

*THE INFLUENCE OF ATFM DELAYS ON
AIRSPACE CAPACITY
A QUANTITATIVE STUDY ON THE EFFECTS OF DELAY
RECOVERY AT AMSTERDAM AIRPORT SCHIPHOL*

Joep Boekhout
Amsterdam,
02-02-2018

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PREFACE & ACKNOWLEDGEMENTS

This thesis report is made for the Knowledge & Development Centre Mainport Schiphol and without doubt can I say that I am very grateful for this opportunity and learning experience.

I would like to thank Evert Westerveld and Cerial Janssen for taking the time to review and consult on my work and enable me to reach results by providing me with data.

Also, I wish to thank Frenchez Pietersz for all the time and effort you have put in my research. Whenever I had a question, you had time to answer it, which really helped me.

I would also like to thank Alina Zelenevska for all the scrum-sessions and always staying results-oriented. This really helped me to get where I am now in the research.

The development of my research topic is partly the initiative of Yoram Obbens. Thank you for the brainstorming sessions, these were really helpful.

Special thanks to my colleagues, Niek Jacobsen, Ramsey Kanis and Huib de Jong. I really think the cooperation between the four of us took our work to the next level.

For the reader I would like to note that this research is made in alignment with the ethical standards of the Netherlands and the Amsterdam University of Applied Sciences. It is in no way meant to be harmful towards any person and or organization. A non-disclosure agreement has been signed. Therefore, if any of the data in this report is used or referred to, it requires written consent from the Knowledge and Development Centre Mainport Schiphol.

I hope you enjoy your reading.

- Joep Boekhout -

- Amsterdam -

- 02-02-2018 -

ABSTRACT

Joep Boekhout, Aviation Logistics, Amsterdam University of Applied Sciences
Abstract of Graduation Thesis, Submitted 2 February 2018:
The Impact of ATFM Delays on Airspace Capacity

The primary purpose of this thesis is to investigate a possible relationship between ATFM delay recovery and the negative capacity effects this has for Amsterdam Airport Schiphol. The study was conducted in the period September 2017 until February 2018 as a graduation thesis for Aviation Logistics at the Amsterdam University of Applied Sciences. The method that was used was mainly statistical data analysis of flights in the Eurocontrol region with destination Amsterdam Airport Schiphol. Flight specific data has been analyzed on trip time recovery by airlines, aircraft types, origins, per month and cross sectional. The results support the expectations that ATFM delayed flights result in more trip time recovery than non-regulated flights. In addition, cutting off route length and ATFM delay recovery have a small but significant correlation. On basis of these results, it can be concluded that deviations in trip time cause ATFM delays to have a negative impact on airspace and aerodrome capacity.

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LIST OF ABBREVIATIONS

A

AAS	Amsterdam Airport Schiphol
ADP	ATFM Daily Plan
AFP	ATC Flight Plan Proposal
ANM	ATFM Notification Message
ANSP	Air Navigation Service Provider
AO	Aircraft Operator
ARO	Air Traffic Service Reporting Officer
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Movements
ATM	Air Traffic Management
ATO	Actual Time Over

C

CASA	Computer Assisted Slot Allocation
CFMU	Central Flow Management Unit
CHMI	Collaboration Human Machine Interface
COM	Current Operations Manager
CTFM	Current Tactical Flight Model
CTO	Calculated Time Over
CTOT	Calculated Take-Off Time

D

DCT	Direct Routing
DDR	Demand Data Repository
DLH	Lufthansa
DSF	Data Steward Function

E

ECAC	European Civil Aviation Conference
EHAM	Amsterdam Airport Schiphol (ICAO)
ENV	Environment
ERDA	En-Route Delay Absorption
ETFMS	Enhanced Tactical Flow Management System
ETOT	Estimated Take-Off Time

F	
FIR	Flight Information Region
FMP	Flow Management Position
FMS	Flight Management System
FPS	Flight Planning Services
FTFM	Filed Tactical Flight Model
I	
IFPS	Integrated Flight Plan Processing System
K	
KDC	Knowledge and Development Centre
L	
LVNL	Luchtverkeersleiding Nederland
N	
NEST	Network Strategic Tool
NLR	Netherlands Aerospace Centre
NM	Network Manager
NMOC	Network Manager Operations Centre
O	
OCC	Operations Control Centre
ORM	Operational Reply Message
R	
RFL	Requested Flight Level
RPL	Repetitive Flight plan Processing
S	
SQ	Sub-Question
STT	Standard Trip Time
STW	Slot Tolerance Window
T	
TFMO	Tactical Flow Management Operations
TV	Traffic Volume

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CLARIFICATION OF CONCEPTS

Air Traffic Flow and (Capacity) Management *ATF(C)M*

The regulation of air traffic order to avoid exceeding airport or air traffic control capacity in handling traffic (Eurocontrol, 2016b).

Concept of Operations *CONOPS*

Complex Eurocontrol planning tool that calculates 4d trajectories for each flight.

Cost Index *CI*

Aircraft with a tool in their FMS enabling them to make an economic trade-off between fuel usage and flight time.

Correlated Position Report *CPR*

The actual flown trajectory that is added to Eurocontrol systems by air traffic control surveillance systems. These are usually updated every one to three minutes. The messages are received in the enhanced tactical flow management system to get more accurate sector counts.

Delay recovery and absorption

Recovery is the diminishment of delay where absorption is the contrary; the generation of more delay

Eurocontrol

International organization that is responsible for the central organization of Air traffic services for the 41 member states.

Network Manager *NM*

“The Network Manager is there to address the real issues of the network while ensuring that performance targets are met” Sultana (2014), Director Network Manager.

Passenger hard / soft costs

Defined by Cook et al., (2009) as the direct and indirect costs that result from delay, the latter meaning costs that result from the passenger perception of airline unpunctuality resulting from delay.

Repetitive Flight Planning *RPL*

When an airline files multiple FPL's for one flight, it is called RPL, which negatively effects the plan stability.

Trip Time Recovery *TTR*

Regardless of regulations, TTR is the reduction of total planned trip time from actual take-off time until actual time over (FIR entry). In other words, TTR is based on the airborne part of a flight.

EXECUTIVE SUMMARY

In the Dutch airspace and aerodromes, there is an industry wide problem that the integral capacity of the current situation is reaching its limits. Therefore, the sector is in need of research on how to make capacity gains to meet the ever-growing demand.

This research focusses on the effectiveness of the regulation of traffic towards Amsterdam Airport Schiphol. This thesis has the following main research question:

How do airline/pilot decisions influence the current effectiveness of the ATFM measures for flights in the Eurocontrol region with destination Amsterdam Airport Schiphol?

In this research, the 50 airlines with the highest number of flights in the dataset of 198k flights (all Schiphol inbounds in one year originating from the Eurocontrol ATFM region) have been analysed on the way trip time is recovered. To view whether ATFM delays lead to a similar arrival delay, hence effective regulations, ATFM delayed and non-delayed flights originating in the Eurocontrol region and arriving at Amsterdam Airport Schiphol are compared.

The research, conducted on behalf of the Knowledge & Development Centre Mainport Schiphol, is focussed on plan stability, predictability and capacity optimization. The research has some interesting conclusions:

- There is significant trip time recovery; there is a small correlation between trip time recovery and cutting off route length. Most of the variation in trip time recovery in case of an ATFM delay is declared by the origin. The summer months lead to significantly higher ATFM delay recovery than the rest of the year.
- Airlines have multiple tools to recover delays and, from the data combined with the results of interviews with four airlines, it is concluded that airlines that do not have the hub-function make no distinction in delay recovery for regulated or non-regulated flights.
- There is a negative capacity impact resulting from the non-adherence to ATFM delays. This is influenced by all flights deviating from the planned situation. The airlines that recover most ATFM delay compared to non-regulated flights are KLM Cityhopper, KLM and EasyJet. However, in total numbers of trip time recovery, the airlines Swissair, Norwegian Shuttle, TUI fly and EasyJet Switzerland deviate more from the planned situation.

On the basis of the results that have led to these conclusions, two recommendations are done. The first is to stretch this research out over the entire Eurocontrol region to view what deviations of airspace users are doing to the effectiveness of the regulatory system. This is required to gain acceptance by airlines that currently prefer their commercial drive over the network approach. A quantification of the integral

network situation, should change the idea that the commercial drive and ATFM delay adherence do not concur. The second is recommendation offers short-term solutions for the local problem at Amsterdam Airport Schiphol. By introducing an incentive/penalty system for the airborne adherence to regulations, airspace users are more obliged to adhere to the planned situation. For NATS this resulted in improvements to the ATM system that are not numerically specified.

1 INTRODUCTION

The introduction starts with the background situation (1.1). This results in the problem (1.2, see p. 7) of the research, the motivation (1.3, see p. 7), the research goal (1.4, see p. 7), the research questions (1.5, see p. 8) and finally the structure (1.6, see p. 8).

1.1 Background

The background situation starts with a broad description and narrowing down from what the Network Manager is, what the different Flow Management phases are to how the regulation mechanism works and what the industrial relevance is.

The Network Manager

A Network Manager Operations Centre (NMOC, formerly CFMU-Central Flow Management Unit), a Eurocontrol initiative, provides ATFCM services in the 44 states: members of the European Civil Aviation Conference (ECAC) and some adjacent areas (**Figure 1**). Shown in dark blue is the ATFCM area where all flights can be subject to ATFM measures, while the yellow area indicates the states in the ATFCM adjacent area. Flights from the yellow area flying to or crossing the ATFCM area may be subject to ATFCM measures (LVNL, 2016).

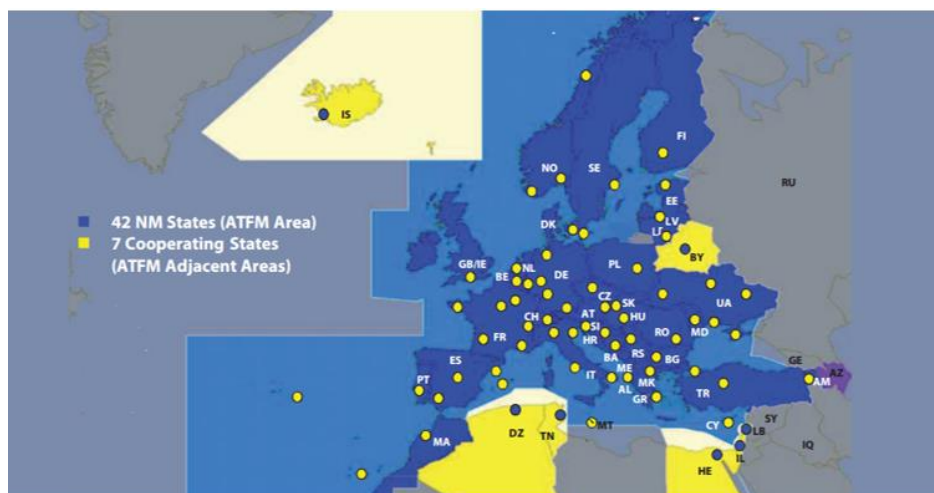


Figure 1 Coverage area of the Network Manager (NM)

Chapter 1: Introduction

At NMOC, ATFCM is applied in several divisions. These are described in ‘*A guide to the NMOC / Eurocontrol*’ (European Commission, 2017a). The divisions and their most important tasks are (ordered similar to the Eurocontrol report):

- Real-Time-Systems Operations & Monitoring (**A**)
- Flight Planning Services (**B**)
- Current Operations Manager (COM) (**C**)
- Tactical Flow Management Operations (**D**)
- Military Liaison Officer (MILO) (**E**)
- Short-term Strategic and Pre-tactical Flow Management Operations (**F**)
- Airspace Data Management (**G**)

A Real-Time-Systems Operations & Monitoring

The real time systems operations & monitoring department is responsible for the monitoring NM applications, infrastructure, systems and networks to ensure the ATFM service stays active.

B Flight Planning Services (FPS)

Operate the Initial Flight Plan Processing System (IFPS). They are also responsible for Repetitive Flight Plan (RPL), which feeds the IFPS with flight plans. Next to this, there is the Demand Data Repository (DDR) and Data Steward Function (DSF). The function of DDR is described in the guide as ‘Maintains IATA and ICAO code matching tables for aircraft operators, airports and aircraft types and specific schedules of flight data for DDR and PRISME’ (European Commission, 2017a). Finally, the FPS deals with the Flight Efficiency Support, which delivers a contribution to efficiency in the form of assisting in better flight planning.

C Current Operations Manager (COM)

Manages the NMOC day-to-day operations with the goal is to minimize disruptions in the system.

D Tactical Flow Management Operations (TFMO)

This department is the most relevant to this research. Here the Enhanced Tactical Flow Management System (ETFMS) and Computer Assisted Slot Allocation (CASA) system are located. CASA is used to calculate slots and TFMO communicates with the flow managers from the air traffic control organizations.

In addition, an aircraft operator liaison communicates with the aircraft operators in case of any ATFCM measure.

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E Military Liaison Officer

Not relevant to this research since they do not influence regulations but in this division, the civil and military coordination is handled.

F Short-term Strategic and Pre-tactical Flow Management Operations

This department handles two important ATFCM functions: optimise available capacity to meet forecast demand and manage demand to minimise delay and cost (European commission, 2017a).

G Airspace Data Management

This department is in charge of the aeronautical infrastructure; Standard Indicated Departures (SID's), Standard Arrival Routes (STAR's), Conditional Routes (CDR's) etc. and the operational airspace structure, which is updated in a system linked to the ETFMS, called ENV (defined later on). The most important divisions to this research are the TFMO, FPS and airspace data management (ordered in importance to the research).

The TFMO sector handles the optimisation of capacity/demand in the form of operation of the slot calculation system. They also carry out delay management to aircraft that are affected by a regulation by offering alternatives and minimizing delay.

The FPS sector is responsible for the processing and distribution of flight plan data. In the results (3, see pp. 22 - 39), the correspondence of the planned data (flight plans) with actual trajectories is measured which has resemblance with the FPS department. The airspace data management is the last sector that is very applicable to this research. As described before, this sector feeds the network system that produces optimal routes with changes in the airspace. There are certain city pairs that deviate much more in the actual trajectory from the planned route than other city pairs (3.4, see p. 29). This might be the wrongdoing of this system.

Flow management phases

The ATFM measures are set in three phases; strategic, pre-tactical and tactical flow management, linked to the time-span until the moment of operation. Strategic flow management occurs seven or more days before the operation where the NM mainly focusses on matching traffic demand with the declared capacity and identifying potential new problems including large-scale events. The outputs of this phase are a capacity plan, route allocation plans and sets of other plans (LVNL, 2016).

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In the pre-tactical phase, the strategic planning is fine-tuned from six days before the day of operation. The output is an ATFM Daily Plan (ADP) and an ATFM Notification Message (ANM) that serve as a tactical plan for the next day.

In the tactical phase, the ATFM measures that were determined in the pre-tactical phase are set. If actual situations differ from the expected situation, the parties that are involved as well as the measures are updated. The output of this phase is re-routing and level capping of aircraft. If this is not possible, slot allocation is applied.

After the day of operations, there is the post-operational phase. In this phase, analyses are done to measure, investigate and report on operational processes, “this allows us to develop best practices and/or lessons learnt to improve those operational processes and activities” (Eurocontrol, 2016b).

Regulation mechanism

The systemic structure Eurocontrol uses is complex, consisting of over ten interconnected systems (**appendix I**). The description of these systems is mainly focussed on the CTOT creation. When slot regulation is applied, the ETFMS produces a slot list and new departure slots can be calculated in the CASA. In the situation that is planned by the Network Manager, in cooperation with the Flow Management Positions (FMP), there is no difference between Calculated Off-Block Time (COBT) and Actual Off-Block Time (AOBT), Calculated Take-Off Time (CTOT) and Actual Take-Off Time (ATOT) or Calculated Time Over (CTO) and Actual Time Over (ATO). If this is the case, the actual situation adheres to the higher levels of planning (strategic/pre-tactical), resulting in a more predictable traffic flow in the sectors, Terminal Manoeuvring Area (TMA) and on the ground. The difference between CTOT and ATOT, called the Slot Tolerance Window (STW) is already being measured by Eurocontrol, **Figure 2**.

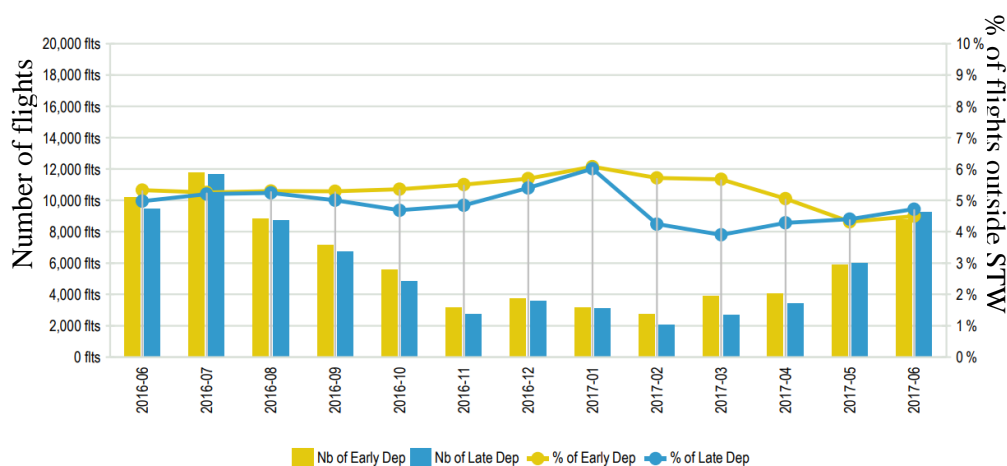


Figure 2 Monthly ATFCM slot adherence (Eurocontrol, 2017c)

Chapter 1: Introduction

This, together with the absence of control on CTO adherence are the main reasons this research focusses on the airborne part of operations.

Industry Relevance

The main relevance of this research is to demonstrate that effective ATFM measures result in a more efficient Air Traffic Management (ATM) system, reducing total delays. This mainly has to do with the benefits of predictability in the Air Traffic System (ATS); explained further in the problem (1.2, see p. 7).

