

# D-1 prediction

## *Validating and improving the prediction of the demand at the day before operation*

Thesis

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Thesis

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## Preface

This thesis is the result of the research to the prediction made a day before the day of operation within the Air Traffic Control the Netherlands (LVNL). This report was written to proof the competence for obtaining the Bachelor of Science degree of Aviation Studies, specialisation Flight Operations Engineering, at the Amsterdam University of Applied Sciences (AUAS). The graduation period for the thesis was from February 2019 to July 2019.

This thesis is commissioned by the Knowledge and Development Centre (KDC) – Centre of Excellence (CoE), for the LVNL, Amsterdam Airport Schiphol (AAS) and The Royal Dutch Airlines (KLM). The KDC CoE collaborates with the AUAS with the objective to research capacity management. This research assignment was established by the Capacity Management and Analytics department of the LVNL, together with the D-1 project team.

The research and analyses I did during this graduation internship were very challenging and informative and I would like to thank everyone who supported me to finally come to this result. Therefore, I would like to thank my company supervisors and product owners Leo Hoogerbrugge and Jeroen Devilee, for supporting me for keeping the research in the right direction and providing the necessary information and feedback. Also, the KDC supervisor Frenchez Pietersz and the AUAS supervisor Catya Zuniga were valuable for me for providing feedback and taking my research to a higher level.

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Flore Wassenberg,

Schiphol, 22-05-2019

## Abstract

Concrete steps regarding the development of capacity management are made in 2018. One of the results was the D-1 project. This is the project that should provide more insight into the day of operation (D0) at the day before operation (D-1). Within the project team of D-1, it was unknown how operable the information about the traffic demand was, generated at D-1 for the D-1 project and for the operation because the prediction generated was not quantitatively evaluated afterward. To explore the reliability and usability of the prediction at D-1, research is performed to understand the reliability of the D-1 prediction compared to the day of operation. This means that the last submitted flight plans at D0 are compared to the data predicted on D-1 of a sample of a three months trial for further use of the data. The answer to the reliability of the traffic demand prediction for the day of operation on the day before operation at Schiphol and LVNL controlled airspace is unambiguous because of different opinions. For this research, including the assumptions and scope that were necessary to determine, the conclusion is that the prediction is not accurate enough for the operation for making regulation. This is based on multiple analyses:

- construction of the D-1 data at Eurocontrol;
- the relevance of the D-1 project for KLM and the D-1 planning at KLM;
- comparison and statistical analysis of the D-1 data with the D0 data;
- interview with experts about the accuracy of the D-1 prediction for the operation.

Improvements are necessary for the D-1 prediction before it will be implemented, to finally create a more predictable process and more stability for the operation.

Keywords: Air Traffic Control the Netherlands, traffic demand prediction, capacity management.

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## List of abbreviations

<b>Abbreviation</b>	<b>Definition</b>
a/c	Aircraft
AAS	Amsterdam Airport Schiphol
ACC	Area Control
ACM	Airspace Capacity Management
ADP	ATFCM Daily Plan
AIRAC	Aeronautical Information Regulation and Control
ANSP	Air Navigation Service Provider
APR	Aircraft operator Position Reports
ATC	Air Traffic Control
ATFCM	Air Traffic Flow Capacity Management
ATM	Air Traffic Management
AUAS	Amsterdam University of Applied Sciences
AUP	Airspace Use Plan
Avg	Average
CACD	Central Airspace and Capacity Database system
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit
CIFLO	Collaboration Interface for Flow Management Positions
CMA	Capacity Management and Analytics (department at LVNL)
CoE	Centre of Excellence
D+1	Day after the operation
D0	Day of operation
D-1	Day before the operation
DDR	Demand Data Repository
DDR1	DDR phase 1
DDR2	DDR phase 2
DDS	Data Distribution System
DMP	Data Management Plan
DOP	Daily Operating Plan
DWH	Data Warehouse
ECAC	European Civil Aviation Conference
EHAM	Schiphol Airport
EIBT	Estimated In-Block Time
EOBT	Estimated Off-Block Time
ETFMS	Enhanced Tactical Flow Management System
FIR	Flight Information Region
FMP	Flow Management Position
FMPC	Flow Management Position Controller
FTFM	Filed Technical Flight Model
IFPS	Initial Flight Plan Processing System

KDC	Knowledge and Development Centre
KLM	The Royal Dutch Airlines
KNMI	The Royal Dutch Meteorological Institute
LVNL	Air Traffic Control the Netherlands
MAD	Mean Absolute Deviation
MAPE	Mean Absolute Percentage Error
MFE	Mean Forecast Error
MSD	Mean Squared Deviations
MSE	Mean Square Error
NAT	North Atlantic
NATS	National Air Traffic Services (of the United Kingdom)
NEST	Network and Strategy Tool
NM	Network Manager
NMOC	Network Manager Operations Centre
NOP	Network Operations Portal
NOTAM	Notices To Airmen
OPS	Operations (department at LVNL)
P&S	Procedures and Systems (department at LVNL)
RMSE	Root Mean Square Error
RPL	Repetitive Flight Plan
RWY	Runway
SIBT	Scheduled In-Block Time
SOBT	Scheduled Off-Block Time
STAM	Short Term ATFCM Measures
STRATFOR	Statistics and Forecasts
SWIM	System Wide Information Management
TMA	Terminal Manoeuvring Area
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
WLM	Workload Model

