-CDM. The operational benefits are found to be improved spreading of workload among ATC controllers in adjacent centre MUAC due to increased plan stability of traffic originating from Schiphol, potential reduction of inbound holding, reduced unnecessary Radio Telecommunication load for ATC tower controllers and increased utilization of scarce runway capacity at Schiphol.

To further increase A-CDM effectiveness, it is recommended that last-minute runway changes are reduced as much as possible and communicated to the network through timely and accurate take-off time predictions, amongst others.

Keywords:
A-CDM, predictability, plan stability, Schiphol, EUROCONTROL, Network Management, ATFCM

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List of Abbreviations

A – R

A-CDM	Airport – Collaborative Decision Making
AAS	Amsterdam Airport Schiphol
ACC	Area Control Centre
AMS	Amsterdam Schiphol Airport (IATA-code)
ANSP	Air Navigation Service Provider
AO	Aircraft Operator
APP	Approach
ARDT	Actual Ready Time
ATC	Air Traffic Control
ATC-NL	Air Traffic Control the Netherlands *NL: Luchtverkeersleiding Nederland (LVNL)*
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATOT	Actual Take-Off Time
AUAS	Amsterdam University of Applied Sciences *NL: Hogeschool van Amsterdam (HvA)*
B2B	Business-to-Business
CASA	Computer Assisted Slot Allocation
CDG	Paris Charles de Gaulle Airport (IATA-code)
CDM	Collaborative Decision Making
CoE	Centre of Excellence
CPDSP	Collaborative Pre-Departure Sequencing Planner
CTOT	Calculated Take-Off Time
DCO	Departure Controller
DPI	Departure Planning Information
ECAC	European Civil Aviation Conference
EFD	ETFMS Flight Data
EOBT	Estimated Off-Blocks Time
EUROCONTROL	European Organisation for the Safety of Air Navigation
EXOT	Estimated Taxi-Out Time
FMP	Flow Management Position
FRA	Frankfurt am Main Airport (IATA-code)
GC	Ground Controller
KDC	Knowledge Development Centre
KLM	KLM Royal Dutch Airlines
KPI	Key Performance Indicator
LHR	London Heathrow Airport (IATA-code)
Local-CDM	Local – Collaborative Decision Making
MUAC	Maastricht Upper Area Control Centre
NM	Network Manager
NMIR	Network Manager Interactive Reporting
NMOC	Network Manager Operations Centre
OPL	Outbound Planner
PRU	Performance Review Unit
RC	Runway Controller
RRT	Ready Reaction Time

S – U

STAM	Short-Term ATFCM Measures
STW	Slot Tolerance Window
TOBT	Target Off-Blocks Time
TPI	Traffic Prediction Improvement
TSAT	Target Start-up Approval Time
TTOT	Target Take-Off Time
TTOT’	Target Take-Off Time (earliest possible)
TWR	Tower
UAC	Upper Area Control

Definition of Terms

Key research terms

Effectiveness

In this research, the effectiveness of A-CDM and its relation to local-CDM are mainly determined based on the performance score of two primary KPIs of take-off time predictability and the non-compliance to imposed take-off slots. Both are subject to a performance target set by the Schiphol Performance Review Unit. If a primary KPI (or one of the secondary KPIs) score at or above the target, it is regarded as being effective to the associated version of CDM.

Plan stability

A timely and accurate exchange of flight-specific milestone predictions by the individual CDM operational partners. These stakeholder-specific predictions should be the output of planning-systems incorporating an accurate probability of unpredictable events. These predictions should be provided in a timely manner while considering a realistic planning-horizon, enabling useful anticipation by all A-CDM partners.

CDM terms

Imposed take-off slot (CTOT STW)

If necessary, the EUROCONTROL Network Manager imposes a Calculated Take-Off Time (CTOT) to specific departing movements. This take-off time may be deviated from by -5/+10 minutes which is defined as the Slot Tolerance Window (STW), forming the more tractable term of ‘imposed take-off slot’.

Non-compliance to imposed take-off slots

EU regulation demands departing movements from Schiphol subject to an imposed take-off slot to take-off within that slot. If this has not been the case, the associated aircraft has been non-compliant to the imposed take-off slot.

Ready phase

The time-phase between the Actual Ready Time (the actual time at which the aircraft is ‘ready’) and Actual Off-Blocks Time (the time at which the aircraft crosses the red line clearance dividing the parking stand from the taxiway). During this period, the pilot exchanges information with ATC tower controllers and the push-back driver to guarantee a safely coordinated start of the taxi-out process.

Target Off-Blocks Time (TOBT)

The predicted time at which the main ground handling agency expects a specific aircraft to be ‘ready’ for departure from the gate (doors closed, push-back vehicle attached and equipment and boarding bridge removed)

Target Start-up Approval Time (TSAT)

The flight-specific time calculated by the CPDSP algorithm for the purpose of creating an optimal sequence of aircraft prior to departure from the parking stand. It is the time at which the aircraft can expect start-up clearance from ATC. And determines the ‘TSAT time-window’. It is used as indicator for the planning of push-back vehicles by the main ground handling agency. The five minutes before and after the TSAT is the ‘TSAT time-window’ or ‘TSAT window’, which is defined as the timeframe within which the pilot is allowed to request the ATC tower controller (Outbound Planner) for approval to depart from the parking stand.

Target Take-Off Time (TTOT)

A flight-specific take-off time prediction calculated by the CPDSP algorithm. It is calculated by adding the Estimated Taxi-Out Time (EXOT) to the Target Off-Blocks Time (TOBT) and correcting for any restrictions such as runway capacity or an imposed take-off time.

Executive summary

Increasing air traffic levels in Europe and throughout the world have caused the European ATM system to become congested. Measures taken by the EUROCONTROL Network Manager in the operational phase to enable stable flows of traffic (imposed take-off slots) requires predictable and accurate planning information from airports. Since May 2018, Schiphol has implemented A-CDM which means that it connected with the Network Manager and shares accurate operational planning information. The research aims to answer the following main question:

What are the operational benefits of Schiphol's connection with the Network Manager?

To answer the main question, the research:

1. Identifies changes made since the connection
2. Determines the effectiveness of A-CDM at Schiphol
3. Determines the effectiveness of A-CDM in relation local-CDM

The changes related to the connection of Schiphol with the Network Manager are indicated by means of interviews with A-CDM partners at Schiphol and in the network. The changes are found to not only consist of sharing more accurate data but also in procedural changes and human factors.

Effectiveness of A-CDM at Schiphol
Effectiveness of A-CDM at Schiphol is determined by data analysis into take-off time predictability and non-compliance to take-off slots imposed by the Network Manager. It is supported by means of interviews with A-CDM partners at Schiphol and in the network. Based on these two primary KPIs and their performance targets, A-CDM at Schiphol is found to be effective although almost all factors considered in the research to be associated to take-off time predictability still require performance improvements to reach their individual performance target.

Effectiveness of A-CDM in relation to local-CDM
Effectiveness of A-CDM in relation to local-CDM is determined by the same data analyses as applied to the effectiveness of A-CDM and by comparing the data analysis results with prior KDC CoE research related to CDM and an already existing analysis related to the first 100 days since the connection of Schiphol with the network. It identifies that the connection has positively influenced take-off time predictability (including almost all of the associated factors considered in the research) and Schiphol's non-compliance to take-off slots imposed by the Network Manager. It also indicates several aspects challenging the effectiveness of A-CDM to require further improvements, which were already present prior to the connection during local-CDM.

Operational benefits since the connection of Schiphol with the Network Manager
The answer to the main question is approached based on the effectiveness of A-CDM in relation to local-CDM. Benefits for A-CDM partners in the network include less workload for ATC controllers in adjacent centre MUAC due to improved communication of take-off times at Schiphol. Improvements in CDM KPIs related to the Schiphol outbound flow are indicated and related to a potential reduction in inbound holding, reduced unnecessary Radio Telecommunication load for ATC tower controllers and increased utilisation of runway capacity at Schiphol.

For further improvement in A-CDM effectiveness, it is recommended that last-minute runway changes are reduced as much as possible and communicated to the network through accurate take-off time predictions. The level of non-compliance to take-off slots imposed by the Network Manager is found to be low, especially in relation to similar airports. Therefore, further improvement in this KPI is recommended not to be a short-term priority. Besides, it is supported by further improving take-off time predictability. Other support for A-CDM effectiveness is found to be in performance monitoring (in collaboration with network-partners), infrastructural improvements and a maintained focus on human-factors in relation to CDM.
Last but not least, follow-up research is recommended to consider plan-stability as common ground among the CDM partners with predictability of operational planning information as its main focus.

1 Introduction

1.1 Background

Over the previous years, air traffic levels at European airports have increased rapidly. Combined with increasing air traffic over-flying Europe and lacking growth in capacity of airports and airspace, the European Air Traffic Management (ATM) system has become congested.

All partners in the European ATM system collaborate in minimizing the negative effects of congestion. An example is to avoid overloading airports and airspace. A key element in doing so is the EUROCONTROL Network Manager imposing take-off slots to individual flights resulting in added time on the ground or 'stand-delay'. The imposed take-off slots are determined based on operational planning information such as the take-off time and flight route, amongst others. These flight-specific planning calculations can be regarded as predictions and are determined based on operational planning information of the main operational partners[4] at Schiphol.

This process of collaboratively sharing information to create operational planning predictions, such as an accurately predicted take-off time, is part of Collaborative Decision Making (CDM). After CDM has been implemented at an airport and sends accurate take-off time predictions to the Network Manager, it can be regarded as 'Airport-CDM'. As described by EUROCONTROL, 'Airport CDM (A-CDM) aims at improving the overall efficiency of airport operations by optimising the use of resources and improving the predictability of events. It focuses especially on aircraft turn-round and pre-departure sequencing processes.' (EUROCONTROL, 2018).

Since 2015, Schiphol was running CDM locally (local-CDM). This means accurately calculated take-off time predictions were only shared among the CDM partners at Schiphol. The Network Manager's Operations Centre (NMOC) was provided with less accurate take-off time predictions to distribute the imposed take-off slots. Since May 2018, the accurately calculated take-off time predictions (amongst other operational planning information) are also shared with the NMOC (A-CDM). Since this data connection, it is expected that the NMOC has been able to provide more accurate imposed take-off slots based on the accurate take-off time predictions shared by Schiphol.

1.2 Problem statement

In the network, take-off time predictions of departing movements from individual airports are used to balance airspace demand with the available capacity. For example, the upper airspace of the Benelux and Western Germany is controlled by EUROCONTROL organization MUAC. Similar to Schiphol, this organization is increasingly facing capacity restrictions, which is induced by unpredictable take-off times such as those of Schiphol prior to the connection with the network. In turn, flights destined for Schiphol are delayed prior to departure and en-route by MUAC, which might be partially caused by Schiphol's own unpredictability.

In the years leading up to the connection, several operational benefits of connecting with the network were expected by partners at Schiphol and in the network. Insight into the (intended) operational benefits of the connection is required.

As present in any multi-stakeholder project, perspectives on operational benefits may differ. Plan stability is regarded as common ground among the operational partners for further growth accommodated in a sustainable way. Therefore, an operational benefit is regarded to be valuable if it supports this philosophy.

[4] ATC (runway-planning), Airport (gate-planning), Aircraft Operators (flight-planning) and Ground Handling Agencies (turnaround-planning)

1.3 Research objectives

The aim of this research is to extend the in-depth but partially limited analysis on the first 100 days since the connection. The '100-day analysis' is mainly quantitative and focuses on the CDM operation at Schiphol (Chapter 3).

The main objective is to provide the KDC main stakeholders with insight into the operational benefits of connecting with the Network Manager. Especially the perspective of A-CDM partners in the network is regarded to be valuable. Supporting objectives are matched with the KDC objectives described in Table 1.

Table 1 - Relation to KDC objectives

KDC objective	Relation of research
Capacity of airport resources	The connection was intended to provide increased traffic predictability for A-CDM partners related to Schiphol. Both influence the expected demand for, and utilization of, airport and airspace resources to a large amount.
Constraints when various stakeholders converge on limited space	CDM is directly related to managing constraints when various stakeholders converge on a limited space. An effective use of CDM is critical to managing these constraints and to secure the intended benefits of A-CDM.
Operational continuity	CDM is intended to deliver operational predictability, supporting the pro-active management of critical airport resources to secure operational continuity, both in 'regular' as well as 'adverse' conditions
Collaboration with fellow students	Fellow KDC CoE researchers Casper Moll and Marc Riebeek focus on the arrival flow. Research findings on this part can support and/or supplement findings in this research focusing on the outbound flow. This statement is reciprocal.
Building upon results from previous KDC CoE research	Prior research related to A-CDM at Schiphol has been carried out by Huib de Jong (implementation of an Airport Operations Centre) and Roel Wouters (impact of local-CDM on operational efficiency). This research aims to build upon their research findings.

1.4 Research relevance and significance

Intended benefits of any project in a collaborative setting are critical to maintain involvement. The same applies to the implementation of A-CDM at Schiphol. The validation and quantification of (intended) operational benefits are critical to determine the effectiveness of collaborative efforts over several years. Also, if present, it might indicate the need of further improvements.

For example, one of the most valuable expected operational benefits is the ability for the Network Manager to improve its decisions impacting many flights departing from Schiphol. Its decisions include imposed flight-specific take-off slots with the aim to support network-wide stability in air traffic flows. These decisions are pro-active and dependent on the variety and quality of flight-specific information being shared since the connection by Schiphol.

The pro-active decisions made by the Network Manager to avoid en-route congestion or holding at the destination airport directly impact the productivity of parking stands at Schiphol. In the operational phase, this has the potential to trigger reactionary delay. Related to this are unwanted phenomena such as 'inbound-holding', in which aircraft arriving at their assigned gate unexpectedly need to wait (with engines running) for an unexpectedly delayed departing aircraft.

Chain-reactions such as these eventually impact the level of Safety in airport operations as they add to ground congestion. This directly impacts the potential for ground collisions. From a financial perspective, solving these chain-reactions in a reactive instead of pro-active way slows down the return on investment for costly airport infrastructure and its users. Hence, the need for predictability intended by CDM.

1.5 Research questions

The operational benefits are distilled by researching the changes made since the connection and the effectiveness of A-CDM in relation to local-CDM at Schiphol. The following main question is considered:

What are the operational benefits of Schiphol's connection with the Network Manager?

The following sub-questions provide insight into the changes made since the connection and the effectiveness of A-CDM at Schiphol:

1. What changes have taken place since Schiphol's connection with the Network Manager?
2. What is the effectiveness of A-CDM at Schiphol?
3. What is the effectiveness of A-CDM in relation to local-CDM?

1.6 Research scope

As explained in the introduction, A-CDM focusses especially on aircraft turnaround and pre-departure sequencing processes. In the sequencing process, the optimal take-off time from the runway is calculated. Due to the nature of the calculation, this research regards this calculation to be a take-off time prediction. The turnaround and sequencing processes take place in the operational planning phase, which will be considered in the data analysis.

The connection was carried out on the 16th of May in 2018. With the research commencing in September 2018, a sufficient amount of time has passed by to research medium-term effects or 'impact' of the connection on the Schiphol operation. Therefore, the vast amount of the research focusses on comparing CDM performance in the summer season of 2018 with the summer season of 2017. Due to various factors influencing a potential change in effectiveness of CDM over a large time-scale (such as changes in air traffic characteristics or new infrastructure), data analysis also includes changes in the non-compliance to take-off slots in the week before and after the connection.

As explained in the Problem statement (Section 1.2), plan stability is regarded as common ground among the operational partners for further growth accommodated in a sustainable way. Therefore, an operational benefit is regarded to be valuable if it supports this philosophy.

1.7 Thesis structure

In Chapter 2, the Methodology describes the research design choices. Chapter 3 contains a literature study into the context of the European ATM system and operational benefits related to A-CDM. Also, a 'contextual analysis' is provided to simplify and explain the context considered in the research design.

The research contains two analysis chapters (Chapter 4 and 5). Chapter 4 focusses on the take-off time predictability and associated operational factors. Chapter 5 researches the non-compliance of Schiphol to take-off slots imposed by the Network Manager (based upon the take-off time predictions) and how this performance relates to similar airports.

In Chapter 6, the results of the two analysis chapters are correlated amongst themselves and combined with literature to form research findings in terms of the effectiveness of A-CDM at Schiphol and the operational benefits related to plan stability.

Chapter 7 concludes the research by providing conclusions combined with a discussion of the research. Based on Chapter 6, recommendations to support existing or generate new operational benefits related to A-CDM are provided in Chapter 8.

2 Methodology

This chapter describes the design of the research (Section 2.1) and its underlying characteristics such as the research hypotheses (Section 2.2), research instruments (Section 2.3), research samples (Section 2.4), data sources (Section 2.5), the individual data analysis objectives (Section 2.6) and the techniques and tools to carry out the research (Section 2.7).

2.1 Research Design

The research is designed according to the 'before-and-after design' as described in Kumar (2014). Prior KDC CoE research into local-CDM carried out by Wouters (2018) provides the 'before' or 'pre-test' sample. The 'after' or 'post-test' results of this research into A-CDM benefits are compared. Where necessary, the 'pre-test' information is supplemented. Due to this research being carried out after the connection with the Network Manager (i.e. 'A-CDM'), this only applies to the quantitative analyses.

Kumar (2014) lists the following advantage and disadvantages related to the 'before-and-after design':

- Advantage
    - 'It is the most appropriate design for measuring the impact or effectiveness of a programme' and 'its ability to measure change in a phenomenon or to assess the impact of an intervention'
- Disadvantages
    - 'it measures total change … it is not possible to quantify the contribution of independent and extraneous variables separately' - substantiating the exact cause of an operational benefit might require advanced statistical modelling
    - 'maturation effect' - operational benefits might be related to extraneous factors such as CDM-training or variation in traffic volumes and traffic characteristics
    - 'reactive effect' - expectations of A-CDM benefits in local-CDM research might affect how a benefit is interpreted by interviewees
    - 'regression effect' - the attitude of a CDM partner towards A-CDM might have altered, influencing how a benefit is interpreted

Another potential disadvantage is the lacking perspective on the network-side in the local-CDM scenario related to Schiphol, which is key to this research.

Reference period

Classifying this research on the reference period, it is regarded as a retrospective study. Kumar (2014) describes this as investigating 'a phenomenon, situation … that has happened in the past'. The phenomenon applied to this research is the connection with the Network Manager in May 2018.

Nature of the investigation

With this research commencing approximately three months after the connection, it inherits a core element of an experimental study. In an experimental study, 'the researcher (or someone else) introducing the intervention that is assumed to be the 'cause' of change, and waiting until it has produced – or has been given sufficient time to produce – the change.' (Kumar, 2014). This approach starts from the cause to establish its effects. The research also contains elements of a non-experimental study. In a non-experimental study 'the researcher starts from the effect(s) or outcome(s) and attempts to determine the causes.' (Kumar, 2014). This is applied to indicators for operational benefits already identified prior to the research, such as a lasting increase in compliance to imposed take-off slots since the connection with the Network Manager.

Due to both experimental and non-experimental elements being present, the nature of this investigation is regarded as 'semi-experimental'.

2.2 Research Hypotheses

The connection with the Network Manager in May 2018 is intended to have provided operational benefits. Research hypotheses in Table 2 are based on those intentions and incorporates fore-seeing system-effects based on prior research.

Table 2 - Hypotheses supporting A-CDM operational benefits

Relation to problem/main question	Expected benefit
Effectiveness of the A-CDM process	Increased adherence to performance targets related to collaboratively agreed upon CDM KPIs
	Improved allocation of imposed take-off slots by the Network Manager due to improved take-off time predictions shared by Schiphol since the connection
Impact on network plan stability	Improved plan stability in the operational phase for A-CDM partners in the network

2.3 Research instruments

Various instruments are applied to answer the main question and sub-questions. Research instruments applied to qualitative research consists of interviews (structured and unstructured), observation of operational working environments and desk research. The interviews are located in the Appendix.

Research instruments applied to quantitative research consists of data processing and observation of data in case data processing has already been applied.

2.4 Research samples

Research samples related to qualitative research

The qualitative research instruments are applied to the qualitative research samples summarised in Table 3. In selecting the samples related to Schiphol, considerations are made to reflect the perspectives of all A-CDM partners while maintaining focus on critical roles with relevance to the research. At ATC the Netherlands, the Flow Management Position is regarded as the interface between Schiphol and the network which is used for coordinating capacity restrictions used by the NMOC to avoid overloading airspace. This function is located in the operational radar room. The Outbound Planner located in the ATC control tower is critical in maintaining a safe workload for its tower-colleagues and critical in an effective functioning of A-CDM.

Samples related to Schiphol are a process developer and business analyst. The process developer is closely related to airside development, thus directly impacted by an effective functioning of A-CDM. The business analyst has been closely related to implementation of local-CDM and A-CDM at Schiphol.

As representations of the Aircraft Operators, observations are carried out with support of a Duty Hub Manager the KLM Hub Control Centre (HCC) and Flow Control positions at the KLM Operations Control Centre (OCC). Both combined offer a view into the logistics of Air Traffic Management from the perspective of an Aircraft Operator.

Not only KDC-clients are included in the research samples. Due to personal working experience in ground handling at DNATA, a Safety Specialist is interviewed with a focus on operational challenges from the perspective of the ground handler.

On the network-side research samples apply to MUAC and EUROCONTROL. Although MUAC is officially a EUROCONTROL organization, it functions similar to an independent Air Navigation Service Provider. Samples include the TPI project manager and a Capacity Programmes Manager. The TPI project is closely aligned with take-off time predictability, one of the two main focus areas in the research. The Capacity Programmes Manager is in charge of several projects related to utilization of airspace capacity, which is influenced by an effective use of A-CDM through air traffic predictability. Also, a conference call with two A-CDM experts at the EUROCONTROL Airport Unit is carried out to discuss A-CDM implementation at Schiphol and the relation with other A-CDM airports.

Table 3 - Samples related to qualitative research

Location	Role	Sample
Schiphol	ATC	Flow Management Position
		Outbound Planner
	Airport	Process development
		Business-analyst
	AO	Duty Hub Manager (KLM HCC)
		Flow Control (KLM OCC)
	MGHA	Safety Specialist
Network	UAC	TPI project manager (MUAC)
		Capacity Programmes Manager (MUAC)
	ATC Coordinator	Airport Unit (EUROCONTROL)

Research samples related to quantitative research

The first sub-question is answered through qualitative research. The second and third sub-questions are derived from analysis of:

- Take-off time predictability and associated factors (Chapter 4)
- Non-compliance to imposed take-off times in relation to similar airports (Chapter 5)

Chapter 4 considers the take-off time predictability shortly before commencing the taxi-out process (based on the Schiphol PRU KPI) and at fixed times before take-off (based on the output of the MUAC TPI model). The first compares take-off predictability and associated factors for the summer seasons of 2017 and 2018. The second from February 2018 to August 2018.

Chapter 5 considers non-compliance to imposed take-off slots in relation to similar airports. The similar airports are Frankfurt am Main (FRA), London Heathrow (LHR) and Paris Charles de Gaulle (CDG). Data samples consist of daily summary values of one week before and after each airport's connection with the network and daily values over the last four summer seasons.

2.5 Data sources

The analysis of Chapter 4 is carried out with data from the Schiphol Performance Review Unit (PRU) and the output of the TPI model provided by MUAC. Chapter 5 contains analysis using data from the EUROCONTROL Network Management Interactive Reporting (NMIR) tool and EUROCONTROL PRU.

2.6 Data analysis

2.6.1 Take-off time predictability and influencing factors

Throughout the report, the take-off time prediction is regarded to be derived from the ground handler's turnaround predictions (Target Off-Blocks Time, TOBT). This process is visualised in Figure 1.

Based on the TOBT in step 1 (the prediction by the ground handler of when all the ground handling processes are ready), the earliest possible Target Take-Off Time (TTOT') in step 2 is calculated. To do so, a stand-runway matrix is applied to determine the Estimated Taxi-Out Time (EXOT), which is added to the TOBT. Based on the earliest available take-off time (TTOT'), operational constraints are considered to calculate the Target Take-Off Time (TTOT) in step 3. Examples are the departure route/direction (SID), the Wake Turbulence Category (WTC) of the aircraft, the available runway capacity or cases in which the Network Manager has imposed the flight with a Calculated Take-Off Time (CTOT) which needs to be complied to.

To calculate the Target Start-up Approval Time (TSAT) in step 4, the EXOT is detracted from the TTOT. The TSAT is the time at which the pilot is allowed to request the ATC tower controller for approval to leave the parking stand.

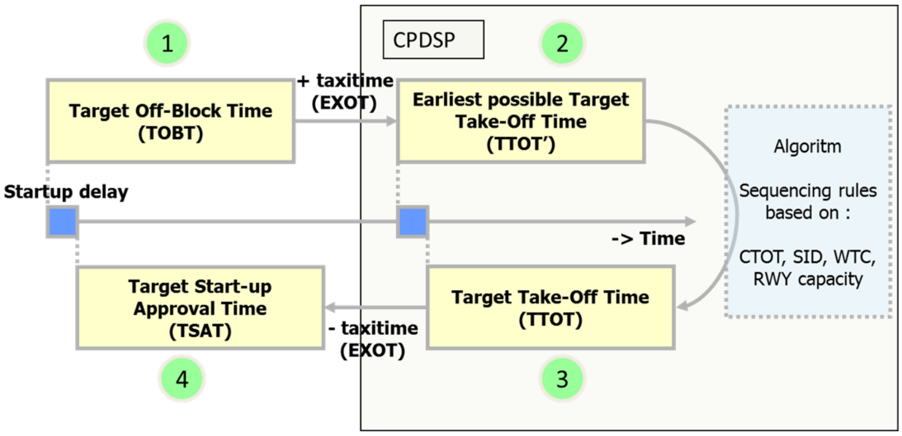


Figure 1 - Collaborative Pre-Departure Sequence Planning system (Schiphol, 2018)

Take-off time predictability and influencing factors

In post-operational analysis, the predictability of take-off times can be determined based on the TTOT at various timestamps in the outbound flow. This analysis considers various timestamps. The first is the predicted take-off time shortly before the taxi-out process commences. It is based on data published by the Schiphol PRU. The second analysis into take-off time predictability is based on the output of the Traffic Prediction Improvement model by MUAC. It applies machine learning to reduce error of take-off times communicated by Schiphol. The output is visualised for thirty, fifteen, ten and five minutes before take-off and at take-off. Based on the amount of error-reduction, the take-off time predictability as perceived by MUAC is approached.

The main objective of this analysis is to provide results to answer the third hypothesis. This hypothesis is focused on improved plan stability in the operational phase for A-CDM partners in the network.

The analysis also considers factors influencing the take-off time predictability. Examples are the updates from the ground handlers (TOBT), the share of pilots adhering to CDM procedures and the amount of cases in which procedures are forgotten or unable to be met.

The objective of analysing the factors influencing the take-off time predictability is to answer the first hypothesis. This hypothesis focuses on the adherence of performance targets related to collaboratively agreed upon CDM KPIs.

2.6.2 Non-compliance to imposed take-off slots in relation to similar airports

Besides Schiphol, three surrounding major-hubs are analysed to compare and relate Schiphol's non-compliance to imposed take-off slots with similar airports in roughly the same geographic area. This analysis compares the week before and after each airport's connection and the performance of each airport over the last four summer seasons. While only the connection of Schiphol is within the range of the latter, performance in non-compliance of the similar airports are still useful to put into perspective any changes in non-compliance by Schiphol.