Eurocontrol, as well as the KDC management, identified there is “an over-delivery of air traffic in regulated sectors” (Eurocontrol, 2009). The reasons are that air traffic:

- Deviates from the initially Requested Flight Level (RFL).
- Departs at times different from the original EOBT or CTOT (**Figure 2**, see p. 4).
- Arrives in the sector earlier or later than originally planned.
- Diverges from their original planned route (direct routing (DCT)) (**Figure 3**, see p. 6).

All these factors can be summarized in deviating from the flight plan. Eurocontrol realizes this is unfavourable. However, research to what extent this deviation occurs in the air is not researched yet. Although this is yet unknown, there is a network impact and according to Eurocontrol (2009), this results in:

- Wasted capacity in some sectors.
- Potentially excessive workload.
- An overall lack of confidence in the accuracy of forecast traffic counts.
- Protective capacity reduction.
- Increased workload, stress or working conditions such that the ability of Air Traffic Controller (ATC) may be significantly impaired and thus a safety issue.

Chapter 1: Introduction

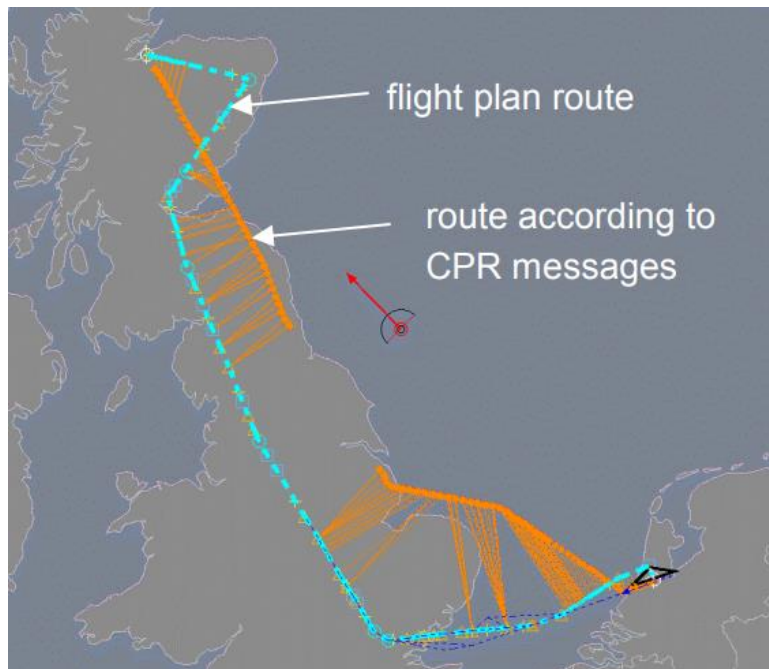


Figure 3 Example of route deviation of the actual flown trajectory (CPR) compared to the filed flight plan (EGPH – EHAM)

“Most Air Navigation Service Providers (ANSP’s) provide guidelines to controllers which typically state that changes to the RFL should only be initiated in exceptional circumstances such as for weather or for ATC reasons, however, it is often the case that controllers ask the crew for their requested level and if circumstances permit it is readily granted” (Eurocontrol, 2009). The actions per stakeholder:

- Aircraft Operations: Inform your pilots of the reason for a lower FL being filed.
- Pilots: High or low, bear in mind there is a good reason behind the filed FL.
- ACC Controllers: Before proposing or agreeing a change to the RFL or using DCT, consider the impact downstream on your fellow controllers.
- ATS Communication: If the RFL needs to be changed, provide means to inform all other ATC concerned via an ATC Flight Plan Proposal (AFP) message.
- Aircraft Operators (AO’s): Adhere to CTOT and update EOBTs for non-regulated flights.
- Tower Controllers: ATC has a joint responsibility with AO’s in CTOT adherence (Eurocontrol, 2009).

1.2 Problem Statement

The main topic of this research is predictability of the ATFM system. For this system, Eurocontrol uses a complex planning tool called the Concept of Operations (CONOPS) where each flight obtains a 4D trajectory. These trajectories lead to network conflicts in different stages. To avoid congestion, a plan is made and when deviations occur, a regulation can be set. Ineffectivity of the regulations; aircraft arriving either early or late, leads to a less predictable and efficient ATM-system.

1.3 Motivation for the research

Schiphol operates near maximum capacity and every potential small gain in capacity is of interest to the stakeholders AAS, KLM and LVNL. The effectiveness of ATFM measures influence the total capacity. To avoid capacity overrun, so-called ATFM delays are set to keep aircraft on the ground longer at their airport of departure.

This is not always actual airport regulation but can also be based on the capacity of a sector or the entire Dutch Flight Information Region (FIR). The client has the expectation that airspace users do not adhere to the planned situation hence ineffective ATFM delays. This is researched using data of flights in the Eurocontrol region with destination Schiphol. The client, KDC management, expects 'a study that provides insight in effectiveness of the regulations and provide airspace users with insight on how their decisions impact the whole system'. The goal is to take a holistic approach to Network Management rather than the current fragmented approach. This means that deviating from the planned situation has negative effects for the total airspace capacity, hence the fragmented approach.

1.4 Research goal

KDC management requested a broad research idea on ATFM delays with a focus on gaining insight in how airspace users deviate from the planned situation and how this influences the total airport and airspace capacity. In terms of capacity, deviations from the planned situation are a negative factor. The knowledge that there is an over delivery of aircraft when a regulation is active has already resulted in overregulating. Overregulating is setting a higher restriction than would be necessary when the demanded amount in the regulation is in accordance with the declared capacity. This is best described by an example. When 75 flights are expected in a given hour, the regulation is sometimes set to 65 Air Traffic Movements (ATM's) while the maximum capacity is 68 ATM's. The regulation is not set to 68 because experience proves the actual demand transcends 68 ATM's.

1.5 Research Questions

How do airline/pilot decisions influence the current effectiveness of the ATFM measures for flights in the Eurocontrol region with destination Amsterdam Airport Schiphol?

Sub-Questions:

How is ATFM delay recovery influenced by pilot/airline decisions?

How is ATFM delay recovery influenced by flight specific factors?

Do the recovery of ATFM delay negatively affect the airspace and/or airport capacity at EHAM?

1.6 Structure

The research is structured in the following chapters:

2. Research Design
3. Analysis of results
4. Conclusions
5. Discussion
6. Recommendations
7. References

2 RESEARCH DESIGN

The research techniques used are mathematical and computational in the form of data analysis, hence the research is quantitative. Before the analysis, the methodology (2.1) describes structure in which the research is executed. Existing literature that is relevant to the subject is listed and elaborated in the literature review (2.2, see p. 15). The research design ends with the scope (2.3, see p. 20).

2.1 Methodology

The total dataset in this research consists of all inbound flights from airports that are subject to Eurocontrol regulations with destination EHAM (in this research, the ICAO code for Schiphol is used) in one year (01-09-2016 / 01-09-2017). The decision to analyse the most recent year is taken because this data is deemed most relevant and to view seasonal influences the time span is set to one year.

The data contains all IFR flight movements to EHAM. All flights in the database that do not meet these criteria are filtered out. Such data are the EHAM – EHAM flights of PXB (Police), PHLAB (Netherlands Aerospace Centre (NLR)) and NCG (Coastguard). This results in a dataset of 197,886 flights. In consult with the stakeholders, only the top 50 airlines, origins and aircraft types (**appendix II**) have been analysed which results in a total dataset of 133,768.

The methodology continues with the description of the research tools that are used, divided per Sub-Question (SQ).

SQ1: How is ATFM delay recovery influenced by pilot/airline decisions?

Methods: desk research, data analysis and statistical validation.

If the incentives for delay recovery in the literature review are significantly present in the data, the pilot decision-making or airline policy is correlated to the level of delay recovery. This will be researched in several steps.

Database build-up

The database is built up by using the Network Strategic Tool (NEST) with DDR2 data and Microsoft office programs Excel and Access.

The DDR data is filtered on all flights entering Dutch airspace, and having destination EHAM. The Traffic Volume (TV) code EHAAFIRAM in DDR is used

Chapter 2: Research design

to specify the end-point of the data. Flights not crossing this point and not having destination EHAM are filtered out. In addition, the time stamp linked to the TV, EHAAFIRAM, equals the variable ATO (explained below).

This filter is applied for both m2 and m3 data for flight lists and airspace entries lists. M2 data is the regulated data, which also contains non-regulated flights; in which case the COBT, CTOT and CTO are equal to the EOBT, ETOT and ETO respectively. The output is linked to a primary key in access (in this case, the Flight ID e.g. ‘AA56158473’). Thereafter, the tables are linked in a query with all relevant data combined (**appendix II**). Here, the variables COBT, AOBT, CTOT, ATOT, CTO and ATO are combined to calculate the delay recovery in minutes (formula one) or in minutes per nautical mile (**formula two**). This variable is then transformed from a timescale to a decimal number. The Regulated Route Length (RIReg) and Actual Route Length (RIAct) are subtracted which results in cutting off (formula three). Other variables are: delay (by regulation), airline, origin and aircraft type. The variable airline is manually filtered by splitting KLM and KLC (KLM Cityhopper) with a function that if airline KLM equals aircraft type E190, F70, F50, E170, E75L or RJ85 then airline becomes KLC. If not, airline stays KLM.

Statistical correlation

First, the correlation between Trip Time Recovery (TTR) with regulated, non-regulated, delayed and non-delayed flights is researched. Since the literature review (2.2) indicates there is no difference in pilot perspective to the reason for their delay, their incentive to recover delays is expected to be similar (or stronger) in regulated versus non-regulated delayed flights. As shown in the next table (**Table 1**), $X^{\text{RegNonDel}}$ and $X^{\text{NonRegNonDel}}$ are expected not to have a significant difference because they both did not obtain a CTOT. $X^{\text{RegNonDel}}$ is marked red because this quadrant does not contain data. Flights cannot be ATFM delayed when there is no regulation active.

	Regulated	Non-Regulated
Delayed	X^{RegDel}	$X^{\text{NonRegDel}}$
Non-Delayed	$X^{\text{RegNonDel}}$	$X^{\text{NonRegNonDel}}$

Table 1 Conceptual model for the differences in delay recovery

As a basis for the calculations, the delay recovery model by Delgado and Prats (2011) is combined and adapted with a Eurocontrol (2016a) model (**Figure 4**, see p. 11). Since the focus in this research is on the en-route part of a flight, TTR is induced by

Chapter 2: Research design

a difference between the CTO and ATO. To isolate the en-route part CTOT-ATOT is then subtracted from CTO-ATO.

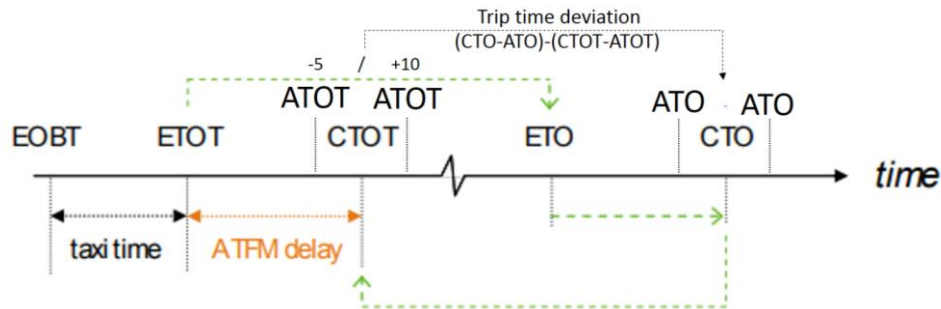


Figure 4 En-Route trip time model (derived from Delgado & Prats, 2011; Eurocontrol, 2016a)

The aforementioned formula to calculate the TTR is listed below:

- 1) $TTR = (CTO - ATO) - (CTOT - ATOT)$
- 2) $TTR \text{ per nm} = ((CTO - ATO) - (CTOT - ATOT)) / RIAct$

$CTO = \text{Calculated Time Over}$

$ATO = \text{Actual Time Over}$

$CTOT = \text{Calculated Take-Off Time}$

$ATOT = \text{Actual Take-Off Time}$

$RIAct = \text{Actual Route Length}$

If 1) or 2) is positive, delay or trip time is recovered. If 1) or 2) is negative, additional delay is generated in the en-route phase. These formulas calculate delay recovery only in the en-route phase of the flight and excludes trip time recovery on the ground.

When there is a significance in the trip time recovery in general, the correlation between this and the percentage of cutting off total route length is analysed. The needed variables are $RIReg$ and $RIAct$ and are defined below:

$RIReg = \text{Route Length Regulated (m2)}$

$RIAct = \text{Route Length Actual (m3)}$

The variables $E/COBT$, $E/CTOT$, E/CTO are calculated by Eurocontrol systems. The calculations Eurocontrol uses include weather data, airspace data updated with actual data, aircraft performance and many more variables (**appendix VIII**). A possible imprecision can be proven by this research. However, a realistic deviation needs to be taken into account.

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SQ2: How is ATFM delay recovery influenced by flight specific factors?

Methods: desk research, data analysis and statistical validation

Next to the pilot / airline influences on delay recovery, flight specific data are included in this research. Four different flight specific factors have been specified.

Airline

The flight specific data start with the airline level. In the database, 505 airlines operate on EHAM. The 50 airlines that have the biggest total presence in the database are analysed. To view which airlines are most relevant to research further, TTR and count are multiplied and results are sorted from large to small by this method. Another factor is the presence of KLM and KLC. Together, they form 52% of the total database, which creates a big influence on the mean. However, since the KLM and KLC's normal distribution (μ and σ) are equally spread around zero minutes, this does not negatively effects other data.

Aircraft Types

The aircraft types are analysed in a similar manner. The most used aircraft types in the database are Boeing 737, Embraer 170's and 190's Airbus 320, 319 and 321, Fokker 70 (KLM stopped flying with F70's since 29th of October 2017), Dash 8, Avro RJ85 and Bombardier CRJ-900. Results of aircraft types will be given per:

- Individual Aircraft type
- Manufacturer

After interviews with the airlines (**appendix VI**), a distinction between aircraft in complexity of their Flight Management System (FMS) is made. The results of the aircraft type analysis are also tested on whether the TTR is influenced by the absence of certain time predictability tools (**method SQ3**) in the FMS.

Origin

In consult with the stakeholders, the top 50 of origins in terms of presence in the database are analysed. These origins have an average presence of 2,623 varying between 6,424 and 1,322. The origins, similar to the airlines and aircraft types are ordered on their relevance to the research. This is done by multiplying TTR and count (n) and then ordering the data from large too small.

Seasonal influences

Another flight specific factor is the seasonal influence on the way delay is recovered. For last year, Riepema (2017) has made an expectation of the busiest days of Schiphol in the summer peak. This peak lasted from June until the end of August. The outbound top pressure was in the whole of August and the inbound top pressure

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from July 7th until August 31st. Other peak periods will also be included; the autumn break (15-10-2016/23-10-2016), the Christmas break (22-12-2016/2-1-2017). Next to testing significant differences on these data, other tests are done for:

- Day of week
- Month

Versus

Finally, the results of the before mentioned flight specific data types; airline, aircraft type and origin are analysed together in three separate analyses:

- Airline versus Origin
- Airline versus Aircraft Type
- Origin versus Airline

The client requests: “Included should be at least a list of the most used regulations with their impact/effectiveness and deviations by users including their impact as well” (derived from the research goals).

To measure the impact of airspace users on regulations, or in other words how deviating from the planned situation impacts the stability of the system, a separate analysis for each flight specific data is not enough. By combining data, more specific influences on the stability of the system can be isolated. As this is what the client has requested, these data are analysed together. For instance, if the separate analyses result in a big difference for Aircraft type X, Origin Y and Airline Z it can be that the combination XYZ is makes up for a big percentage of total airline Z. This result is interesting but it does not necessarily lead to aircraft type X and origin Y to be negative influencers of the system. The unique combination of XYZ affects the system.

SQ3: Do the recovery of ATFM delay negatively affect the airspace and/or airport capacity at EHAM?

Methods: Interviews, desk research, data analysis and statistical validation.

Interviews

Another method to enable making conclusions on the quantitative method, eight airlines have been contacted and asked the following questions:

- *How do you handle flight planning?*

Is a new FPL calculated each day or are FPL's filed for multiple days?

- *How are block times determined?*

Is this statistically done and how many times per year are block times adjusted?

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- *How is the cost index per flight set?*

Does your airline use default CIs for all flights or does the CI vary per flight?

- *What instruments regarding delay recovery are used?*

What actions does your airline take in the execution phase to reduce delays?

The airlines that are questioned are EasyJet, Transavia, Swiss Air, Scandinavian Airlines, British Airways, Deutsche Lufthansa, Alitalia and Turkish Airlines. These airlines have a variety of airline business models and are widely present in the database.

In consult with the stakeholder, a number of incentives for airline TTR are identified. These are:

1. Aircraft type versus Cost Index (CI)
2. Flight planning
3. Block Time
4. Airline structure

Aircraft type versus CI

When there is a delay, ATFM or regular delay, an airline can choose to either recover the delay (partially or fully) or accept the delay. A tool airlines use to recover delays is included in modern FMS. However, aircraft such as the F100, Dh8D, E190 and E170 do not have this tool in the FMS and do not have the option to make tactical delay recovery decisions in the execution phase of the flight. The CI, an accelerated fuel burn tool, is set for flights to make them fly either fuel efficient or fast. This trade-off is made dependant on many variables, discussed in the airline structure.

Flight planning

Many airlines use a system for flight planning that calculates an individual flight plan for each flight. Because the last version of the FPL needs to be submitted in the Eurocontrol system two hours before the flight, much more precise routing data can be included in the FPL than by Repetitive Flight Planning (RPL). RPLs are flight plans related to frequently recurring pre-planned flight operations with identical characteristics and which may be submitted by operators for retention and repetitive use by ATS units for a specified period, thus eliminating the need for an operator to file a flight plan each time one of these flights is operated (ICAO, 2001).

However, the negative effect in terms of network planning stability is that the absence of abovementioned precise data leads to a less predictable system (this is supported by the capacity impact in the literature review **2.2**, see p. 15).

Block time

The block time is defined by Hu (2013) as: “*from the moment the aircraft is pushed back from the gate or starts taxiing from its parking stand for take-off to the moment it comes to a final stop at a gate or parking stand after landing*”. These times influence the amount of legs an aircraft can carry out in a day. Therefore, the airline incentive for block times is logically for them to be as low as possible. To illustrate how block times can negatively influence the network predictability, a flight from LSZB to EHAM carried out by Airline X has a block time of 1.25 hours. The actual time that is currently flown is 1.30 hours but since there are a lot of connecting passengers, the block time needs to be set to 1.20 hours. This can be done by flying a higher CI, which leads to a higher fuel burn.