## Definitions of terms

<b>Airspace segments</b>	Contains sector 2 and 3, the three stacks (ARTIP, RIVER and SUGOL), all the inbounds to Schiphol in the Dutch airspace (EHFIRAM) and arrival and departure on the runway at Schiphol.
<b>Amsterdam Airport Schiphol (AAS)</b>	The stakeholder Schiphol
<b>D0</b>	Day of operation. If used as a dataset, it implies the last submitted flight plans at the day of operation
<b>D-1</b>	Day before operation. If used as a dataset, it implies the PREDICT data generated by Eurocontrol based on the flight schedules of the airlines and an algorithm
<b>D-1 (demand) prediction</b>	The PREDICT data of the demand
<b>D-1 project</b>	The project started in 2018 to predict the capacity, workload and demand at the day before operation
<b>EHARTIP</b>	One of the three stacks in the Dutch airspace: ARTIP
<b>EHFIRAM</b>	All the inbound flights in the Amsterdam Flight Information Region (FIR)
<b>EHRIVER</b>	One of the three stacks in the Dutch airspace: RIVER
<b>EHSECT2</b>	Sector 2 (in the Dutch airspace)
<b>EHSECT3</b>	Sector 3 (in the Dutch airspace)
<b>EHSUGOL</b>	One of the three stacks in the Dutch airspace: SUGOL
<b>Schiphol/EHAM</b>	The airport Schiphol, as a destination or a departure location

## Summary

In 2017 there were some reports of air traffic controllers, that the workload at Area Control sector 3 was too high. Also, the view within the Air Traffic Control the Netherlands (LVNL) was limited for the traffic demand of tomorrow, there were inflexible schedules of the air traffic controllers and there was no consistency between different information sources. In 2017, a proposal was made for concrete steps in 2018 regarding the development of capacity management. One of the results was the D-1 project, which started in 2018. This is the project that should provide more insight into the day of operation (D0) at the day before operation (D-1). Within the project team of D-1, it was unknown how operable the information about the traffic demand generated at D-1 is for the D-1 project and the operation. The prediction generated was not quantitatively evaluated afterward, to know how well this demand prediction matches with the day of operation. To enlighten the reliability and usability of the prediction at D-1, research is required to understand the reliability of the D-1 prediction compared to the day of operation. The D0 data is the last submitted flight plans at the day of operation and the D-1 data is the prediction on the day before the operation of a sample of a three months trial.

The following research question is formulated: **How reliable is the traffic demand prediction for the day of operation (D0) on the day before operation (D-1) at Schiphol and LVNL controlled airspace?** To answer this, the question is divided into smaller sub-research questions:

- SQ1.** What are the differences between the D-1 traffic demand prediction and the demand at the day of operation and what can be causes for these differences?
- SQ2.** How accurate is the D-1 demand prediction?
- SQ3.** How does the quality of the D-1 prediction influence the day of operation and when is the prediction reliable enough for the day of operation?
- SQ4.** How can the reliability of the D-1 prediction be improved?

To answer these questions, the research is divided into four phases. The first phase of the research is desk research, in the form of a literature review and a stakeholder analysis. Phase 2 is exploratory research to the construction of the D-1 prediction data at Eurocontrol and research to the D-1 planning at the Royal Dutch Airlines (KLM). Phase 3 includes the data analysis to obtain insight into the accuracy and reliability of the D-1 prediction. The last phase is performed to know when a prediction is reliable enough for LVNL and the influence of the D-1 prediction on the day of operation, which is in the form of interviews to learn the vision of a supervisor and two Flow Management Position Controllers (FMPCs).

The PREDICT data of Eurocontrol contains historical flight data that is enriched with flight intentions based on schedule data of airlines, airport slot data and a snapshot of the night before with the last received data such of submitted flight plans. The D0 demand data is the data with the last submitted flight plans of the aircraft operation in the Initial Flight Plan Processing System. This data is processed in the Enhanced Tactical Flow Management System to calculate the 4D trajectories to obtain a dataset with entry times.

The differences between the datasets are analysed based on the difference in entry time and on the number of entries for every airspace segment mentioned in the D-1 plan. These segments are sector 2, sector 3, the three stacks (ARTIP, SUGOL and RIVER), the departures and arrivals at Schiphol, all the inbound to Schiphol in the Amsterdam Flight Information Region (FIR) (EHFIRAM) and for the peak hours in the EHFIRAM.