2.7 Techniques & tools

The graphs provided in the analysis chapters are created using the Integrated Development Environment R Studio, using the R language. The type of graph is a 'facet' graph which allows two or more individual graphs to be combined into a single graph.

3 Review of the Literature

3.1 Literature study into the operational benefits of A-CDM

3.1.1 ATM performance in relation to Schiphol and the EUROCONTROL network

Capacity restrictions in the EUROCONTROL ATM-system

Since 2013, after years of relatively sufficient capacity throughout the ATM system of Central Europe, airport and en-route delays are increasing rapidly. According to EUROCONTROL, the total amount of delay related to Air Traffic Flow Management (ATFM) increased by 62% from 15.9 million minutes in 2017 to 25.6 million minutes in 2018. Top three ATFM delay reasons in 2018 were weather (31%), ATC capacity (31%) and ATC staffing (18%) (EUROCONTROL Network Manager, 2019).

Table 4 - Network delay in the EUROCONTROL network (EUROCONTROL, 2019)

ATFM DELAY REASON	2018 TOTAL DLYS (MIN)	2017 TOTAL DLYS (MIN)	% DIFF
WEATHER	7,936,635	5,204,004	52,5%
ATC CAPACITY	7,923,507	4,572,857	73,3%
ATC STAFFING	4,535,220	1,585,167	186,1%
AERODROME CAPACITY	1,894,942	2,302,304	-17,7%
INDUSTRIAL ACTION (ATC)	1,165,450	743,461	56,8%
AIRSPACE MANAGEMENT	633,243	192,231	229,2%
OTHER	480,155	228,115	110,4%
SPECIAL EVENT	466,494	420,346	10,9%
EQUIPMENT (ATC)	410,170	394,048	4,1%
ENVIRONMENTAL ISSUES	130,873	151,102	-13,3%
AERODROME SERVICES	26,514	42,917	-38,1%
ATC ROUTEING	11,046	32,682	-66,7%
ACCIDENT/INCIDENT	6,740	12,180	-45,5%
NOT SPECIFIED	4,096	1,273	266,7%
INDUSTRIAL ACTION (NON-ATC)	2,138	6,916	-68,4%
	25,627,223	15,889,603	

The delay reasons in Table 4 are both causes and effects of system-wide restrictions in (the management of) capacity. The EUROCONTROL User Forum provides insight into perspectives of individual stakeholders related to 2018. From the perspective of easyJet, strikes and lack of staff caused increased workload for the Operations Control Centre. Where possible, collaboration with ANSPs was carried out although this was experienced to be hard due to lack of flexibility. The result is major costs of delay, of which reactionary delay is regarded as major. Measures to prevent it are even more costly such as spare aircraft and the laborious fine-tuning of flight-plans and crew schedules (EUROCONTROL, 2019).

Lisbon airport indicates a ‘chaotic summer’ induced by the inability of the main airline to incorporate the influence of capacity restrictions in the network on its own flights (ATFM regulations). While it regards the measurement of reactionary delay to be hard, it expects to perform turnaround optimization and improve the predictability of take-off times. Supporting this would be the implementation of A-CDM, although more information of the expected benefits would be required from the Network Manager (Lisbon Airport, 2019).

Karlsruhe Upper Area Control (Karlsruhe UAC), a German ANSP in the EUROCONTROL network, indicates increased delay to be due to available staffing capacity and highly unpredictable weather. It indicates the ability to deal with short-term traffic changes to be very limited, a need for more reliable traffic predictions and transparency in the planning decisions of Aircraft Operators and ANSPs (DFS, 2019).

Similar to the stakeholders described above, the EUROCONTROL Network Manager Operations Centre (NMOC) indicates a 'summer of all records' with 'a lot of instability and volatility'. As a result, it experienced a significant amount of workload due to many phone calls made by ATM stakeholders such as ATC and Aircraft Operators regarding operational issues (EUROCONTROL Network Manager, 2019).

Capacity management improvements at Schiphol

Induced by the cap on flight movements until 2020, the management of capacity (i.e. utilizing the available capacity) has become increasingly important to Schiphol. In the ATM 2020+ roadmap, ATC the Netherlands provides insight into potential solutions for improved capacity management. Improved balancing of airspace and airport capacity, along with the identification and use of latent capacity, is expected to provide the following benefits:

- Improved traffic throughput
- More efficient use of airspace
- Less impact of flow measures (less delay)
- Better use of available resources (staffing)

Also, a variety of possible future developments to improve the capacity management functionality are provided:

- More precise slot allocation including better distribution of slots, allocation taking into account airspace capacities or slot allocation based on workload/complexity of flights;
- Optimization of airline schedules, in communication with the airport operator and the ANSP, taking the effects on the network into account;

(ATC the Netherlands, 2018)

3.1.2 Application of Collaborative Decision Making at Schiphol

Congestion at Schiphol and in the EUROCONTROL network induces the need for stable air traffic flows. This stability is supported by predictability, which is provided through the implementation of A-CDM. Airport CDM (A-CDM) aims at improving the overall efficiency of airport operations by optimising the use of resources and improving the predictability of events. It focuses especially on aircraft turn-round and pre-departure sequencing processes.' (EUROCONTROL, 2018).

Procedural CDM architecture avoiding emissions

Unlike most airports outside the EUROCONTROL network, the procedural architecture of CDM aims to avoid aircraft queueing at the runways. Schiphol (2017) indicates the follow objective: 'Schiphol operates since prior CDM with holding at the gate due to limited space to queue many aircraft near the runway. In addition, the CDM concept is based on buffering on the stands for environmental and (fuel) efficiency reasons.'

Performance of local-CDM at Schiphol

The scenario in which accurate take-off time predictions are only shared among the partners at the airport is regarded as local-CDM. Benefits related to local-CDM at Schiphol were regarded by Schiphol to be more transparency, less Radio Telephony, better gate allocation management and passenger bus process and the establishment of a Performance Review Unit (Schiphol, 2017). Schiphol indicated operational challenges of local-CDM to be an increase in the number of flights (+10% for 2015 – 2017), an increased number of flights affected by CTOTs, TSAT dynamics, late TOBT adjustments and an increased number of TSAT expired (Schiphol, 2017).

Prior KDC CoE research by Wouters (2018) provides insight into operational changes stimulated by local-CDM, the impact on operational efficiency and operational benefits. The implementation of local-CDM is regarded to have had a big impact on ATC and ground handlers due to the implementation of the CPDSP[5]. This algorithm strongly influenced the TOBT quality. The impact was decreased workload for ATC, more efficient resource planning for ground handlers and gate planners due to increased predictability (only in regular conditions). The Aircraft Operator was indicated to see no local benefits but expected these to be present after full implementation (A-CDM). It expected to be able to decrease buffers due to increased predictability. The research into local-CDM operational benefits was regarded to be subject to noise factors such as airport infrastructure congestion, weather and airspace regulations. Further CDM improvements were to be expected after full implementation.

3.1.3 Systematic changes related to A-CDM

The implementation of A-CDM is carried out through various systematic changes. The foundation is visualized in Figure 2 which illustrates the cycle of DPI and CTOT messages. Each flight has an individual spot in the departure planning of Schiphol, which is translated into a Departure Planning Information (DPI) message. Based on the predicted take-off time (Target Take-Off Time/TTOT), the Network Manager calculates whether a later departure is necessary or whether the flight should not depart earlier than the predicted time.

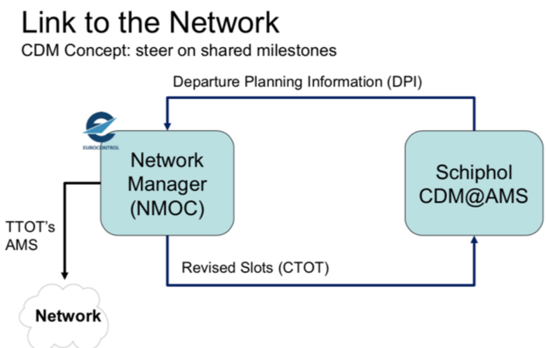


Figure 2 - Simplified airport-network interaction in A-CDM (Schiphol, 2018)

According to EUROCONTROL, 'the purpose of DPI is to make the Network Manager Operations Centre and its partners ((i.e. ATC Units, AOs, airports of destination, …) aware of the situation of a given flight in respect of the pre-departure phase, in particular with regard to the Take-Off - Time (TOT), through a message than can automatically be processed (EUROCONTROL, 2018).

The communication of the DPI messages by airports is carried out in many ways. While Schiphol is the third airport to connect via the B2B connection, almost all A-CDM airports have connected with the network using the AFTN technique. A B2B connection provides 'access to both data and services via a system-to-system interface primarily over the Internet. This allows NM customers to integrate information available to EUROCONTROL in their own systems, according to their business needs.' (EUROCONTROL, 2019).

3.1.4 Influence on processes & influence on outbound flow, impact on plan stability

Operational benefits

Prior to the connection, intended operational benefits related to sending DPIs to the network were identified by Schiphol to be reduced ATFM-delay (due to improved predictability for network planning and flights being automatically ready for slot improvement), more feasible slots, optimised use of runway capacity, improved turnaround process due to an improved gate management and reduction of last-minute changes due to freeze of flight plan and ATFM-slot after leaving the parking stand. For the network, it expected more accurate traffic demand predictions, reduced need for capacity buffers and reduced regulation and delay (Schiphol, 2018).

[5] An algorithm for the purpose of creating, and adapting, a pre-departure sequence with the 'TSAT' as its main output (see 'Definition of terms')

Other sources match these intended benefits. It identified improved adherence to slot times, better use of aircraft gates/stands and equipment and manpower deployment for airports. For airlines, reduced schedule buffering was expected along with more efficient use of ground handling resources and shorter aircraft turn-around time, taxiing and waiting time at the runway. ANSPs would benefit from improved pre-departure sequencing and departure flows and increased runway capacity (CANSO, 2015). DFS also identified airports in the network to benefit from improved estimated landing times (DFS, 2016).

Short-term evaluation of the connection

An evaluation report of the connection published a couple of months after the connection provides insight into short-term impact on the operation. It concludes that, after the connection with the network, punctuality and capacity have not been affected and predictability has increased. It also indicates congestion and disruptions within the network to negatively impact the perception of CDM, along with further improvements to be made in the voice communication between Schiphol and NMOC (Schiphol, 2018).

The ‘100-days analysis’, a follow-up on the evaluation report stretching the 100 days after the connection, indicates the same conclusions. Punctuality has not changed while predictability has improved. In disrupted conditions, the take-off time predictability is best visible.

A-CDM in relation to Safety

Although it is stressed that ‘A-CDM is not a “safety tool” and should not be seen as one’, research into Safety benefits in relation to A-CDM is carried out by EUROCONTROL. It relates closely to the objectives of the Integral Safety Management System (ISMS) research into more predictable traffic flows (Schiphol, 2018). It identifies that a better planning of flows of traffic ‘may have a particular safety benefit in the case of inbounds and outbounds within airport cul-de-sacs and enhances the traffic planning for runways in mixed mode operation. It could potentially reduce the number of aircraft moving simultaneously in proximity.’ Also, Safety benefits related to reduction of last-minute operational changes are identified. ‘Ground handlers should have fewer occasions where they have to travel across the airport in a hurry to react to an unexpected event (EUROCONTROL, 2016).

Impact on plan stability

De Jong (2018) indicates imposed ground delays (ATFCM measures) to ‘impact the plan stability of Schiphol, since imposed ground delays by NMOC trigger a recalculation of the TSATs’. EUROCONTROL provides insight into the reasons for these triggers with the associated lead-time (Appendix IV).

3.1.5 A-CDM effectiveness & best practices

De Jong (2018) indicates socio-technical factors influencing the effectiveness of CDM at Schiphol. Central to the effectiveness is the TSAT as a predicting variable to the actual operations. The following factors causing significant deviation are indicated:

- Runway configuration
- Weather
- TOBT management
- ATFCM measures

A best practice regarding the intentional misuse of the system is indicated to be the (sufficient enough) rewarding of good behaviour. This would increase the likeliness of desired behaviour such as timely and accurate provision of information by A-CDM partners.

In the evaluation report after the connection, Schiphol indicates further improvements to be in communication with the NMOC and increased focus on predictability (Schiphol, 2018).

Compliance to EU regulation
Regarding effectiveness of A-CDM to be directly related to compliance in ATFM departure slots, EU regulation 255/2010 (regulation of air traffic flows) is critical. It indicates that "Member States shall ensure that where adherence to ATFM departure slots at an airport of departure is 80 % or less during a year, the ATS unit at that airport shall provide relevant information of non-compliance and the actions taken to ensure adherence to ATFM departure slots." and "If, at a particular airport, compliance with ATFCM flight slots annually is 80% or less, the air navigation service provider shall submit to the Directorate a plan of measures to improve compliance with the ATFCM slots at that airport." (European Commission, 2010). This regulation underlines the importance of compliance by airports to ATFM-slots, which is one of the main intended benefits of connecting with the network.

Potential threat after connecting with the network
London Heathrow identifies the threat of a 'connection stand-by mode' which was triggered by an airline. Best practices for optimal effectiveness of A-CDM may be related to the underlying reasons. These were indicated to be unacceptable TOBT/TSAT refresh times, inability to push back early to free up a parking stand and increased Radio Telecommunication congestion. Improvements were made based upon feedback and A-CDM went back into live operations in August 2013 (EUROCONTROL, 2013) (Heathrow, 2013).

Best practices from the network perspective
Ultimately, two measurements are critical in a stable airport-network relationship. These are the compliance to ATFM-slots and predictability of when aircraft will take-off. For both, EUROCONTROL recommends an accurate setting of TOBT for an optimal calculation of ATFM-slots. From the network perspective, stability and collaboration with airports are key. All A-CDM partners should understand the dynamics (EUROCONTROL, 2019).

3.2 Contextual framework

Figure 3 provides a simplified view of the inbound and outbound flows related to Schiphol. Highlighted in blue are the focus areas within Schiphol's operational context considered in the research.

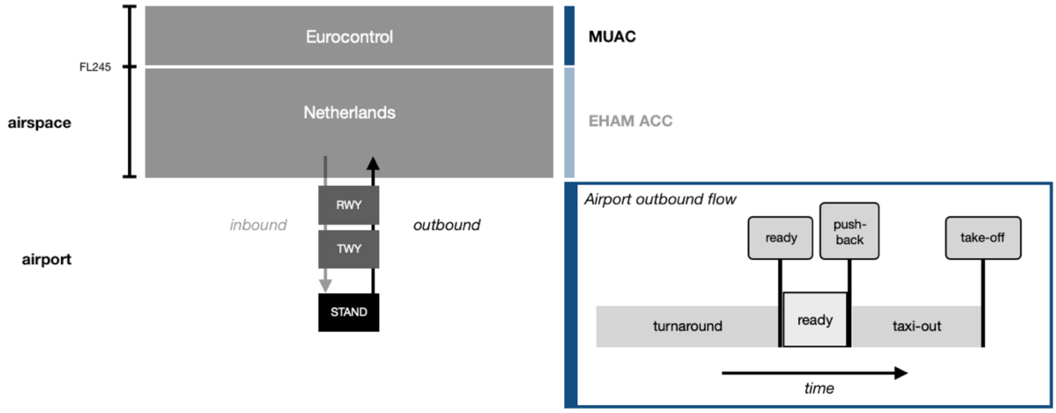


Figure 3 - Contextual simplification for Schiphol air traffic to/from MUAC

Outbound flow scope

The scope of this research is the 'outbound flow'. As visualized in Figure 4, this flow is regarded by the researcher to start from the first calculations performed by the CPDSP algorithm up to the handover from ATC-NL Area Control (ACC) to the adjacent centre (MUAC). For each phase in the outbound flow, Figure 4 describes the controlling entities in this outbound flow. This research only considers the functions of CPDSP, OPL, GC and UAC.

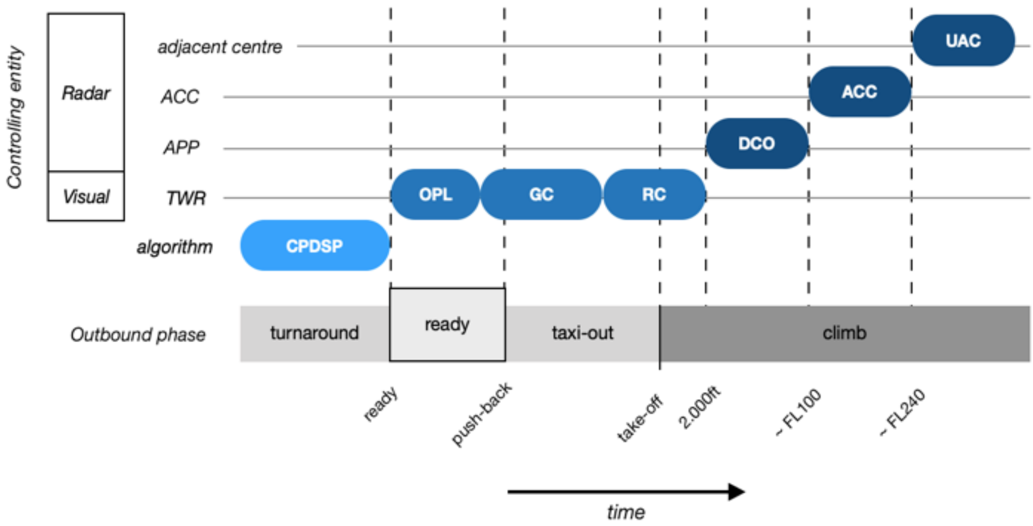


Figure 4 - Controlling entities in the outbound flow

Table 5 provides a simplified explanation of controlling entities' responsibilities in the outbound flow.

Table 5 - Simplified responsibilities of controlling entities in the outbound flow

Controlling entity			Responsibility
Automated		CPDSP algorithm	Calculate optimal time for pilots to request the tower (Outbound Planner) for approval to depart from the parking stand and enter the taxiway
Visual	*TWR*	Outbound Planner	Receive pilot's request and forward request to GC
		Ground Control	Receive pilot's request and give combined approval to start engines and enter the taxi-way
		Runway Control	Approve entrance to the runway and take-off
Radar	*APP*	Departure Control	Receive departing movements from TWR, handover to Area Control (ACC)
	ACC	Area Control Centre	Receive departing movements from Approach (APP), handover to MUAC
	Adjacent centre	Upper Area Control	Incorporate traffic departing from Schiphol into airspace, handover to next adjacent centre

Note: Approach (APP) and Area Control (ACC) are out of scope

Pre-departure traffic sequencing
As described earlier, this research regards the outbound flow to start from the first calculations made by the CPDSP algorithm. As visualized in Figure 5, this algorithm considers flight characteristics, turnaround progression and runway capacity to generate short-term operational predictions. These predictions are critical in controlling workload for tower-functions as well as avoiding congestion of infrastructure such as the taxiways and surrounding airspace. The information is also used by the CDM partners in the allocation of scarce capacity. Examples are the planning of runways by ATC, aircraft parking stands by gate-management, flight schedules by Aircraft Operators (passed on to the respective main ground handling agency) and in a potential future application of dynamic airspace-sector Demand Capacity Balancing by the Network Manager through Short-Term ATFM Measures (STAMs).

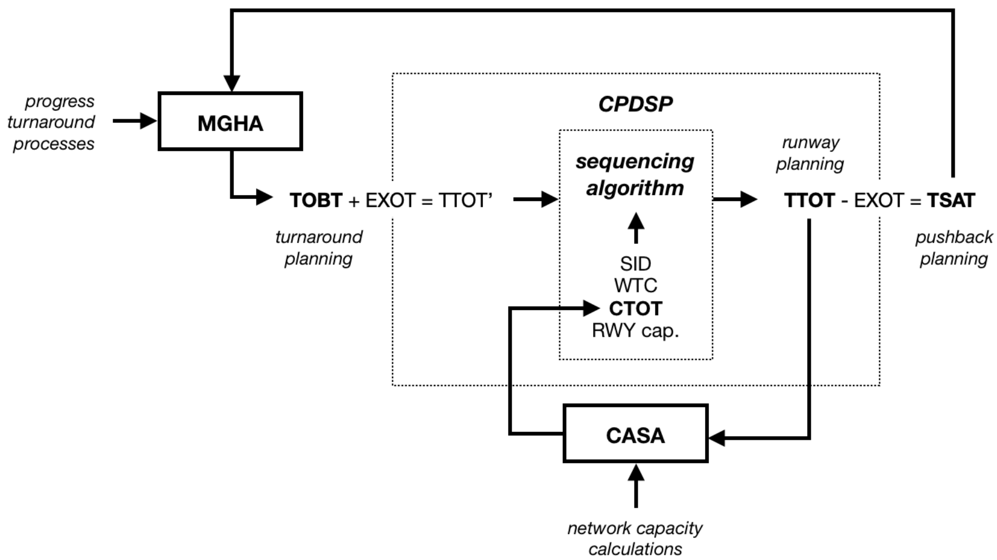


Figure 5 - Collaborative Pre-Departure Sequence Planner

The main output of the CPDSP-algorithm is the Target Start-up Approval Time (TSAT). This time determines the 'TSAT window' (-5m. TSAT +5m.) within which the pilot and tower collaboratively coordinate departure from the parking stand. As visualized Figure 7, the pilot requests start-up approval from the Outbound Planner (OPL) and, after a couple of coordination steps, is given a combined approval by the Ground Controller for push-back and engine start-up.

The TSAT is strongly influenced by the Calculated Take-Off Time (CTOT). This take-off time is calculated and assigned by the EUROCONTROL Network Manager. It determines the 'CTOT Slot Tolerance Window' (-5m. CTOT + 10m.), which may be simplified as an imposed take-off slot. Not all departing movements at Schiphol are subject to this take-off slot, although the share of this 'regulated traffic' has been increasing rapidly in the years leading up to the connection with the Network Manager.

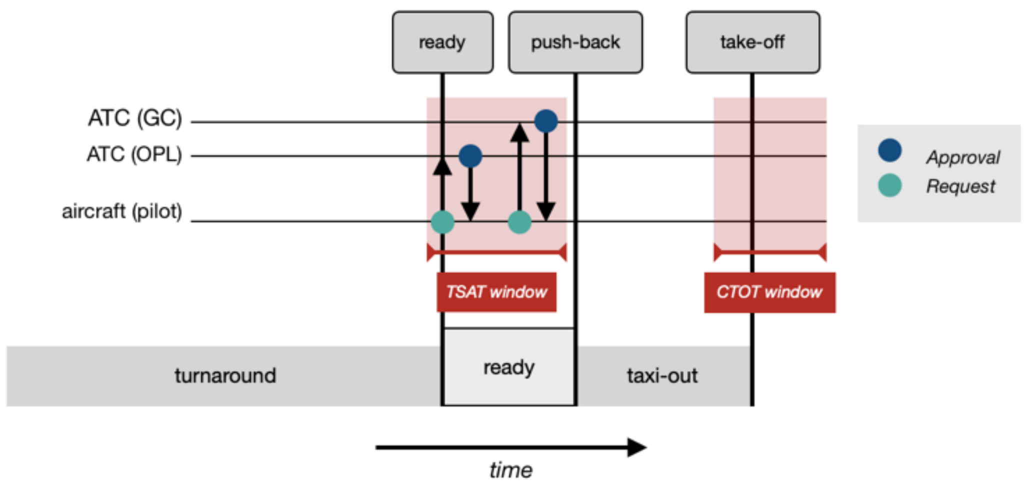


Figure 6 - Information exchange between pilot and ATC in the 'ready' phase (1)

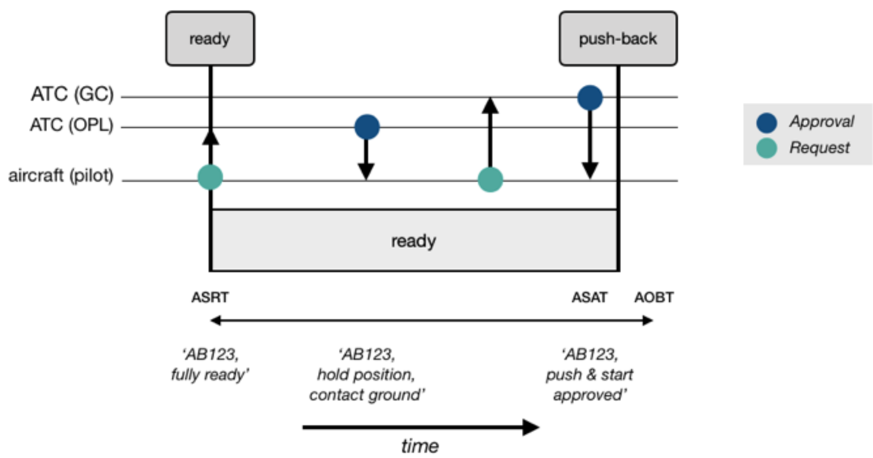


Figure 7 - Information exchange between pilot and ATC in the 'ready' phase (2)

Departing movements subject to ATFM-delay have the potential to propagate delay to the inbound flow. This might be due to an unexpected unavailable parking stand mostly related to high utilization of buffers (different turnaround buffers apply to different business models), resulting in snow-balling effects.

The quantification of operational benefits is pre-determined to be subject to extraneous variables such as:
- Data quality (timely, accurate, and stable, 'cooking the books'[6])
- Contextual changes (CDM training, updates to technical systems, feeling of urgency among operational partners to improve interaction with CDM due to transparency with an external party, etc.)
- Procedural changes (the use of remote stands for servicing instead of buffering)

Interpretation of plan stability in the operational phase
The following definition for plan stability in the operational phase is regarded in this research. It is based on definitions provided in interviews (Appendix XVII – 'Process Development Operations' and 'Member of the Business Expert Team') while considering A-CDM terminology and discussions carried out in the observations at operational partners:

> *A timely and accurate exchange of flight-specific milestone predictions by the individual A-CDM operational partners. These stakeholder-specific predictions should be the output of planning-systems incorporating an accurate probability of unpredictable events. These predictions should be provided in a timely manner while considering a realistic planning-horizon, enabling useful anticipation by all A-CDM partners.*

[6] Deliberately providing incorrect data for personal advantage

4 Take-off time predictability and associated factors

This chapter focusses on the take-off time predictability KPI from the perspectives of Schiphol and MUAC. Section 4.1 contains the perspectives of various A-CDM partners. Section 4.2 contains data analysis into take-off time predictability based on information from Schiphol and MUAC. In Section 4.3, quantitative analysis is provided in which Schiphol PRU KPIs associated to take-off time predictability are analysed as well.

4.1 Perspectives of CDM partners on take-off time predictability and associated factors

ATC the Netherlands
Outbound Planner
A timely and accurate setting of TOBT is regarded by the Outbound Planner to be the basis of the whole CDM concept and of influence on a stable outbound planning. Other operational factors influencing a stable outbound planning are good weather predictions (influencing runway usage and capacity) and as little runway changes as possible. The Outbound Planner also indicates the current sequencer to be insufficient (Appendix XVII).

Amsterdam Airport Schiphol
Business Analyst
Factors influencing the take-off time predictability are also touched upon in an interview with a Business Analyst and member of the Business Expert team at Amsterdam Airport Schiphol. The factors vary from human-factor related influences to infrastructural improvements. Human-factors influencing the general performance of CDM are regarded to be correct information provision from A-CDM partners at Schiphol (ground handlers) and ANSPs in the network.

For example, ground handlers last-minute updating the TOBT of a flight with one or two minutes are considered as wrong interaction with the system. Ground handlers are being trained on improving their contribution to take-off time predictability. An infrastructural influence is the CPDSP or 'outbound sequencer' which is regarded to responsible for unpredictable calculations of the TSAT (Sub-section 2.6.1) (Appendix XVII).