Airline structure

In the foregoing subparagraphs, the most important incentives for TTR are given. These are all linked to the airline structure. Airline structures in this database are based on cost structure, network structure and passenger structure.

The airlines are low-cost (LCC) / full service (FSC), Point-To-Point (P2P) / network and business / leisure / combination carriers.

The eight airlines that have been questioned are:

- | | | |
|--------------------------|---|---------------------|
| 1. EasyJet | - | LCC, P2P, combi |
| 2. KLM | - | FSC, network, combi |
| 3. Transavia | - | LCC, P2P, leisure |
| 4. Swiss Air | - | FSC, network, combi |
| 5. Scandinavian Airlines | - | FSC, network, combi |
| 6. British Airways | - | FSC, network, combi |
| 7. Deutsche Lufthansa | - | FSC, network, combi |
| 8. Alitalia | - | FSC, network, combi |
| 9. Turkish Airlines | - | FSC, network, combi |

2.2 Literature Review

Delays have an impact on aviation operations. Relevant to this research in terms of delay impact are the cost impact, capacity impact and delay recovery models. In addition, literature on the possibilities for the pilot's incentives to recover delays is included.

The cost of delay severely influences airline profitability. The major cost component is typically that associated with delayed passengers, although it is generally poorly

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qualified. (Cook, 2009). The airline cost types of delays are Passenger hard cost, passenger soft cost, crew, maintenance, fleet, fuel and reactionary (Cook & Tanner, 2011). These cost centres are (Cook, 2009) '*hard airline costs result from passenger delay, such as rebooking, compensation and care. Soft costs manifest themselves in several ways. A passenger may perceive an airline to be unpunctual and choose another instead*'.

The financial impact to airlines is also influenced by the length of a delay. Longer delays will tend to have higher per-minute costs than shorter ones (Cook, 2009). Delays have an impact not only on the airlines, but also have profound implications on the cost-efficiency and safety of the system. They contribute to the negative impact of air transport on the environment (Belkoura, Pena & Zanin, 2016). As flight delays increase on a route, fewer passengers will be willing to fly on the route (Cook & Tanner, 2011). The total costs of ATFM delay (calculated with total hard and soft cost for all ATFM delayed flights in Europe) is estimated €1,300 million (Cook & Tanner, 2011). These sources are used to view possibilities for delay recovery in terms of longer flights (Cook, 2009) and therefore used to answer SQ2.

Next to cost impact, delays influence the airport and en-route capacity. '*These delays increase nonlinearly as demand approaches the capacity in the system*' (Ball, Barmhart, Dresner et al., 2010). In ATFM delays, Eurocontrol makes no clear distinction in distance of their original airport in the regulations (Delgado & Prats, 2011). This, and other factors, sometimes lead to inefficient regulations because ATFCM regulations are often cancelled before their initially planned ending time, leading to unnecessary ground delay (Delgado & Prats, 2011). The impact of flight delays is not confined to airlines and their passengers; other segments of the economy are also affected (Ball et al., 2010).

The model used in this research is similar to Delgado and Prats (2011). Their research on the impact of speed reduction on ground and delay cancellation on the actual time of arrival is analysed and adapted into an en-route trip time recovery/generation model.

The relevant variables in Delgado and Prats' (2011) model (**Figure 5**, see p. 17) are (in order of appearance):

D= Delay

ETD = Estimated Time of Departure

CTD = Calculated Time of Departure

ETA = Estimated Time of Arrival

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CTA = Calculated Time of Arrival

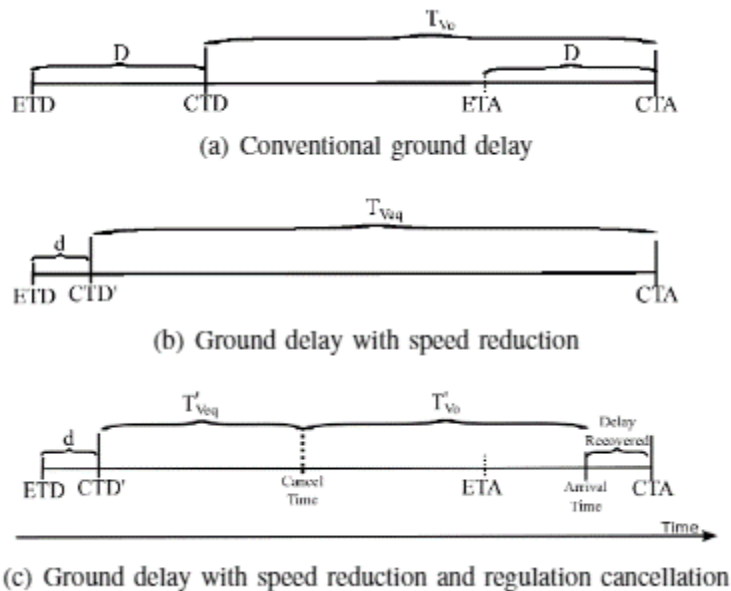


Figure 5 Ground delay with speed reduction and regulation cancellation (Delgado & Prats, 2011)

This model, together with Eurocontrol's ATFM regulation layout (**Figure 6**) are merged to one model as a basis for the formulas in the methodology. This creates the basis for the query structure that form the database and are therefore used primarily to answer *SQ2* and *SQ3*. The relevant variables in this figure are:

EOBT = Estimated Off Block Time

ETOT = Estimated Take off Time

CTOT = Calculated Take off Time

ETO = Estimated Time Over

CTO = Calculated Time Over

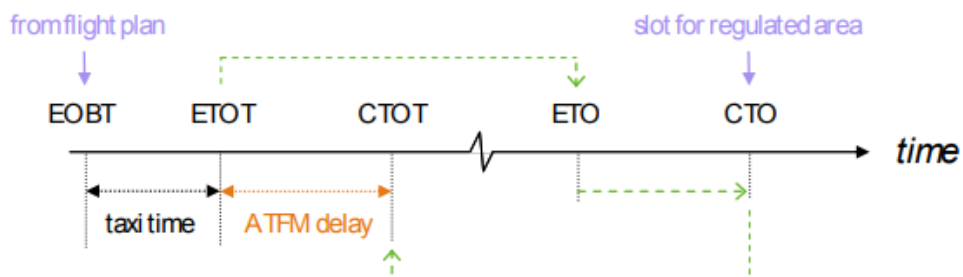


Figure 6 Eurocontrol ATFM regulation layout (Eurocontrol, 2016a)

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To be able to conclude what the pilot's influence on ATFM delay recovery is, prior literature on pilot psychology and airline policy need to be analysed first. The reason for airline policy to pressure pilots to increase their on-time performance is that the airline industry has realized very little return from total economic contributions of the aviation industry (Ball et al., 2010).

'The more time pressured people are, the less likely they will be to engage in creative cognitive processing' (Amabile, Mueller, Simpson, et al., 2002). This is in line with Connel and Wichner (2013) concluding time pressure leads to deviating from procedures and policies which can also impair safety in several ways (Connel & Wichner, 2013).

Lempereur and Lauri (2006) proved pilots feel personal distrust as well as anger towards management. This can be because of the performance being constantly monitored and evaluated by operational management, fellow crewmembers and on new technology aircraft by an on-board monitoring computer. The airline policy regarding delays, although not yet researched, might be this pressured for several reasons. One of which is that poorer operational performance leads to more expensive operations (Ball et al., 2010). The aim here is to view previous research done by Ball et al. (2010), Connel and Wichner (2013), Amabile, et al. (2002) and Lempereur & Lauri (2006) that are all aimed at the incentive for pilots to recover delay *SQL*.

'Another is that from a one-time delay, a passenger may defect an airline as unpunctual due to dissatisfaction' (Cook & Tanner, 2011). These negative effects of delays have positive outcomes for airlines, grasping the opportunity to deliver, though expensive, on-time flights on these perceived difficult legs. *'Thus, delay reductions would lead to a new equilibrium in the supply/demand relationship between the airlines and their passengers with both the airlines and passengers accruing a portion of the overall welfare gain'* (Ball et al., 2010).

The pressure of airlines on their pilots has increased since the surplus of pilots after the 2008 recession. In a newspaper article on starting pilots, Kluviens & Naafs (2016) show that this surplus, together with the cost-efficiency pressure of low-cost carriers caused airlines to abandon their traditional cost structure. An example of the traditional airline pilot was a KLM-pilot in the 90s who flew to Australia, stayed there for three weeks and then had a week off to recover.

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In the new system, the airlines that are listed in this article are Ryanair, KLM, Eurowings, Germanwings, the ME3 (ME3 Refers to the Middle-Eastern airlines Emirates, Qatar Airways and Etihad Airways), Air France, SAS Scandinavian Airlines and Fly Dubai. The increased pressure of these airlines on their pilots has led not only to a decreased safety, a pilot not getting paid for a delay is a reasonable cause to recover a delay. The before mentioned sources (Ball et al., 2010; Kluviens & Naafs, 2016) aim more towards airline policy incentives to recover delays but also the pilot incentive (*SQ1 and SQ2*).

The intent and incentive to recover delays is described by a KLM Operations Control Centre (OCC) promotional video. In this video, the captain of a delayed flight contacts the OCC and they use a Traffic Flow Management Decision Support program that calculates the economic trade-off between cost of delay and accelerated fuel burn. Since the transfer passengers can save 7000 euro's, the OCC advises the pilot to fly faster (KLM, 2011).

The ATFCM user's manual (Eurocontrol, 2016b) is used to form a framework of the Network Manager Operations Centre (NMOC) Systems and main data flows. As illustrated in **Appendix I**, the AO's, Air Traffic Service Reporting Officers (ARO's) and ATC deliver data to the systems the NM uses.

The AO's and ARO's use RPL to submit the first version of a flight plan into the Environment database (ENV). ATC submits all changes to the airspace and those data is sent from the ENV to the IFPS. The AO's and ARO's insert FPLs and receive an Operational Reply Message (ORM) to acknowledge, reject or manual (if errors have been detected) their flight plan. The IFPS distributes the FPLs and FPL changes to all ANSPs that are involved. Next, the FPLs are sent to the ETFMS. The output of the ETFMS, updated with ENV data is a network situation to the AO's, ARO's and ATC and slot rerouting for AO's and ARO's. The ETFMS also provides input to the Collaboration Human Machine Interface (CHMI), which is a graphical interface for the Network Operations users.

The FMP's can monitor the traffic counts per twenty minutes and set a maximum. If this maximum is exceeded, CHMI sends a message to ETFMS, which communicates with CASA. In CASA, a CTOT is calculated in case of a regulation. Other, more favourable measures are STAM and MCP. This system gives AO's and ATC's updated information on flights inbound or crossing their airspace.

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The system however, does not give flights a specific marking so that transit sectors know the flight is regulated. Moreover, the current system regulates based on only traffic volume to take corrective actions. This is not sufficient to the needs, because also relevant are: aircraft trajectories, manoeuvres performed, types of aircraft, their speed and other restrictions (Dmochowski & Skorupski (2016).

Next to this, EU 255/2010 regulation states ‘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’ (European Commission, 2010). This means that 20% of all ATFM regulated flights are allowed to depart outside the CTOT. These flights, and the other ATFM regulated flights can be subject to en-route delay recovery, which, according to Belkoura, Pena & Zanin (2016) is a process based on opportunity i.e. triggered by positive (availability of alternative routes) and negative (high delay at take-off) factors. Belkoura, Pena & Zanin (2016) proved that high delays at take-off are absorbed which ‘*implies a will to recover delays during the en-route phase*’.

Cook et al., (2009b), concluded that ‘recovering an airborne delay, increased fuel burn could be used and/or a change could be requested of ATC for a more direct route’. Note, these conclusions are both drawn for non-ATFM delayed flights. Whether there is a difference between ATFM- and regular delay recovery has not yet been researched and is included in this research. The amount of realizable delay recovery is constrained by the fuel consumption, which again is dependent on: aircraft type, take-off mass, flight distance, etc. (Xu & Prats, 2017). Taking the cost variables into consideration, the optimized number of delay recovery is 11 minutes in terms of accelerated fuel burn costs traded against costs of delay (Cook, 2009). The delay recovery however, is not always accountable to the pilot. Aside from to the pilot recovering delays, an air traffic controller can reduce trip time by opening direct routes (Belkoura, Pena & Zanin, 2016).

2.3 Scope

The Network Manager is a Eurocontrol initiative. It only applies to the pan-European air traffic that have origin/destination Schiphol. Therefore, the data analysis in this research will use data of all European flights with destination Schiphol in the past year. Only inbound flights will be included in the data analysis because there is no relevance to either of the stakeholders to see if outbound flights recover ATFM delays. Outbound flights are only under regulation of other airports. This does not influence the capacity at EHAM, hence outbound flights are out of scope. The delay recoveries are influenced by a number of factors. The most important factors that will be researched are:

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- Route length / Origin
- Airline
- Delay type / area
- Peak / Capacity restriction
- Aircraft type

Time variables that are used are the departure times of European flights to EHAM and the FIR boundary times:

- EOBT
- COBT
- AOBT
- EHFIRAM
- EHAASECT1, 2, 2E, 2I, 3, 4 and 5

These phases of flight are visualized in the next figure (**Figure 7**):

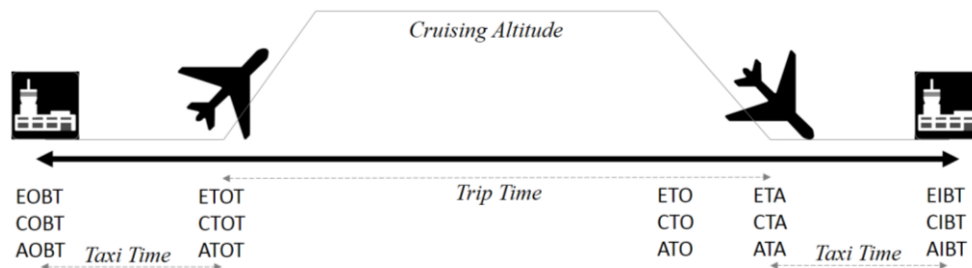


Figure 7 Visualization of the most important variables for this research

In consult with the stakeholders, the decision to limit the research to the moment of take-off from the origin to the moment the flight enters the Dutch FIR is taken to isolate the delay recovery in terms of airspace user decision making. The off-block time until the take-off time is excluded because Eurocontrol already measures the ATFM slot adherence. What else is excluded is the moment flights enter Dutch FIR entry until the moment of arrival. From the FIR entry, flights are under control of LVNL. From that point, sequencing in form of speed and heading variations are applied which would negatively influence the validity of the data.

Lastly, the capacity impact of the instability of the plan will also be included in the report. Since the quantification of capacity impact requires different data and methods than the focus of this research, the quantification is deemed out of scope. The goal of proving a capacity impact occurs in this research is describing what network effects the over-delivery of aircraft has.

3 ANALYSIS OF RESULTS

The results are stated narrowing down from broad to specific. Starting with the results of the broadest analyses (3.1), narrowing down to analyses on flight specific data level (3.2; 3.3; 3.4, see pp. 24, 25 and 29 respectively), a comparative analysis (3.5, see p. 31), seasonal influences (0, see p. 35) and airline validation (3.7, see p. 39).

3.1 Data validation

The data model consists of four quadrants (**Table 2**): Regulated and delayed, not regulated and delayed (this quadrant does not contain data since a flight cannot obtain a CTOT when there is no regulation active), regulated and not delayed and not regulated and not delayed.

TTR	Regulated	Non-Regulated
CTOT	CTOT X_{RegDel}	X
No CTOT	$X_{RegNonDel}$	$X_{NonRegNonDel}$

Table 2 Four quadrants of data

Trip time recovery over all flights

In general means that data of all four quadrants is tested on the recovery of trip time. This is tested by two hypotheses:

H0: There is no recovery of trip time

H1: There is recovery of trip time

Chapter 3: Analysis of results

T-TEST

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
TTR	197,837	1.01	3.805	.009

One-Sample Test				
	t	Df	Sig. (2-tailed)	Mean Difference
TTR	117.764	197,836	.000	1.007

Table 3 SPSS T-Test results

Significance = Probability = $P = 0.000 < 0.05$ (**Table 3**)

Therefore, H_0 is rejected and H_1 is supported.

Trip time recovery and cutting off route length

Whether delay recovery and cutting off are correlated, a matched pairs means analysis is used.

H_0 : There is no relationship between $TTR = X_1$ and $Cutting\ Off = X_2$

$H_0 = X_1 = X_2$

H_1 : There is a relationship between TTR and Cutting off

$H_1: X_1 \neq X_2$

T-TEST

Paired Samples Statistics				
	Mean	N	Std. Deviation	Std. Error Mean
TTR	1.01	197,837	3.805	.009
Cutting Off	-0.007	197,837	.043	.000

Paired Samples Correlations			
	n	Correlation	Sig
Pair 1	197.837	.210	.000

Paired Samples Test				
	Mean	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
Pair 1	197,837	3.796	.008	.000

Table 4 SPSS Correlation results

Chapter 3: Analysis of results

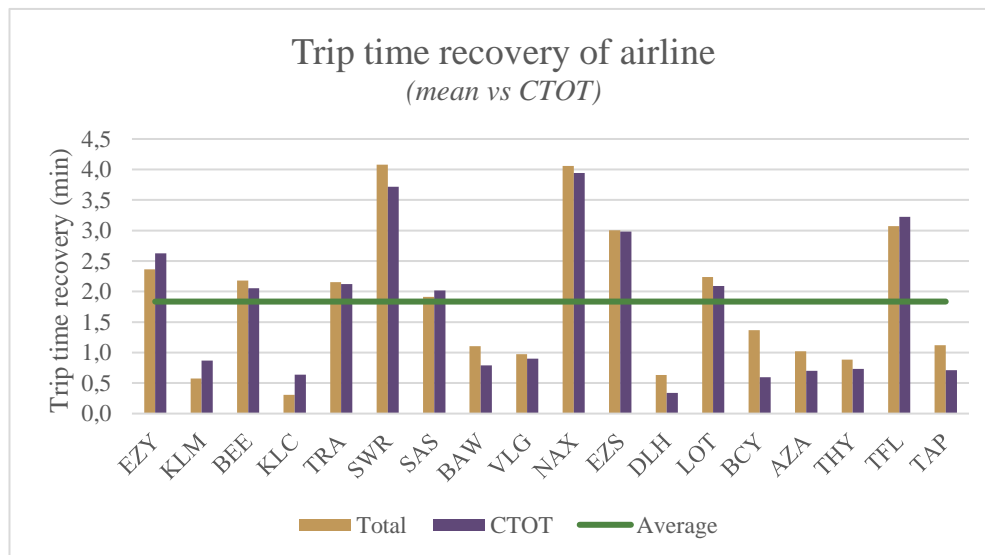
Significance = Probability = $P = 0.000 < 0.05$ (Table 4)

Therefore, H_0 is rejected and H_1 is supported. Although the correlation is small, there is a significance.