The reasons for the difference in entry time are because a flight is later, earlier, not predicted, not present in D0 or changed its route. For sector 2, sector 3, the three stacks and the EHFIRAM is the highest percentage of flights earlier than predicted. For the departures at Schiphol, the highest percentage is on time and for the arrivals at Schiphol, the highest percentage of flights arrive earlier or later depending on the comparison, D-1 with D0 or D0

with D-1. If a flight was not predicted in the same sector or the same stack, it is possible that another route is filed in the flight plan than predicted. For sector 2 the most flights moved to sector 3, for sector 3 the most flights moved to sector 2, for the stack ARTIP the most flights moved to RIVER, for SUGOL the most flights moved to RIVER and for RIVER the most flights moved to ARTIP.

The difference in the number of entries is analysed with five different statistics:

- The average difference. The difference is the number of entries of D-1 minus the number of entries of D0. When the difference becomes negative, there is more demand at D0 than predicted and when the difference becomes positive, there is more demand predicted than at D0.
- The standard deviation (including the percentage). The standard deviation is a value to quantify the amount of variation or dispersion of a set of data values. Within this research, the standard deviation indicates the number of entries that can vary per hour. The percentage standard deviation of total aircraft per hour provides more insight into the height of the standard deviation compared to the number of flights in that airspace segment.
- The Mean Forecast Error (MFE). This is the mean deviation of the forecast demand for the actual demand. A negative MFE means that there is less aircraft at D0 than predicted and a positive MFE means that there are more aircraft at D0 than predicted.
- The R-square. This provides a percentage of how much of the D0 data is explained by the prediction.
- The Related-Samples Wilcoxon Rank test. This test compares the D-1 demand data with the D0 demand data. The null hypothesis is that the median of differences between the D-1 data and D0 data equals zero. This hypothesis can be retained or rejected, considering a significance of 0.50.

A summary of all these statistics is visualised in Table 1.

Table 1. Summary statistics difference in the number of entries

Airspace segment	Average difference	Standard deviation	% standard deviation of total	MFE	Percentage (R-square)	Decision to hypothesis of Wilcoxon test
Sector 2	-0.21	3.66	19.6	0.214	92.3	Reject
Sector 3	-0.21	3.62	18.9	0.21	92.6	Reject
ARTIP	0.07	2.62	23.8	-0.068	90.8	Retain
SUGOL	0.15	2.5	28.4	-0.153	90.3	Retain
RIVER	0.04	2.27	32.9	-0.045	83.8	Retain
EHFIRAM	0.32	4.2	15.7	-0.32	95.8	Retain
EHAM Arrival South	0.31	4.26	16	-0.309	95.8	Retain
EHAM Arrival North	0.3	4.26	16	-0.309	95.8	Retain
EHAM Departure South	-0.34	4.49	16.8	0.341	95.8	Reject
EHAM Departure North	-0.34	3.83	14.3	0.341	96.9	Reject
EHFIRAM all peak hours	2.04	5.28	11.9	-2.04	88.7	Reject
EHFIRAM 1th peak hour	2.67	5.87	10.9	n/a	87.1	Reject
EHFIRAM 5th peak hour	1.37	5.52	13.1	n/a	91.2	Reject

The statistics found are validated with the supervisor and FMPCs. The two FMPCs consider the accuracy insufficient because the deviation of the standard deviation is more than 10 percent of the total flight in the hour. This deviation should be maximal 10 percent. The answer to the main question, if the D-1 demand prediction of the first three months of the D-1 trail is reliable enough for the day of operation, is questionable because of different opinions of the experts. The safe conclusion will be that the D-1 demand prediction of the first three months of the D-1 trail, containing January, February and March, are not usable enough for the operation, based on the scope and assumptions made in this research. However, the accuracy varies during the day and at some moments of the day the accuracy is acceptable. Some statistics present that the prediction is accurate while the other statistics contradict this.

There is chosen to interview three experts working within the operation of LVNL, however, with the opinion of these three, it is not possible to provide a decisive answer about the reliability of the prediction for the operation. To provide a more decisive answer, more experts should be interviewed about their opinion about the accuracy of the D-1 prediction.

There are improvements possible for the D-1 prediction in different subjects. The main goal is to improve the accuracy, to make the D-1 prediction usable enough for the operation. More inputs should be implemented in the D-1 data such as weather conditions or special conditions such as a strike. There should be more alignment and cooperation between the Air Navigation Service Providers and the Network Manager of Eurocontrol. Also, more communication between KLM and LVNL is of importance, while a substantiated capacity provided by the LVNL on the morning of D-1 is very important for the KLM. They use this to determine if flights must be cancelled or delayed, to prevent that KLM must pay compensation. Another improvement can be to create a D-1 prediction within LVNL.