DNATA – Safety Coordinator
Underlying reasons for late TOBT updates are generated from an interview with a Safety Coordinator at DNATA. The updates are generated due to unexpected turnaround delay which are regarded to be due to late passengers or technical reasons such as a faulty door. It is allowed to load a bag when the passenger has checked-in and forbidden to depart without the passenger and bag travelling together on the same plane. This needs to be taken seriously, thus motivates last-minute changes to the TOBT instead jeopardizing the turnaround delay further when choosing to search for and removing the bag. Other reasons, although rare, are due to urgency such as a donor-heart or kidney or radio-active material. These are generally added shortly before the TOBT.

A turnaround delay might also be caused by starting late due to lack of equipment. A ground handler needs preparation to receive a new aircraft. Many times, there is a lot of mess on the platform. This needs to be removed and new equipment needs to be prepared on the stand. This may be up to 10 freight dollies, 15 to 20 container dollies and 4 to 5 baggage carts (Appendix XVII).

MUAC
Capacity Programmes Manager
The notes in Appendix XVI provides insight into how traffic predictability is experienced from one of the adjacent centres. The Capacity Programmes Manager indicates general improvements in the accuracy of take-off times since the connection of Schiphol to the network. However, although traffic predictability has improved, it is considered not to be perfect yet. The system is influenced in many ways resulting in reduced effectiveness of CDM.

To be more precise, the Departure Planning Information (DPI) messages sent by Schiphol to the Network Manager increases the predictability of traffic departures from airports and en-route. The DPI messages are transformed into ETFMS Flight Data (EFD) which is used by MUAC to predict traffic levels per airspace sector. Simply put, EFD are DPI messages transformed into less accurate traffic patterns. It is based on the most recent Target Take-Off Time (TTOT) sent by Schiphol.

It is identified that take-off time predictability in an early stage is beneficial for departures subject to an imposed take-off slot. If present, it is possible to improve imposed take-off slots. However, airlines need to adjust the flight-plan to the early assigned imposed take-off slot.

Project Manager Traffic Prediction Improvement
When A-CDM was introduced at Schiphol, no significant systematic changes went into force at MUAC. As touched upon in the Literature Review (Chapter 3), the Traffic Prediction Improvement project was applied to departing movements from Schiphol months before.

The goal of the research leading up to the TPI project was to improve traffic prediction through the application of Machine Learning. One of the main motivations was the lack of precision in take-off time predictions as communicated to the network by Schiphol via the Network Manager. Models of several airports are made containing statistics of average taxi-times, active runways, queueing of aircraft in front of the runways and typical Minimum Turnaround Times. The logical was initially applied to Schiphol before A-CDM implementation (Appendix XVII).

The influence of the connection of Schiphol to the TPI model has been significant. Due A-CDM, the quality of unmodified EFD for flight departing from Schiphol has improved. Particularly in the time-window close to the flight plan (EOBT). There is almost no need for the TPI-model but it is still used for inbounds to Schiphol which is useful for long-term traffic forecasts. MUAC knew upfront that a proper A-CDM interface with the Network Manager would cancel the benefits of the TPI model (Appendix XVII).

The model is still useful to enrich EFD data in unexpected situations. For example, last-minute runway changes are sometimes not being communicated, affecting predictability. Although not directly being related to Schiphol, it is noticed that some airports have a ‘quirky way of data management’ influencing the quality in the flow of information towards MUAC (Appendix XVII).

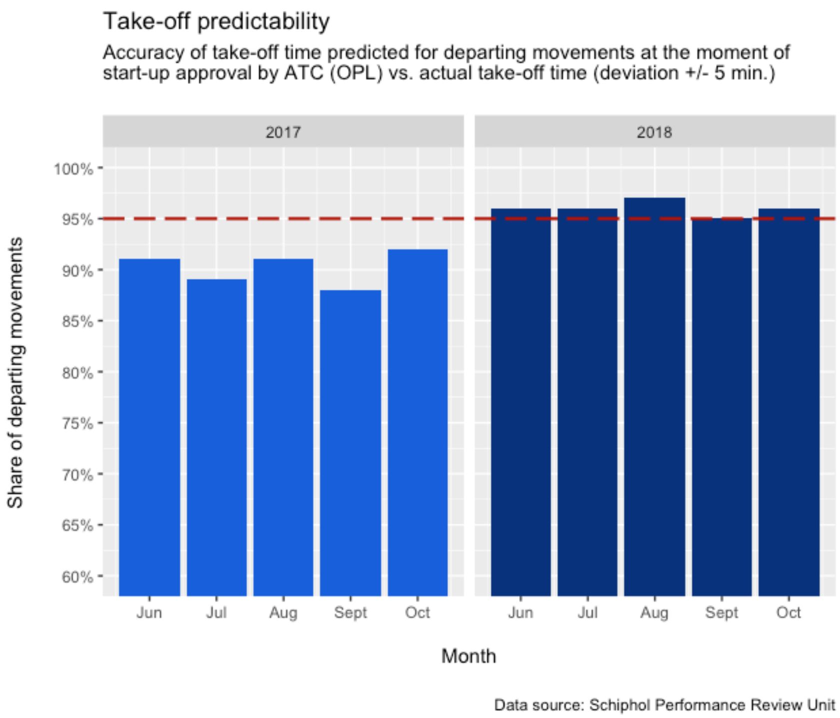
4.2 Data analysis into take-off time predictability

In this section, two perspectives on take-off time predictability are set out. The first analysis considers take-off predictability as published by the Schiphol PRU (Sub-section 4.2.1). In the second analysis, Take-Off Time Error Reduction from the perspective of MUAC is analysed (Sub-section 4.2.2).

4.2.1 Take-off time predictability as published by the Schiphol PRU

Take-off time predictability as calculated and published by the Schiphol PRU is determined by the take-off time predicted for departing movements at the moment of start-up approval by the Outbound Planner. Hereafter, the pilot requests the combined start-up and push-back to the Ground Controller and carries out the taxi-out process until entering the runway threshold and being cleared for take-off by the Runway Controller. This take-off time predicted before the taxi-out process is commenced is compared with the Actual Take-Off Time (ATOT). In case the predicted take-off time is within the allowed deviation of +/- five minutes, the predicted take-off time is regarded to have been predictable.

In the summer season of 2017 (during local-CDM), this was the case for approximately 90% of all departing movements (Graph 1). In the summer season of 2018 (during A-CDM) this KPI performed at or above 95% each month. This is above the monthly target of 95%, which is indicated by the red dashed line.

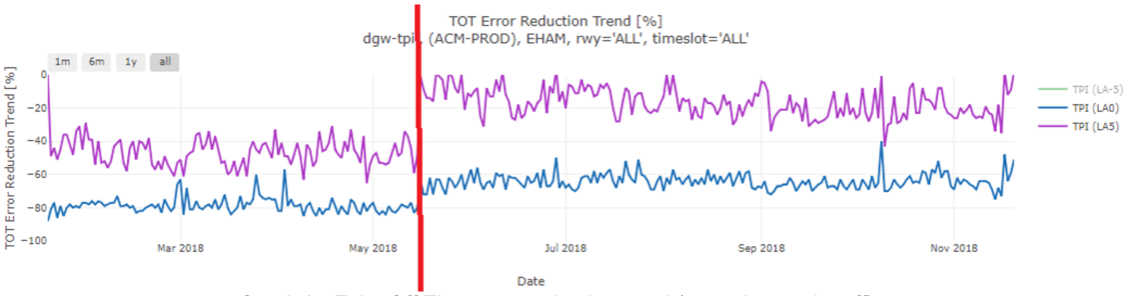


Graph 1 - Take-off predictability (S17 vs. S18)

4.2.2 Take-Off Time Error Reduction Trend by MUAC

Take-Off Time Error Reduction Trend (until t – 5 min.)

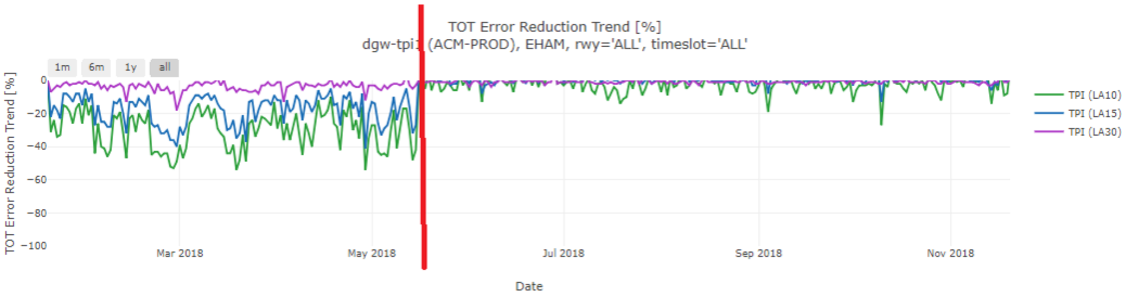
Graph 2 includes the error reduction trend of the TPI model at take-off (LA0) and five minutes earlier (LA5). Although a decrease in error reduction trend is visible in both observations (especially in LA5) error reduction is still present after the connection.



Graph 2 - Take-Off Time error reduction trend (t - 5 min. to take-off)

Take-Off Time Error Reduction Trend (until t – 30 min.)

Graph 3 includes the error reduction trend of the TPI model at ten, fifteen and thirty minutes before take-off. Before the connection, the error reduction trends of LA10 and LA15 are the highest and the error reduction trend of LA30 was hardly present. After the connection, all error reduction trends are hardly present, except for a few outliers in the error reduction trend of LA10.

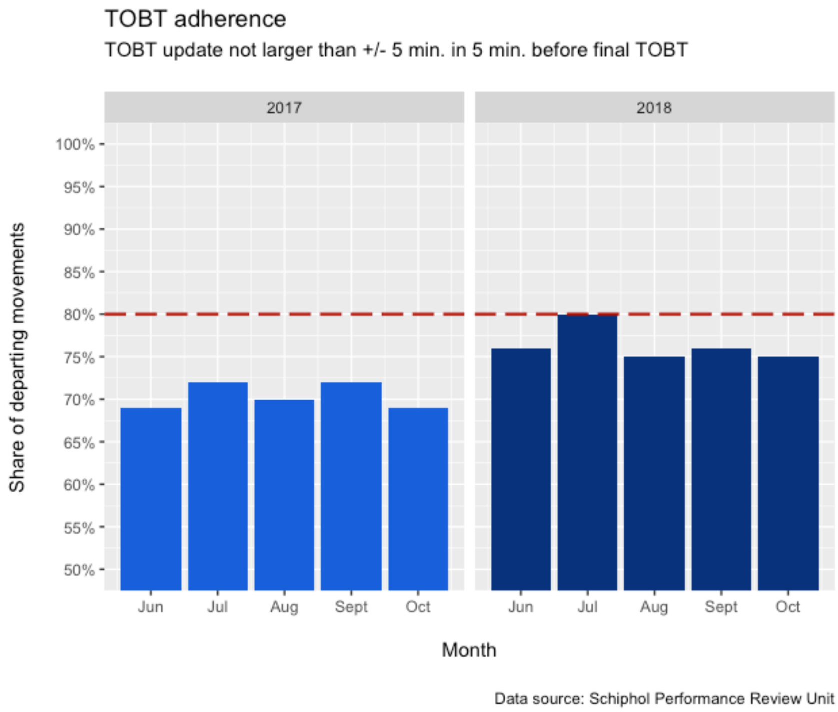


Graph 3 - Take-Off Time error reduction trend (t - 30min. to t - 10min.)

4.3 Adherence to CDM procedures and factors associated to take-off time predictability

TOBT adherence

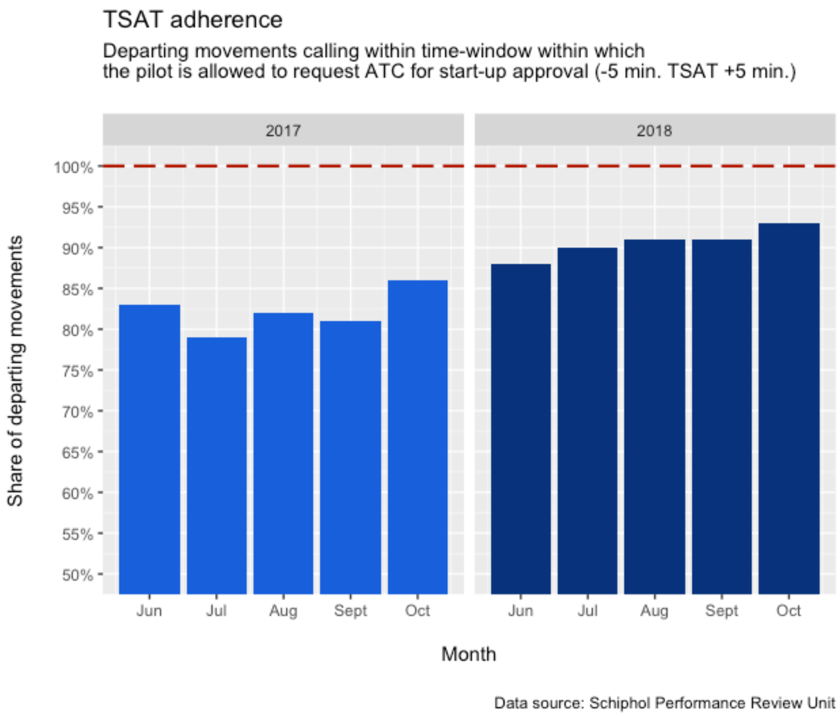
In Graph 4, the adherence to TOBT is visualised for the summer months of 2017 and 2018. It directly influences the take-off time prediction (Figure 1) (Appendix V). It determines the share of departing movements of which a TOBT update in the five minutes before the final TOBT was not larger than +/- five minutes. In 2017 the monthly average was 70% of all departing movements. In 2018 the monthly average was 76% of all departing movements. The target is set at 80% of all departing movements. It is indicated by the red dashed line.



Graph 4 - TOBT adherence (S17 vs. S18)

TSAT adherence

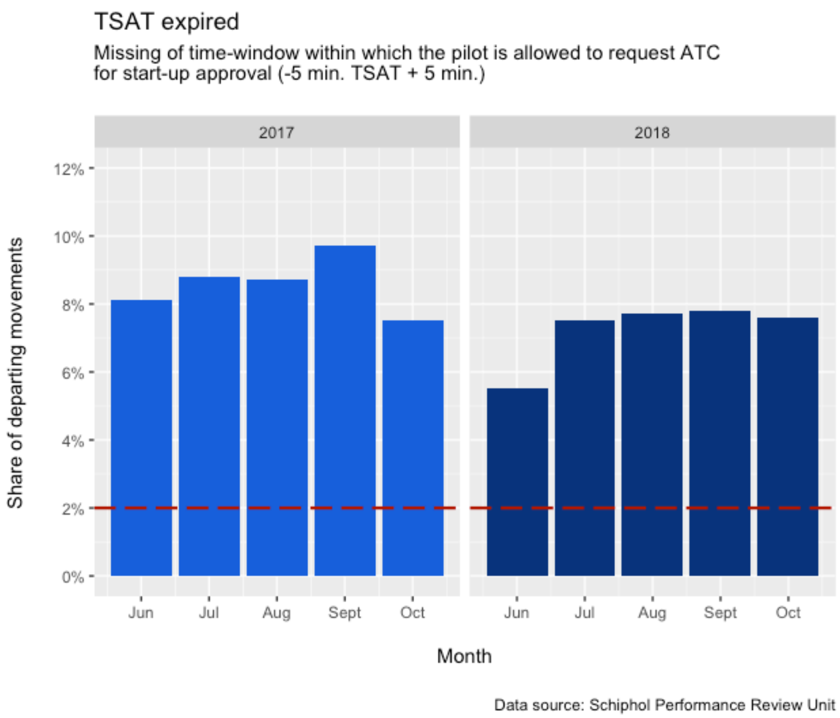
Graph 5 visualises the adherence to the time-window within which pilots are allowed to request the ATC tower controller for approval to leave the parking stand (TSAT window). It is directly related to the first hypothesis which focuses on the adherence to CDM procedures. In the summer months of 2017, the monthly average was 82% of all departing movements. This means that for 18% of all departing movements in the average month, the pilot called too early. The monthly average for the summer season of 2018 is 91%. The target is set at 100% of all departing movements. It is indicated by the red dashed line.



Graph 5 - TSAT adherence (S17 vs. S18)

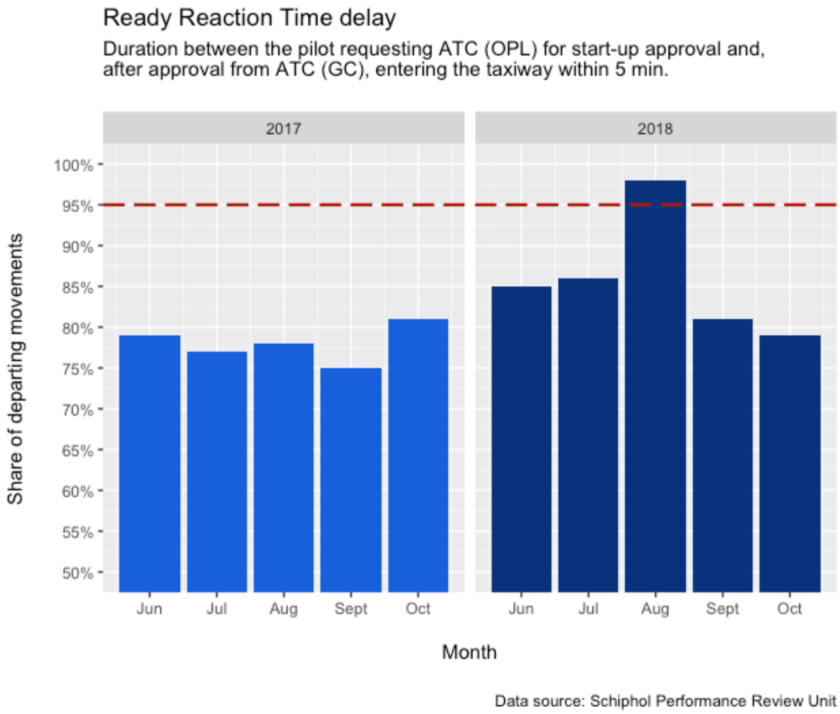
TSAT expired

Cases of which flights missed the time-window within which the pilot is allowed to request the ATC tower controller to leave the parking stand (TSAT window) are visualised in Graph 6. In any of these cases, the pilot is expected to contact its ground handler for a new TOBT. Based on this update, the CPDSP algorithm will calculate a new earliest take-off time which is generally many minutes later. In 2017, the monthly average was 8.6% of all departing movements. In 2018 the monthly average was 7.6%. The target is set at 2%, which is indicated by the red dashed line.



Graph 6 - TSAT expired (S17 vs. S18)

Ready Reaction Time delay
One of the KPIs to determine the efficiency in the outbound flow is the Ready Reaction Time delay. It is defined as the share of departing movements of which the duration between the pilot requesting the first ATC tower controller for approval to leave the parking stand and actual approval from the second ATC tower controller is less than five minutes. This process is visualised in Figure 6 and Figure 7. In the summer season of 2017, the monthly average was 78%. In 2018 the monthly average was 86%. The target is set at 95% of all departing movements. It is indicated by the red dashed line (Graph 7).



Graph 7 - Ready Reaction Time delay (S17 vs. S18)

Start-up delay
Another key performance variable it the start-up delay. It is used as indicator to determine the delay caused by idle time between the aircraft being ready for departure from the parking stand (TOBT) and the time at which it is allowed to request approval to leave the parking stand. It is calculated by detracting the final TOBT from the final TSAT. It is defined as the share of departing movements with a start-up delay less than five minutes. In the summer of 2017 the monthly average was 60% of all departing movements. In the summer of 2018 the monthly average was 65% of all departing movements. The target is set at 75%, which is indicated by the red dashed line (Appendix X).

Outbound punctuality
Critical to the Aircraft Operators is the outbound punctuality. It is defined as the share of departing movements with a departure delay of fifteen minutes or less. In 2017 and 2018 the monthly average was 65%. This KPI does not have a target (Appendix X).

Conclusion
To conclude, in this chapter the take-off time predictability and associated factors were analysed. In Section 4.1, perspectives of various CDM partners provided insight into how take-off time predictability and (especially) its associated factors were perceived after the connection. Topics included the occurrence of unwanted human influence in CDM updates, outdated or lack of CDM infrastructure and contextual complexities of Schiphol inducing unpredictable scenarios in operational planning shortly before take-off which affects plan stability. Also touched upon was insight into the effect of the connection on the TPI model at MUAC, which provided insight into take-off time predictability at several points in the outbound flow before take-off from Schiphol.

Section 4.2 and 4.3 included data analysis into take-off time predictability and associated factors. In Section 4.2, take-off time predictability was analysed at fixed points in the outbound flow and from the perspectives of Schiphol and MUAC. Based on the take-off time prediction at Schiphol shortly prior to the taxi-out process is commenced, more than 95% of departing movements in the summer season of 2018 took off within a deviation of -5/+5 minutes which is regarded as predictable. The perspective of MUAC was based on the amount of error reduction carried out by the TPI model for departing movements from Schiphol and visualised for specific times before take-off. Clear differences in the amount of error reduction before and after the connection of Schiphol is identified, especially in the phase between thirty and ten minutes before take-off.

In Section 4.3, the associated factors (KPIs) were analysed for the summer seasons of 2017 and 2018. Where applicable, the performance target related to the KPI was included. KPIs focused on the conformance of CDM partners at Schiphol

Insights from these analyses will be elaborated upon and applied in determining the effectiveness of A-CDM and its relation to local-CDM, from which the operational benefits will be distilled (Chapter 6).

5 Non-compliance to imposed take-off slots in relation to similar airports

This chapter explains the second KPI (compliance to imposed take-off slots) used to determine the effectiveness of A-CDM in relation to Schiphol. Insight is generated through qualitative research (Section 5.1) and quantitative research (Section 5.2).

5.1 Perspectives of CDM partners on non-compliance to imposed take-off slots

ATC the Netherlands

Outbound Planner

The Outbound Planner indicates decreased non-compliance to take-off slots to be due to various factors. A system-change has resulted in generally no changes in imposed take-off slots during the taxi-out phase. A procedural change is the standardisation of the same TSAT window for all departing movements. Before the connection, departing movements subject to an imposed take-off time had more flexibility with a TSAT window of -5/+10 minutes. Since the connection, this is standardised to the regular -5/+5 minutes. The third factor is the Outbound Planners being stricter in handling departing movements subject to an imposed take-off time. For example, calls with the NMOC are made in case an imposed take-off slot is likely to be missed (Appendix XVII).

Flow Management Position

Graphs provided by the Flow Management Position indicate a clear reduction in the exceedance of the 'Slot Tolerance Window' (STW) (Appendix). This is the window around the imposed take-off time (-5/+10 minutes), forming the imposed take-off slot (Appendix XVII).

ATM Procedures

The member of the ATM Procedures department also indicates the standardization in the TSAT time-window. It indicates that prior to the connection and with local-CDM, this window was only applicable to non-regulated flights (those not subject to an imposed take-off slot) at Schiphol. Regulated flights were using a TSAT time-window of -5/+10 minutes, which is equal to the Slot Tolerance Window around the imposed take-off time (forming the imposed take-off slot). This change is indicated to be an enabler for improved slot adherence (Appendix XVII).

Prior to the connection, the Flow Management Position at ATC the Netherlands is regarded as the focal point between Schiphol and the Network Manager Operations Centre (NMOC) for air traffic flow management purposes. The connection has added a voice communication link between the Schiphol ATC tower and Network Manager Operations Centre (NMOC). As regulated flights are forbidden to take-off outside the STW, this communication link is mainly used in case a flight is expected to be unable to depart inside its STW and therefore a slot extension is required. The advantage of this new voice connection is the ability to solve operational issues in a direct way (Appendix XVI).

MUAC

Capacity Programmes Manager

At MUAC, it is underlined that ATFM-slots (imposed take-off slots) are assigned by the Network Manager which need to be adhered to. When the probability is high that an imposed take-off slot will be missed, which might be due to unexpected turnaround delay, a new imposed take-off slot is assigned. In many cases, this take-off slot is much later than the previous one and might be referred to as a 'slot-penalty'.

EUROCONTROL

Airport Unit

The EUROCONTROL Airport Unit indicates the measurement of adherence to imposed take-off slots is performed by airports themselves and EUROCONTROL. In general, a sustained increase in compliance is visible in the three years after the connection with the network. The amount of improvement differs from airport to airport but airports that were already performing well also showed small increases.

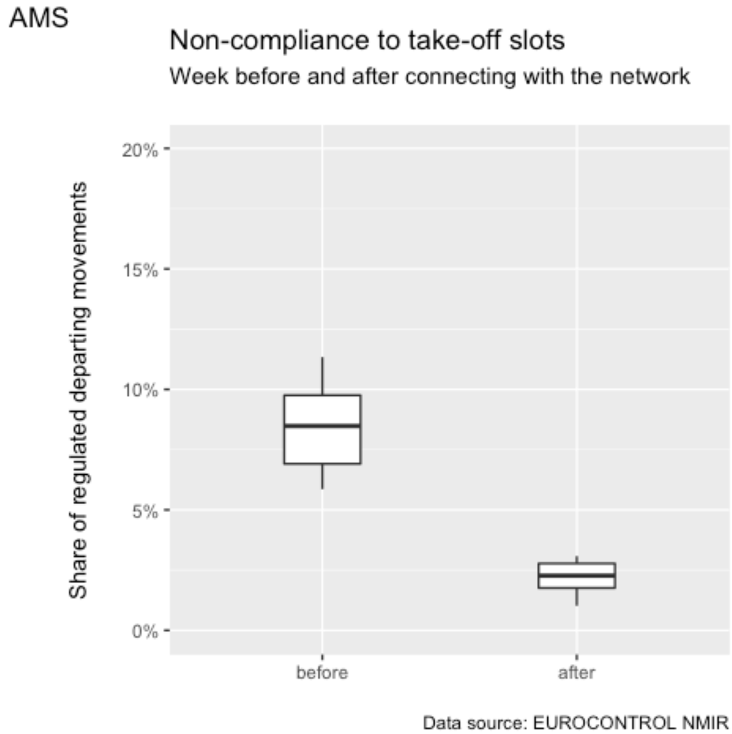
More improvements of ATFM-slots are related to more accurate information (DPI messages) since the connection of Schiphol and due to the True Revision Process[7] at EUROCONTROL which runs every minute in 2018 instead of every five minutes in 2017.

5.2 Data analysis into non-compliance of Schiphol to imposed take-off slots

5.2.1 Non-compliance of Schiphol and similar major-hub airports to take-off slots assigned by the Network Manager

For Schiphol (AMS), London Heathrow (LHR), Frankfurt am Main (FRA) and Paris Charles de Gaulle (CDG), two comparisons are carried out. The first is the trend in non-compliance between S14 and S18, while the second comparison focusses on non-compliance in the week before and after the connection of the respective airport.

Amsterdam Airport Schiphol (AMS)
Graph 9 clearly shows multiple trends between S14 and S18. As indicated by the two grey horizontal lines, Schiphol ran local-CDM in S16 and S17. S18 was the first summer season in which Schiphol ran A-CDM. Between S17 and S18 a large drop in non-compliance is visible. Also, similar to Appendix XIII, the year-on-year increase in regulations is clearly visible. Outliers of non-compliance visible in June, September and October of S17 are not present in S18 with all daily values being below 10% for all five months. Graph 8 visualises daily non-compliance in the week before and after the connection with the Network Manager. Both standard deviation as well as the mean improved.