3.2 Analysis of results for airlines

In the graph on the next page, (**Graph 1**) the airlines are analysed in the way trip time is recovered with or without an ATFM delay. All codes for airlines, aircraft types and origins that are used in the database are added to **appendix II**. Airlines that recover most time (with n for the number of flights and TTR for trip time recovery in minutes) are:

Airline:	n:	TTR:
1. SWR	1,402	4.08
2. NAX	912	4.05
3. TFL	398	3.07
4. EZS	901	3.00
5. EZY	11,847	2.35
6. LOT	2,403	2.23

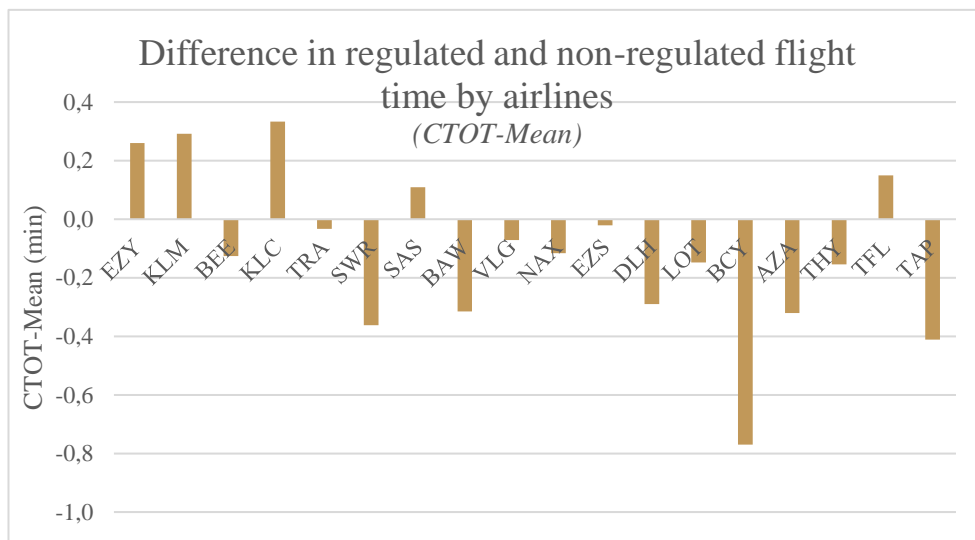


Graph 1 Trip Time recovery on airline level on mean vs CTOT

Chapter 3: Analysis of results

In the next graph (**Graph 2**), the difference between trip time recovery in case of a regulated delay and the mean is illustrated on airline level. The biggest deviations are:

Airline:	n:	CTOT - Mean (min):
1. KLC	30,206	0.33
2. KLM	42,071	0.29
3. EZY	11,847	0.26
4. TFL	398	0.15
5. SAS	2,834	0.11



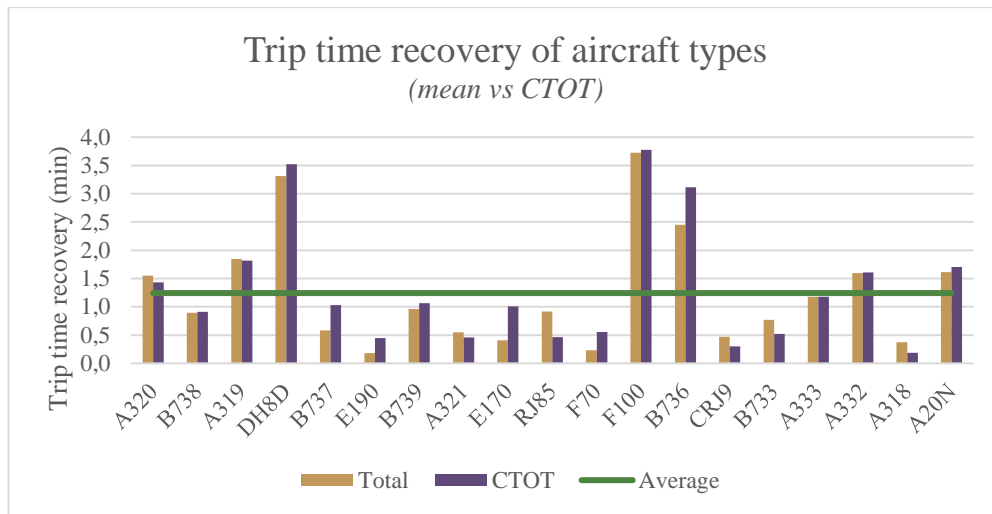
Graph 2 Mean subtracted from CTOT on airline level

3.3 Analysis of results for aircraft types

In the next graph (**Graph 3**), the aircraft types are analysed on the way trip time is recovered with or without an ATFM delay. Aircraft types that recover most time are:

Aircraft Type:	Flown by:
1. F100	LOT, SWR, AUA (n = 154; 36; 15)
2. Dash 8 Q400	BEE (n = 3,619)
3. B736	SAS (n = 301)

Chapter 3: Analysis of results

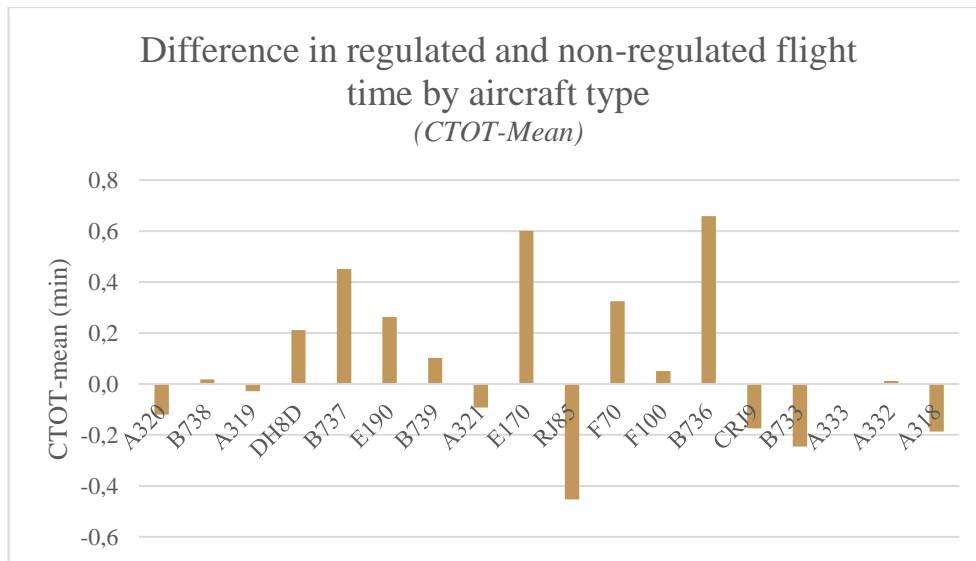


Graph 3 Trip time recovery on aircraft type level for mean vs CTOT

In the next graph (**Graph 4**), the difference between trip time recovery in case of a regulated delay and the mean is illustrated on aircraft type level. Here, the biggest deviations are:

Aircraft Type:	Flown by:
1. B736	SAS (n = 301)
2. E170	KLC, BEE, CFE, LOT (n = 3,126; 1,528; 772; 403)
3. B737	KLM, SAS, TRA, ROT, TFL (n = 16,215; 492; 373; 294; 1)
4. F70	KLC (n = 6,179)

Chapter 3: Analysis of results

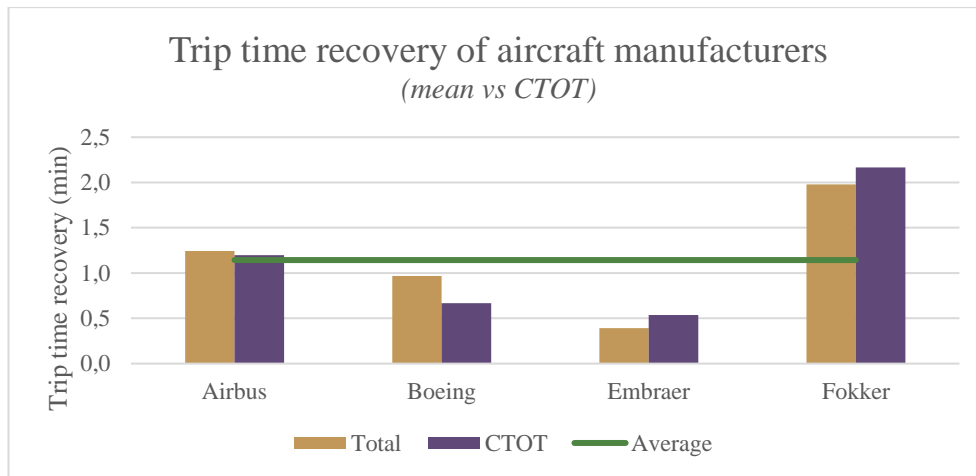


Graph 4 Mean subtracted from CTOT on aircraft type level

To compare the biggest aircraft manufacturers in the database, the following graph is illustrated (**Graph 5**, see p. 28). General trip time recovery (both with and without a CTOT) is the highest with Fokker. This might be caused by the absence of some functionalities in the FMS in F100 and F70 that measure cost index and possible delay recovery. Most modern airlines equip the FMS of their aircraft with advanced tools to enable them to fly faster. Aircraft such as the F100, E190, and E170 do not have these capabilities in their FMS. KLC however, equips the pilots of their E190's with a tool on a tablet to enable them to have the same capabilities as on their other aircraft.

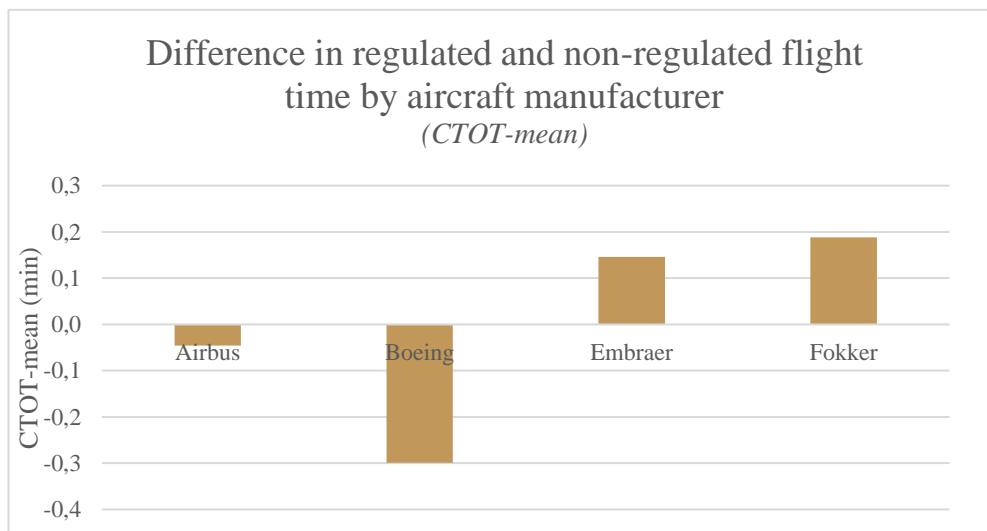
Aircraft manufacturer:	Count:
1. Boeing	51,355
2. Airbus	38,590
3. Fokker	28,841
4. Embraer	6,384

Chapter 3: Analysis of results



Graph 5 Trip time recovery on aircraft manufacturer level for mean vs CTOT

After comparing CTOT with the mean (**Graph 6**), Fokker has the highest ATFM delay recovery in minutes per flight (0.19 minutes higher than mean). After Fokker is Embraer, with 0.15 minutes higher TTR in case of a CTOT compared to the mean. Airbus and Boeing both have a higher TTR without a CTOT than with (-0.05 and -0.30 minutes respectively). To be able to make conclusions on the influence of brands of aircraft, hence manufacturers, the number of aircraft and number of types are important to list first (**Table 5**, see p. 29, ordered on count).



Graph 6 Mean subtracted from CTOT on aircraft manufacturer level

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Airbus	n	Boeing	n	Embraer	n	Fokker	n
A320	19,702	B738	29,746	E190	22,901	F70	6,179
A319	11,715	B737	17,375	E170	5,829	F100	205
A321	6,105	B739	3,790	E195	111		
A333	317	B736	301				
A332	208	B733	525				
A318	476	B734	121				
A20N	67	B788	22				
TOTAL	38,590		51,355		28,841		6,384

Table 5 Aircraft manufacturers and aircraft types with count in database

In general, the results of all the aircraft types need to be compared with the airlines and origins to view whether the deviations in trip time are applicable to the aircraft type or other factors.

3.4 Analysis of results for origins

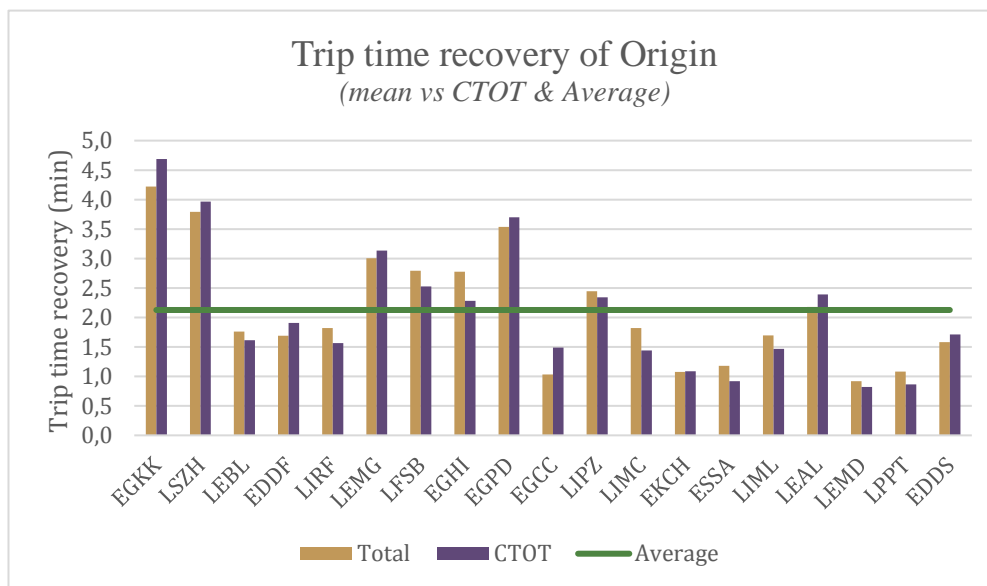
On origin level, the origins with the biggest presence and highest delay recovery in the database have been analysed (**Graph 7**, see p. 30, ordered on TTR ranking). These are:

ICAO	Airport name	n	ICAO	Airport name	n
EGKK	London Gatwick	3,647	LIPZ	Venezia Marco Polo	1,756
LSZH	Zürich	3,749	LIMC	Milan Malpensa	2,223
LEBL	Barcelona-el Prat	4,082	EKCH	Kopenhagen Kastrup	3,753
EDDF	Frankfurt am Main	4,055	ESSA	Stockholm-Arlanda	3,142
LIRF	Rome Fiumicino	3,635	LIML	Milaan Linate	2,129
LEMG	Malaga-Costa del sol	1,980	LEAL	Alicante-Elche	1,451
LFSB	Basel	2,048	LEMD	Madrid-Barajas	3,344
EGHI	Southampton	2,051	LPPT	Lisbon	2,776
EGPD	Aberdeen	1,516	EDDS	Stuttgart	1,879
EGCC	Manchester	4,473			

As described before, the origin results are ordered on TTR ranking. These are the origins with the highest count and the highest TTR. This results in the following list of origins with corresponding airlines:

Chapter 3: Analysis of results

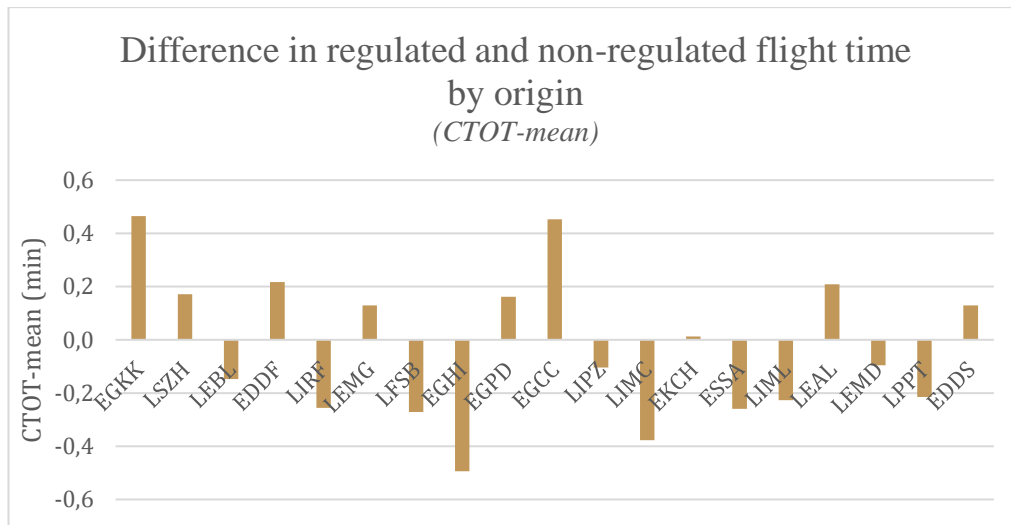
Origin:	Flown by (most frequent):
1. EGKK	EZY, BAW (n = 2,559; 1,083)
2. LSZH 106; 22)	SWR, KLM, KLC, EZY, TRA (n = 1,402; 1,292; 788; 136;
3. EGPD	KLM, KLC (n = 777; 738)
4. LEMG	TRA, TFL, VLG, EZY, KLM (n = 883; 276; 275; 194; 151)
5. LFSB	KLC, EZY, EZS (n = 1,251; 416; 378)
6. EGHI	BEE, KLC (n = 1,482; 566)
7. LIPZ	KLM, EZY, KLC, TRA (n = 1,021; 318; 281; 134)
8. LEAL	TRA; KLM; VLG (n = 795; 345; 256)



Graph 7 Trip Time Recovery on origin level for mean vs CTOT

In the graph on the next page (**Graph 8**), the difference between trip time recovery in case of a regulated delay and the mean is illustrated on origin level. Here, the biggest deviations are:

	Origin:	Flown by:
1.	EGKK	EZY, BAW (n = 2,559; 1,083)
2.	EGCC	KLM, BEE, EZY, KLC (n = 1,657; 1,478; 1,278; 311)
3.	LEAL	TRA; KLM; VLG (n = 795; 345; 256)
4.	EDDF	DLH; KLC (n = 2,049; 1,986)
5.	LSZH	SWR, KLM, KLC, EZY (n = 1,402; 1,292; 788; 136)
6.	EGPD	KLM, KLC (n = 777; 738)



Graph 8 Mean subtracted from CTOT on origin level

3.5 Comparative analysis

After analysing the separate flight specifics with and without a regulated delay, now the flight specifics are combined to view which deviations are caused by what. Three pairs have been made and analysed on CTOT TTR. The pairs are:

1. Airline versus aircraft type
2. Airline versus origin
3. Aircraft type versus origin

The total database consists of 133,768 flights. For analysis purposes, a top four or five has been selected by minutes of TTR and count in the database. The top four aircraft types make up for 30,000 flights of data. The top four airlines; KLM, KLC, EZY and SAS, make up for 87,000 flights of data. The top five origins; EGKK, EGCC, EDDF, LEAL and LSZH, make up for 17,000 of flights of data.