A recommendation is to continue with the D-1 project while it provides extra value to the operation. When the D-1 plan is received, it is possible to start earlier with regulating traffic and making restrictions which creates a more predictable process and more tranquillity. Before implementing the D-1 project, further research is necessary. A more detailed evaluation should be executed when more data is obtained, more experts should be interviewed, a more detailed analysis to the causes of the differences should be performed and overall the accuracy should be improved. However, some parts of the prediction might already be useful for the operation, as long as it is considered that the prediction deviates.

## 1. Introduction

This research is performed within the Knowledge and Development Centre (KDC), at the Centre of Excellence (CoE). The KDC is founded by the Amsterdam Airport Schiphol (AAS), the Royal Dutch Airlines (KLM) and the Air Traffic Control the Netherlands (LVNL) which goal is to find innovative and valuable solutions for the sustainable development of the Mainport Schiphol. The CoE is a cooperation with universities and the KDC and started a collaboration with the Aviation Academy from the Amsterdam University of Applied Sciences (AUAS) and the Delft University of Technology. The students within the CoE are open-minded and perform research with an independent view on subjects in line with the KDC's objective: Air Traffic Control (ATC), aircraft use and airport development (KDC-Mainport, n.d.). In general, the researches cover capacity management.

The research is commissioned by LVNL and this research will especially provide a recommendation for the LVNL. How the research is founded (see section 1.1), what the main problem (see section 1.2) and objective (see section 1.3) is, why this research is relevant to perform (see section 1.4), what the main and sub-research questions (see section 1.5) are for this research, the scope of the research (see section 1.6), some assumptions that were necessary to made (see section 1.7) and finally the thesis structure (see section 1.8) are described.

### 1.1 Background

In 2017 a research to 'Initiation Phase Capacity Management' is performed because in the summer of 2016 there were some reports of air traffic controllers, that the workload at Area Control (ACC) sector 3 was too high. The research was to define an initiation phase for the development of capacity management to propose concrete steps in 2018. That research found that there were some imperfections in the pre-tactical planning. There was preliminary work done towards better pre-tactical planning with temporary procedures of the Procedures & Systems (P&S) department, but there were no implementation options that are possible to use in the development of a D-1 plan. There was limited organisation and tools that can execute a D-1 process (Westerveld, Lieshout, Obbens, Devilee, & Delden, 2017), while a D-1 process would help LVNL's operation. It appeared that LVNL has possibilities to improve compared to some other Air Navigation Service Providers (ANSPs) in Europe. The information about the day of operation in terms of capacity is not transparent for the stakeholders, such as the airlines, the airport and the ground handlers. They don't know what to expect of the LVNL's operation. There is just a common prediction of the capacity of each day, but when there are changes in the capacity, this will be announced on the day itself.

Within the LVNL there were some imperfections and limitations mentioned in the business case of the establishment of the D-1 project:

- LVNL has a limited view of the traffic demand of tomorrow. This makes that the residual capacity is not used.
- Inflexible schedules of the air traffic controllers, which makes LVNL unable to respond to the need at the day of operation.
- Within the operation, there is no consistency between the information of Notices To Airmen (NOTAM's), announcements, Daily Operating Plan (DOP), Airspace Use Plan (AUP), etcetera.
- There is a reluctance to take capacity limited measurements because the results are unknown.
- The traffic demand in the Dutch airspace is not adapted to the capacity, so the number of delays increases as the traffic demand increases (Lieshout, Devilee, & Obbens, 2017).

In 2018 LVNL started the project called D-1, which is the result of the findings of the researches about capacity management executed in 2017. The D-1 project should provide a better prediction of the operation on a day before the operation, which provide LVNL a better insight into the operation of the next day so that they can anticipate to it. The stakeholders

might experience some benefits as well. A trial of this project started in January 2019, where two till three times in the week a prediction is created at D-1 for D0. This prediction is explained in detail in a D-1 plan. Within this D-1 plan, a selection of airspace parts within the Netherlands is visualised with demand and capacity figures. These are sector 2 and sector 3, the three stacks: ARTIP, RIVER and SUGOL, the arrival and departure at Schiphol and the inbound flights to Schiphol within the Amsterdam Flight Information Region (FIR). These together will be called during this research *airspace segments*. The locations of these airspace segments within the Dutch airspace are marked green (Figure 1).