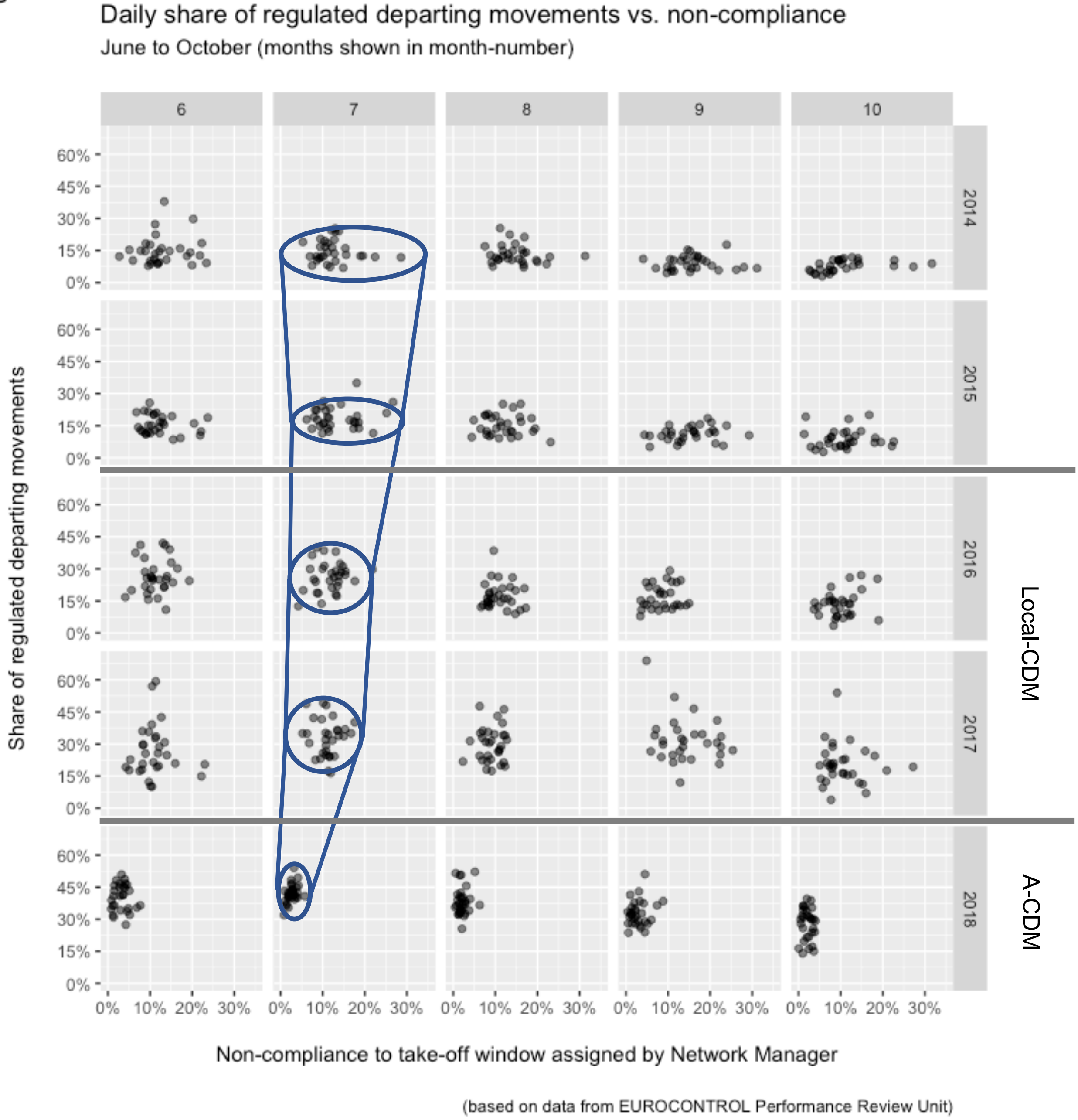


Graph 8 - Non-compliance of Schiphol to take-off slots in the week before and after connecting with the Network Manager

Non-compliance	Before	After
Mean	8.4%	2.2%
Standard deviation	2.0 %	0.8%

[7] The automatic mechanism that routinely attempts to improve the slot of allocated flights (EUROCONTROL, 2018)

AMS



Graph 9 - Non-compliance to take-off slots vs. share of regulated departing movements in the summer season (S14 - S18, AMS)

London Heathrow (LHR)
London Heathrow connected with the Network Manager in June 2013. Comparing the week before and after the connection of London Heathrow with the Network Manager (Appendix XV), the non-compliance slightly increased from 15.4% to 16.9%.

The same type of graph as Graph 9 is created for London Heathrow (Appendix XI). Although its year of connection is out of range for the visualisation, a special effect is visible in the daily non-compliance observations. Comparing S14 and S15 a large drop from approximately 15% to approximately 4% is visible. Between S17 and S18 this non-compliance improved even more towards approximately 2.5%.

Non-compliance	Before	After
Mean	15.4%	16.9%
Standard deviation	3.6%	6.5%

Paris Charles de Gaulle (CDG)
Paris Charles de Gaulle connected with the Network Manager in November 2010. Comparing the week before and after the connection with the Network Manager (Appendix XV), the non-compliance reduced from 15.6% to 9.2%.

The same type of graph as Graph 9 is created for Paris Charles de Gaulle (Appendix XI). Its year of connection is out of range for the visualization. Comparing S17 and S18, a reduction in non-compliance is visible but not large in size.

Non-compliance	Before	After
Mean	15.6%	9.2%
Standard deviation	5.2%	3.7%

Frankfurt am Main (FRA)
Frankfurt am Main connected with the Network Manager in February 2011. Comparing the week before and after its connection (Appendix XV), non-compliance increased from 5.4% to 8.5%.

The same type of graph as Graph 9 is created for Frankfurt am Main (Appendix XI). Its year of connection is out of range for the visualization. From S14 onwards, non-compliance at Frankfurt am Main remained constant at approximately 7.5% with an improvement visible between S17 and S18.

Non-compliance	Before	After
Mean	5.4%	8.5%
Standard deviation	2.5%	5.1%

Conclusion
To conclude, in this chapter the non-compliance to imposed take-off slots were analysed for Schiphol and three similar airports. Section 5.1 provided insight into the importance of complying to imposed take-off slots and the measures taken by CDM partners at Schiphol to increase compliance. In Section 5.2, data analysis provides insight into the non-compliance of Schiphol and similar airports in the week before and after the connection and the compliance over the last four summer seasons. For Schiphol, unlike the similar airports, a large reduction in non-compliance is visible. Comparing the trends in non-compliance over the last four summer seasons among the similar airports indicates clear difference in non-compliance by Schiphol since the introduction of A-CDM which is not visible in the performance of the similar airports.

Insights from this analysis will be elaborated upon and applied in determining the effectiveness of A-CDM and its relation to local-CDM, from which the operational benefits will be distilled (Chapter 6).

6 Effectiveness of A-CDM at Schiphol and operational benefits related to plan stability

In this chapter, insights from analysis into take-off time predictability (Chapter 4) and non-compliance to imposed take-off slots (Chapter 5), are applied to determine the effectiveness of A-CDM at Schiphol. Based on the effectiveness of A-CDM at Schiphol (Section 6.1) and A-CDM in relation to local-CDM (Section 6.2), the operational benefits related to plan stability are determined (Section 6.3).

6.1 Effectiveness of A-CDM at Schiphol

6.1.1 Take-off time predictability and influencing factors

Two analyses are carried out to gain insight into take-off time predictability. The first analysis is based on data from the Schiphol PRU monthly reports. It indicates each month in the summer season of 2018 (during A-CDM) to have scored at or above the target of 95%. This means that for more than 95% of all departing movements in the given month, the predicted take-off time was regarded to be predictable. The moment of prediction in the outbound flow is shortly before the taxi-out phase. The exact explanation can be found in the respective analysis (Section 4.1). This performance is effective in terms of A-CDM at Schiphol as take-off time predictability is one of the most important objectives of local-CDM and A-CDM. Another substantiation for its effectiveness is the consistent exceedance of the target.

The second analysis is based on the output of the Traffic Prediction Improvement (TPI) model in operation by MUAC. Since the connection of Schiphol to the network, the output of the model indicates almost no Take-Off Time Error Reduction to be taking place at thirty, fifteen and ten minutes prior to take-off. This observation is effective in terms of A-CDM at Schiphol as take-off time predictability is one of the primary objectives in CDM.

The take-off time predictability in the five minutes before take-off and influencing factors of take-off time predictability are described in Sub-section 6.1.3.

6.1.2 Non-compliance to imposed take-off slots in relation to similar airports

Data analysis indicates the non-compliance of Schiphol to imposed take-off slots to be low. The report considering the first hundred days since the connection indicates a consistent compliance of approximately 96% between the June 2018 and August 2018. This means a non-compliance of 4%. The graphs provided by the Flow Management Position indicates a monthly average of 5.4% in non-compliance in the summer season of 2018.

Data analysis comparing Schiphol's non-compliance in the summer season of 2018 with similar airports indicates Schiphol (together with London Heathrow) to be a top-performer in this KPI. Frankfurt Airport and Paris Charles de Gaulle also score below the mandatory 20% in non-compliance norm although higher at approximately 7.5%. All non-compliance results related to Schiphol during A-CDM are far below the annual norm of 20% (a norm of 80% in compliance) as laid down in EU regulation. For this reason, this KPI supports the effectiveness of A-CDM at Schiphol.

6.1.3 Challenges in A-CDM effectiveness

Since the connection of Schiphol to the network, the take-off time predictions in the five minutes before take-off and at take-off are prone to error reduction by the TPI model. Qualitative research related to the Outbound Planner and the Project Manager Traffic Prediction Improvement, indicates this phenomenon to be due to last-minute runway changes. If correct, this is not effective in terms of A-CDM at Schiphol as take-off time predictability is one of the primary objectives of CDM.

Ground handling updates
The CDM updates from the ground handlers indicate predictions of when the aircraft will be 'ready' (TOBT). In qualitative research, the Outbound Planner regards a timely and accurate setting of these updates to be the basis of the whole CDM concept and of influence on a stable outbound planning. The AAS Business Analyst indicates these updates to be prone to incorrect provision of information in CDM. It also indicates it to be a source for instability of the CPDSP algorithm, which directly influences the take-off time predictability (Section 4.1).
As touched upon in Chapter 4 (TOBT adherence), this performance scores a monthly average of 76% which is below the 80% target. This is also the case in the report considering the first hundred days since the connection. Due to the importance of the ground handling updates (TOBTs) and consistent performance below the target, the TOBT updates are regarded to be challenging A-CDM effectiveness at Schiphol.

Other factors challenging A-CDM effectiveness at Schiphol are indicated to be in the TSAT expired, TSAT adherence, start-up delay and Ready Reaction Time delay (Section 4.3). All perform below their respective target during A-CDM. Also, as already recommended in the 100-day analysis to be investigated, the voice communication between the ATC tower controllers at Schiphol and the NMOC is regarded to increase work complexity.

6.2 Effectiveness of A-CDM in relation to local-CDM

6.2.1 Take-off time predictability and influencing factors

Comparing the two analyses of take-off time predictability (Section 4.2), it is clear that A-CDM is more effective in relation to local-CDM. The 100-day analysis indicates more than two minutes in predictability improvement in the last sixty minutes, and especially the last thirty minutes, before take-off. On a disturbed day this increase is identified to be even larger with more than 5 minutes predictability improvement in the two hours, and especially the final forty minutes, before take-off.

The first analysis using information derived from the Schiphol PRU (Sub-section 4.2.1) reports indicates an improvement between the summer season of 2017 and 2018. During local-CDM the reports indicate the KPI to have scored consistently under the target with a monthly average of 90%. This means an increase of six percentage points to the monthly average of take-off time predictability during A-CDM (Graph 1).

The second analysis consisting of the Take-Off Time Error Reduction by the MUAC TPI model (Sub-section 4.2.2) indicates a large drop at the timestamps of thirty, fifteen and ten minutes before take-off (Graph 3). Qualitative research indicates this drop to have been expected when Schiphol would start sharing DPI messages with the Network Manager (Section 4.1).

The same analysis includes Take-Off Time Error Reduction at the timestamps of five minutes before take-off and at take-off (Graph 2). For these timestamps an improvement is visible between local-CDM and A-CDM, although not as large as observed in the timestamps of thirty to ten minutes before take-off.

Considering the two analyses considering take-off time predictability described above, A-CDM is more effective in relation to local-CDM.

Comparing the monthly averages of the summer of 2017 and 2018, performance improvements in almost all KPIs are indicated. The performance improvements per CDM KPI are summarized in Table 6. All improvements contribute to the fact that A-CDM is more effective in relation to local-CDM.

Table 6 - Monthly average improvements in CDM KPIs (S17 vs. S18)

CDM KPI	*Target*	S17	S18	YoY (%-point)
TOBT adherence	*80%*	70%	76%	+ 6
TSAT expired	*2%*	8.6%	7.2%	-1.4
TSAT adherence	*100%*	82%	91%	+ 8
Start-up delay	*75%*	60%	65%	+ 5
Ready Reaction Time delay	*95%*	78%	86%	+ 8
Take-off predictability	*95%*	90%	96%	+ 6

In the 100-day analysis, the TOBT adherence and TSAT expired were mentioned not to have changed while the data analysis indicates improvements in both KPIs.

The operational benefits related to the improvements in Table 6 are provided in Section 6.3. It contains operational benefits related to increased plan stability of which take-off time predictability is considered as main KPI and supported by its influencing factors listed in Table 6.

6.2.2 Non-compliance to imposed take-off slots in relation to similar airports

Qualitative analysis indicates various reasons for reduced non-compliance to imposed take-off slots. The Outbound Planner and member of the ATM Procedures department at ATC the Netherlands both indicate the standardisation in TSAT window (+/-5m.) for all departing movements.

Where the Outbound Planner only indicates a stricter handling of departing movements with an imposed take-off time, the member of the ATM Procedures department also indicates the introduction of a voice communication between the ATC tower and the NMOC since the connection of Schiphol with the Network. It identifies its benefit of being able to solve operational issues in a direct way. Qualitative research related to MUAC underlines the importance of this communication, as missing an imposed take-off time generally results in a slot-penalty.

In Section 6.1, the non-compliance of Schiphol to take-off slots in relation to similar airport is indicated to be low during A-CDM. When compared with local-CDM, the amount of non-compliance related to Schiphol has reduced. Analysing similar airports for the week before and after the connection of each airport indicates that Schiphol improved its performance with a larger amount than similar airports. This was discussed during the conference call with the EUROCONTROL Airport Unit which identified that overall the compliance of airports improves after implementing A-CDM and if not, the compliance was already high. The 100-day analysis also indicated the connection to have a positive effect on the compliance to imposed take-off slots.

6.2.3 Challenges in determining A-CDM effectiveness in relation to local-CDM

Some KPIs challenge the effectiveness of A-CDM over local-CDM. For example, the share of regulations (departing movements subject to an imposed take-off time) has increased during A-CDM. Data analysis indicates this to have been the case for similar airports (Appendix XIII). The monthly average of added stand-delay due to these regulations has been maintained at approximately ten minutes. It is likely that with local-CDM, this level of regulations and the associated added stand-delay would have been the same or even higher. Discussions with various CDM partners indicates this to be complex to substantiate. For example, some mention the requirement of a ‘time-machine’ in doing so.

Another factor challenging the effectiveness of A-CDM in relation to local-CDM is the CPDSP algorithm. In qualitative research, various CDM partners at Schiphol identify the outbound sequencer to be outdated. This was already the case during local-CDM as identified by Wouters (2018) and de Jong (2018). As explained in Figure 1, the CPDSP algorithm is responsible for calculating the Target Take-Off Time (TTOT). As the imposed take-off slots are calculated with the TTOT as primary value, an outdated or inefficient CPDSP algorithm is harmful to both local-CDM and A-CDM effectiveness.

6.3 Operational benefits related to plan stability

Section 6.2 indicates A-CDM to be more effective in terms of the two main KPIs of take-off time predictability (and influencing factors) and non-compliance to take-off slots in relation to similar airports. Sub-section 6.3.1 lists the operational benefits related to increased take-off time predictability. Sub-section 6.3.2 does the same for reduced non-compliance for imposed take-off slots in relation to other airports.

6.3.1 Operational benefits of increased take-off time predictability and associated factors

Based on analysis into take-off time predictability (Chapter 4), the level of plan-stability of Schiphol towards the network can be determined. Not only has plan-stability towards the network improved due increased transparency, but also due to procedural changes such as the freezing of the imposed take-off time during the taxi-out process. The largest improvements in plan-stability are in the phase of thirty to ten minutes before take-off. Another improvement, although smaller in size, is in the five minutes before and at take-off.

The associated benefit of this increase in plan-stability is the improved effectiveness of the dynamic capacity calculations performed by MUAC. Each fifteen minutes, MUAC organizes its airspace sector differently to ensure optimal spreading of workload among the available staff. In turn, these capacity calculations based on more accurate take-off time predictions directly influence the amount of departing movements with an imposed take-off slot and the associated duration. This reduces the potential for snow-balling effects to occur on the ground at Schiphol, along with the associated delay propagation.

This improvement is beneficial to each CDM partner. Theoretically, each partner can expect increased resource utilization due to reduced stand-delay induced by unpredictable traffic flows from Schiphol into the network. For KLM, this is beneficial in terms of its network product. In case of stand-delay, a connecting flight at an outstation may be missed. For gate-management at Schiphol, reduced snow-balling effects reduce the need for frequent manual changes to the original gate-planning. For ATC the Netherlands, in case inbound holding on the ground induces inbound holding in the air, a more expeditious flow of traffic is realized. Ground handling agencies benefit from reduced stand-delay due to imposed take-off times by being able to allocate staff on airside to a new aircraft earlier.

On the long term, more predictable flows of departures from Schiphol may reduce the amount of conservative ATFCM measures which will strengthen the benefits described above.

6.3.2 Operational benefits of reduced non-compliance to imposed take-off slots

The operational benefits related to reduced non-compliance are considered to be improved functioning of the Network Manager’s function, which is to stabilise air traffic flows throughout the European ATM system and thereby avoid overloading airspace and airports.

6.3.3 *Operational benefits of improvements in factors associated to take-off time predictability*

Other increases in effectiveness are visible in the KPIs related to the factors influencing take-off time predictability. The operational benefit related to increased TOBT adherence supports the operational benefits related to the predictability of take-off times described in the paragraph above.

The reduction in TSAT expired throughout the summer season of 2018 is beneficial to the runway utilisation as each case of TSAT expired directly results in scarce runway capacity to be lost. This is also beneficial in avoiding 'slot-penalties' which are imposed to flights not meeting the imposed take-off slot. Indirectly, this reduces the potential for reactionary delay or 'snow-balling' effects.

The increased share of pilots adhering to the TSAT window is beneficial for the Outbound Planner who in return experiences reduced unnecessary Radio Telecommunication due to pilots requesting the tower before the TSAT window, thus too early.

The increased share of departing movements with a difference between the TOBT and TSAT (start-up delay) being less than five minutes is an indicator for reduced idle time for the airline and ground handling agencies at the parking stand. The same is applicable to the Ready Reaction Time delay. In theory, this supports one of the main goals of CDM which is the increased utilisation of resources.

7 Conclusion and Discussion

This chapter contains the Conclusion of the research (Section 7.1) after which the conclusions are interpreted by the researcher and discussed in the Discussion (Section 7.2).

7.1 Conclusion

Increasing air traffic levels in Europe and throughout the world have caused the European ATM system to become congested. Measures taken by the EUROCONTROL Network Manager in the operational phase to enable stable flows of traffic (imposed take-off slots) requires predictable and accurate planning information from airports. Since May 2018, Schiphol has implemented A-CDM which means that it connected with the Network Manager and shares accurate operational planning information. The following main question remained:

What are the operational benefits of Schiphol's connection with the Network Manager?

To answer the main question, the research:

1. Identified changes made since the connection
2. Determined the effectiveness of A-CDM at Schiphol
3. Determined the effectiveness of A-CDM in relation local-CDM

The changes related to the connection of Schiphol with the Network Manager are found not to only consist of the technical side of the connection but also in procedural changes and human factors. A-CDM at Schiphol is found to be effective in terms of take-off time predictability and non-compliance to take-off slots imposed by the Network Manager, although factors associated to take-off predictability still require performance improvements.

The research also found A-CDM at Schiphol to be more effective than local-CDM. Since A-CDM, the take-off time predictability has improved from both the perspective of Schiphol and the CDM partners in the network. Throughout the summer season after the connection, with more than 95% of departing movements to have taken off with an accurate take-off time prediction, the take-off predictability KPI surpassed its target. During A-CDM Schiphol also performed better in terms of non-compliance to imposed take-off slots. Although the level performance was already well beneath the norm of 20%, Schiphol's improvement directly after the connection can be regarded as exceptional.

The research also considered three hypotheses. Although the research does not statistically test the hypotheses, it contains qualitative and quantitative substantiation. The first hypothesis tested the increased adherence of CDM partners at Schiphol to CDM procedures, which is validated through data analysis. The second hypothesis tested the improved allocation of imposed take-off slots due to the sharing of data. This hypothesis is validated through qualitative research. The third hypothesis tested an increase of plan stability in the operational phase for CDM partners in the network. This hypothesis is validated by interviews and data analysis.

To conclude, the operational benefits related to Schiphol's connection with the Network Manager are approached based on the effectiveness of A-CDM in relation to local-CDM. Benefits on the network-side include improved spreading of workload among ATC controllers in adjacent centre MUAC. Improvements in CDM KPIs related to the Schiphol outbound flow are indicated and related to a potential reduction in inbound holding, reduced unnecessary Radio Telecommunication load for ATC tower controllers and increased utilisation of the available runway capacity at Schiphol.

7.2 Discussion

Validity of the research methodology
The research applied two main KPIs to determine effectiveness of A-CDM and A-CDM in relation to local-CDM, from which the operational benefits were distilled. These two KPIs, in combination with KPIs related to influencing factors and the combination of both qualitative and quantitative research methods has generated a quite complete view on the effects of the data connection. It is clear that not only the data connection itself has generated the effectiveness of A-CDM in relation to local-CDM and the associated operational benefits.

Interesting research findings
Take-off time predictability and associated factors
One of the most interesting findings of the research is the output of the MUAC TPI model. It clearly indicates the positive effect of transparency generated by the connection of Schiphol with the Network Manager.

Compliance to imposed take-off slots in relation to similar airports
The compliance to take-off slots by Schiphol is high in relation to the other airports. This is due both the data connection (more feasible take-off slots) as well as more effort by ATC tower controllers and KLM OCC staff communicating more frequently with the NMOC. These efforts should not be overlooked as they increasingly add to workload of operational staff. The implementation of the E-Helpdesk and integration into the Schiphol tower (as identified in Appendix XVI) would be beneficial in reducing the workload for both tower controllers and NMOC operational staff. Especially with increasing regulations to be expected during the summer-season of 2019.

Effectiveness of A-CDM and A-CDM in relation to local-CDM
With KLM as one of the most punctual airlines in the world, it is personally regarded to be strange that the Outbound Punctuality is not subject to a target. With punctuality decreasing along with plan stability over the previous years, adding a target could add focus for the CDM partners.

Another large influence in the effectiveness of CDM is general is the CPDSP algorithm.

Follow-up research
It was advised not to consider adverse scenarios in the scope of this research, although in hindsight this would add valuable insight. As included in research on A-CDM benefits as performed by EUROCONTROL (2016), the amount of departures within a specific time period after an adverse scenario would be interesting. The more realistic imposed take-off slots since A-CDM at Schiphol would play a large role in this analysis.

8 Recommendations

The main recommendation is to consider the take-off time predictability as the main KPI in continuous operational improvement of A-CDM effectiveness.

Timely communication and reduction of last-minute runway changes
The predictability of last-minute runway changes should be improved and the amount of changes should be reduced as much as possible. These last-minute changes should be integrated into the operational outbound planning. These unpredictable events should be considered in the testing phase of the new outbound sequencer. This would further improve the take-off time predictability for CDM partners in the network such as MUAC, thus support operational plan stability. As the Target Take-Off Time calculation directly influences the TSAT, the increased runway predictability would also improve the stability of the TSAT calculations which would in turn also provide operational plan stability for CDM partners at Schiphol.

Maintain current level of non-compliance to imposed take-off slots
The non-compliance is already far below the annual norm of 20% (a compliance norm of 80%). Also, in relation to similar airports, Schiphol is a high-performing airport on this KPI. Therefore, the level of non-compliance by Schiphol to take-off slots must be maintained at the current level and further improvement should not be a short-term priority. Instead, efforts should be put into relieving the efforts of ATC tower controllers to request changes to the NMOC on imposed take-off slots for last-minute delayed departures.

It is recommended to carry this out by implementing the E-Helpdesk for ATC staff such as the ATC tower-controllers and the Flow Management Position. As requests by A-CDM airports are expected to be prioritized over airports not running A-CDM, this would further increase the effectiveness of A-CDM at Schiphol. The associated benefit would be more flexibility in the outbound planning in relation to airports not running A-CDM. This would be beneficial in terms of runway utilisation. In time, the integration of the (voice) communication with the NMOC into the consoles of the ATC tower should be carried out to reduce work complexity for ATC tower controllers.

Other support for A-CDM effectiveness at Schiphol
As identified in the conference call with the EUROCONTROL Airport Unit, post-operational performance monitoring is highly important for continuous improvement of A-CDM after implementation. Performance of A-CDM KPIs such as TOBT and TSAT adherence should be made competitive by publishing the performance-trends per Main Ground Handling Agency or Aircraft Operator. This has been proven to be effective in A-CDM improvement at London Heathrow. It is already carried out by the Schiphol PRU although without performance trends over time. Next to the performance monitoring of A-CDM processes at Schiphol such as the TOBT and TSAT adherence, network-performance should be included to provide the sector partners with insight into network effects on operational performance at Schiphol.

In the years ahead, Schiphol aims to improve punctuality while also improving plan stability. In doing so, sector-wide performance monitoring should include a target similar to other A-CDM KPIs. This would make the continuous improvement of punctuality a higher priority.

Next to post-operational analysis, infrastructural developments supporting A-CDM effectiveness should be carried out short-term. Examples are the CDM screens and CDM mobile application as identified by the interview with the AAS Business Analyst (Appendix XVII). Further training of operational staff on what-if scenarios in A-CDM would also support its effectiveness.

Further research into A-CDM effectiveness and related operational benefits
As carried out by EUROCONTROL (2016), research should be carried out into the number of departures within (for example) an hour after the departure flow was temporarily suspended. This would bring more light to the benefit of more feasible imposed take-off slots since A-CDM at Schiphol. Also, collaboration with CDM partners in the network would improve the situational awareness by CDM partners at Schiphol of Schiphol's influence on network-stability.

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Appendix

I. Reflection

Similar to prior and fellow KDC CoE researchers, the STARR method is applied to reflect on the research. It reflects on primary research skills and the SCRUM and bi-weekly sprint sessions. The STARR method consists of a description related to the Situation, Task, Action, Result and Reflection.

Primary research skills

The research consisted of a wide range of research activities. Qualitative research consisted of interviews and observations of operational working environments. Quantitative research included personally challenging data analysis and visualisation using the programming language R in the Integrated Development Environment R Studio. The following information is related to primary research skills gained in research activities of both qualitative and quantitative research activities.