The results of combining these three types of data are several interesting sets of data that have a combination of a high count (n) and high TTR (in minutes) (**Table 6**, see p. 32).

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Scandinavian			EasyJet			KLM and KLC			Remaining		
B736	301	n	A320	5,582	n	EDDF	1,986	n	B738	331	n
SAS	2.45	TTR	EZY	2.50	TTR	KLC	2.07	TTR	TFL	3.47	TTR
B737	492	n	A319	6,226	n	LSZH	1,292	n	EDDF	2,049	n
SAS	2.03	TTR	EZY	2.24	TTR	KLM	3.94	TTR	DLH	1.34	TTR
A320	856	n	EGKK	2,559	n	LSZH	788	n	LSZH	1,402	n
SAS	2.05	TTR	EZY	4.50	TTR	KLC	2.81	TTR	SWR	4.08	TTR
			EGCC	1,012	n				EGCC	1,478	n
			EZY	1.26	TTR				BEE	1.81	TTR
									E170	403	n
									LOT	2.64	TTR

Table 6 Results of the combination of flight specific data

Airlines that are most important to further analyse in this research are the airlines that cause the most over deliveries. The five airlines that have the highest percentage of mean TTR and CTOT TTR and are analysed in depth are (1) SWR, (2) NAX, (3) TFL, (4) EZS and (5) EZY.

1) SWR

Airline name: Swissair

Main aircraft types: A320, A321 and A319 (TTR: 4.00; 3.90 and 4.49 min. respectively)

Main origin: LSZH (Zürich) (TTR: 4.08 min).

Aircraft types: SWR has 679 of 19,702 flights with A320's and their average TTR is 2.44 min higher than the mean. They have 356 of 6,105 flights with A321's and their average TTR is 3.35 min higher than the mean. They have 300 of 11,715 flights with A319's and their average TTR is 2.64 min higher than the mean.

City pair: SWR has 1,402 of 3,749 flights on LSZH and their average TTR is 0.29 minutes higher than the mean.

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2) NAX

Airline name: Norwegian Air Shuttle

Main aircraft types: B738 (TTR: 4.21 min)

Main origins: ESSA (Stockholm) and ENGM (Oslo, TTR: 5.51 and 3.39 min respectively).

Aircraft types: NAX has 865 of 29,746 flights with B738's and their average TTR is 3.32 min higher than the mean.

City pairs: NAX has 354 of 3,142 flights on ESSA and their average TTR is 4.33 min higher than the mean. NAX has 382 of 3,010 flights on ENGM and their average TTR is 2.89 min higher than the mean.

3) TFL

Airline name: TUI fly

Main aircraft types: B738 (TTR: 3.45 min)

Main origins: LEMG (Malaga, TTR: 3.88 min)

Aircraft types: TFL has 331 of 29,746 flights with B738's and their average TTR is 2.99 min higher than the mean.

City pairs: TFL has 276 of 1,980 flights on LEMG and their average TTR is 0.87 minutes higher than the mean.

4) EZS

Airline name: EasyJet Switzerland

Main aircraft types: A319 and A320 (TTR: 3.12 and 2.86 min respectively)

Origins: LFSB (Basel) and LSGG (Genève, TTR: 4.69 and 1.79 min respectively).

Aircraft types: EZS has 515 of 11,715 flights with A319's and their average TTR is 1.27 minutes higher than the mean.

City pair: EZS has 378 of 2,048 flights on LFSB and their average TTR is 2.0 minutes higher on this connection than other airlines. EZS has 523 of 2,945 flights on LSGG and their average TTR is 0.94 minutes higher than the mean.

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5) EZY

Airline name: EasyJet

Main aircraft types: A320, A319 (TTR: 2.50 and 2.25 min respectively)

Main origins: EGKK (London Gatwick), EGGW (London Luton), LIMC (Milan), EGCC (Manchester), EGPH (Edinburgh), LFSB (Basel), LIRF (Rome) and LSGG (Genève, TTR: 4.51; 1.16; 1.80; 1.26; 1.26; 4.99; 2.79 and 3.30 min respectively).

Aircraft types: EZY has 5,582 of 19,702 flights with A320's and their average TTR is 0.69 higher than the mean. EZY has 6,226 of 11,715 flights with an A319's and their average TTR is 0.65 minutes higher than the mean.

Since there are so many origins, they have been added to the table (**Table 7**, ordered on count) (n = number of EasyJet flights on that origin and total is the total number of flights):

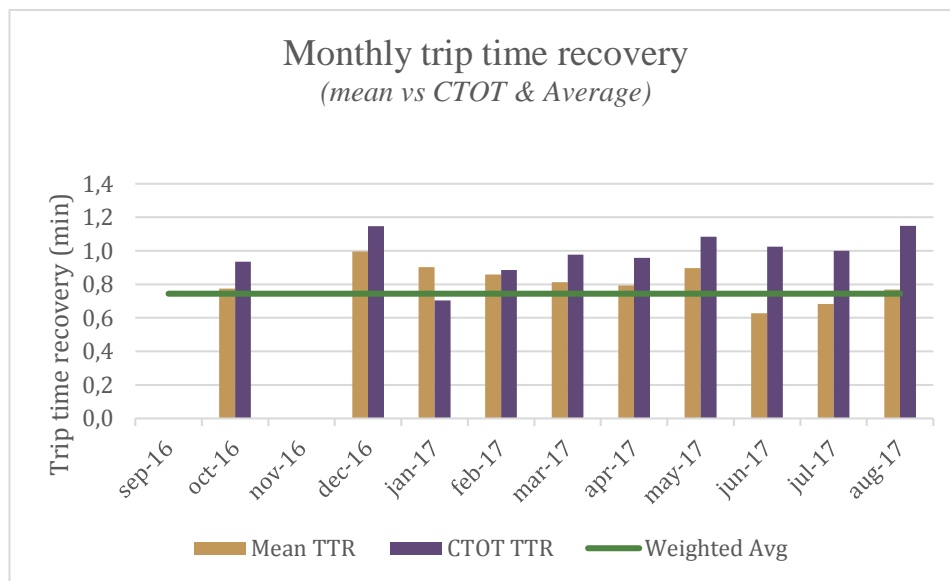
Origin:	n	Total	Percentage	Difference Mean
EGKK	2,559	3,647	70.2%	0.29
EGGW	1,884	2,627	71.7%	0.52
LIMC	1,269	2,223	57.1%	-0.02
EGCC	1,012	4,473	22.6%	0.23
EGPH	654	2,718	24.1%	0.84
LFSB	416	2,048	20.3%	2.20
LIRF	357	3,635	9.8%	0.97
LSGG	267	2,945	7.35%	2.44

Table 7 EZY city pairs results

3.6 Seasonal influences

The seasonal analysis is done by analysing the impact of TTR (CTOT and mean) for each month, day of week and peak versus off peak. The peak periods have been set to the vacations in 2016/2017 compared to normal periods.

These periods are specified in the methodology. This results in a graph with the monthly TTR for regulated and non-regulated flights (**Graph 9**, see p. 35).

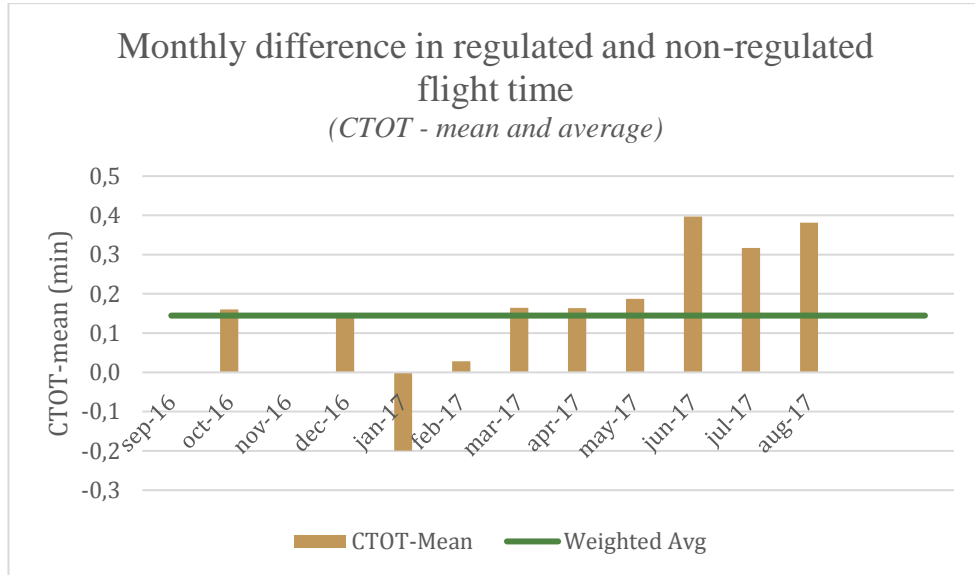


Graph 9 Trip time recovery on monthly level for mean compared to CTOT

The months September 2016 and November 2016 are filtered because the values were very divergent. September 2016 was a month with very much wind influences (derived from interviews and European Commission, 2017b). The results of November 2016 were talked through with the stakeholders and the decision to filter was taken because of the absence of any literary, anecdotal or exemplary clarification.

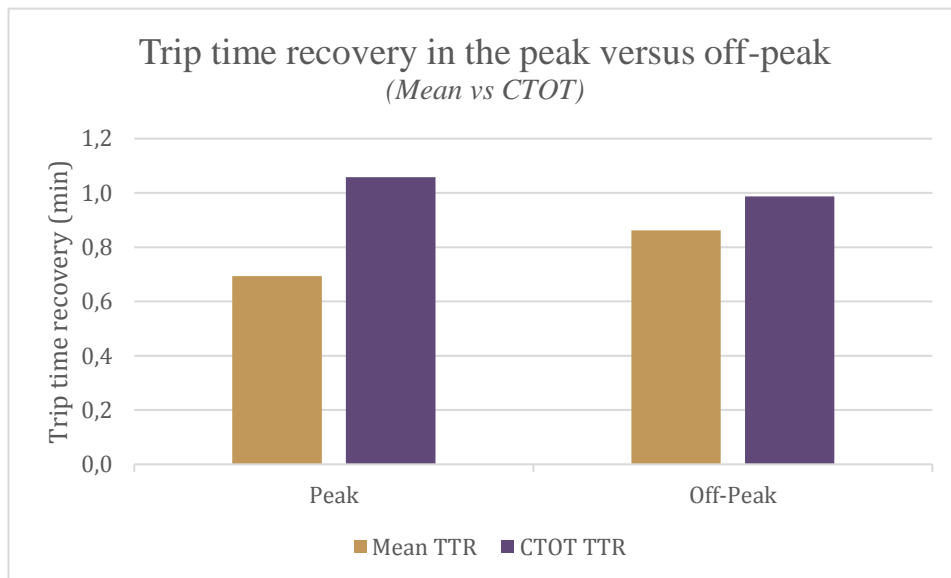
This results in a higher CTOT TTR than Mean TTR for most cases. As for the other analyses, the mean TTR is subtracted from the CTOT TTR to view the differences (**Graph 10**, see p. 36).

Chapter 3: Analysis of results



Graph 10 Mean subtracted from CTOT on monthly level

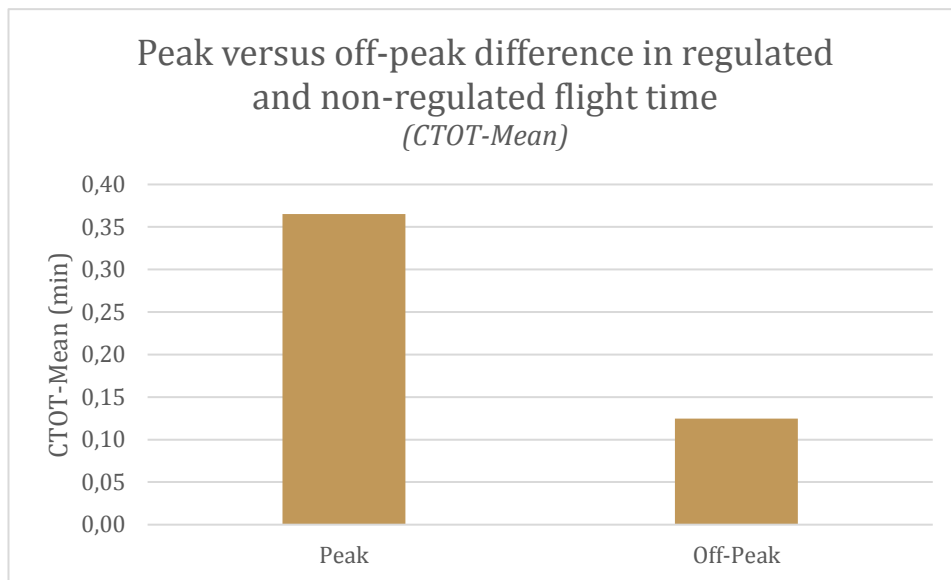
In **(Graph 10)**, the line is the weighted average and the summer months clearly deviate from the other months, which proves a seasonality difference. To view whether there is an incentive to recover trip time in case of a regulated delay, the peak versus off-peak analysis is done **(Graph 11)**.



Graph 11 Trip time recovery in the peak versus the off-peak months for mean and CTOT

Chapter 3: Analysis of results

In this graph, the CTOT TTR is higher than the mean TTR for both peak and off-peak. It is already visible from this graph that the amount of TTR for CTOT compared to mean is higher in the peak. In the next graph, CTOT is subtracted from the mean to view this difference (**Graph 12**).

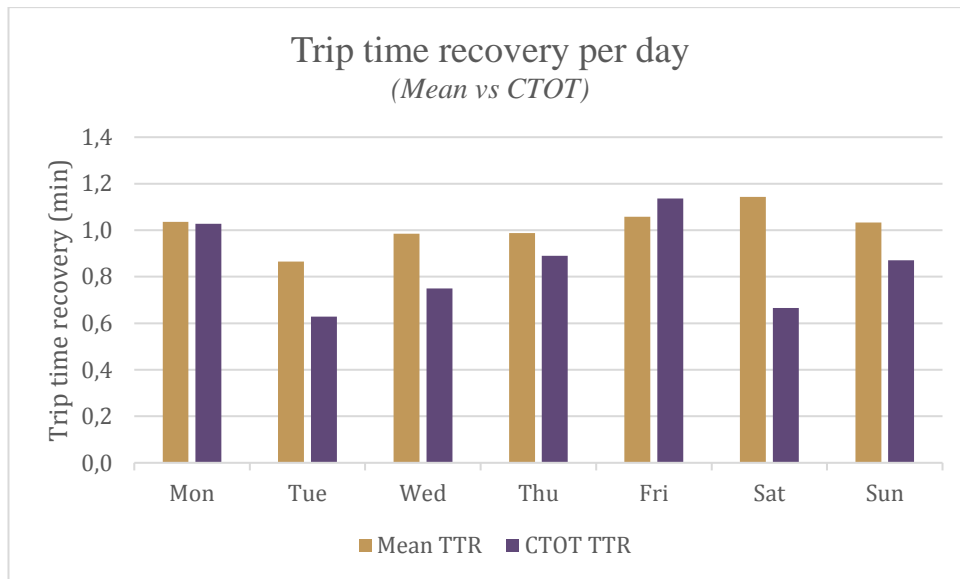


Graph 12 Mean subtracted from CTOT in the peak versus off-peak months

In this graph, both TTR for the peak and off-peak are influenced more by CTOT flights than the mean. In the peak months, CTOT TTR is higher than in the off-peak. These are interesting results and might have to do with the incentive for the higher on-time performance in the summer months. Since most airline revenue is earned in the summer peaks and, *'the result of such peaks and valleys in travel patterns was that airline revenues rose and fell significantly through the course of the year. This pattern continues today, although it is less pronounced than in the past'* (AvJobs, 2010). This is a possible explanation for the recovery of delay (regulated or not) to be higher.