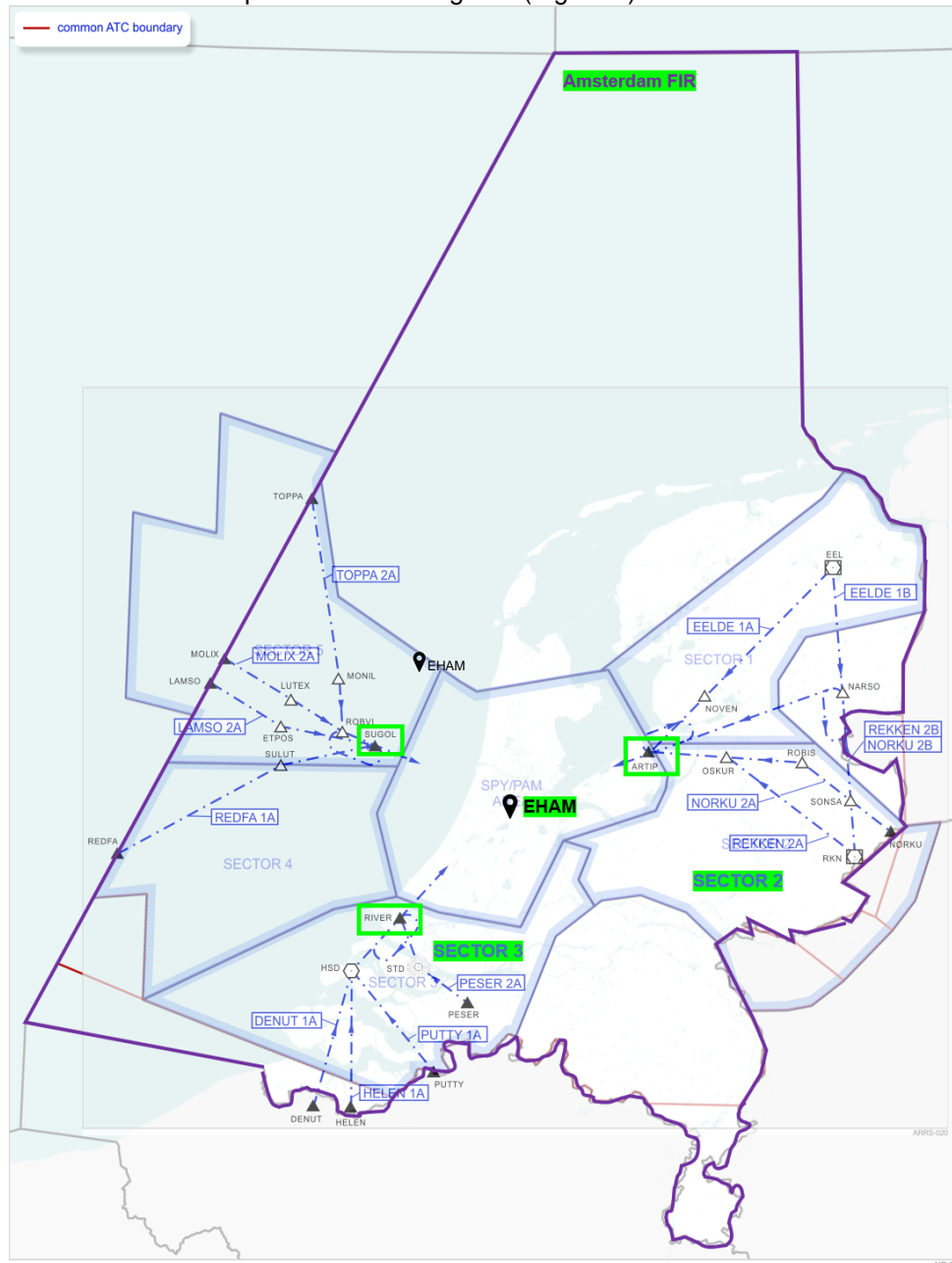


Figure 1. Dutch airspace with airspace segments, combined by the author (LVNL, 2017)

Within LVNL the airspace segments have the prefix: 'EH'. The airspace segments locate within the Netherlands and the first two characters of the ICAO code of the airports within the Netherlands have EH. During this research the airspace segments will be mentioned as:

- EHSECT2 for sector 2;
- EHSECT3 for sector 3;

- EHARTIP, EHRIVER and EHSUGOL for the three stacks;
- EHFIRAM for the inbound flights to Schiphol within the Amsterdam FIR;
- EHAM Departure and EHAM Arrival for the departures and arrivals at Schiphol.

## 1.2 Problem statement

Within the project team of D-1, it is unknown how operable the information about the traffic demand generated at D-1 is for the D-1 project and the operation. The generated prediction is not quantitative evaluated afterward to know how well this demand prediction matches with the day of operation. This research to the D-1 prediction is necessary to enlighten the reliability and usability of the prediction at D-1 and the day of operation. This is of importance to obtain the usability of the D-1 prediction for the operation when the trial of the D-1 project is finished. The first three months of the trial (January, February and March) generate the D-1 prediction data sample which will be analysed during this research. It would be valuable to know if there are improvements possible in the traffic demand prediction that is used within the D-1 Project.

LVNL expects that with the D-1 project, the capacity can be used more efficiently, which provides an improvement of the performance, which subsequently can result in less delay for the airlines and for the operators to plan their daily operations more appropriate. LVNL wants to lower the workload for the air traffic controllers and accommodate the ACC supervisors by providing more technical support. The ideal situation is to have the supply and demand at least the day before operation correlated with each other (Lieshout, Devilee, & Obbens, 2017). After all, the goal of the D-1 project is to be more transparent to the airlines and the airport and better usage of the capacity.