Situation

The KDC main stakeholders requested research into the operational benefits in relation to the connection with the EUROCONTROL Network Manager (A-CDM). It was commenced a couple of months after the actual connection, which allowed some time to pass by for medium-term post-operational data analysis purposes.

Task

The main objective or ‘task’ of the research was providing insight into the operational benefits. Especially the perspective of the network was regarded to be valuable to CDM partners at Schiphol. Similar to prior KDC CoE research related to CDM, both qualitative and quantitative research would be necessary to form coherent research findings.

Action

A couple of weeks into the research it was decided to research the effectiveness of A-CDM since the connection from which the operational benefits were to be distilled. Also, a focus on plan stability was chosen to foster the multi-stakeholder discussion of operational benefits.

Qualitative research was gained through a variety of sources. Examples are feedback from KDC main stakeholder representatives and colleagues at the bi-weekly sprint reviews, training manuals for ATC operational staff, cold-calling and mailing those physically distanced to Schiphol, visiting MUAC, a conference call with A-CDM experts at the EUROCONTROL Airport Unit, Aviation Academy alumni at AAS and ATC the Netherlands, a recent colleague at DNATA, new contacts gained by way of an A-CDM workshop, contacts gained through a symposium at EUROCONTROL in Brussels and even informal chats with ATC controllers while climbing the dunes of the Dutch coast in the middle of one of the running events regularly organized by ATC the Netherlands.

Information related to qualitative research was also gained through a variety of sources. Examples are graphs resulting from qualitative research (Appendix IX and XII), public and semi-public data sources such as the Performance Review Units of EUROCONTROL and AAS and data visualisations from EUROCONTROL and AAS.

Various qualitative research methods such as structured or unstructured interviews or observations were applied to consider different types of A-CDM stakeholders. Also, at the end of the research qualitative research outcomes were reviewed and validated for publication purposes to protect the privacy of those sharing their personal perspectives and representing an organization.

Result
The large sum and variety of collected information created valuable insights which took some time to digest and organize based on the research sub-questions. This is reflected in the research as independent sections for analyses related to the airport (take-off time predictability) and network (non-compliance to imposed take-off slots).

Based on personal skills and the time available I think the report provides quite a complete view on the A-CDM 'playing field' related to Schiphol since the connection with the network by combining both airport and network perspectives. Indications for operational benefits are present although their quantification is personally regarded to be complex.

Reflection
Concerning qualitative research, it was very educative and motivating observe the operations of ATC the Netherlands, KLM and MUAC. In the future, I hope to be able to visit the NMOC in order to improve my perspective on network management. In terms of interviews, more thought into forming a coherent qualitative approach, such as a single set of questions for all structured interviews, would have made the correlation process easier and potentially enable another round of interviews in the available amount of time. Also, I would have documented the observations in a more precise way.

Although being advised by a KDC alumni to start early with data analysis, it took up more time than expected. Data from EUROCONTROL related to quantitative research has been used in prior KDC CoE research, although this research was the first to combine both qualitative and quantitative research activities in relation to EUROCONTROL. Although communication with those at EUROCONTROL was experienced to be less formal than initially expected, arranging insight into the TPI model, the visit to MUAC and a conference call with A-CDM experts at the Airport Unit enabled me to gain skills in formal communication and organization of research activities.

The use of the Integrated Development Environment R Studio for data analysis and visualisation purposes has provided visualisations different from those available in data analysis tools such as Microsoft Excel. An example is the 'facet' graph (Appendix XI). The use of R Studio as primary data analysis tool was time-consuming as it was the first time in which I used it with a real dataset which is different from tutorials in which data sets are prepared and easy to use. Prior to the research I already spend a couple of weeks on online tutorials to learn the R language and the use of R Studio. This created the personal motivation and objective to convert these skills into real-life results.

Although it was advised to contact a data analysis specialist at ATC the Netherlands I was too protective in maintaining focus and potentially missing out on gaining data analysis skills in using R Studio which I prepared prior to the research. Looking back, I could have at least shared the findings and insights of my developments in data analysis using R Studio with the advised data specialist at ATC the Netherlands. This is personally regarded as a missed opportunity. Also, I could have used more information from the EUROCONTROL NMIR dashboard to generate more insight into the impact of CDM partners in the network on flights departing from Schiphol, before and after the connection. It has been used in the draft of a dashboard design and digital map of airports which is not included in this research although related to the recommendation of increasing collaboration in post-operational data analysis between CDM partners at Schiphol and EUROCONTROL.

My personal opinion is that the quantification of operational benefits such as increased capacity, saved emissions or saved delay costs should be carried out carefully to maintain objectivity among the CDM partners at Schiphol and in the network. It would be much more effective to distribute such findings based on more detailed substantiation using more advanced quantification tools such as computer simulation (enabling the ability to perform scenario-specific calculations in a relatively simple way) in combination with statistical methods such as multiple regression. This could open up the capability to regress an effective use of A-CDM such as compliance to CDM procedures with potential operational benefits such as reduced perceived or calculated workload for an ATC controller.

SCRUM sessions and sprint reviews

Situation
The KDC supports its Centre of Excellence students in their graduation process by providing SCRUM sessions twice a week and a sprint review every two weeks. The SCRUM sessions are chaired by a SCRUM master and aim to discuss short-term progress and solutions in case of a potential roadblock. Next to the SCRUM master, fellow KDC CoE students are present for the purpose of transparency and to offer support by sharing their perspectives. Each student is provided with approximately ten minutes to be used for exchanging progress and feedback.

The sprint reviews are chaired by SCRUM master Alina and includes the presence of representatives related to the KDC main stakeholders ATC the Netherlands, AAS and KLM. The progress of the previous two weeks is shared after which the representatives, who are knowledge field experts, provide feedback.

Task
The task of the SCRUM sessions and sprint reviews is to condense the sharing of personal progress in a relatively short amount of time to ensure that side-information is reduced and only primary topics are discussed. The SCRUM sessions are pure dialogue while the sprint-reviews are prepared with presentation slides.

Action
The SCRUM sessions took place in the morning, while traveling to Schiphol I summarised progress since the previous SCRUM sessions a couple of days earlier and created a priority list of items to share during the SCRUM session. At the start of the research I used a digital SCRUM board used earlier during my minor. This SCRUM board (Trello) is ideal to collaboratively keep track of research activities in planning, in progress and those finished. Each activity or digital card included subject-tags and a check-list to partition it into small research activities.

The slides of the sprint reviews were prepared a couple of days prior to the sprint reviews and in many cases I changed its contents on the day of the sprint review itself. The sprint review itself mainly consisted of presenting and discussing feedback.

Result
The Trello board was used for a couple of weeks although my frequent changes to the research design and reluctance to motivate others to use it as well eventually made me decide to move back into the 'safe zone' of intuitive research development. The SCRUM method bridged the gap between personal ideas and actual research progress and triggered me to turn the ideas into actual research activities.

During the sprint-reviews I often ran out of time to allow enough time for feedback. Also, I was reminded of the fact that technical language is hard to follow along with and more applicable to other types of meetings. It took a couple of sprint reviews to integrate a generally understandable approach to communication of CDM matter which made discussions and feedback easier. Looking back on the sprint reviews, many deviations from research design are visible which I think can be traced back to the personal approach of constantly trying to find the perfect path for progress, which is almost impossible.

Reflection
What I would do differently in future SCRUM sessions would be to accept and communicate my personal desire to explore in the start of the research and to create and stay disciplined to a realistic planning. The need for efforts in creating 'personal plan stability' has been very relevant. I think the SCRUM sessions added a lot of value by triggering me to pro-actively create a concrete (short-term) plan of approach instead of being too intuitive and reactionary to research developments. I want to thank Alina and Frenchez for their efforts in thinking along with the many iterations I chose to go through in finding the 'perfect' research design and for triggering me to focus on critical matters in cases of over-thinking.

The over-thinking mainly took place in the chicken-and-egg problem of where to start researching. For example, personal hesitation included the following; 'Would an open interview with a network-partner deliver enough value? Would I be able to correctly interpret their perspectives without considering potential changes in traffic levels, procedures and infrastructure at Schiphol?'.

Eventually I chose to start at Schiphol first, but with an unrealistic data analysis concept. After a couple of weeks, fundamental research activities were carried out such as visualising procedures in the outbound flow at Schiphol and carrying out exploratory research into runway utilization and CDM statistics reported by the Schiphol PRU. These results provided me with the confidence of having quite a clear view on where operational benefits could be found in the network and to contact MUAC and, at the end of the research, the EUROCONTROL Airport Unit.

What I have learned and therefore will apply in similar future settings is not to feel the need to fully consider all the feedback into the next research iteration but to take a step back after each session, organize the feedback and most importantly to get back to those providing the feedback on how I have considered it in the planning of the next research iteration.

Also, I have learnt the importance to balance individual directorship/ownership of the multi-stakeholder research subject and stakeholder-sensitivity. Looking back, it would have been helpful to prepare the sprint reviews together with the team to maintain focus on primary subjects and to design the slides with the purpose of co-creation in mind.

The support of the KDC through the SCRUM sessions and sprint reviews will definitely be useful for future working activities and was experienced as one of the most educative parts of the research.

Final remarks

To conclude, this research was personally the first time carrying out research in a multi-stakeholder setting outside of the Aviation Academy with a challenging research subject which is aimed for standardisation and sharing information among somewhat conservative stakeholders with differing but important stakeholder-specific responsibilities.

Although challenging to combine results from the various research activities into coherent research findings, it was very motivating and educative to meet with people from different organizations in different settings with different tasks although all impacted by an effective functioning of A-CDM. It showed the socio-technical nature of Aviation, the potential impact of a single change in procedures and the potential for operational improvement through increased transparency between CDM partners at Schiphol and in the network.

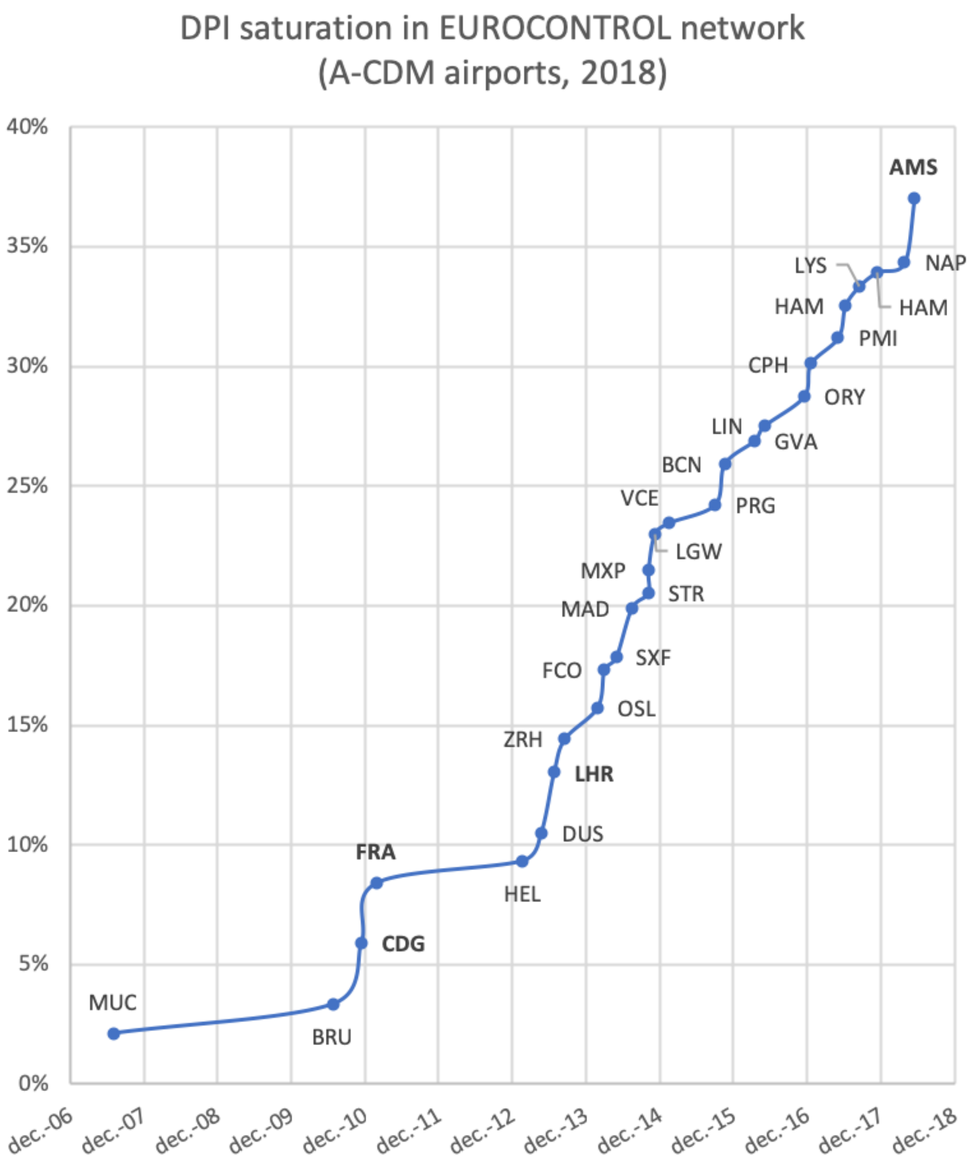
KDC CoE development

This research, combined with those of Roel Wouters and Huib de Jong provide a fundamental view on operational performance in terms of stability and efficiency. Research by Marc Riebeek and Casper Moll creating insight into capacity restrictions resulting from arriving traffic flows, while Tessa Rietema created insight into core elements of airport and airspace capacity such as physical airport infrastructure (parking stands) or the way in which flights are controlled by ATC. I think all combined, the individual the subjects might come across, provide a coherent view on key capacity management challenges and therefore where future efforts should be focused on.

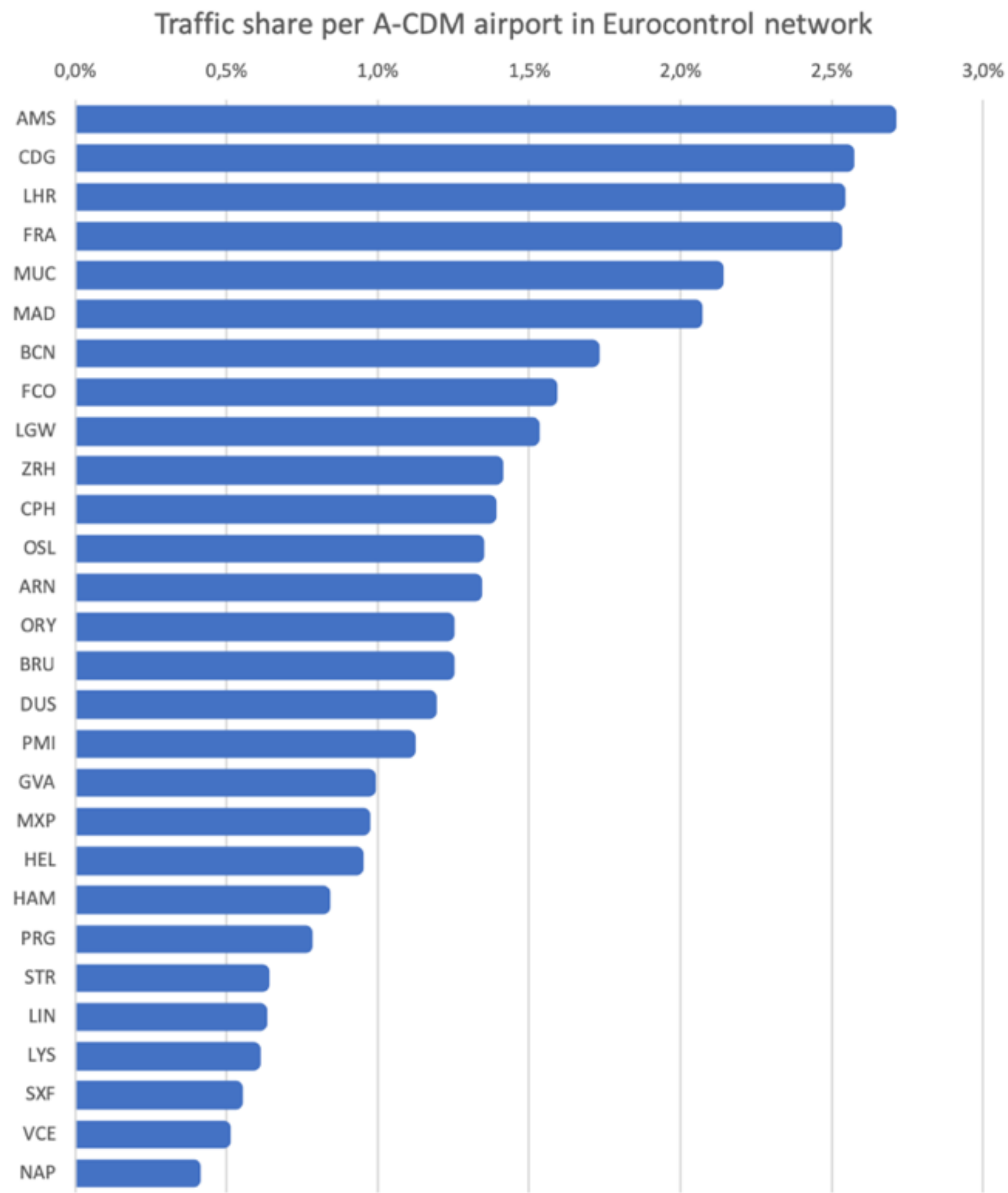
I think it would be very useful for the KDC (CoE) to create a single simulation model of Schiphol on which different simulation studies are performed. This could be in collaboration with the KDC partner universities or existing organizational capabilities related to the KDC main stakeholders.

To conclude, I want to thank all those for contributing to the research through the SCRUM sessions and sprint reviews.

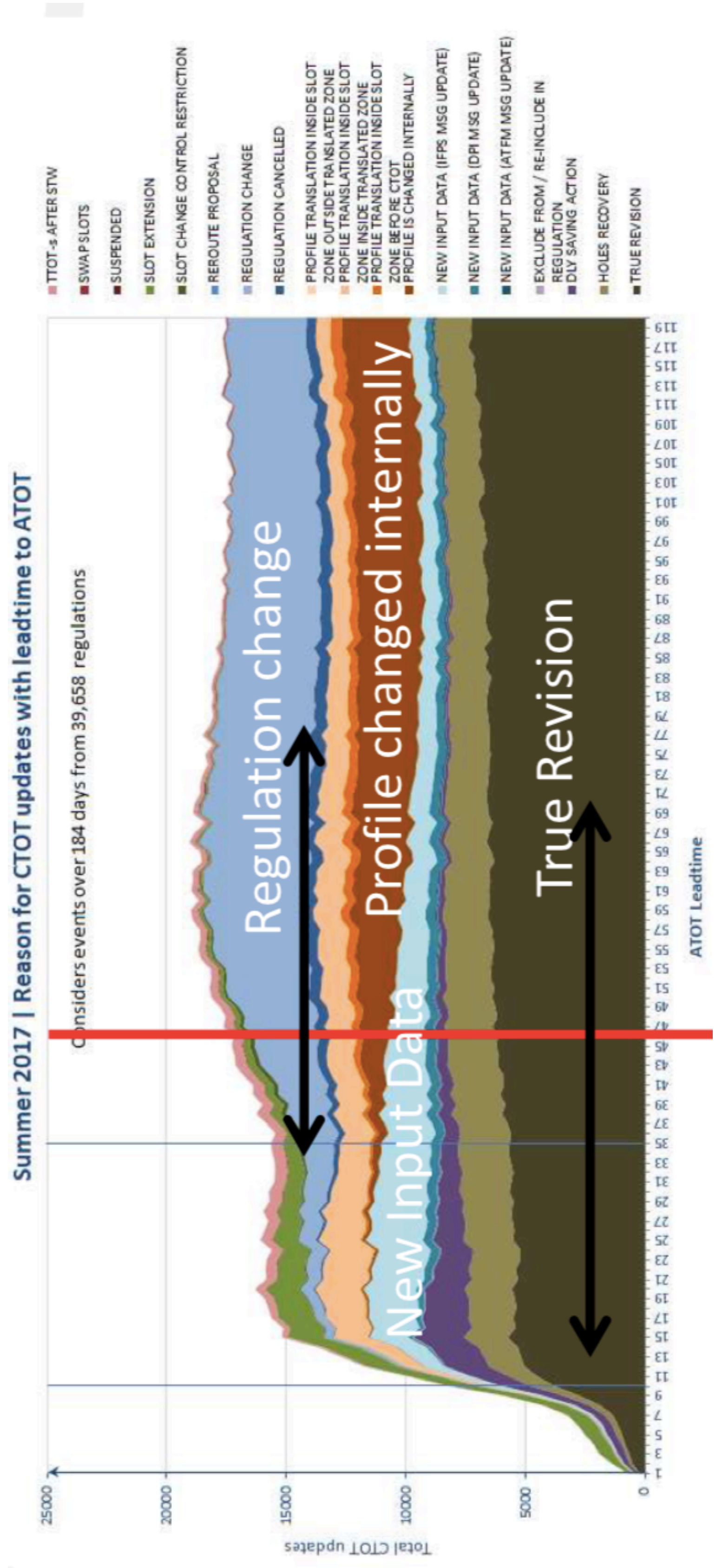
II. DPI saturation in EUROCONTROL network (A-CDM airports, 2018)



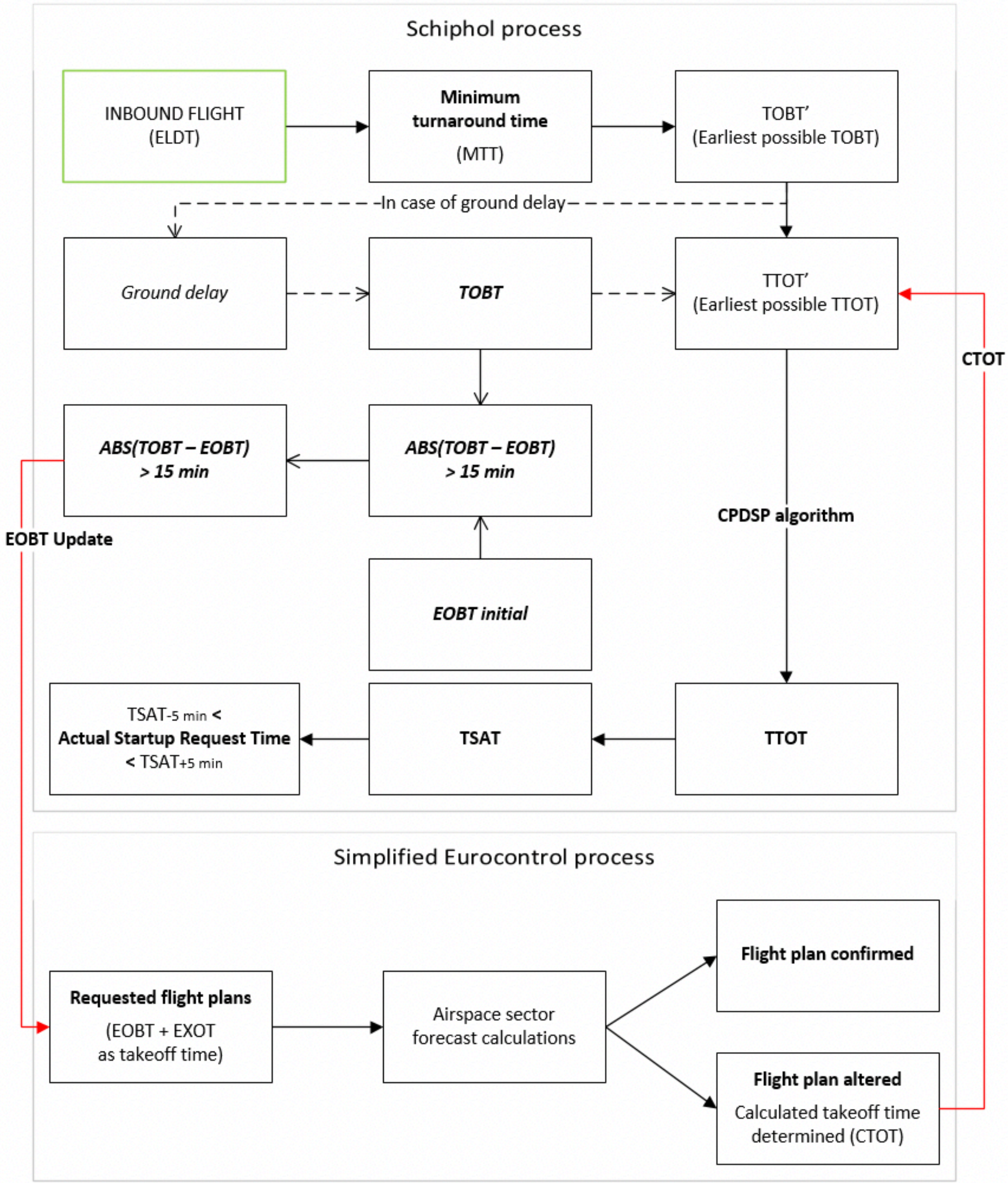
III. Traffic share per A-CDM airport in EUROCONTROL network



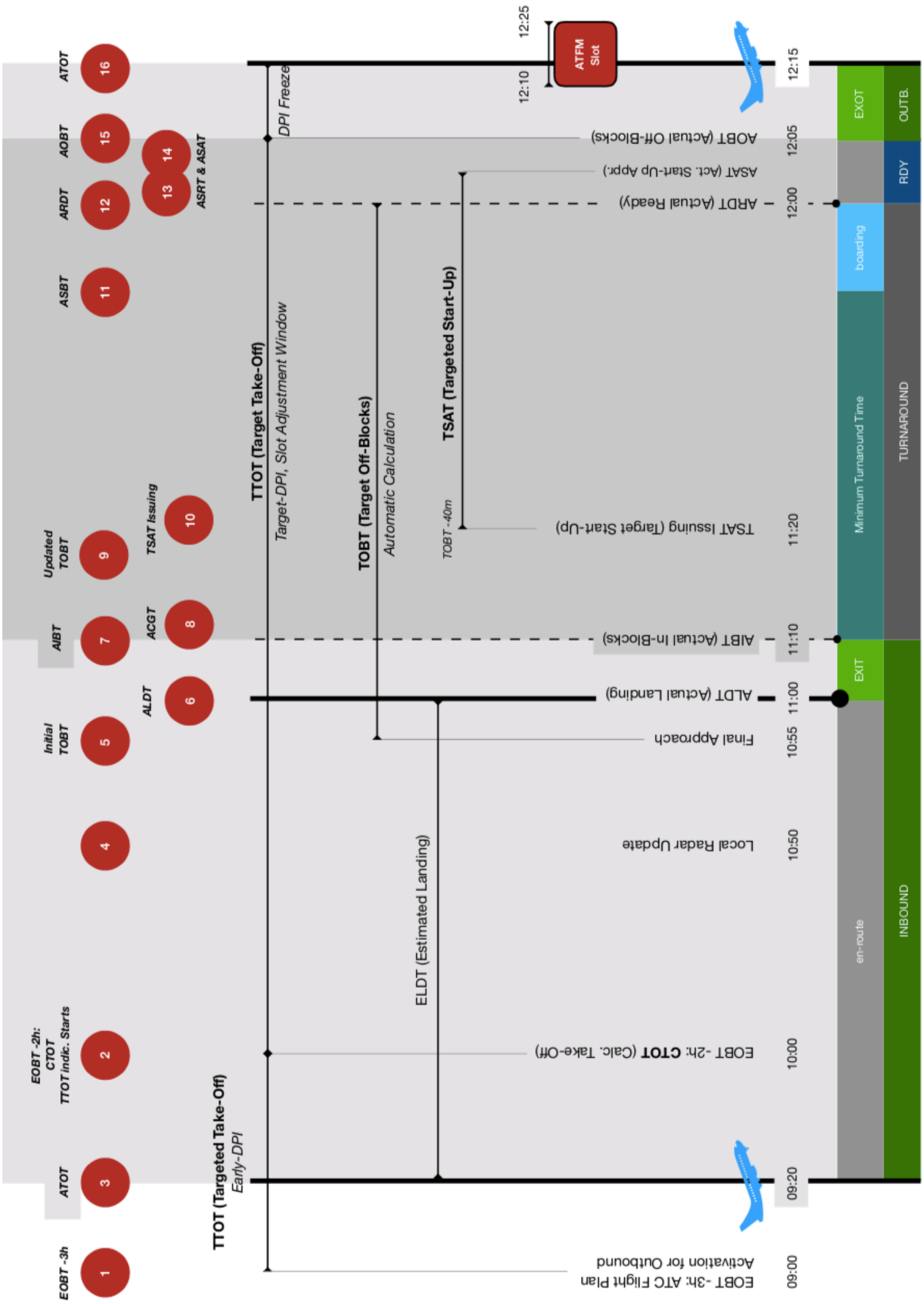
IV. Reason for CTOT updates with lead-time to ATOT (EUROCONTROL, 2019)