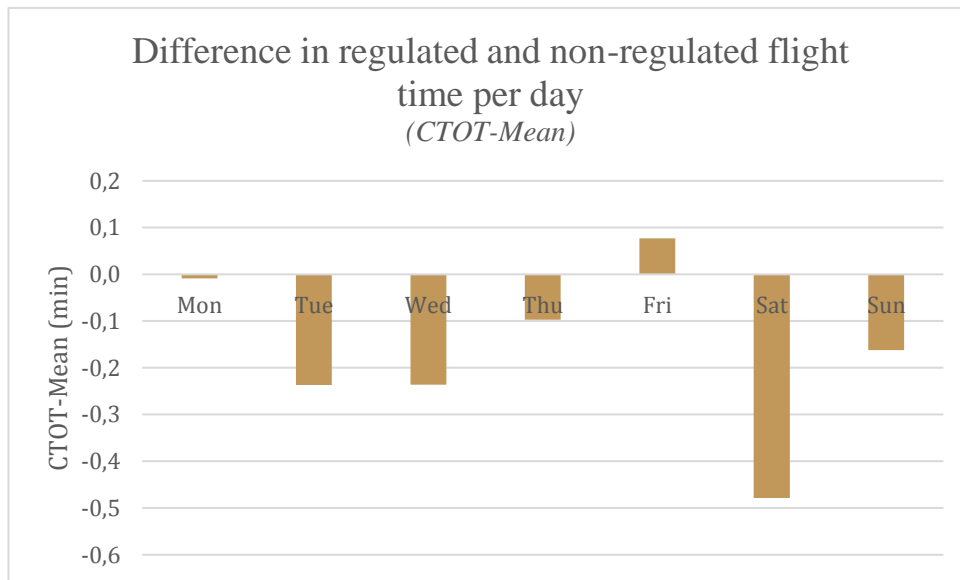
The next analyses are on daily level. The next graph (**Graph 13**, see p. 38) shows how much trip time is recovered per day for non-regulated and regulated flights. The differences on Saturday are clearly visible, which is explained in the next graph. Next to this, there is a trend for both TTR's during the week. From Tuesday until Friday, both TTR's develop in an increasing manner. The trend for CTOT is even more visible.

Chapter 3: Analysis of results



Graph 13 Trip time recovery on daily level for Mean and CTOT

After subtracting the mean from the CTOT (**Graph 14**), most days have a negative TTR. Only on Friday, the CTOT TTR is higher which means more delay is recovered for regulated flights than all other flights.



Graph 14 Mean subtracted from CTOT on daily level

3.7 Airline validation

The interviews with airlines result in an explanation of the airline policy incentive for TTR. As described in the methodology, certain measures and incentives to recover trip time result from the interviews listed in the appendices (**appendix VI**). The four subjects that are questioned are:

- Flight planning
- Block times
- Cost index
- Instruments for delay recovery

Flight planning

Repetitive flight planning leads to more instability in the system, since less precise variables are included (**2.1**, see p. 9). However, all airlines that are interviewed use new FPL's for each day. The expectation was that low-cost carriers entered more FPL's for a similar flight but this was not the case (**Graph 1**, see p. 24).

Block times

Block times that are not updated regularly are a reason for unpredictability. The questioned airlines all use statistical evaluation of block times of the past year, which is updated twice yearly: in the summer and winter. Airline three stated: *“For Airline 3, block times are adjusted seasonally based on the previous year's data. So we have a winter and summer schedule. We would like to change this to monthly, but this doesn't fit with the airport slot allocation process”* (**appendix VI**).

Cost index

The cost index in the FMS is a tool to make an economic trade-off between fuel burn and trip time. The airlines that have been interviewed (**appendix VI**) are questioned on strategy towards cost index strategy which views tools for delay recovery. The airlines answered:

Airline one: CI is similar for each flight, only dependent on the aircraft type. The actual cost index is between 10 and 14 (which is low).

Airline two: CI varies per aircraft type and fuel price.

Airline three: CI for each aircraft type but it is adjusted for punctuality reasons.

Airline four: CI is based on the results of an algorithm. Based on aircraft type and sometimes on city pair.

Instruments for delay recovery

Next to cost index, airlines may have other tools for delay recovery that have not resulted from the literature review. Therefore, the last question to the airlines was an open question on what delay recovery instruments they use, the answers are:

Airline one: Route planning (minimum track time instead of minimum cost track), Lower FL, higher CI and required time of Arrival mode in FMS.

Airline two: Quick turn-around on ground, increase speed, rerouting to shorter/faster routing.

Airline three: Re-routing

Airline four: Different kinds of delay require different actions. The only tool stated by airline 4 to recover delay is to vary the cruise speed.

4 CONCLUSIONS

The conclusions are ordered similarly to the results; narrowing down starting broad. The main research question: ‘How do airline/pilot decisions influence the current effectiveness of the ATFM measures for flights in the Eurocontrol region with destination EHAM?’ can now be answered. This will be done by giving answer to the sub-questions:

- *How is ATFM delay recovery influenced by the flight specific factors?*
- *How is ATFM delay recovery influenced by pilot/airline decisions?*
- *Do the recovery of ATFM delay negatively affect the airspace and/or airport capacity at EHAM?*

In this research, the difference between a planned situation and the actual situation is researched with Eurocontrol data. In addition, the impact of the instability of planning on total airport capacity is researched. Through statistical testing, the significance of trip time recovery is confirmed (**formula 1; 2**). A T-Test on the dependent variable TTR was done. The result is a P-value (= significance) of 0.000, which is significant. Therefore, it is concluded that general trip time recovery significantly occurs. This is important because the effectiveness of ATFM delays is measured by deviations in trip times. When regulated and not regulated flights do not significantly deviate from the planned situation, further research within this method is unnecessary.

Since this was not the case, a correlation between TTR and cutting-off route length is researched with a T-Test including a paired samples correlation. The correlation is low: 0.210 but it is significant. Therefore, in case of a CTOT, there is a small correlation between TTR and cutting off route length (**Formula 3**).

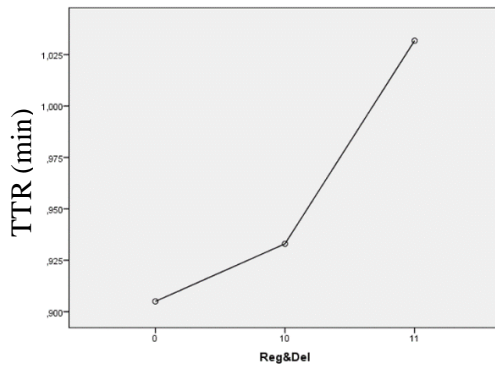
The difference of ATFM delay recovery versus trip time recovery of non-regulated flights is measured by comparing means of two types of data:

CTOT: *regulated – CTOT* is one part of the data (n = 39,751).

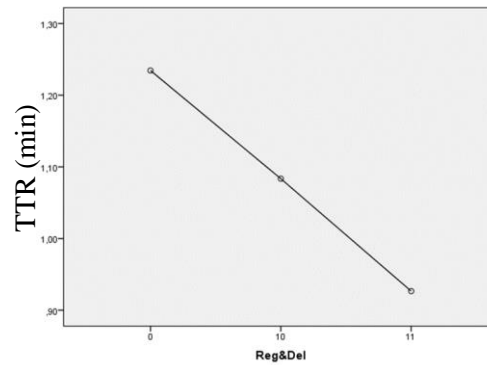
Mean: *no CTOT – Regulated* and *no CTOT – non-regulated* is the other part of the data (n = 94,017).

Chapter 4: Conclusions

These data have been used for the analysis of the airlines, aircraft types, city pairs, cross sectional and seasonal influences. These three are closely linked because each flight an airline flies with an aircraft type from an origin. An SPSS analysis resulted in the following three graphs (**Graph 155**; **Graph 6**; **Graph 16**, see p. 43) the data that is explained by each variable is visualized.



Graph 155 Estimated marginal means for origin

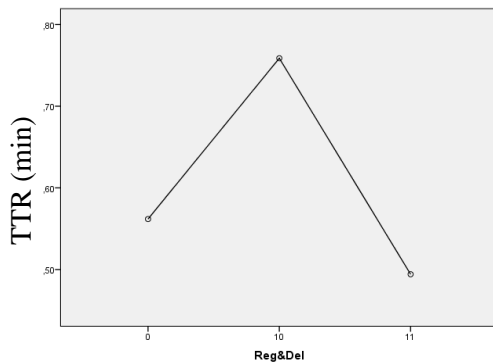


Graph 16 Estimated marginal means for airlines

4.1 Flight specific conclusions *SQ1 and SQ2*

The three graphs, lead to the conclusion that most of the variation in the dataset in case of an ATFM delay is caused by the origins. This means that origins cause for the system to be most ineffective. There are two options to explain this, the first is that pilots are asking directs (Eurocontrol, 2009) which is also explained by the correlation by cutting of route length and TTR. The other option is that Eurocontrol calculations for the planned routes deviate from the actual situation so often they are concluded to be insufficient.

Chapter 4: Conclusions



Graph 16 Estimated marginal means for aircraft type

The origins cause for the most ATFM delay recovery, however, there are airlines such as EZS and EZY that cause for high TTR as well. EZS is a franchise of the brand EasyJet. They are considered as different airlines but use the same aircraft types and have the same policy. Therefore, the difference in TTR's is accountable to the city pairs they fly. Both airlines fly the destinations LFSB and LSGG. The TTR on LFSB for EZS and EZY are 4.8 minutes average while the other airline on that route: KLC has an average TTR of 1.49 over 1,251 flights. On LSGG, the TTR of EZS is 1.79 minutes and EZY 3.30 minutes.

Conclusions on seasonal level SQ1 and SQ2

The seasonal analyses are done on three levels:

- Month
- Day of week
- Peak vs Off-peak

Both in the monthly and peak versus off-peak, it is clearly visible that much more trip time is recovered in the summer months (and peak months, **Graph 9**, see p. 35), with a peak difference between CTOT and mean of 0.36 minutes per flight.

To conclude on the interviews, airlines use multiple tools (Cost index, accelerated fuel burn and tactical route planning) to recover delays. Since none one of the questioned airlines indicated a difference in delay recovery decision making in case of an ATFM delay, these tools are incentives to recover delays. In addition, *'the airline industry has realized very little return from total economic contributions of the aviation industry'* (Ball et al., p. 2, a. 2, 2010). This results in a high operational pressure on airlines that is a big incentive for delay recovery.

4.2 Capacity impact as a result of plan instability *SO3*

After these separate analyses, a general calculation has been made for the capacity impact because of plan instability. In the final analysis, the 39,751 regulated and delayed flights have a weighted average TTR of 1.01 minutes.

All non-regulated flights; $n = 94,017$, have an average TTR of 0.86 minutes. The weighted average TTR of the entire set of 133,768 flights is 0.90.

A flight with a CTOT recovers 0.14 minutes of average delay than non-regulated flights. This is proven significant which means that ATFM delays, in terms of flight time, lead to more plan instability than regular delays. As described in the literature review, an over-delivery of aircraft leads to a reduction in total airspace and/or aerodrome capacity (Delgado & Prats, 2011; Ball, Barmhart, Dresner et al., 2010). The deviation in over-deliveries appears to be small (0.14 minutes). However, this is the average difference of 133,768 flights. Some flights have a small variation where others deviate more.

Therefore, the current system of ATFM delays when purely analysing flight time has a negative influence on total airport capacity.

4.3 Overall conclusion

The general conclusion on how the ATFM delay recovery is influenced by the flight specific factors is that, next to these interesting flight specific data, which are included in the recommendations (6, see p. 47), the data cannot prove what exactly leads to delay recovery. Some variables cause a big difference between CTOT and mean TTR, which can be understood as an incentive to recover an ATFM delay, but which of the anomalies come from what flight specific data cannot be concluded on here.

So to answer the main research question: ‘How do airline/pilot decisions influence the current effectiveness of the ATFM measures for flights in the Eurocontrol region with destination EHAM?’

Airline policy and pilot psychology do influence the effectiveness of ATFM measures. In this research, effectiveness of ATFM delays is measured by comparing the amount of trip time that is recovered for ATFM delayed flights compared to non-ATFM delayed flights. This leads to the result that the effectiveness of ATFM delays is, although by a small difference, negatively influenced by airline and pilot decision making.

The airlines cause the most significant deviations to ATFM delays compared to non-regulated flights are: KLC, KLM and EZY (0.33; 0.29; 0.26 minutes respectively for CTOT minus mean). However, in total numbers of TTR, the airlines SWR, NAX, TFL and EZS score higher (4.08; 4.05; 3.07; 3.00 minutes respectively).

5 DISCUSSION

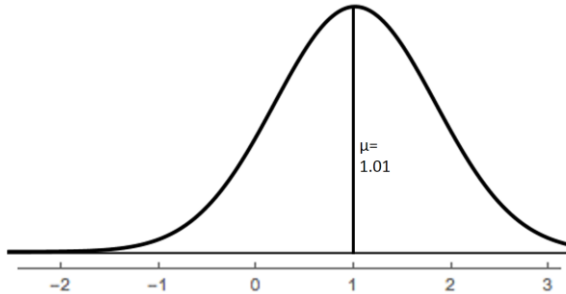
As in every research, after the analysis and conclusions, new insights that are obtained during the research process on how different decisions could have led to other, sometimes better results, are discussed here.

In early period of research (September/November 2017), the decision was made to analyse all data of one year starting in September 2016 until September 2017 because that was the most recent available data in that period. This resulted in a total dataset of 198 thousand flights. With the current knowledge after the results, it might have been better to take several years to view more detailed seasonal results. In addition, more months could have been added that became available during the process.

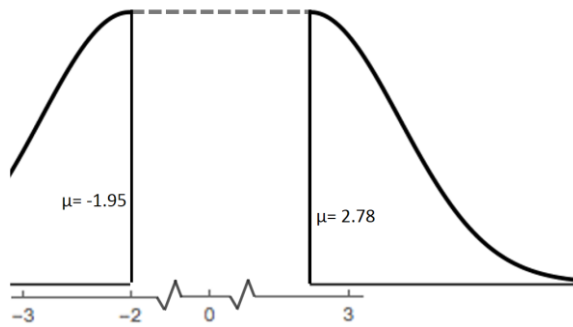
Another point of discussion is the influence of KLM (both KLC and KLM) on the dataset. With a total presence of 52% of all flights, their influence on the averages is very big. In this research, this problem was tackled by separately analysing KLM. Their average TTR and CTOT TTR were around the 0 minutes so the mean almost equalled the desired situation.

Another remark to the results of this research is the way trip time recovery is divided around the zero line. In this research, an average number of trip time recovery in minutes for regulated flights and, the complement, non-regulated flights are compared. This number, however, tars both negative and positive recovery with the same brush. Both negative and positive TTR negatively influence the predictability of the system. The impact and difference over the entire database is shown in the graphs on the next page (**Graph 17; Graph 18**). 1.01 is the average TTR over the entire dataset. -1.95 and 2.78 are the mean TTR's for the same dataset when negative and positive deviations from the ETO/CTO are separately calculated.

Chapter 5: Discussion



Graph 17 Example of μ TTR in the used normal distribution



Graph 18 Example of change in normal distribution if both sides of TTR were separately analysed

Lastly, the quantification of the capacity impact of trip time recovery on ATFM delayed flights is eventually deemed out of scope. However, in potential follow-up research, the influence of these flights on the priority flights of KLM should be measured to isolate a capacity impact.

6 RECOMMENDATIONS

The recommendation is segmented in two components. First, the option for the network system in combination with Eurocontrol (6.1) is given. Then, the possible equilibrium for airspace users (6.2, see p. 48) is recommended on.

6.1 Eurocontrol

A valid option to strengthen the predictability of the system and thus the capacity is to optimize the Eurocontrol system for calculating the estimated times (EOBT, ETOT and ETO). This research has proven how flights deviate from the estimated times. Since Eurocontrol is not a direct stakeholder in this system, the recommendation is to inform them on what their current method for calculating estimates results in.

To elaborate on the last part, the current method for forecasting (schematized in **appendix VIII**), should be evaluated. However, since variables as airspace structure, airport capacities etc. are subject to change, the statistical analysis on adherence to ETO/CTO should be included partially, in a weighted form.

To reach this goal, this research should be used as a blueprint for Eurocontrol how flights deviate from the planned trip time. This is only for flights to EHAM but the same method can be applied to other airports. In addition, it can be used as an introduction to the capacity impact. Further research definitely needs to be done on the capacity impact of flight deviations on aerodrome and airspace capacity. Since it is concluded that deviations in CTOT trip time recovery have a negative capacity impact, there is a wider applicability, useful to Eurocontrol and aerodromes in the 42 NM states and 7 cooperating states.

Next to the general trip time recovery, there is another challenge to tackle ATFM delay trip time recovery. Each flight deviates 0.14 minutes more from the CTO in case of a CTOT. Currently, Eurocontrol advises airspace users to follow the filed flight plan “*Aircraft Operations: Inform your pilots of the reason for a lower FL being filed. Pilots: High or low, bear in mind there is a good reason behind the filed FL*” (Eurocontrol, 2009). Since the airlines are commercially driven, advising does

not result in the wished adherence to the CTO. A SESAR program called Target Time of Arrival (TTA), is an initiative to relinquish ATFM delay trip time recovery because the TTA concept more or less obliges pilots to arrive within a CTA window. This method can be compared to the CTOT's, ANSP's have a window of minus five and plus ten minutes around the departure slot and adhere to this in 80% of cases.

6.2 Airspace users

It is questionable who, except from the KLM, benefit from adherence to ATFM delay and are willing to partially diminish on operational performance to achieve this ideal image (in the network perspective).

This equilibrium is perhaps a bridge too far and taking previous research in mind (Cook & Tanner, 2011; Eurocontrol 2009; Ball et al., 2010), and expected to not be realistic. Therefore, it is recommended to contact the bigger airspace users on the impact of their behaviour after follow-up research is done with a quantification of capacity impacts of TTR for ATFM delayed flights. The airspace users with a higher presence on EHAM benefit more from plan stability and are thus more likely to engage in a cooperative system. Both network carriers and low-cost carriers benefit from the cooperation, which is currently unknown.

Since the awareness of airspace users towards ATFM delay adherence is commercially driven, other ANSP's use more incentive/penalty based targets to motivate airspace users to adhere to the CTO. NATS (the ANSP in the United Kingdom) presented a performance scheme (Figure 8, see page 48) for ATFM performance at the ICAO ATFM Global Symposium (NATS, 2017). With this scheme, they reward the airlines that adhere to the planned situation and punish the airlines that do not. There is no clear explanation in the NATS presentation (2017) of what tools are used for incentive/penalties.