Within the KDC, the Aviation Academy of the AUAS contributes to the subject 'Capacity Management'. This means the capacity of the airport's processes, capacity constraints as well as limited resources such as runways, taxiways, gates, terminal or airspace. Capacity management is of importance in ensuring that the operations run smoothly, which will reduce delays and controller workload (KDC-Mainport, n.d.).

## 1.3 Research objective

The objective is to understand the reliability of the D-1 prediction compared to the day of operation, i.e., the last submitted flight plans at D0 by comparing the data predicted on D-1 of a sample of a three months trial for further use of the data.

## 1.4 Research relevance

Within the KDC, capacity is a very important subject. It is a challenge to keep up with the growing air traffic rate. The Mainport Schiphol aims for higher efficiency of operations to increase the capacity. The stakeholders require capacity data to plan their operations and rely on airports to provide these. This is of importance because capacity underestimation leads to unnecessary cancellation costs, inefficient use of the system, customer dissatisfaction and delays. An accurate capacity forecast provides an increase in predictability and more efficiency in the system.

The importance of the client LVNL, the department Capacity Management and Analytics (CMA), is to provide more insight into the data (D-1 demand prediction) they are using for the trial of the D-1 project.

## 1.5 Research questions

To understand how operable the information about the traffic demand generated at the day before operation is, the next research question is necessary to answer.

**How reliable is the traffic demand prediction for the day of operation (D0) on the day before operation (D-1) at Schiphol and LVNL controlled airspace?**

To answer the main research question, the question is divided into smaller parts, which support to answer the main research question. This results in the next sub-research questions (SQs):

- SQ1.** What are the differences between the D-1 traffic demand prediction and the demand at the day of operation and what can be causes for these differences?
- SQ2.** How accurate is the D-1 demand prediction?
- SQ3.** How does the quality of the D-1 prediction influence the day of operation and when is the prediction reliable enough for the day of operation?
- SQ4.** How can the reliability of the D-1 prediction be improved?

## 1.6 Research scope

Within the D-1 plan (Appendix V), multiple information is given. Only the data to retrieve the traffic demand graphs will be used. These graphs are made for sector 2 and sector 3, for the stacks (EHARTIP, EHRIVER and EHSUGOL), which are the entry points in the Terminal Manoeuvring Area (TMA), all the inbound traffic to Schiphol within the Amsterdam FIR (EHFIRAM) and for the arrivals and departures at the runway. Only these airspace segments will be researched within this project. This includes both inbound and outbound flights, as well as transit and regional traffic. The other sectors (1, 4 and 5) are not within the scope of this research. The other information of the D-1 plan, such as the workload, air traffic controller configuration, etcetera will not be considered. In addition, the probability of weather conditions will be considered for determining nominal or special days.

In the graphs of the D-1 prediction in the D-1 plan, a red line with the nominal capacity is provided. This capacity is of importance because it presents a possible overload in demand. Sometimes when the weather conditions are not optimal, there is a nonstandard capacity, but this will not be considered when this is not yet known at D-1.

The input parameters that will be used for the data analysis of D-1, will mainly be flight plan data, while the dataset that is used contains the date, the sector, flight-id, callsign, aircraft type, departure airport, destination airport, off-block time, entry time in the sector and exit time in the sector. Other input parameters will be the weather, containing the visibility, wind and the humidity and the runway use on Schiphol, especially north or south runway use and special conditions or events mentioned in the D-1 plan. These are the parameters that influence traffic demand the most.

The difference in entry time and in the number of entries will be analysed, together with possible causes for the differences. The exact reason for the cause will not be investigated because this should then be performed for every unique flight.

The opinion of the people working in the operation within LVNL will be considered. They may have some causes for the differences found with the data analysis.

KLM also creates a kind of prediction for the next day, therefore an interview with KLM might help for possible improvements for the D-1 demand prediction of LVNL. Their opinion about the D-1 prediction will not be considered, because for the airlines only the capacity prediction is of importance and not the traffic demand.

In addition to KLM and LVNL, the other stakeholders included in this research are some ANSPs for the literature, AAS for providing information about infrastructure and Eurocontrol for providing data.

## 1.7 Assumptions and limitations

### Assumptions

The last submitted flight plans at the day of operation will be the reference for D0, which will be used for the comparison with the D-1 demand prediction. Therefore, the D0 will not be the actual operation. The reason for this choice is explained in 5.1.

The D-1 project is constant, which means there is no difference between the decisions made by different people, whereby there is no different influence on the output of the D-1 process.

The days considering in the research, after filtering the special days, are on average representative days, even though there are not always perfect weather conditions. The special days are removed of the data to obtain a more representative view about the accuracy of the D-1 prediction.

The highest demand value should fall exactly in the middle of the peak hour. This must be assumed to compare the moment of the provided highest demand value with the moment of measured highest demand value.

### Limitations

The reason and moment for changes in the flight plan are not available in the data, causing this is not considered during the research, even though it might be of extra value.