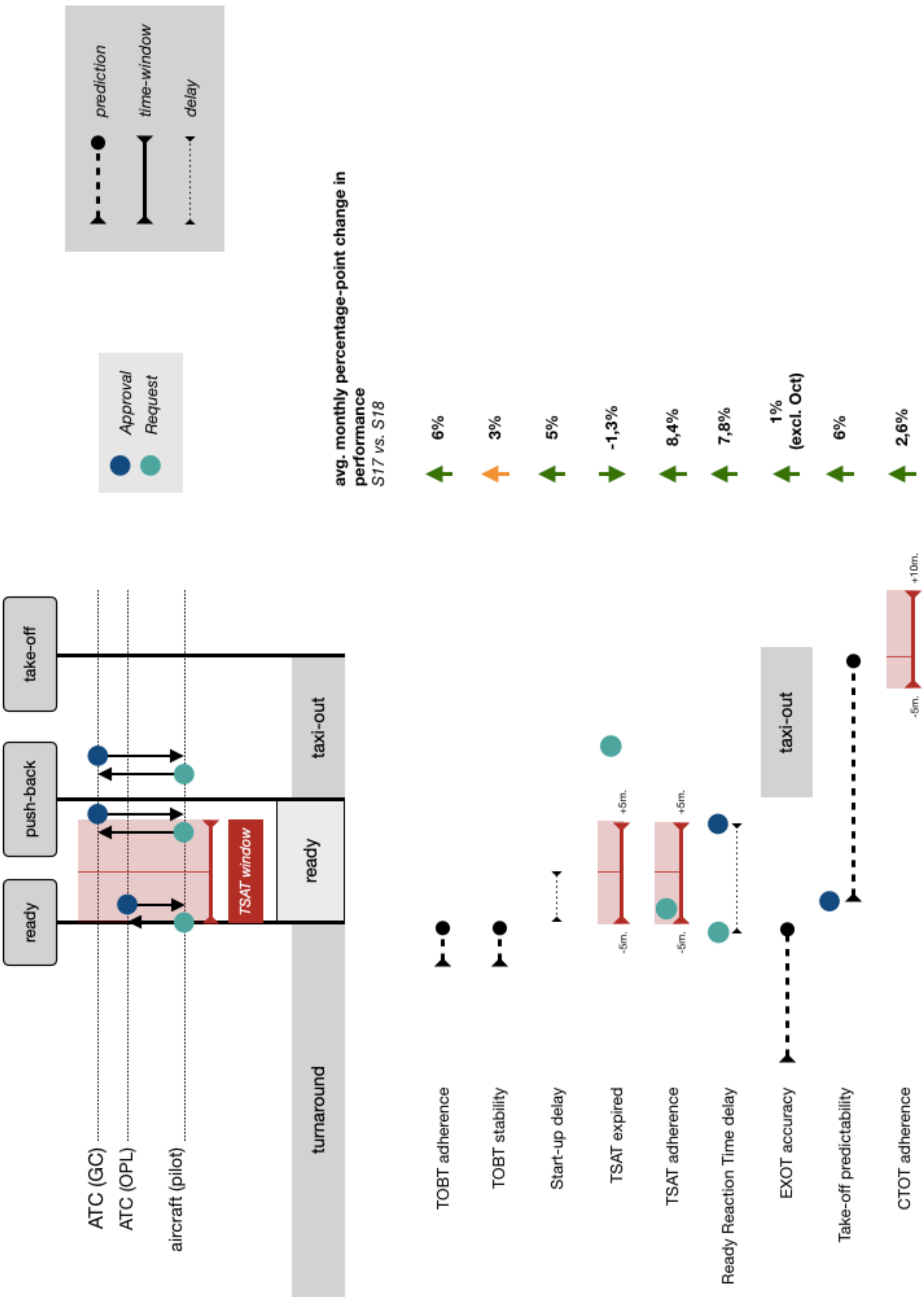
V. Conceptual model (de Jong, 2018)



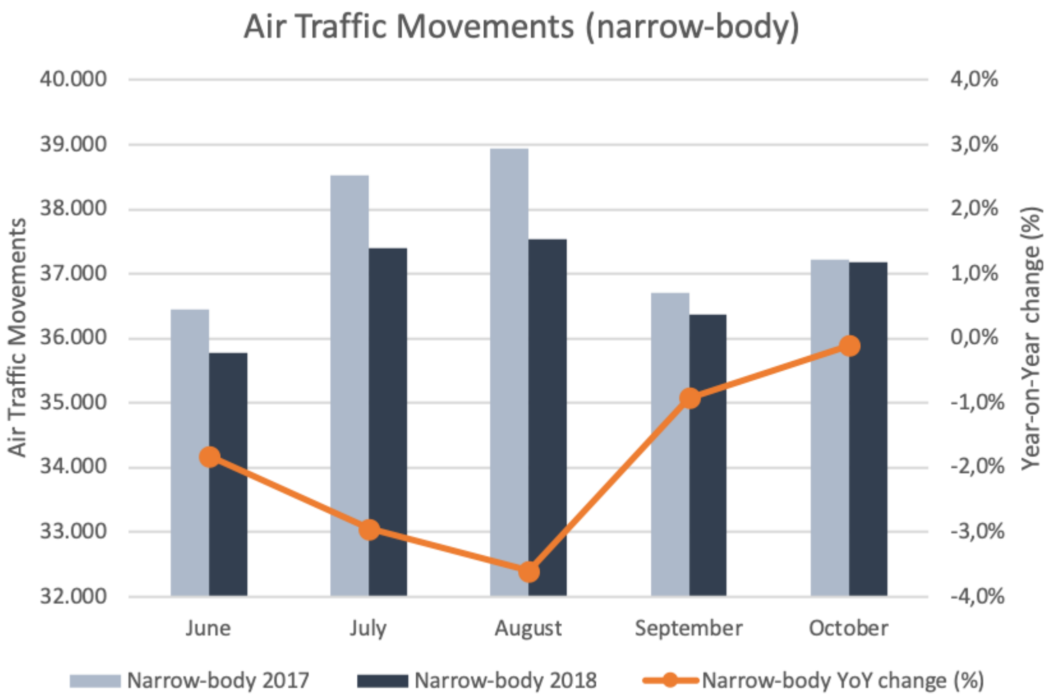
VI. CDM milestone visualisation

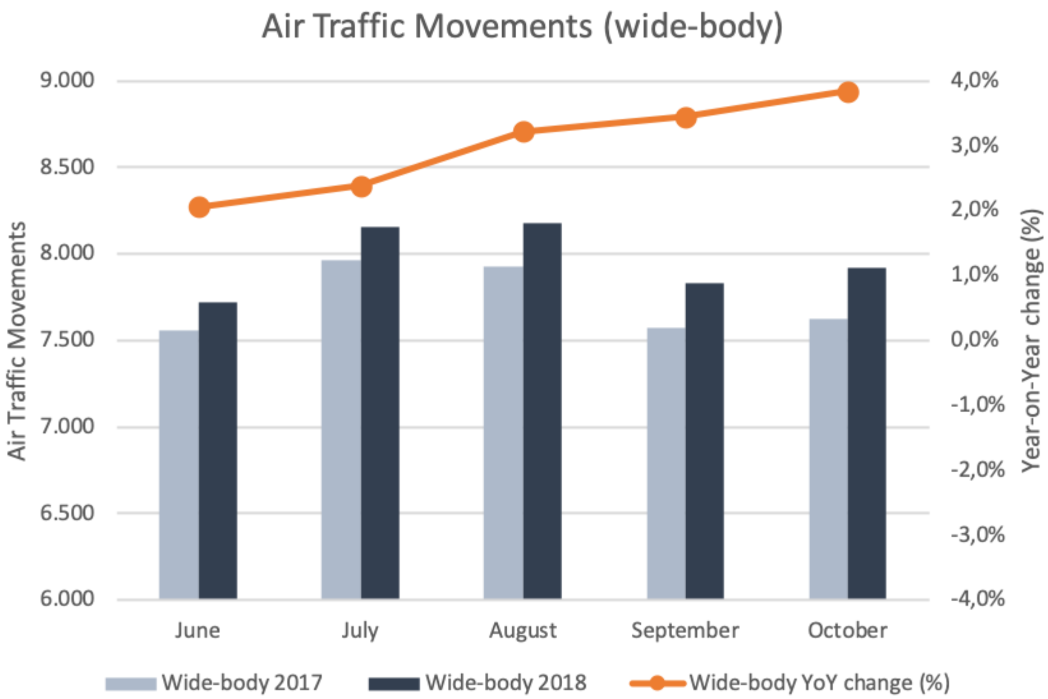


VII. Visual summary of monthly A-CDM reports (S17 vs. S18)

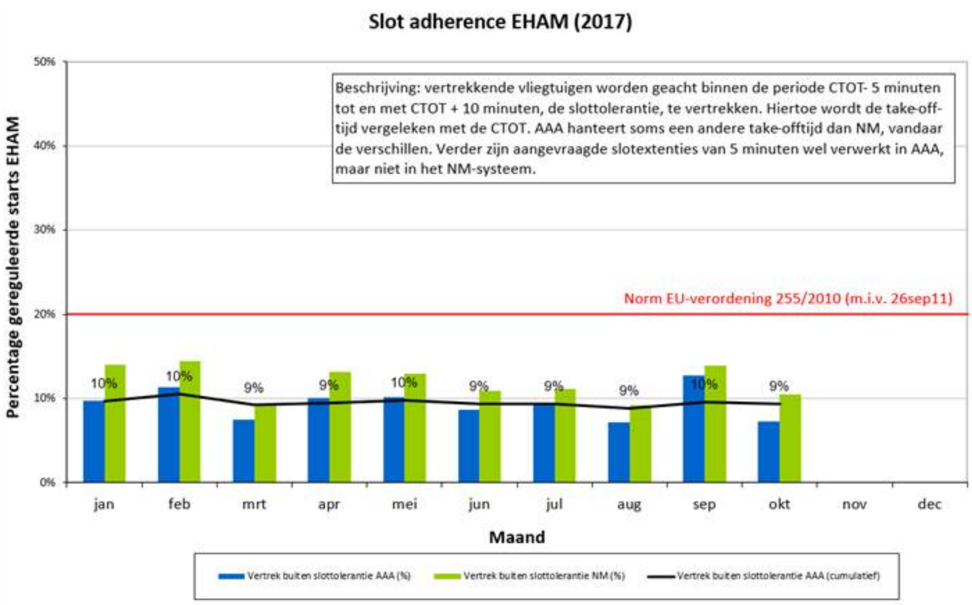


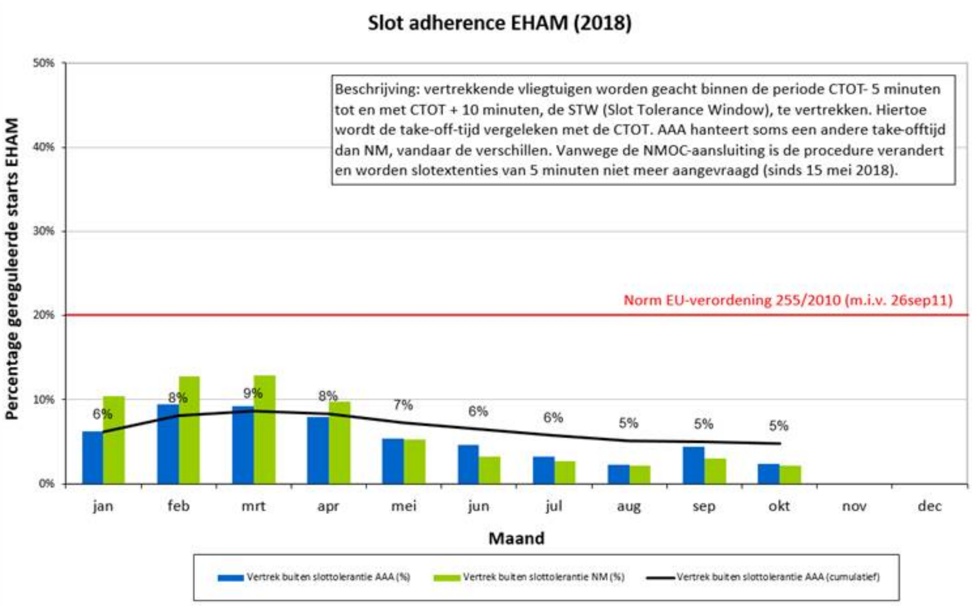
VIII. Change in traffic characteristics (aircraft size, S17 vs. S18)



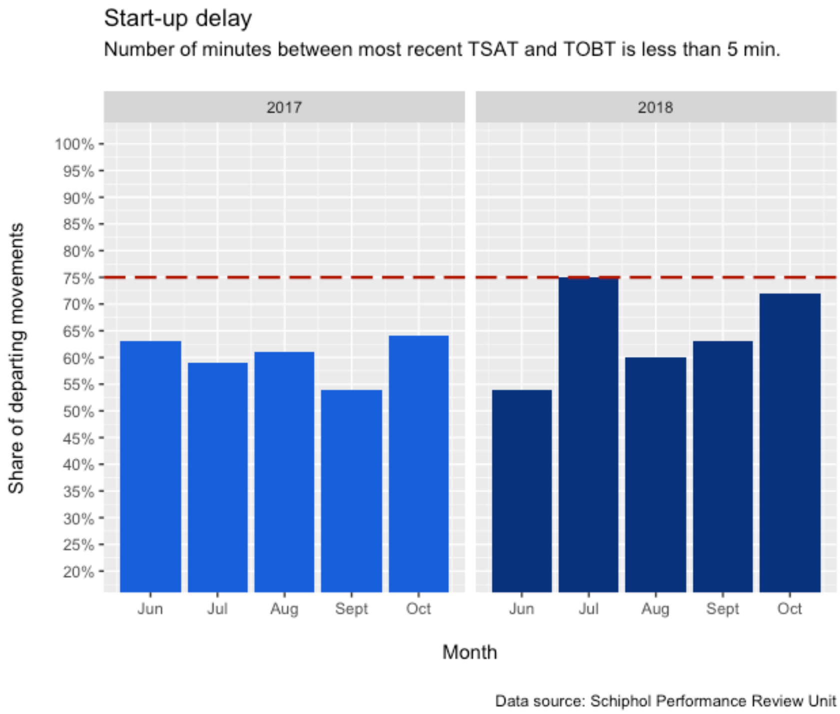


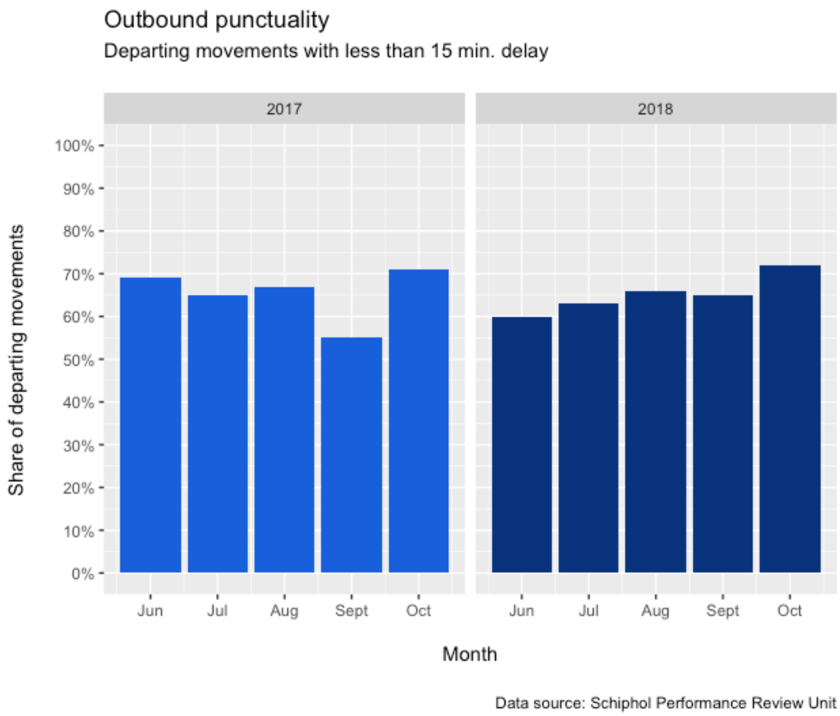
IX. Compliance to ATFM-slot (ATC-NL vs. NM)

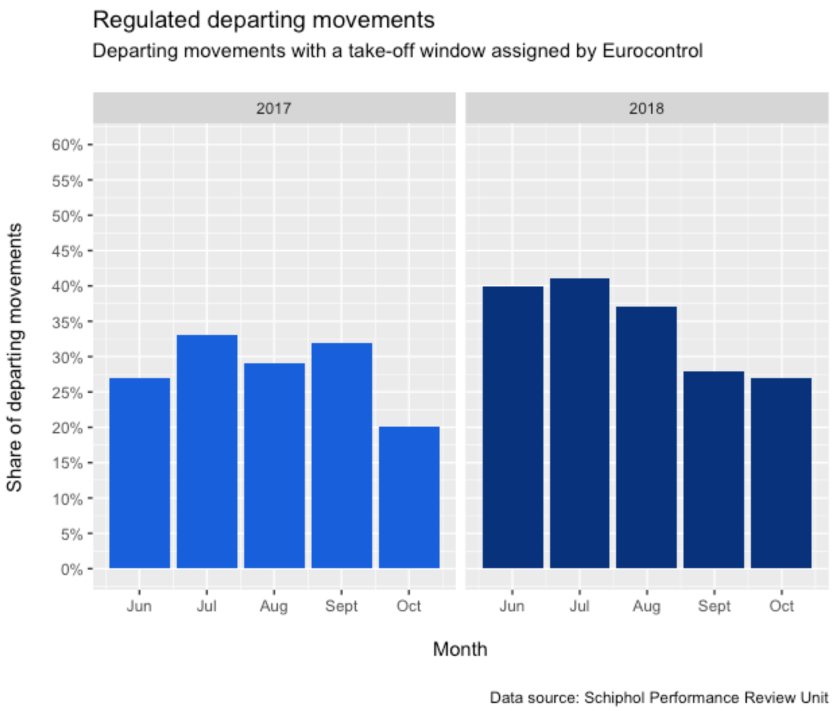


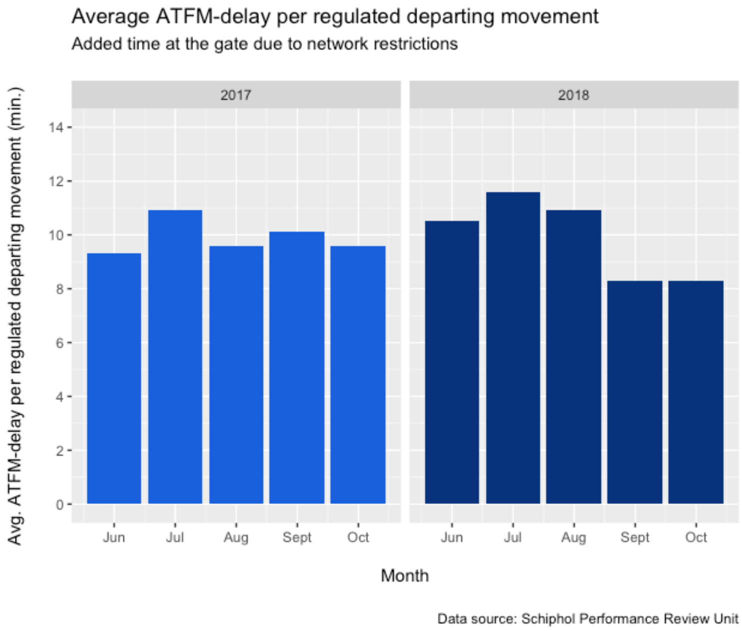


X. Summary statistics of monthly CDM performance



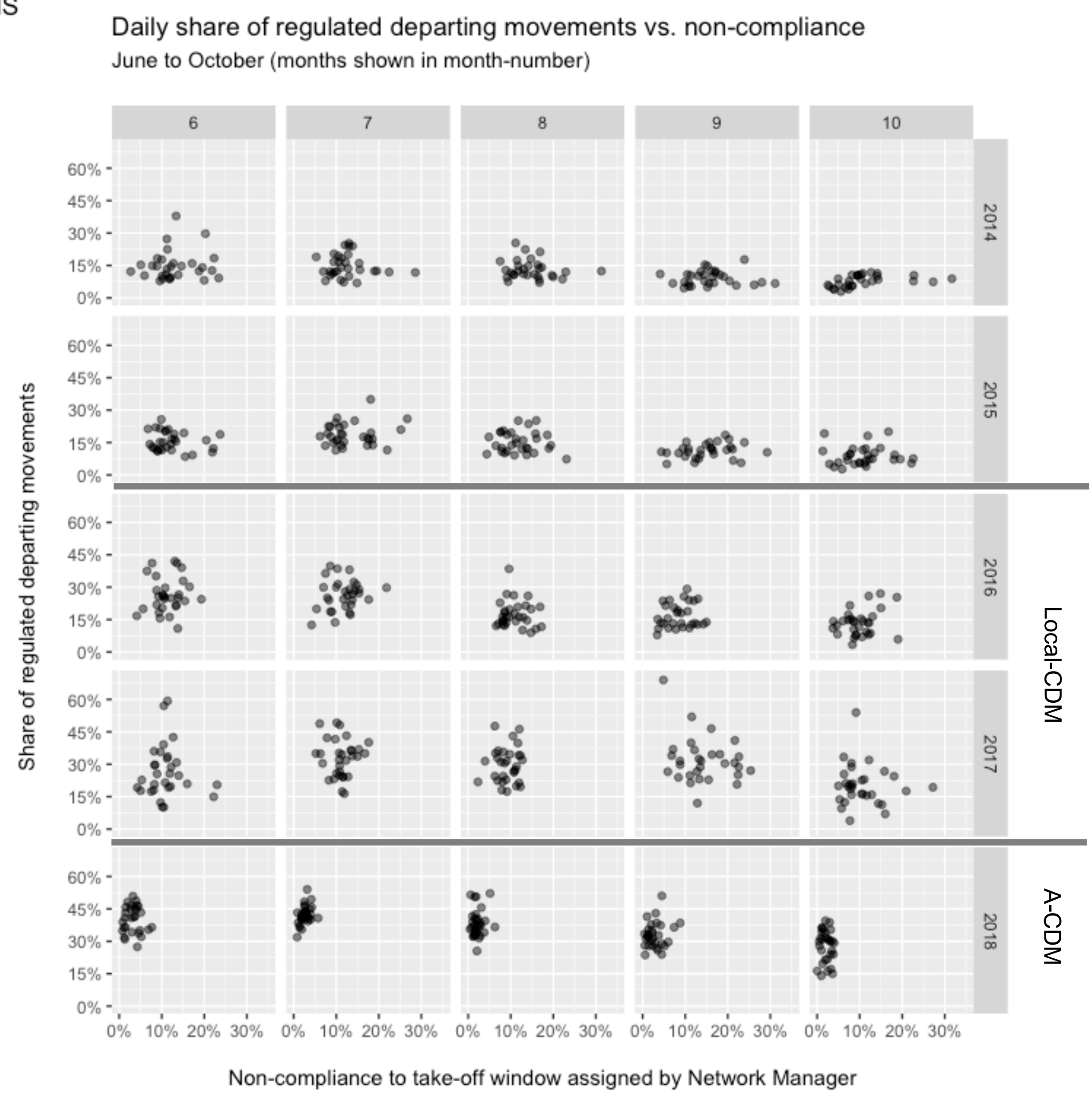



Regulated departing movements
Departing movements with a take-off window assigned by Eurocontrol
2017
2018
Share of departing movements
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Jun
Jul
Aug
Sept
Oct
Month
Data source: Schiphol Performance Review Unit


Average ATFM-delay per regulated departing movement
Added time at the gate due to network restrictions
2017
2018
Avg. ATFM-delay per regulated departing movement (min.)
14
12
10
8
6
4
2
0
Jun
Jul
Aug
Sept
Oct
Month
Data source: Schiphol Performance Review Unit

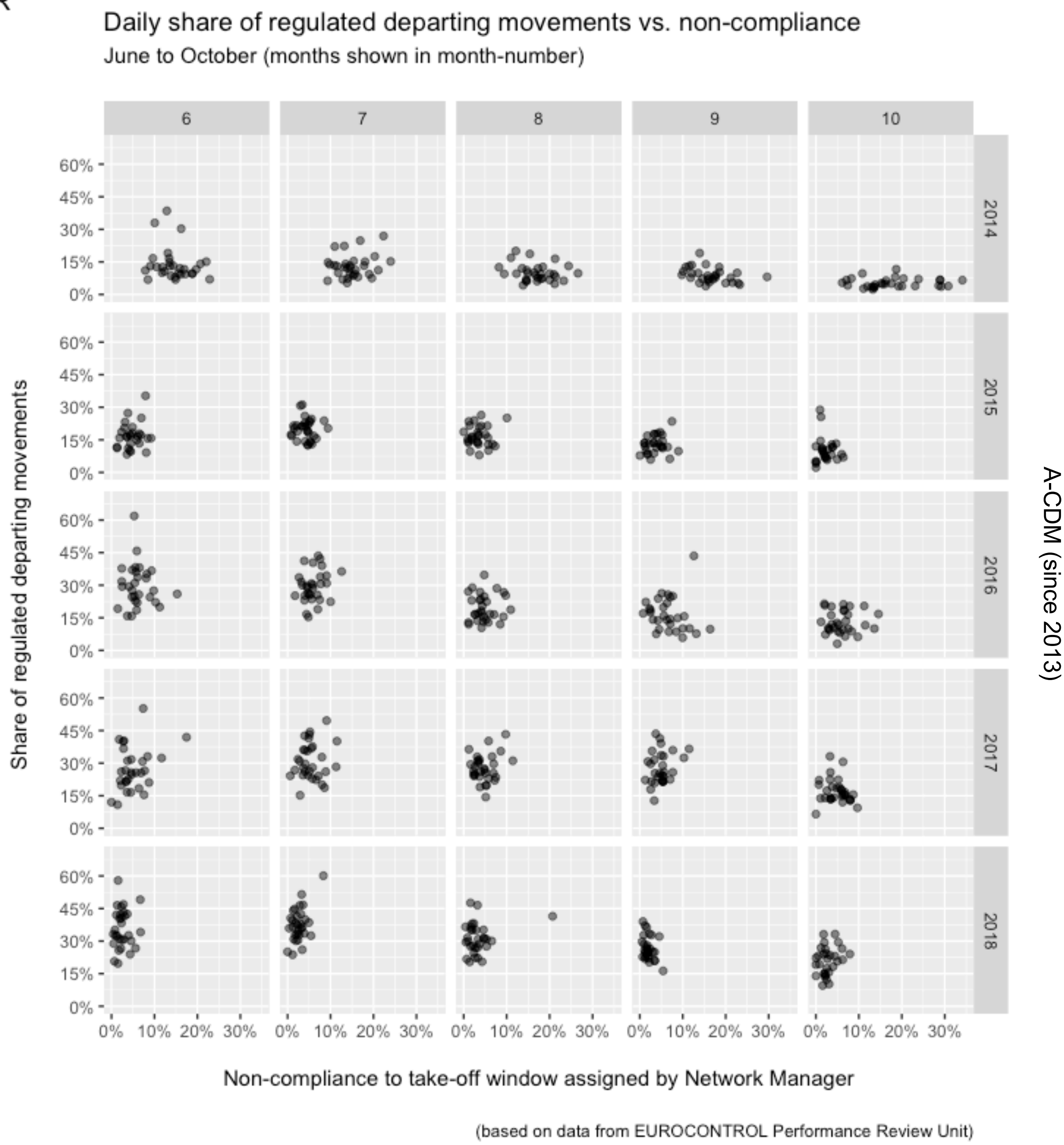
XI. Daily share of regulated departing movements vs. non-compliance to Network Manager restrictions