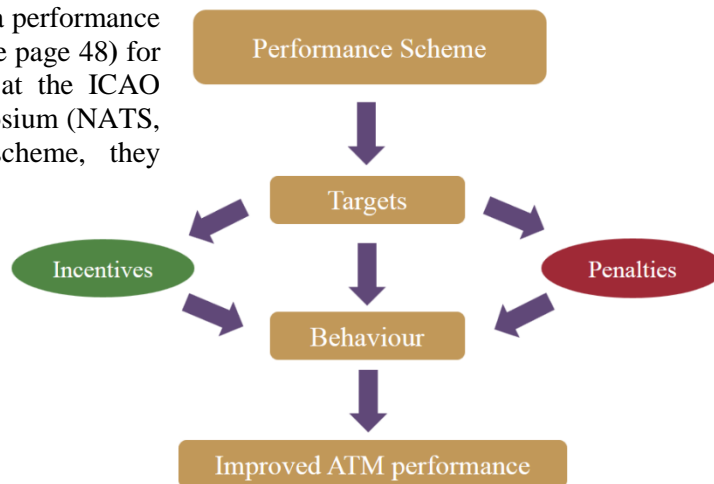


Figure 8 NATS reward / penalty system ATFM adherence NATS, 2017)

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7.1 Learning goals

The learning goals for a graduation internship at the Amsterdam University of Applied Sciences are listed on the HvA website (HvA, 2017) as follows:

1. Demonstrate the ability to solve an actual, complex industry issue or problem based on "state of the art" solutions, taking into consideration the most recent industry developments and the context of the issue.
2. Apply the relevant industry insights and scientific/academic research, concepts and theories and conduct field and desk research towards solving the issue.
3. Establish a logical and visible link between the issue being researched, the related theories and research, and the proposed solution. The proposed solution applies to the specific issue and context in which it is being examined.
4. Apply the issue and solution to a client (or other interested party) for whom the research has value and is willing to implement the proposed solution.

7.2 Experiences and situations

1 Structuring work

With this experience, I mean that I have learned to structure work into small manageable pieces

Situation

During the entire period of the internship, the scrum method was used. This method is usually used in software development and has a focus on dividing big tasks into smaller bits to reach a goal. For this internship, some of the scrum methods were used: Scrum board, daily scrum sessions and sprint reviews. The persons that were involved were:

- Stakeholders: Evert Westerveld, Cerial Janssen
- Supervisor: Frenchez Pietersz
- Scrum master: Alina Zelenevska

Role

My role was to structure the tasks to be done for the research in a scrum-board. A scrum board has several *stories* (i.e. data analysis, writing report and prepare interviews), a *to-do* list with all tasks per story to be done, *doing* with the task currently being worked (one at a time) on and *done* where finished tasks are. In the introduction to this method I thought, this is a very good method for me because I normally work quite unstructured so I really dived into this method to gain from it.

KDC management decided to use this method as a pilot. Therefore, there was no pressure as to what was expected from me. If I had found the method not useful, there was enough freedom to tell. Although there was no external pressure, I wanted to learn to work more structured so this was my personal goal.

Action

Every Monday, Tuesday and Thursday there was a scrum session. These sessions took 15 minutes for three persons to tell what they have worked on, what they are going to work on that day and what is withholding them from achieving that goal. On my travel to work, I always tried to think of these three questions, this helped me focus on small bits that eventually end up in one thesis. Every other Thursday I had a sprint review, a session with the stakeholders to present what the last two weeks of work resulted in and which of those results are useable or needed to change. After a few of these sprint reviews, I realized that I changed from feeling a need to share the best results to working together to reach a better result for our joint goal.

Result & Reflection

Scrum definitely worked for me because my working method changed from quite chaotic to very structured and results-oriented. I wanted this way of working for a longer time but I did not have the tools to do it. Therefore, I think the method to dive into it and really take it serious helped me and was a good learning lesson. I will definitely apply this in other situations where I have to structure a big task.

2 Quantitative data analysis

Situation

My research was quantitative and a big part was data analysis. This required computational skills that I did not have at the start of this internship. In consult with a performance expert, we decided that I need SQL, excel and SPSS knowledge.

Role

My role was to develop the skills needed for creating a database and doing analyses on it. Since I recognized that these skills are very handy in further work, I really wanted to learn something from it. There was no pressure from management on obtaining these skills but my research depended on it. If the data analysis did not work, the research failed.

Action

For SQL, I used Microsoft Access because in consult with the performance expert (Yoram Obbens) we decided that this was easier than learning SQL language. My method was to watch online lessons and then figure out how to apply it to my dataset

with trial and error. There was not much overlap with my study because we did not learn to form databases with complex queries in it. I used this method because there was not enough time available from experts to teach me so the principles I had to learn myself.

Result & Reflection

After a lot of trial and error, the result was a well working access database, SPSS analyses and excel analyses. Now, I know the basics of SQL and how to link different data sources using a primary key. On the other hand, I now know the possibilities of SQL and want to learn much more. Therefore, I am happy with the results but I want to learn more about this.

Depending on the work I am going to do, I will take this knowledge with me and continue to use it or maybe not. I do know that I find it interesting and might therefore influence some of my future work.

3 Usability of the product

Situation

With all the scrum meetings (as described in 7.2), the client demanded a presentation to view whether there was alignment in goals. In addition, before the internship started, the goal of the KDC to strengthen the cooperation within the parties that are active at the Mainport Schiphol was made clear. After my studies, I realized this was a big problem at the Mainport and therefore I found it very important to hand in a useable product.

Role

My role was to build a research that meets the HvA graduation standards and at the same time deliver a useable product for the stakeholders LVNL, KLM and AAS. The main goal of an internship is for the student to learn. Next to this goal, for me a personal goal was to create a product that will be used by the stakeholders.

Action

To reach this goal, I tried to stay in consult with the stakeholders in the analytical process to view what the actual problem is and how this can be resolved. The scrum method helped to do this and a new skill I learned during the process is to take a step back to view the problem that is keeping me from some results. This helicopter view, as the theory describes what I have applied.

Result & Reflection

Creating this useable product has partially worked for me. Perhaps it was not entirely realistic to want to create something that would change a big part of the operations. There are projects that have teams of multiple FTE that have a smaller impact than the one I wished to have. However, this does not feel like my goal is not met. I think I still deliver a useful product and have several learning experiences. The new skill I have obtained which I called the helicopter view (also described above), made me do some more research on this topic. I then recognized I can identify myself more with a bird's eye view rather than a helicopter view. As described by Sharma (2016), in the bird's eye view, we can see the actions but cannot interfere to change or correct. We can see the wrong or the mess but are unable to speak up. The point is to find REAL FAULT without being a party to it and with no attachments or strings or influence. This is something that I will use to improve this skill and try not to be prejudiced.

7.3 Reflective conclusion

After I graduate, I continue to work for the LVNL in a different function. Also doing analyses but in a different department. I will use the skills I have obtained here and take the learning lessons with me to maximize my performance in this new position. The biggest skills / lessons that I have learned in the past half year can be split up in two sections:

1) Personal skills

2) Business skills

Personal skills

From the experiences that I described above, I have learned to be have a results-oriented working attitude and the ability to take a step back and overview the situation (bird's eye view). My results-oriented working attitude I will definitely continue to use in future work because it worked really well for me. The bird's eye view made me realize that I quickly try to interfere, change or correct which can sometimes withhold me from finding the real fault. In future work I will try to set my biases and prejudices aside to change the bird's eye view into helicopter view.

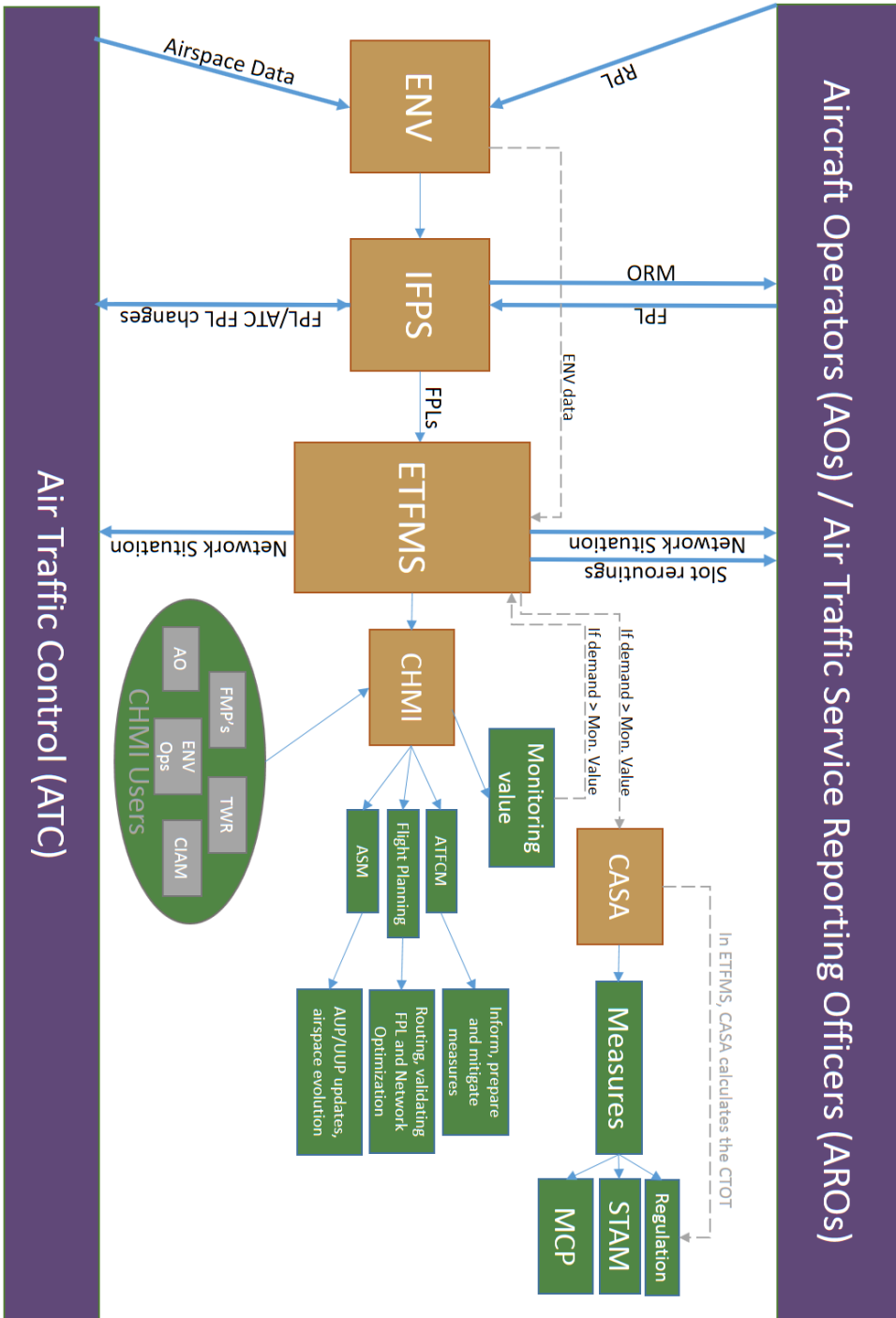
Business skills

The business skills that I have obtained are mostly computational. In the upcoming job I am also analysing data and creating a database, therefore these new skills are very handy and will be applied and further developed. I realized in doing this, that data analysis is something that I like to do and am talented in.

APPENDICES

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APPENDIX I: SYSTEMIC STRUCTURE EUROCONTROL



APPENDIX II: DATABASE CLARIFICATION

For the database, three types of data are coded for SPSS; airlines, origins and aircraft types. After these are listed below, the database is explained

Airlines

Code	Airline
ADR	Adria Airways
EIN	Aer Lingus
AFL	Aeroflot
BTI	Air Baltic
ABW	Air Bridge Cargo
AEA	Air Europa
AFR	Air France
AZA	Alitalia
KKK	Atlasglobal
AUA	Austrian
BAW	British Airways
CFE	CityFlyer
BCY	CityJet
CAI	Corendon
CND	Corendon
CTN	Croatia Airlines
CSA	Czech Airlines
EZY	EasyJet
EZS	Easyjet Switzerland
BCS	European Air
EWG	Eurowings
FIN	Finair
BEE	FlyBe
GWI	Germanwings

IBS	Iberia Express
EXS	Jet2
KLC	KLM Cityhopper
KLM	KLM Royal Dutch Airlines
LOT	Lot Polish airlines
DLH	Lufthansa
NJE	NetJets
NAX	Norwegian Air Shuttle
PGT	Pegasus
RYR	Ryanair
SAS	Scandinavian Airlines
SXS	SunExpress
SWR	Swiss Air
TAP	TAP Portugal
ROT	Tarom
TRA	Transavia
TFL	TUI Fly
THY	Turkish Airlines
VLG	Vueling

Origins

Code	Origin
EBAW	Antwerpen Deurne
EBLG	Liege
EBOS	Oostende
EDDB	Berlin Schoenefeld
EDDC	Dresden
EDDF	Frankfurt
EDDG	Münster-Osnabrück International Airport

EDDN	Nurnberg
EDDS	Stuttgart
EDDT	Berlin Tegel
EDDV	Hannover
EDDW	Bremen
EDFH	Hahn
EDJA	Memmingen Airport
	Paderborn Lippstadt
EDLP	Airport
EDLV	Airport Weeze
EDLW	Dortmund Airport
EDNY	Friedrichshafen Airport
EFRO	Rovaniemi Airport
EGAC	Belfast City
EGBB	Birmingham
EGCC	Manchester
EGFF	Cardiff
EGGD	Bristol Lulsgate
EGGW	London Luton
EGKK	London Gatwick
EGLC	London City
EGMC	Southend
EHBK	Maastricht
EHEH	Eindhoven
EIDW	Dublin
EKBI	Billund
EKCH	Kobenhavn Kastrup
ELLX	Luxembourg
ENAL	Alesund
ENBR	Bergen Flesland

ENGM	Oslo Gardenmoen
EPKK	Krakow Balice
ESGG	Goteburg Landvetter
ESMS	Malmö Airport
ESSA	Stockholm Arlanda
ESSB	Stockholm-Brommo Airport
EVRA	Riga Airport
EYVI	Vilnius Intl
GCTS	Tenerife Sur Reina Sofia
LBBG	Burgas
LBWN	Varna
LCPH	Paphos
LDDU	Dubrovnik
LELC	Murcia-San Javier Airport

Aircraft Type

Code	Origin
A20N	Airbus A320-NEO
A306	Airbus A300-600
A318	Airbus A310-800
A319	Airbus A310-900
A320	Airbus A320
A321	Airbus A321
A332	Aibus A330-200
A333	Airbus A330-300
B733	Boeing 737-300
B734	Boeing 737-400
B735	Boeing 737-500
B736	Boeing 737-600

B737	Boeing 737-700
B738	Boeing 737-800
B739	Boeing 737-900
B744	Boeing 747-400
B748	Boeing 747-800
B752	Boeing 757-200
B763	Boeing 767-300
B788	Boeing 787-800
C56X	Cessna Citation Excel
C680	Cessna Citation Sovereign
CL35	Canadair Challenger 350
CRJ7	Regional Jet CRJ-700
CRJ9	Regional Jet CRJ-900
CRJX	Regional Jet CRJ-100
DH8D	Bombardier Dash 8 Q400
E145	Embraer 145
E170	Embraer 170
E190	Embraer 190
E195	Embraer 195
E55P	Embraer Phenom 300
F100	Fokker 100
F2TH	Dassault Falcon 2000
F70	Fokker 70
	Bombardier Global
GLEX	Express
GLF5	Gulfstream V
H25B	Raytheon Hawker 800
RJ85	AVRO Rj-85

Database

Excel

GndDelay	TTR	RIReg	Cutting Off	CTOT	Reg	Date	Day	Hour	Month	Airline	Origin	AcType
2	7.92	1,511.32	-2.04%	0	0	1	1	2	1	453	101	27
0	12.12	1,510.62	-1.92%	0	10	1	1	2	1	63	101	27
4	1.72	1,107.39	-0.48%	28	11	1	1	2	1	464	94	27
2	0.82	332.64	-8.61%	0	0	2	2	3	1	43	9	3

This is the coded version of the database that has been used in this research as an input for SPSS. The variables that are used are:

1. GndDelay: minutes of delay on ground
2. TTR: trip time recovery (**formula 1**)
3. RIReg: the regulated Route Length in nautical miles
4. Cutting Off: difference between regulated and actual route length
5. CTOT: Calculated Take-Off Time or in other words the slot in case of an ATFM measure
6. Reg: code for the type of data:

0	=	NonRegNonDel
10	=	RegNonDel
11	=	RegDel (CTOT)
7. Date: the date of departure
8. Day: the day of the week
9. Hour: the time of the day
10. Month: the month of the year
11. Airline: coded airline name
12. Origin: coded origin name
13. AcType: coded aircraft type

APPENDIX III: SPSS SYNTAX AND OUTPUT

Airline Syntax

```
DATASET ACTIVATE DataSet1.  
UNIANOVA TripTimeRecover BY Airline RegDel  
  /METHOD=SSTYPE(3)  
  /INTERCEPT=INCLUDE  
  /PLOT=PROFILE(Airline)  
  /PLOT=PROFILE(RegDel)  
  /EMMEANS=TABLES(Airline) COMPARE(Airline)  
  /EMMEANS=TABLES(RegDel) COMPARE(RegDel)  
  /EMMEANS=TABLES(Airline*RegDel) COMPARE(Airline)  
  /PRINT=ETASQ DESCRIPTIVE HOMOGENEITY  
  /CRITERIA=ALPHA(.05)  
  /DESIGN=Airline RegDel Airline*RegDel.
```

```
ONEWAY TripTimeRecover BY Airline  
  /MISSING ANALYSIS  
  /POSTHOC=BONFERRONI ALPHA(0.05).
```

```
ONEWAY TripTimeRecover BY Airline  
  /MISSING ANALYSIS  
  /POSTHOC=BONFERRONI ALPHA(0.05).
```

```
DATASET ACTIVATE DataSet1.  
UNIANOVA TripTimeRecover BY Airline  
  /METHOD=SSTYPE(3)  
  /INTERCEPT=INCLUDE  
  /PLOT=PROFILE(Airline)  
  /EMMEANS=TABLES(Airline) COMPARE(Airline)
```

/PRINT=ETASQ DESCRIPTIVE HOM

Origin Syntax

DATASET ACTIVATE DataSet1.