## 1.8 Thesis structure

An overview of the remaining chapters is stated below:

Methodology

Desk research

- Air Traffic Flow Capacity Management (ATFCM) at Eurocontrol
- Benchmark D-1 planning at other ANSPs
- Planning at LVNL
- Validating a prediction
- Conclusion of the literature
- Stakeholder analysis

Exploratory research to D-1

- Construction of the D-1 prediction data
- D-1 planning at KLM

Data analysis of D-1 demand prediction

- Framework for the analysis
- Comparison of the D-1 prediction demand with the D0 demand
- Validating the D-1 demand prediction

Conclusion

Discussion

Recommendations

References

Appendices

## 2. Methodology

This section explains the steps necessary to accomplish the research to understand what results will be retrieved. The research is divided into four phases (Figure 2). The first phase of the research will be desk research, in the form of a literature review and a stakeholder analysis. The field research that will be performed is both quantitative and qualitative and are phase 2, 3 and 4. Phase 2 is exploratory research to the construction of the D-1 data at the source of the data and research to the D-1 planning at an airline. Phase 3 is quantitative, including data acquisition, data manipulation and data analysis to obtain insight into the accuracy and reliability of the D-1 prediction. Phase 4 contains qualitative research which will be performed to know when a prediction is reliable enough for LVNL and the influence of the D-1 prediction on the day of operation, which will be in the form of interviews to learn the vision of experts. The first two sub-questions are answered in phase 3, the third sub-question in phase 4 and the last one is a combination of all the results of the four phases, which will be in the form of a recommendation. The input for possible improvements will be obtained with both quantitative and qualitative research, with the results of the data analysis and interviews at LVNL, KLM and Eurocontrol.



Figure 2. Flow diagram of research design with phases

Some hypotheses are made (see section 2.1), which afterward are confirmed or rejected. The construction of the D-1 and D0 data, which period is used and how the data is collected, but also the sample size of the interviews (see section 2.2) are explained. The activities within the phases are explained in section 2.3 for phase 1, section 2.5 for phase 2, section 2.6 for phase 3 and section 2.4 for phase 4. The research method that is used during the research is explanatory because a connection between two datasets (D-1 prediction and D0) is analysed and explanations for these differences and the reliability of the D-1 predicted are analysed by interviews.

### 2.1 Research hypotheses

The data that is used for the D-1 demand prediction originates of Eurocontrol. They use historical information and a model to create the D-1 prediction. There will be expected that the information Eurocontrol receives to create the prediction is correctly implemented. Hypothesis 1 will be: The D-1 demand prediction deviates not significant compared to D0 demand.

The D-1 project started in 2018 with the goal to be more transparent to the stakeholders of LVNL. This is of importance to obtain a more stable operation. The first step is to create a D-1 plan to support the air traffic controllers in their work. Hypothesis 2 will be: The D-1 demand prediction within the D-1 plan has a positive effect on the day of operation.

### 2.2 Sample and collection of data

The sample period for the D-1 dataset and the D0 dataset is the period starting from January 2019 to the end of March 2019. This period is chosen to analyse because these months are the first three months of the D-1 trial. More data is not yet available, but three months are just enough to perform a representative analysis. The two datasets are assembled to perform the analysis. The structure of the data is explained in a Data Management Plan (DMP) (Appendix II). The two datasets will be analysed with the programs Microsoft Excel, TIBCO Spotfire and SPSS.

The collection of the D-1 demand data and the D0 data is explained in 5.1. The D-1 data contains the date of the flight, D-1 date, traffic volume (which will be called during this research airspace segment), flight identification, call sign, aircraft type, departure and destination

airport, entry and exit time in the airspace segment and delay time. The D0 data contains the same information as the D-1 data, additionally, the entry and exit flight level in the sector, the duration to cross the airspace segment and the length to cross the airspace segment.

The sample size of the experts to obtain a vision of the usability of the D-1 prediction is three. This sample size is chosen because, with three people, there is always a decisive opinion, while with two it may be that there are two contradictory opinions.

By collecting information with interviews, some ethical considerations are maintained. These are in Appendix III.

### 2.3 Phase 1: Desk research



Figure 3. Activities phase 1

Five activities will be performed in the first phase. Information is collected of the different planning phases at Eurocontrol, a benchmark is achieved at other ANSPs, information about the planning at LVNL is researched and statistical methods for validating a prediction are collected with literature. Finally, stakeholder analysis will be executed with the information collected with the literature (Figure 3).

Information will be collected about the different Air Traffic Flow Capacity Management (ATFCM) phases at Eurocontrol. Operation manuals are used for this literature.

Documents of other ANSPs will be used for a benchmark to obtain more information about the pre-tactical and tactical phase, primarily focused on D-1 planning. ANSPs that will be used are Skyguide (2017) of Switzerland and the National Air Traffic Services (NATS) (2017) of the United Kingdom because they have D-1 planning. The D-1 project team has visited and interviewed them in 2017, which is valuable as literature.