AMS

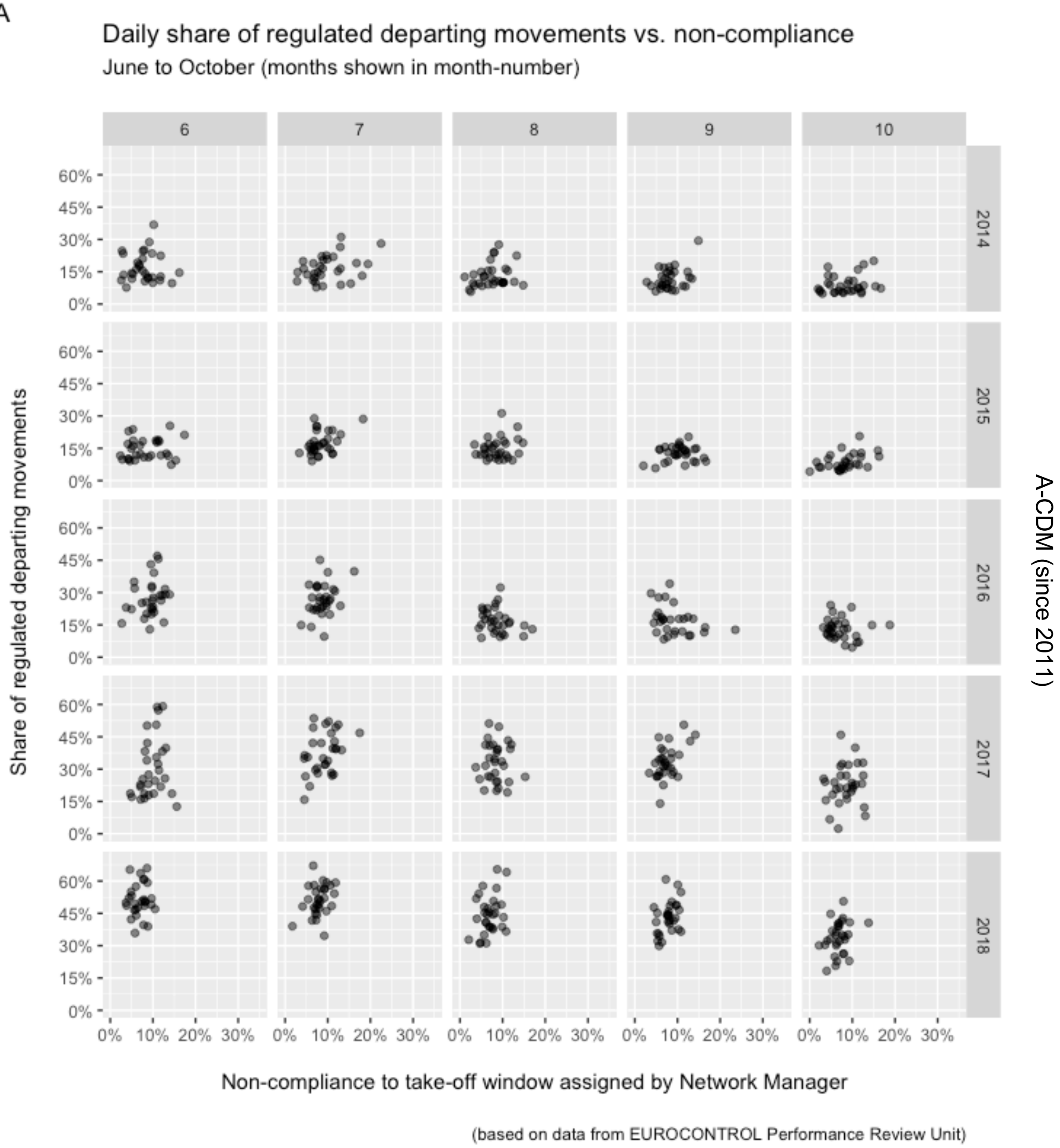


(based on data from EUROCONTROL Performance Review Unit)

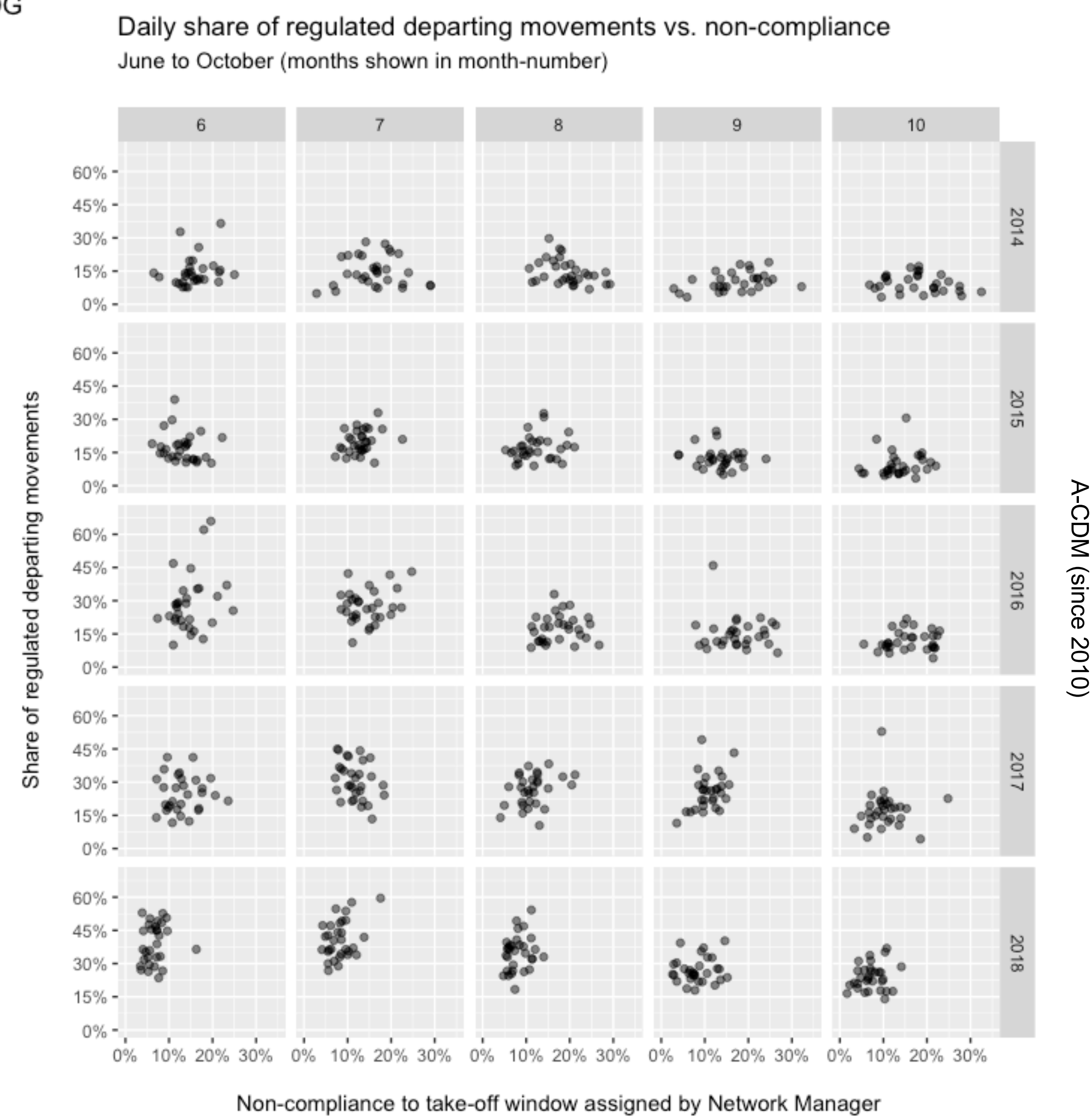
LHR


Daily share of regulated departing movements vs. non-compliance
June to October (months shown in month-number)
6
7
8
9
10
2014
2015
2016
2017
2018
60%
45%
30%
15%
0%
0%
10%
20%
30%
Share of regulated departing movements
Non-compliance to take-off window assigned by Network Manager
A-CDM (since 2013)
(based on data from EUROCONTROL Performance Review Unit)

FRA

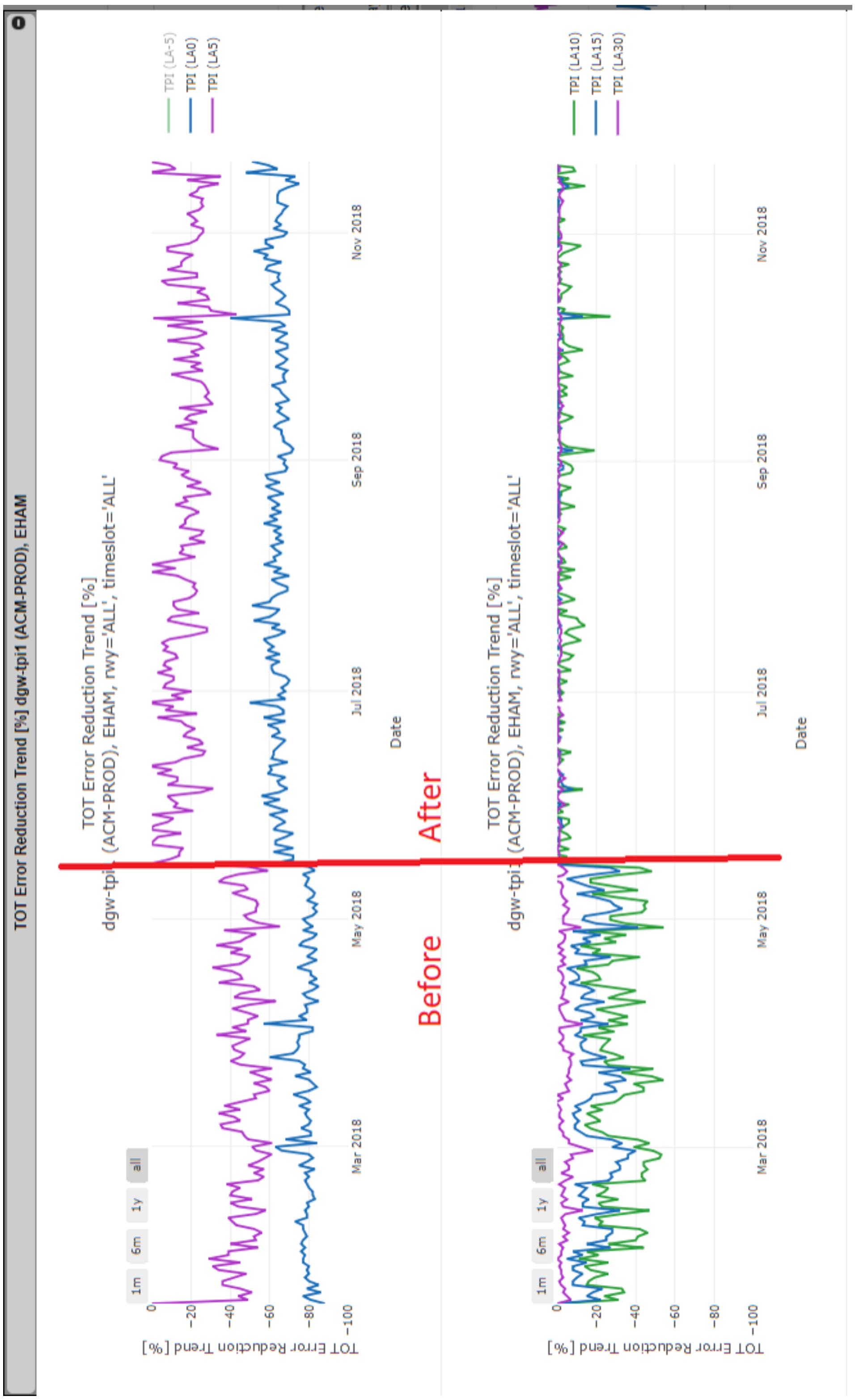

Daily share of regulated departing movements vs. non-compliance
June to October (months shown in month-number)
6
7
8
9
10
2014
2015
2016
2017
2018
60%
45%
30%
15%
0%
0%
10%
20%
30%
Share of regulated departing movements
Non-compliance to take-off window assigned by Network Manager
A-CDM (since 2011)
(based on data from EUROCONTROL Performance Review Unit)

CDG



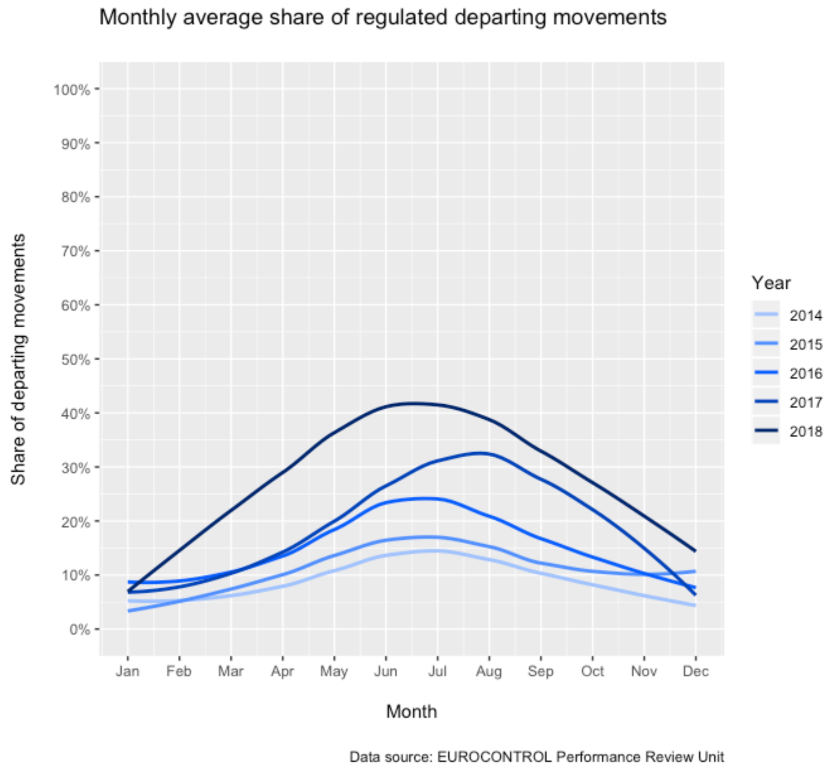
(based on data from EUROCONTROL Performance Review Unit)

XII. Output of the Traffic Prediction Improvement model (MUAC)

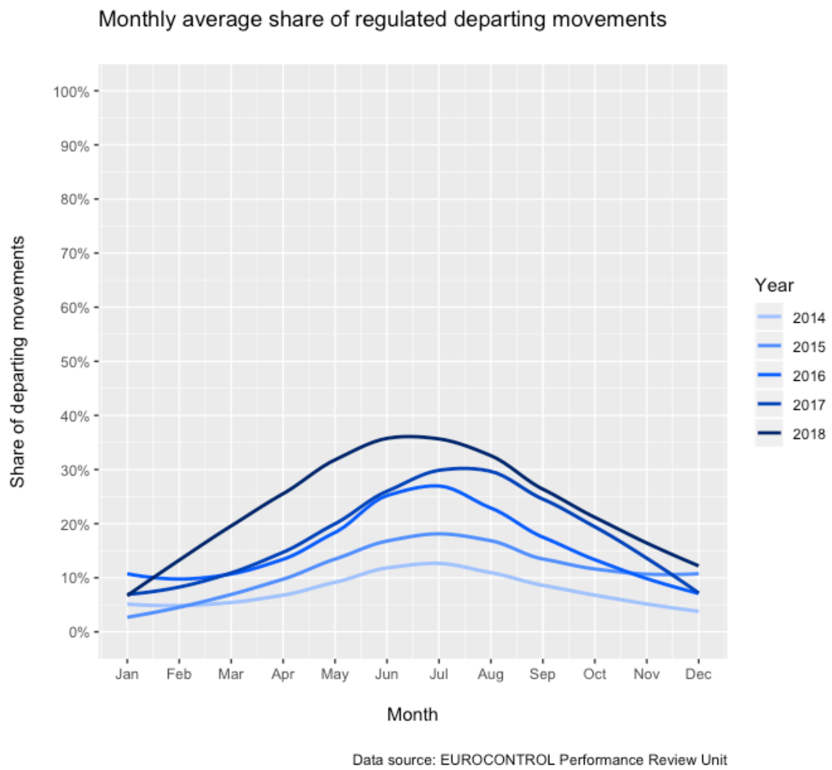


XIII. Increasing share of regulations

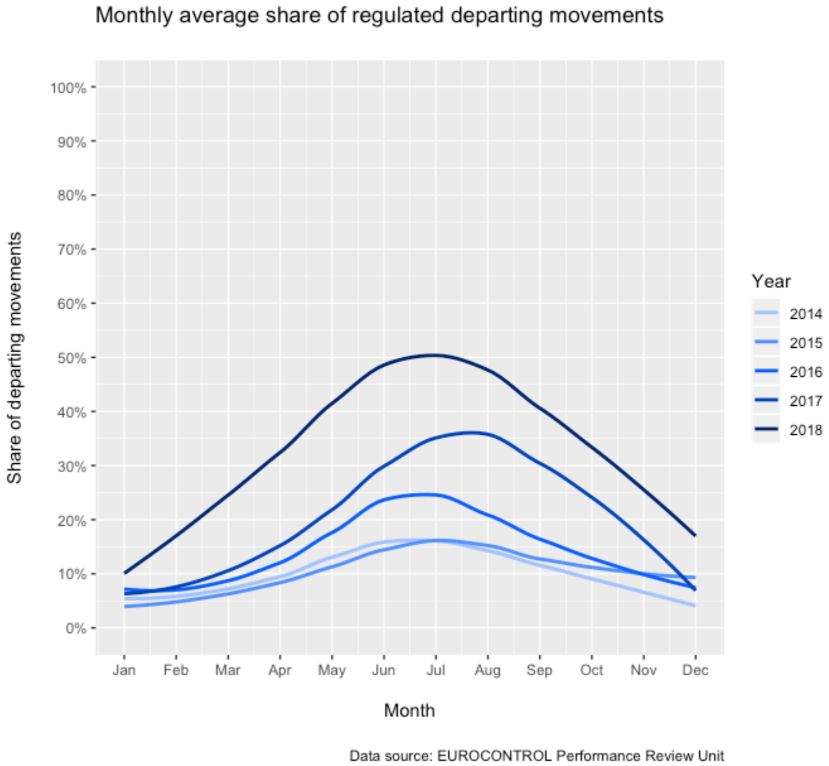
AMS



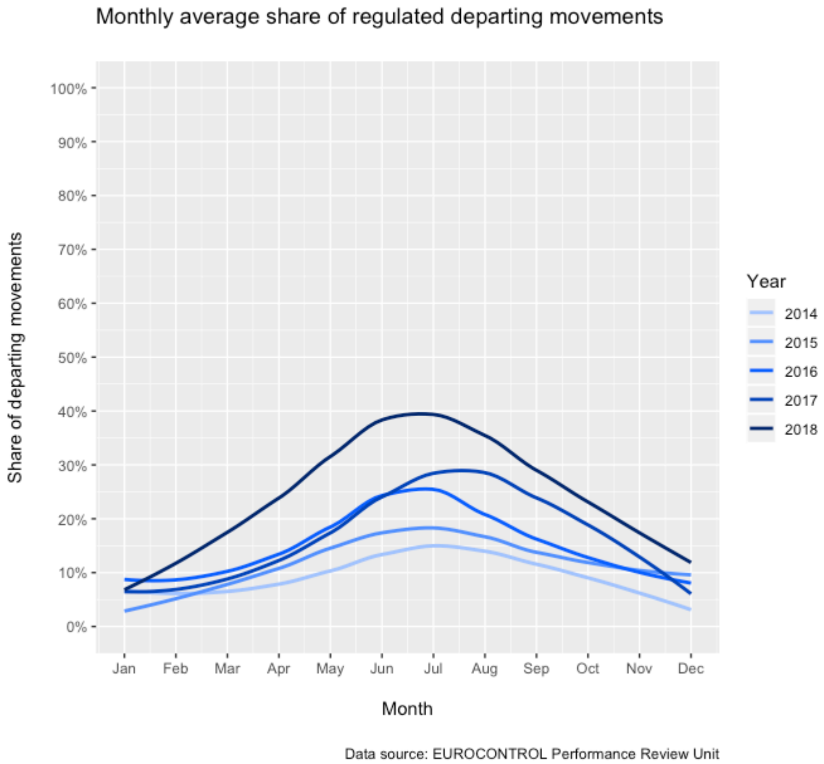
LHR



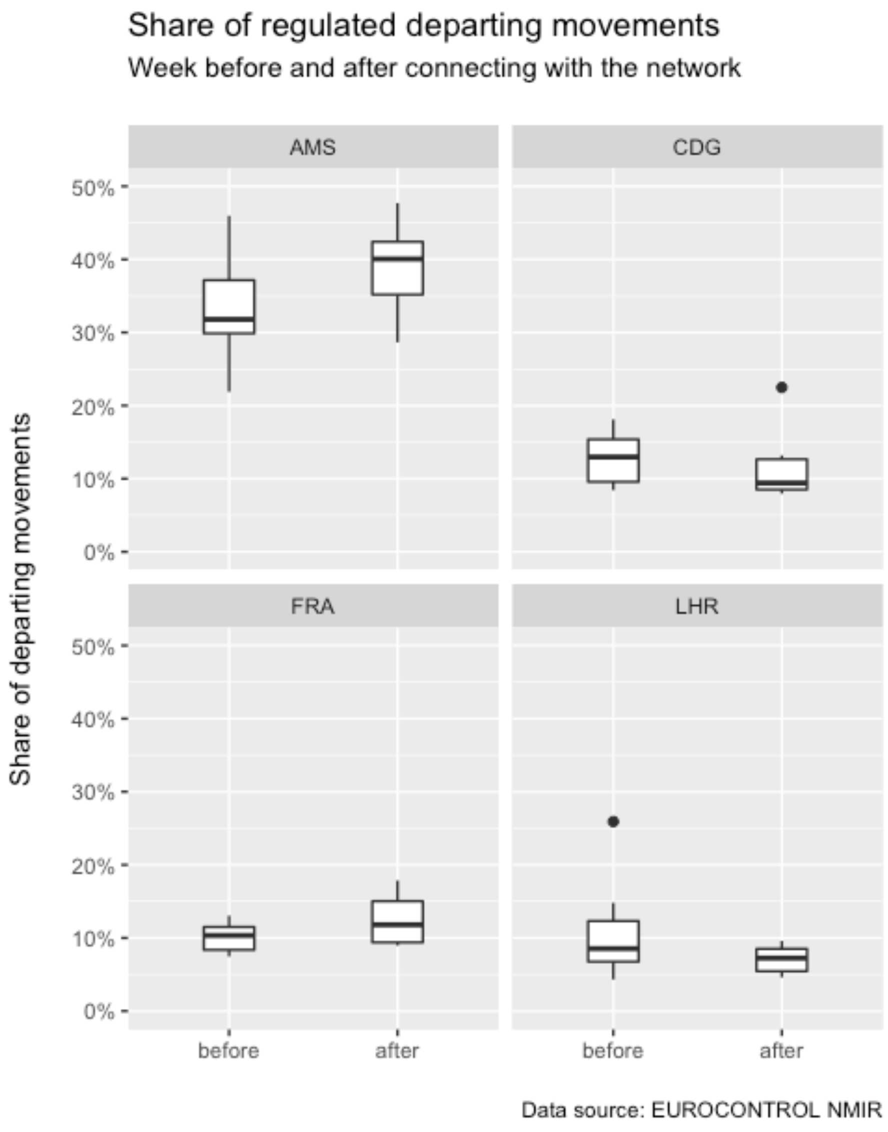
FRA


Monthly average share of regulated departing movements
Share of departing movements
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Year
2014
2015
2016
2017
2018
Data source: EUROCONTROL Performance Review Unit

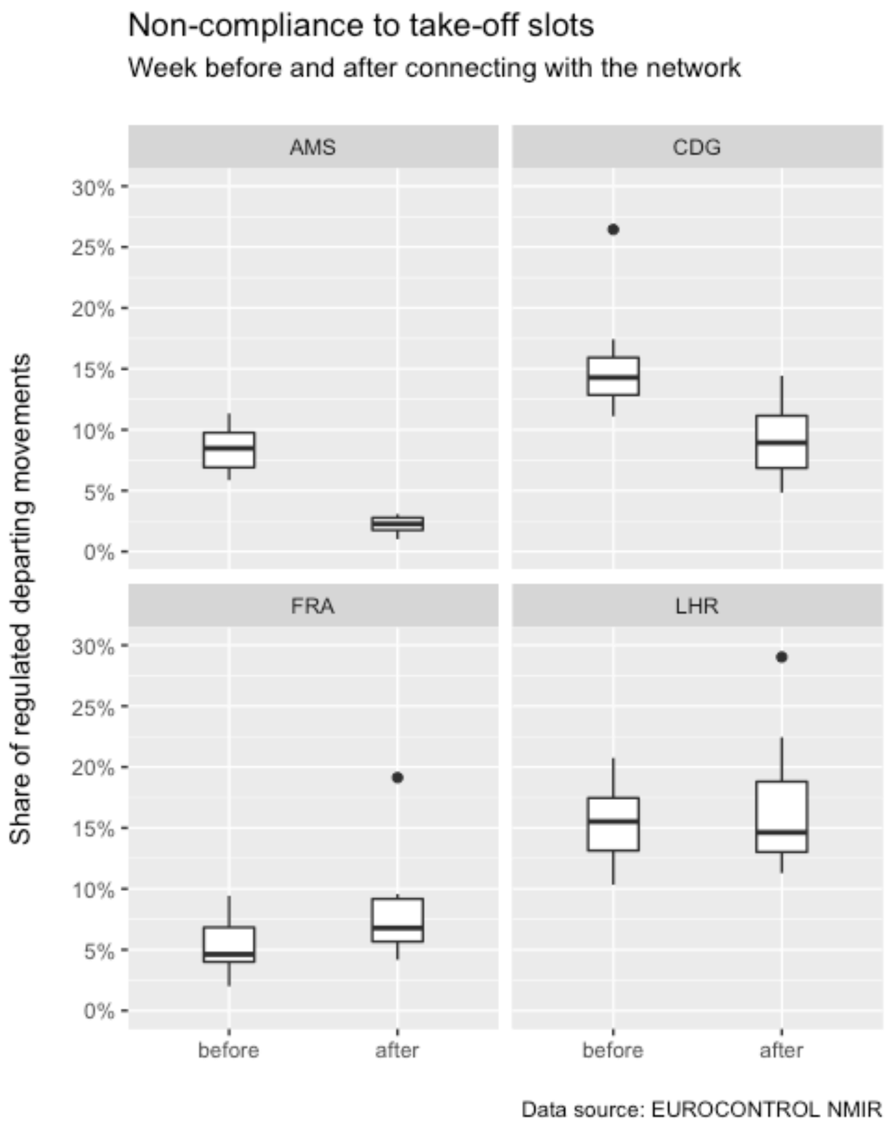
CDG


Monthly average share of regulated departing movements
Share of departing movements
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Year
2014
2015
2016
2017
2018
Data source: EUROCONTROL Performance Review Unit

XIV. Share of regulated departing movements in the week before and after the connection with the Network Manager



XV. Non-compliance to take-off slots in the week before and after the connection with the Network Manager



XVI. Notes

Capacity Programmes Manager (MUAC)
Reviewed by Ferdinand Dijkstra (present at the meeting)

Email
Since the connection of Schiphol to the network, general improvements can be observed in the accuracy of take-off times. Besides, specific phenomena take place:

- Seemingly large and apparently unnecessary outliers after take-off, which may or may not be noticed successfully and are dealt with by human intervention
- Very unsettling course, seemingly connected with the phenomenon of events that may affect the departure time planning process

It is questionable whether this is caused by or worsened through the way in which A-CDM is integrated in the network. In other words, a (new) hypothesis could be:

"A-CDM causes greater instability in specific circumstances"

At the moment we are in the phase in which non-concrete answers originate: "what is exactly happening here?" and "could this course of events have been prevented?"