UNIANOVA TripTimeRecover BY Origin RegDel

/METHOD=SSTYPE(3)

/INTERCEPT=INCLUDE

/PLOT=PROFILE(Origin)

/PLOT=PROFILE(RegDel)

/EMMEANS=TABLES(Origin) COMPARE(Origin)

/EMMEANS=TABLES(RegDel) COMPARE(RegDel)

/EMMEANS=TABLES(Origin*RegDel) COMPARE(Origin)

/PRINT=ETASQ DESCRIPTIVE HOMOGENEITY

/CRITERIA=ALPHA(.05)

/DESIGN=Origin RegDel Origin*RegDel.

ONEWAY TripTimeRecover BY Origin

/MISSING ANALYSIS

/POSTHOC=BONFERRONI ALPHA(0.05).

ONEWAY TripTimeRecover BY Origin

/MISSING ANALYSIS

/POSTHOC=BONFERRONI ALPHA(0.05).

DATASET ACTIVATE DataSet1.

UNIANOVA TripTimeRecover BY Origin

/METHOD=SSTYPE(3)

/INTERCEPT=INCLUDE

/PLOT=PROFILE(Origin)

```
/EMMEANS=TABLES(Origin) COMPARE(Origin)
/PRINT=ETASQ DESCRIPTIVE HOMOGENEITY
/CRITERIA=ALPHA(.05)
/DESIGN=Origin
```

Aircraft type Syntax

```
DATASET ACTIVATE DataSet1.
UNIANOVA TripTimeRecover BY AcType RegDel
/METHOD=SSTYPE(3)
/INTERCEPT=INCLUDE
/PLOT=PROFILE(AcType)
/PLOT=PROFILE(RegDel)
/EMMEANS=TABLES(AcType) COMPARE(AcType)
/EMMEANS=TABLES(RegDel) COMPARE(RegDel)
/EMMEANS=TABLES(AcType*RegDel) COMPARE(AcType)
/PRINT=ETASQ DESCRIPTIVE HOMOGENEITY
/CRITERIA=ALPHA(.05)
/DESIGN=AcType RegDel AcType*RegDel.
```

```
ONEWAY TripTimeRecover BY AcType
/MISSING ANALYSIS
/POSTHOC=BONFERRONI ALPHA(0.05).
```

```
ONEWAY TripTimeRecover BY AcType
/MISSING ANALYSIS
/POSTHOC=BONFERRONI ALPHA(0.05).
```

```
DATASET ACTIVATE DataSet1.
UNIANOVA TripTimeRecover BY AcType
/METHOD=SSTYPE(3)
```

```
/INTERCEPT=INCLUDE  
/PLOT=PROFILE(AcType)  
/EMMEANS=TABLES(AcType) COMPARE(AcType)  
/PRINT=ETASQ DESCRIPTIVE HOMOGENEITY  
/CRITERIA=ALPHA(.05)  
/DESIGN=AcType
```

APPENDIX IV: ATFM MESSAGES

2.3.2 ATFM Messages

2.3.2.1 ATFM Flight Progress messages – Originated by AO/ATS

2.3.2.1.1 APR – Aircraft (operator) Position Report

1. APR giving a report for a Lat/Long:

- TITLE APR
- ARCID BAW12
- ADEP WSSS
- EOBT 1546
- EOBD 000316
- POSITION
- PTID GEO01
- TO 0215
- FL F350
- ADES EGLL
- GEO
- GEOID GEO01
- LATTD 544129N
- LONGTD 0254412E

2. APR giving an ETA at the aerodrome of destination:

- TITLE APR
- ARCID AFR135
- ADEP VABB
- EOBT 2110
- EOBD 000316
- POSITION
- ADID LFPG
- TO 0656
- ADES LFPG

2.3.2.1.2 DPI – Departure Planning Information

1. E-DPI with TTOT:

- TITLE DPI
- DPISTATUS EARLY
- ARCID DLH4564
- ADEP EDDM
- ADES EGLL
- EOBT 1155
- EOBD 000112
- TAXITIME 0035
- TTOT 1219
- SOBT 1155
- SID xxx1A

2. E-DPI without TTOT:

- TITLE DPI
- DPISTATUS EARLY
- ARCID DLH4564
- ADEP EDDM
- ADES EGLL
- EOBT 1155
- EOBD 000112
- TAXITIME 0013
- SID xxx1A

3. A-DPI with TTOT and updated taxitime and 24bit ICAO address:

- TITLE DPI
- DPISTATUS ATC
- ARCID CSDNJ
- ADEP EHRD
- ADES LFPB
- EOBT 1300
- EOBD 000112
- TTOT 1308
- TAXITIME 0012
- SID REFSO2C
- ARCTYP H25B
- REG OOAD
- IFPLID AA12295633

4. C-DPI:

- TITLE DPI
- DPISTATUS CNL
- ARCID AF762SD
- ADEP LFPG
- ADES LFST
- EOBT 1310
- EOBD 991223
- IFPLID BB76297483

2.3.2.1.3 FSA – First System Activation

1. FSA for Take-Off:

- TITLE FSA
- ARCID MAH9554
- ARCTYP B733
- ADEP LHBP
- EOBT 1050
- EOBD 991007
- POSITION -ADID LHBP -TO 1110
- FURTHRTE BAKOL LALAT
- ADES LFPG

- TITLE FSA
- ARCID MAH123
- ARCTYP B757
- ADEP LHBP
- EOBT 1030
- EOBD 991007
- POSITION -ADID LHBP -TO 1100
- ADES LFPG

2. FSA at airspace entry (not a departure) and using IFPLID:

- TITLE FSA
- IFPLID BB76297483
- ARCID THY1905
- ARCTYP B738
- ADEP LTAC
- EOBT 0600
- EOBD 991007
- POSITION -PTID BABIT -TO 0812 -FL F350
- FURTHRTE BABIT DIMLO GRZ ERKI KOGOL KPT
- ADES LSZH

- TITLE FSA
- IFPLID AA05072741
- ARCID KLM123
- ARCTYP B757
- ADEP EBBR
- EOBT 1340
- EOBD 991007
- POSITION - PTID NICKY - TO 1355 - FL F220
- ADES EHAM

3. FSA with lat/long point:

- TITLE FSA
- IFPLID AA76297483
- ARCID FIN821F
- ARCTYP MD80
- ADEP EFHK
- EOBT 0605 - EOBD 991225
- POSITION -PTID GEO01 -TO 0736 FL F310
- FURTHRTE DETNI ARGAD TRT MAG FUL
- GEO

- GEOID GEO01
- LATTD 545500N
- LONGTD 0142039E
- ADES EDDF

- TITLE FSA
- IFPLID AA76297483
- ARCID FIN821F
- ARCTYP MD80
- ADEP EFHK
- EOBT 0605 - EOBD 991225
- POSITION -PTID GEO01 -TO 0736 FL F310
- FURTHRTE DETNI ARGAD TRT MAG FUL GEO02
- GEO - GEOID GEO01 - LATTD 545500N - LONGTD 0142039E
- GEO - GEOID GEO02 - LATTD 545510N - LONGTD 0142139E
- ADES EDDF

4. FSA with bearing/distance point:

- TITLE FSA
- IFPLID AA76297483
- ARCID FIN821F
- ARCTYP MD80
- ADEP EFHK
- EOBT 0605 - EOBD 991225
- POSITION -PTID REF01 -TO 0736 FL F310
- FURTHRTE DETNI ARGAD TRT MAG FUL
- REF
 - REFID REF01
 - PTID BAKOL
 - BRNG 123
 - DISTNC 020
- ADES EDDF

5. FSA with SID:

- TITLE FSA
- IFPLID AA19600528
- ARCID TRA165
- ARCTYP B733
- ADEP EHAM
- EOBT 0810
- EOBD 000528
- POSITION -ADID EHAM -TO 0825
- FURTHRTE LEKKO INKET GEO01 INKET WILMA THN NW
- GEO
 - GEOID GEO01
 - LATTD 514853N
 - LONGTD 0044619E
- SID LEKKO50
- ADES EHBK

6. FSA for holding:

- TITLE FSA
- IFPLID BB76297483
- ARCID THY1905
- ARCTYP B738
- ADEP LTAC
- EOBT 0600
- EOBD 991007

- POSITION -PTID BABIT -TO 0812 -FL F350
- FURTHRTE BABIT DIMLO GRZ ERKIR KOGOL KPT
- STAY

- STAYIDENT STAY1
- TIME 0025
- PTID DIMLO
- PTID GRZ

- ADES LSZH

- TITLE FSA
- IFPLID AA05072741
- ARCID KLM123
- ARCTYP B757
- ADEP EBBR
- EOBT 1340
- EOBD 991007
- POSITION - PTID NICKY - TO 1355 - FL F220
- STAY

- STAYIDENT STAY1
- TIME 0025
- PTID NICKY
- PTID NICKY

- ADES EHAM

- TITLE FSA
- IFPLID AA05072741
- ARCID KLM123
- ARCTYP B757
- ADEP EBBR
- EOBT 1340
- EOBD 991007
- POSITION - PTID NICKY - TO 1355 - FL F220
- STAY

- STAYIDENT STAY1
- TIME 0100
- PTID NICKY
- ADID EHAM

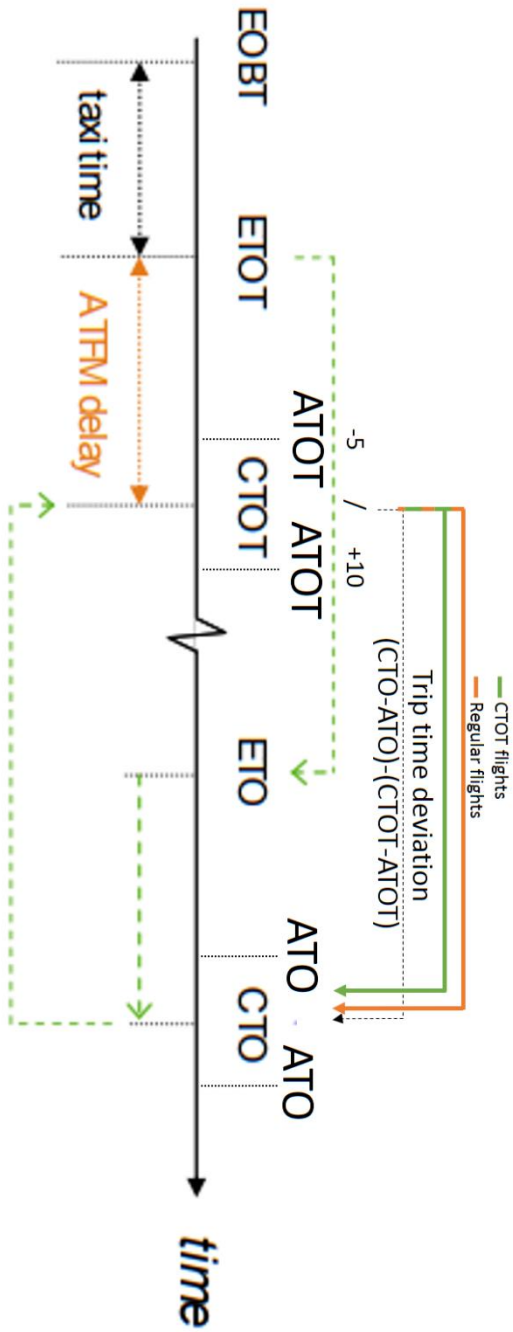
- ADES EHAM

-TITLE FSA
-ARCID POKER91
-ARCTYP F18
-ADEP LETO
-EOBT 0830
-EOBD 041127
-POSITION -PTID VJZ -TO 0910
-STAY

-STAYIDENT -STAY1
-TIME 0010
-PTID VJZ
-PTID VJZ

-ADES LETO
-FURTHRTE VJZ BAN REN01
-RENAME
-RENID REN01
-PTID VJZ

APPENDIX V: DATA MODEL WITH RESULTS



APPENDIX VI: INTERVIEWS

Airline 1

- How do you handle flight planning?
 - Is a new FPL calculated each day or are FPL's filed for multiple days?

De FPL worden voor elke dag opnieuw berekend en gefiled. Airline 1 maakt geen gebruik van repetetive flightplan. De routes worden berekend met in achtneming van de laatste weergegevens, flow restricties en vliegtuiggegevens (zoals gewicht)

- How are block times determined?
 - Is this statistically done and how many times per year are block times adjusted?

De bloktijden worden bepaald obv de statische gegevens over het afgelopen seizoen. Daarin wordt onderscheid gemaakt tussen zomer en winter. De bloktijden worden voor het publicatie van het schema (ongv 6 maanden) van te voren vastgelegd en alleen in uitzonderlijke gevallen in een lopend seizoen aangepast.

- How is the cost index per flight set?
 - Does your airline use default CI's for all flights or does the CI vary per flight?

De standaard cost index is afhankelijk van het vliegtuig type/ variant en voor alle vluchten gelijk. Op dit moment onderscheiden wij 3 types. Type 1 en 2 (afgeleverd voor 2008) en type 3 (afgeleverd na 2008). Het onderscheid heeft te maken met het verschil in de tijd gerelateerde kosten van nieuwe versus oudere vliegtuigen. Met oog op de bloktijd is de delta vliegtijd op 1 vlucht verwaarloosbaar. De Costindex wordt 1x per jaar geevalueerd. Afhankelijk van veranderingen in de geprojecteerde brandstofprijzen en of tijdsgerelateerde kosten kan deze enkele punten veranderen. De actuele cost index is tussen de 10 en 14, afh van het type/variant.

- What instruments regarding delay recovery are used?
 - What actions does your airline take in the execution phase to reduce delays?

Er zijn diverse instrumenten / middelen om delay recovery toe te passen. Ik concentreer me alleen op de mogelijkheden tijdens de vlucht. Dit zijn:

Route planning op minimum Time Track ipv Minimum Cost Track

Verhogen van de Costindex, eventueel icm met aanpassen naar lower FL.

Gebruik van RTA (required Time of Arrival) mode in FMC.

Binnen de operatie van airline 1 wordt Delay recovery incidenteel toegepast om een DBC te voorkomen, curfew om EIN/RTM te halen en of vanwege crew duty.

Airline 2

- How do you handle flight planning?
 - Is a new FPL calculated each day or are FPL's filed for multiple days?

Yes

- How are block times determined?
 - Is this statistically done and how many times per year are block times adjusted?

We determine the block times by using the medium of the block hours (65th percentile), and it is adjusted twice a year.

- How is the cost index per flight set?
 - Does your airline use default CI's for all flights or does the CI vary per flight?

CI may vary depending on aircraft type and fuel prices. A320 use lower CI then B737-800 and A340.

- What instruments regarding delay recovery are used?
 - What actions does your airline take in the execution phase to reduce delays?

Aircraft and/or crew change, quick turn-around on ground, increase speed, rerouting to shorter/faster routing.

Airline 3

- How do you handle flight planning?

- Is a new FPL calculated each day or are FPL's filed for multiple days?

A Flight Plan is created for each flight for efficiency and safety reasons. Two days are never the same in respect of the winds, so to use the same flight plan for a given Flight Number on multiple days would be inaccurate in terms of fuel required and possible alternates available.

- How are block times determined?
 - Is this statistically done and how many times per year are block times adjusted?

We create lines of work for aircraft based on statistically created block times using certain business rules. The block time consists of taxi-out, flight time, taxi-in, plus a statistical allowance for ATM/Airport delays. For Airline 3, block times are adjusted seasonally based on the previous year's data. So we have a winter and Summer schedule. We would like to change this to monthly, but this doesn't fit with the airport slot allocation process.

- How is the cost index per flight set?
 - Does your airline use default CI's for all flights or does the CI vary per flight?

We have a default Cost Index for each aircraft type, but we do adjust this if we need to speed up or slow down for punctuality reasons.

- What instruments regarding delay recovery are used?
 - What actions does your airline take in the execution phase to reduce delays?

We re-route to save on ATFM delays where necessary i.e. taking a longer routing due to capacity constraints on the preferred routing.

Airline 4

- How do you handle flight planning?
 - Is a new FPL calculated each day or are FPL's filed for multiple days?

Each day, flight by flight a new flight plan is filed based on updated information per specific flight such as weather (METAR & TAF), Payload, planned fuel, aircraft type and performance factor, routing and so on.

- How are block times determined?

- Is this statistically done and how many times per year are block times adjusted?

Do you mean planned block times or actual block times? Planned block times are calculated previously by a dedicated department taking into account estimated stick time and estimated taxi times and operational aspects as well as economical needs. Cost index also plays a role, especially in case of adjustments of the planned block time.

- How is the cost index per flight set?
 - Does your airline use default CI's for all flights or does the CI vary per flight?

Cost Index is based on the results of an algorithm; the Cost Index is the ratio between the cost of minute (USD/min) and the fuel price (USD/kg); for instance increasing the fuel price the Cost Index decreases. We use to apply a specific CI based on Aircraft Type i.e. A320 family has a fixed CI, Long Haul instead could vary since it's made in interactive mode. In special conditions CI could be based on city pairs.

- What instruments regarding delay recovery are used?
 - What actions does your airline take in the execution phase to reduce delays?

Different kind of delays produce different actions; some delays could be mitigated by varying the cruise speed some other need to be necessary coordinated by Network Manager (Eurocontrol), ATC and Airports (regarding slot) especially when meteo issues occur. A-CDM is an instrument put in place in some airports such as Fiumicino with the purpose to reduce delays.

APPENDIX VII: RESULTS IN TABLE FORMAT

Code	SWR			NAX			TFL TUI Fly		
	Name	Count (min)	TTR diff	Name	Count (min)	TTR diff	Name	Count (min)	TTR diff
Airline name	Swissair			Norwegian Air Shuttle					
	Main aircraft type(s)								
	A320	679	4.00	B738	865	4.21	B738	331	3.45
	A321	356	3.90						
	A319	300	4.49						
	Main origin(s)								
	LSZH	4.08		ESSA	865	5.51	LEMG	276	3.38
				ENGM	382	3.39			0.87
	Code			EZY					
	Airline name			EasyJet					
Main aircraft type(s)									
EZS									
EasyJet Switzerland									
Name			Count (min)	TTR	diff	mean			
A319	515	3.12		1.27		A319	5582	2.50	0.69
A320		2.86				A320	6226	2.25	0.65

APPENDIX VIII: EUROCONTROL FORECASTING METHOD

This is the method used for calculating the initial annual forecast (European Commission, 2017).