Notes during meeting
Compared to the 'delay-messages' (DLA) used prior to CDM, the use of 'Departure Planning Information messages' (DPI) increases the predictability of traffic departures from airports and en-route.

The Network-Manager assigned 'ATFM-slots' which need to be adhered to. When the probability is high that an ATFM-slot will be missed, which might be due to unexpected turnaround delay, a new ATFM-slot will be assigned. In many cases this take-off window is much later than the previous one and might be referred to as a 'slot-penalty'.

With CDM, traffic predictability has improved, but is not perfect yet. The system is influenced in many ways resulting in reduced effectiveness of CDM.

It is possible to improve ATFM-slots, this depends on the expected take-off time in a very early stage. It stands out that flight-plans are often not adapted to the early assigned ATFM-slot, in the hope for slot-improvement.

Low-level, MUAC determines traffic predictability per sector based on EFD data originating from the Network Manager. To put it simply, EFD are Departure Planning Information (DPI) messages transformed into less accurate traffic patterns. It is based on the most recent Target Take-Off Time (TTOT). The B2B connection provides more freedom as this enables insight into earlier TTOTs as well.

There is no direct DPI-connection between Schiphol and MUAC, although this would be beneficial.

Concerning the 'slot-penalties', further integration between airports and the Network Manager would be benefial. Overall, non-CDM airports receive less penalties than airports running A-CDM. This is not the way it should be.

In the EFD data, traffic demand is translated into 'entry-rates' for specific points in the airspace. This is a mismatch with the way in which MUAC allocates capacity. The sectors within MUAC change every fifteen minutes. The reason for this being 'efficiency-pressure' due to staffing availability.

The Network Manager determines traffic demand predictions based on the most up-to-date flight plan information. MUAC has the tools to enable estimations with improved accuracy. It has the ability to apply these tools as it can always fall-back on the EFD data.

Based on this data, the Network Manager and MUAC (partly via NM) predict capacity shortages. Due to higher accuracy, MUAC is leading in determining capacity shortage. This reduces ATFM-slot delay and prevents unnecessary 'slot-penalties'. It is estimated that roughly 40% of delay due to 'slot-penalties' has been unnecessary.

Two options may improve further improvements to dealing with instability from AMS:

- Pro-active prevention of instability before take-off
- Reactive measures to intercept sudden instabilities (especially after take-off)

Further improvement is critical for MUAC to protect vulnerabilities. One example is the way in which workload is estimated. This is mostly done by way of occupancy counts, which is not precise enough. Furthermore, it is no longer the case that a sector is regarded as an 'island' within which a single controller takes up all responsibility. Increasingly, collaboration with neighbouring sectors takes place between ATCOs responsible for different sectors.

Also, the human factor plays a role. Sometimes the controller does not consider the 'new' way of working (collaboration among sectors) but falls back on the 'old-fashioned' way in which the sector is regarded as an 'island'. This influences the actual capacity (which is based on a complex workload-model) in comparison to a declared capacity which might have been higher. This affects flights with a route through MUAC as the capacity restriction (if present) is translated in a later take-off time, increasing the potential of inbound flights to wait before connecting at the gate which increases airport congestion.

MUAC has a high efficiency which might be related to the governance structure. It is a non-profit, which means it needs to 'put up' with the financial resources made available by the EU. This year, the costs for MUAC are roughly €160 million with an estimated revenue of roughly €500 million.

KLM is very innovative and far-reaching, it can be regarded as a pioneer. A system-view is very important, the priority list in the ATM Portal is a perfect example between considerations to work together and increase network benefits (see 'Observation of operational room' below).

It would be valuable to gain insight into TTOT variability reasons. CDM is not working as expected, a lot of improvement is possible, the predictability is much better than before.

A lot of ineffective aspects can be related back to the behaviour of CDM partners (how the system is utilized). Airlines always steer towards the scenario with minimal delay, the network steers on stability translated into a departure slot (ATFM-slot).

In cases of slot-improvement seen by MUAC (which has more precise tools to determine available capacity), the Network Manager could decide to override due to calculations made by the CASA (Computer Allocated Slot Algorithm) algorithm within the Network Manager. This is counterproductive.

Observation of operational room

In the operational room at MUAC, next to the integrated Flow Management Position (iFMP) and traffic predictions by the Network Manager, the operational staff has the capability to view aircraft-specific schedules at least a day ahead. This is collected through the B2B connection and communicated by the ATMP tool (ATM Portal). It allows to make careful decisions on whether critical flights to an AOs network or flights nearing the curfew at an airport should be subject to a restriction of MUAC. This restriction is translated into a later take-off time (CTOT) which has the potential to affect the airline's productivity.

Projectmanager TPI project (MUAC)

Herbert Naessens (validated by mail)

Email

In my project ADS-B data is used to observe aircraft on the ground. Estimated take-off times that we receive from NM (EFD data) are updated based on detected movements. We have built models of several airports, including statistics about average taxi-times, and keep track of the runways that are in use at a given moment + aircraft queueing in front of the runways.

The logic was initially applied for Schiphol (Q1 2018, before A-CDM implementation) and has been extended to other airports since then. Schiphol was chosen because it is a large airport feeding a lot of traffic into our airspace and, at the time, was suffering from high unpredictability in the EFD data.

The ADS-B logic improved accuracy. But when Schiphol implemented A-CDM in May, these improvements were no longer visible in the 0-40min look-ahead. The quality of EFD data that we receive from NM has increased considerably thanks to A-CDM.

There is still a small improvement in longer look-ahead intervals because ADS-B data is also used to detect late arrivals; we collect statistics of minimum turn-around times per airport/actype/airline and shift departure times accordingly.

We knew upfront that a proper A-CDM interface with NM would cancel the benefits, because we are using ADS-B to detect events already known to the airport (it makes much more sense for the airport to share this knowledge instead of us trying to reverse engineer), but it was amazing that the effect was so visible in the stats.

Unfortunately, a lot of airports do not have A-CDM. For those, the ADS-B logic still makes sense.

Notes from phone-call

The goal of the research leading up to the TPI project was to improve traffic prediction through the application of Machine Learning.

One of the elements degrading traffic predictions are estimates of take-off times.
Even though certain operational choices are planned, last-minute changes may occur at an airport that are not communicated in a timely manner to MUAC.

MUAC receives traffic information of Schiphol through EFD messages via the Network Manager.
Prior to the TPI project, trajectory prediction for MUAC started at the Estimated Take-Off Time reflected in the EFD message. Unfortunately it was highly unpredictable whether a specific aircraft would actually take-off and enter the MUAC airspace at the estimated times. It incidentally occurred that EFD data assumed a specific aircraft to be in the air although it was still on the ground within the ETOT window.

To address this problem, the TPI logic uses ADS-B observations to detect which runways are in use and which aircraft are already taxiing. In combination with statistics about average taxi times, the TPI logic can adapt the times in the EFD message.

Additionally, the TPI logic detects late arrivals and shifts the estimated take-off time in EFD message taking into account typical minimum turn-around times at the airport. Minimum turn-around times depend on the airport, destination, airline and aircraft type, and have been derived by machine learning.

The TPI logic has been applied successfully for multiple airports.
It was observed that the quality of the unmodified EFD messages for flights departing in Schiphol improved a lot since the introduction of A-CDM, in particular in the time window close to EOBT.

However, further improvements are still possible in the time window a bit longer before EOBT. MUAC would benefit from having a better view on airport and airline operations (TOBT, TTOT) and from stability in the way these operations are managed. Last-minute changes incidentally occur which are hard to foresee.
Focus of the next phase of the TPI project is to use machine learning to predict departure times in longer horizons. The prediction logic will take into account the propagation of delays and operations/reactivity of airlines and airports.

Although the situation improved for Schiphol, many airports do not have A-CDM or only coordinate take-off times at a certain threshold. Some airports have structured this way of sharing information in a quirky way which makes it hard to predict take-off times.
For those airports, the current ADS-B driven TPI logic still results in clear benefits.

Airport Unit (EUROCONTROL)

Validated by mail (David Booth)

Participants

- David Booth and Hans Koolen (EUROCONTROL Airport Unit)
- David Zwaaf (ATC-NL Strategy) and Stefan Knijnenburg (ATC-NL Capacity Management & Analytics)
- Marc Voogt (Knowledge Development Centre – Mainport Schiphol)

Notes from conference call

Feedback (especially related to operational benefits) by other airports or ANSPs on the connection of Schiphol with the network is not known.

To EUROCONTROL, CTOT compliance and take-off time predictability are regarded as key performance indicators. The measurement of adherence to ATFM slots is performed by airports themselves and EUROCONTROL. In general, a sustained increase in compliance is visible in the three years after the connection with the network. The amount of improvement differs from airport to airport but airports that were already performing well also showed small increases.

Next to the technical side of the connection, Schiphol also changed some procedures in favour of optimal airport-network integration. It is not clear whether this was present at other airports too but it is definitely clear that after the connection with the network, post-operational analysis for further improvement is highly important. More improvements of ATFM-slots are related to more accurate information (DPI messages) since the connection of Schiphol and due to the True Revision Process[8] at EUROCONTROL which runs every minute in 2018 instead of every five minutes in 2017.

Airlines are ‘scared’ of triggering re-calculation of (a worse) ATFM-slot and are therefore sometimes reluctant to update their TOBT. It is advised that the TOBT is used as indicator as this is used as reference value for the target take-off time. Discussions are active on whether the EOBT should be used as reference value only, while using the TOBT would preferable to calculate ATFM-slots. Airlines fearful of losing control over flights should improve coordination with the handling agent.

Schiphol is the third airport to be connected via B2B after Nice and Copenhagen. It is the first major hub to be connected to the network via B2B. It can be expected to see more airports being connected through B2B instead of AFTN. EUROCONTROL is looking to convert those airports already connected via AFTN to a B2B connection, if an airport is willing to do so. There are still concerns over the protection of B2B as it’s over the internet.

B2B, whilst not critical for connection with the network, is being actively promoted by EUROCONTROL as the future method of connecting. As well as data such as DPI messages it also offers the possibility of exchanging many other types of data such as flight plans. It allows for different ways of cooperating.

A post-operational environment can significantly contribute to airport-network collaboration. Some airports have seen A-CDM deteriorating over time. This doesn’t help at all. Post-operational analysis could look at TOBT accuracy and start comparing TOBT with ARDT. For example, London Heathrow produced statistics about handling agents and aircraft operators. After a while they started publishing league tables after which handling agents started competing on TOBT quality daily. It is important to always address handling agents in a constructive way. Similar statistics are produced and published by the Performance Review Unit at Schiphol. The runway configuration tool expected at Schiphol will support Schiphol in providing more accurate taxi-time predictions.

On the potential of a direct DPI link with MUAC, the question is whether this information is not already reflected in the EFD data shared by the Network Manager.

One should not expect Airport-CDM to solve everything.

[8] This is the automatic mechanism that routinely attempts to improve the slot of allocated flights (EUROCONTROL, 2018)

ATM Procedures (ATC-NL)

Marcel van Delden (validated by mail)

Background

The TSAT time-window of -5+5 is defined by the Airport CDM Implementation manual of Eurocontrol. Prior to the connection and with local A-CDM, this window was only applicable to non-regulated flights at Schiphol. Regulated flights were using a TSAT time-window of -5+10 equal to the Slot Tolerance Window (STW), the time window in which regulated flights shall depart. This resulted in the side-effect of increasing the potential of flights not being able to depart inside the STW. Since the connection of Schiphol with the network, this window is harmonised to -5+5 for all departing movements. This is an enabler for improved slot adherence.

Since before the connection, the Flow Management Position at ATC the Netherlands is regarded as the focal point between Schiphol and the Network Manager Operations Centre (NMOC) for air traffic flow management purposes. The connection has added a voice communication link between the Schiphol ATC tower and Network Manager Operations Centre (NMOC). As regulated flights are forbidden to take-off outside the STW, this communication link is mainly used in case a flight is expected to be unable to depart inside its STW and therefore a slot extension is required.

Experienced limitations

The advantage of this new voice connection is the ability to solve operational issues in a direct way. However, at the time of the A-CDM connection a lot of ATFM-slots were issued throughout Europe (including Schiphol). Next to added complexity due to increased traffic, intense weather and lack of ATC staff in Central Europe, a significant increased number of calls were made over voice communication from FMPs and TWRs in Europe to NMOC. AOs were using an application called e-helpdesk for their requests. For some flights, more than one request per flight was made in which both the AO and ATC tried to do a request. Due to this situation the workload at NMOC was increased significantly. This often resulted in calls not being answered in time and congestion of the voice communication due to technical limitations at NMOC side. The effect was a dead line when trying to call NMOC.

Way forward

Altogether, the use of voice communication adds workload to the ATC tower and NMOC. This is expected to be solved by way of another communication technique, which is the E-Helpdesk application from Eurocontrol. It is a Business-to-Customer solution which can be easily accessed through a browser. As mentioned before it is already used by AOs, but will be extended for use by FMPs and TWRs before the summer of 2019. In addition to the e-helpdesk NMOC provides new functionality to put certain requests via DPI message exchange. This would require adaption of CDM systems in the TWR and airport and requires longer time to realize at Schiphol.

To reduce the number of requests NMOC will filter and prioritize requests via e-helpdesk. These will be based on airport function (TWR > FMP > AO) and how the airport is connected to the network (A-CDM > Advanced Tower > standard TWR).

XVII. Interviews

Process Development Operations (AAS)

Boudewijn Lievegoed (validated by mail)

How would you define plan stability? What are the benefits?
A system which is stable/robust in itself (built-in design-principles for plan stability), flexibility needs to be present to intercept unexpected developments such as a turnaround overshooting its planned end-time.

How does this apply to gate management?
Plan stability is critical to avoid congestion for specific locations on the apron. Consecutive flights should not be planned with too little buffer in between. For a couple of years, plan stability has been sacrificed in exchange for capacity to accommodate more traffic.

In which cases is plan stability critical and what are the consequences in case it is lacking?
The consequence is the presence of so called 'snow-balling effects'. An unexpected turnaround delay induces reactionary delay on inbound flights. If this is not intercepted pro-actively, the consequence is inbound holding, resulting in added emissions and congestion around the taxiways.

Which factors influence plan stability?
The current gate-management procedure considers demand for towing-movements. This adds movements to the central area, inducing complexity and reliance. It is sensitive to 'snow-balling effects'. Everything combined adds workload to the management of these movements. An example is added workload for Ground Control as it needs to keep an eye on towing-movements.

Which activities/developments are active within Schiphol to govern or improve plan stability?
- Medium term
Avoid concentrating aircraft in a central system. Instead, create a solution similar to a 'pressure relief valve' in which aircraft are pro-actively distributed on the remote aprons, reducing the probability for snowballing-effects and reactionary effects such as inbound holding or reactive measures such as relocating an aircraft to a remote apron. Pro-active distribution of aircraft (remote servicing) should increase overall plan stability. Furthermore, it avoids waiting time for aircraft in inbound holding, reducing emissions and improving airline punctuality.

- Long term
Potential solutions include infrastructural changes to accommodate this decentralized concept. Examples are an Automated People Mover to relieve demand for bus-movement on airside. Eventually, the Clean Apron Concept could become an interesting topic.

Safety Coordinator (DNATA)

Bertus Snelting (validated by mail)

What are your thoughts on plan stability?

It is hard to relate the philosophy of plan stability to the cargo operation. An interesting perspective would be to take away the main cargo supply line and thereby restricting the supply of cargo towards passenger aircraft. A worst-case example would be the route Nairobi - Amsterdam - Flower Auction - England. Taking away the route Nairobi - Amsterdam would affect the flower auction. Ryanair adds value to the airport, the cargo business adds value to the surrounding economy. It is important to keep in mind the added value of full-freighters when increasing focus on plan stability.

What are underlying reasons for late TOBT updates?

Often, the gate closes at 10 minutes prior to departure case of a missing passenger a bag needs to be off-loaded. It is hard to know where in the belly of this plane the bag is located. There is no time to wait loading a bag until the passenger has boarded the plane. It is allowed to load a bag when the passenger has checked-in and forbidden to depart without the passenger and bag traveling together on the same plane. This needs to be taken seriously.

Other reasons are due to urgency such as a donor-heart or kidney or radio-active material. These can be added shortly before TOBT but are rare.

From the perspective of a ground handler, updating the TOBT to wait for late passengers is a better trade-off than removing the bag from the plane which would increase the delay much more.

What are underlying reasons for unexpected turnaround delay?

Most delays are due to late passengers, other reasons are mainly due to technical reasons such as a faulty door. A turnaround time of 30 minutes is only possible in case everything goes as planned.

Other reasons for delay are turnarounds starting late due to lack of equipment. A ground handler needs preparation to receive a new aircraft. Many times, there is a lot of mess on the platform. This needs to be removed and new equipment needs to be prepared on the stand. This may be up to 10 freight dollies, 15 to 20 container dollies and 4 to 5 baggage carts.

Do you have any best-practices for plan stability?

It is very important for stakeholders at the airport to understand each other’s processes and the small margins present in the planning.

Member of the Business Expert Team & Business Analyst CDM@AMS (AAS)
Yiannis Alexopoulos (personal views)

What are the goals of the Business Expert Team and how are these translated into its activities?
The BE team is a relatively young team with the goal to take care of CDM related subjects which are not within a project scope. It is seen as a 'line' organisation. In the BE consult, CDM related issues are discussed, but also other developments of CDM such as 'where do we want to be with CDM in x amount of years?'. Furthermore, it is good to know that the BE team is subject to the Tactical Board, so the TB is our point of escalation. To gain a sense of subjects we discuss in BE 'what are the consequences of a call in the TOBT window instead of the TSAT window'.

How would you define plan stability in the outbound-planning process, and to what extent is correct provision of information of importance?
In my opinion, correct information provision is key in realizing a stable outbound planning. However, it is important to know that not only information sourced from local operations (Schiphol) supports this, but also information from the network. For example, if other ANSPs above Europe constantly change the capacity, the stability and predictability at Schiphol is affected. Besides, there is always a trade-off between stability and (for example) less delay. For example, in case of last-minute runway availability for a specific flight, this capacity could be used for a flight, but that also means that his TSAT will change and therefore less stability/predictability is created. So my definition for plan stability is: knowing when departure is allowed early in the process and changes of departure times carried out in such a way in which all involved parties can anticipate (AO, ANSP, MGH, Airport).

What is regarded as 'incorrect' way of sharing information? (for example, number of updates in the final x minutes before the approximated off-block time)
Incorrect sharing of information is information which is deliberately provided in a wrong way or information changing last minute for no reason (think of TSAT fluctuations). Last minute TOBT updates are not wrong in my opinion, because the handler communicates that it will be on time. But this is different in case of last minute TOBT change of 1 or 2 minutes which has 0 predictive value.

To what level does this apply to TSAT instability? Are there any factors having the same or even more influence in sequencer recalculations?
The problem with the sequencer has two causes: TOBT updates and an outdated sequencer. We need to realise that CDM relates to the operation and that the operation can be unpredictable. In my opinion, the sequencer should be able to take a beating. Of course, we also need to realise that if the process stays unpredictable, the TSAT will also be unpredictable. Therefore, it is important that as an airport we need to keep working on predictability of all processes (also consider PAX processes). Analysis does show us that those last minute TOBT updates of 1 or 2 minutes cause quite a lot of fluctuation.

What measures are undertaken (and considered) by the Business Expert Team to improve the provision of TOBT changes by ground handlers or airlines?
At the moment I'm providing the sector with CDM training sessions. In these training sessions I explain why predictability is so important and how they can support the CDM process (such as getting rid of those last minute TOBT updates of 1 and 2 minutes). The MGHs tell me that they change this TOBT last minute because they are scared of the sequencer. They do everything to achieve their TOBT to the last moment, because otherwise airlines would complain. So I think that the new sequencer will increase the trust of MGHs in the system and improve updates. Furthermore, AAS will be placing CDM screens on the aircraft stands. This will bring down the TSAT expired occurrences, resulting in less need for TOBT updates. These are all initiatives running outside of the BE team.

Are significant improvements to be expected or would extra measures be necessary to improve the provision of information? If applicable, which measures would be applicable and to what extent do they have the potential to improve stability in the outbound-planning?
Initiatives: new sequencer, training, cdm screens, research to call in TOBT window, (potentially) an app allowing MGHs to administrate CDM times to improve the quality. There are many more initiatives but I think these are very important.

Flow Management Position (ATC-NL)

The FMP is regarded as the interface between the airport and Network Manager, which operational information is communicated from this position with the Network Manager?
That's right, the FMP is regarded as the interface between ATC-NL and NM. From NM this is laid down in the NM agreement which includes appointments between ATC-NL and NM, amongst others. Furthermore, the FMP acts based on the 'ATFCM Operations Manual'. It includes descriptions of procedures as regarded by NM in relation to the network and therefore also the FMPs. Besides, we also have some additional procedures which are specifically applicable to the local situation (only within the Netherlands). These are described in VDV7.

In which planning-phases could Flow Management be divided and what are the primary activities per phase? (example: Tactical Flow Management/day of operations -> refinement of Demand/Capacity imbalances)

- NM regards a couple of defined phases:
  - Strategic phase (from seven days onwards)
  - Pre-tactical phase (one to six days onwards)
  - Tactical phase (day of operation)
  - Post-ops phase

- ATC-NL partially regards the same phases:
  - Strategic phase: the FMP has no tasks in the strategic phase
  - Pre-tactical phase: FMP has a limited set of tasks
  - Tactical phase: the vast amount of tasks are present in this phase
  - Post-Ops phase: FMP has no tasks in this phase (yet)

Which phase generally results in the most workload? Is this evenly distributed?
By far, the tactical phase is responsible for the most workload. Spread over the day the emphasis is on the morning and afternoon. This is due to the spread of traffic demand. Besides, workload is strongly dependent of external conditions, such as weather, availability of infrastructure or other circumstances.

In the first 100 days since the connection, a clear difference can be observed in delay related to the initially assigned CTOT. The actual delay has barely changed in relation to the situation before the connection. Has this resulted in an increased number of changes/optimizations in CTOTs and to what extend does this add complexity for the FMP? (do these changes take place before day of operations or shortly/during pre-sequencing?, is this information stable enough to carry out Demand/Capacity balancing in an optimal way?
This is hard to explain. The process runs almost completely automatic on the background and the only input on the system is at the tower. What has changed is the complexity of the system which has increased enormously in relation to the situation before the connection. Especially in cases of problems and/or questions about the system, this creates a challenge for the FMP. A tower specialist might be able to elaborate on this.

Which communication is present between the FMP and Outbound Planning and which tools are used to gain insight into the performance of Outbound Planning?
There is little communication between the FMP and Outbound Planning because the system largely runs automatically. The communication is mainly about problems with individual flights and in cases in which flights need extra start-up time. In those cases, we are the intermediary between OPL and NM. Furthermore, we have access to the CDM-portal which provides us with insight into the actual status of a flight.

Are any other clear changes observed since the connection with the Network Manager? (for example, usability/stability of CDM information such as EOBT and CTOT)
A clear reduction in the exceedance of the slot tolerance window is observed (STW, for regulated flights) and departure tolerance window (DTW, for non-regulated flights). Hereby two images for October 2018 and October 2017.

Outbound Planner (ATC-NL)

Which supporting tools does an Outbound Planner have available for the purpose of operational insight? Which (CDM) information is critical?
We have a Display (EDD) on which we have insight into the preplanning of flight until approximately 1,5hrs before departure. Several aspects are critical:
- TOBT
- Declared runway capacity
- SID spreading over the outbound runways

Which operational factors are of influence on a stable outbound planning? (for example, SID spreading, runway changes, changes in the TOBT and ATFM-slot/CTOT as primary sources of information, etc.)
A timely and accurate setting of TOBT, by far. This is the basis of the whole CDM concept. A good weather prediction, based on this ATC-NL is able to declare runway usage and capacity. As little runway changes as possible, a runway change disturbs the planning per definition.

Since the connection the compliance to CTOT windows has improved strongly, this could partially be due to improved CTOT calculations by the NMOC and partially through procedural changes (such as higher priority of regulated flights), how is this experienced from the perspective of OPL?
CTOT adherence is mainly improved due to the fact that:
- Because of the connection we generally don’t receive any slot changes during taxi-out (system)
- Because the TSAT window for aircraft with a slot is changed to -5+5, was -5+10 (system)
- Slots are distributed based on TOBT and not on EOBT (flight plan does not consider ground handling and TOBT does)
- Also we are stricter as OPL and call with Brussels in case a slot comes in danger (procedural)

Does increased compliance in ATFM-slots have an effect on the flexibility in the outbound planning? (when do changes of these imposed take-off times occur and, in case these change shortly before TSAT, what influence does it have on an optimal runway planning?
When there are a lot of restrictions due to ATFM slots, data analysis shows that delay for non-regulated flights increases. This is because the planning is more ‘rigid’, there is less flexibility. A planning with many ATFM slots makes it harder for us to fill the declared runway capacity because we are less flexible in determining the planning.

The FMP position indicates increased system-complexity for the tower-function since the connection, how is this experienced?
That’s right. Our current sequencer is insufficient. We also miss planning-tools in our current system. There are a lot of work-arounds, handlings and patches an OPL needs to perform to maintain control over the planning. Especially during disrupted days this adds an enormous amount of workload on our side.