The pre-tactical and tactical phase at LVNL will be researched with internal documents of the LVNL. These are the Project Plan of the D-1 project, the Business Case of the D-1 project, the preliminary investigation to Capacity Management and more.

Literature about different methods of data analysing, focusing on validating and the reliability of a prediction and what conclusions there are possible to make about the accuracy and reliability are necessary to perform the data analysis. Researches will be obtained via ResearchGate, ProQuest and Elsevier.

Not all the stakeholders are directly involved within this research, some of them encounter impact in a later stadium. A stakeholder analysis will be done to understand the roles, impact and interest of the stakeholders within this research.

### 2.4 Phase 2: Exploratory research to D-1

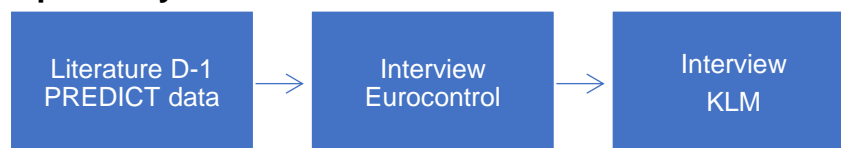


Figure 4. Activities phase 2

The second phase contains three activities: finding literature about the construction of the PREDICT data, interview Eurocontrol and an interview to gather information about the D-1 planning made by KLM (Figure 4).

The construction of the PREDICT data will be researched to notice if there are particularities in the creation of the data. To obtain this information, more literature must be obtained by Eurocontrol itself to obtain more information than found with the desk research. For more explanation, an interview will be held with a person of the department that analyse or construct the PREDICT data at Eurocontrol. This interview will be semi-structured, with some pre-determined questions which will be determined after the literature is obtained.

External knowledge will be retrieved at KLM about managing a prediction. KLM develops a prediction as well, so they might have ideas which LVNL can use. Pre-determined questions are made but these are not strict. The interview that will be held is semi-structured and are focused on the planning made a day before the operation for the day of operation. The pre-determined questions are in Appendix VIII.

## 2.5 Phase 3: Data analysis of D-1 demand prediction

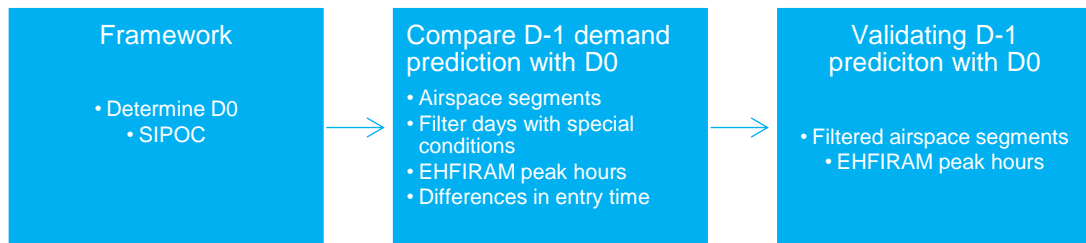


Figure 5. Activities phase 3

The three main activities of phase 3 (Figure 5) are: realizing a framework for the start of the analysis (see section 2.5.1), comparing the D-1 demand prediction with the D0 demand (see section 2.5.2) and validating the D-1 prediction with D0 with some statistics (see section 2.5.3).

### 2.5.1 Framework

First, it is necessary to understand what dataset will be used as 'D0'. In general, this is the day of operation, but there are different moments where data can be retrieved at the day of operation. At which moment this data will be retrieved must be determined.

To understand the input and output variables of D-1 and D0, a SIPOC chart will be made. The benefit of a SIPOC is to understand a process and to think about what needs to be measured in the process, to gather knowledge of the possibilities to improve (Morgan & Brenig-Jones, 2009).

SIPOC means (Morgan & Brenig-Jones, 2009):

- Suppliers: the people, department or organisation that provide the input for the process.
- Inputs: information, materials, resources, systems, data or people required to execute the process.
- Process: a set of activities that transform a set of input into outputs, providing value to the stakeholders or customers.
- Outputs: the product or services that result from the process, which can be new input for the next process.
- Customers: internal or external recipients that receive outputs of the process.

### 2.5.2 Comparison of the D-1 demand prediction with D0 demand

The datasets of the D-1 demand prediction and the D0 demand will be set next to each other, to compare what they have in common and the differences in the demand and entry time. All the D-1 data of the trial that started in January 2019 will be used, with the corresponding days of the D0 data. The period that will be used is January 2019 until the end of March 2019.

The number of entries in the corresponding airspace segment must be calculated to be able to compare the datasets. This is performed by counting the number of entries that have an entry time in brackets of one hour. The number of entries is counted per hour rolling per 20 minutes. For example: when an aircraft has an entry time of 01:21:23, this aircraft is counted between 00:40:00 and 01:40:00, between 01:00:00 and 02:00:00 and between 01:20:00 and 02:20:20 (Figure 6).

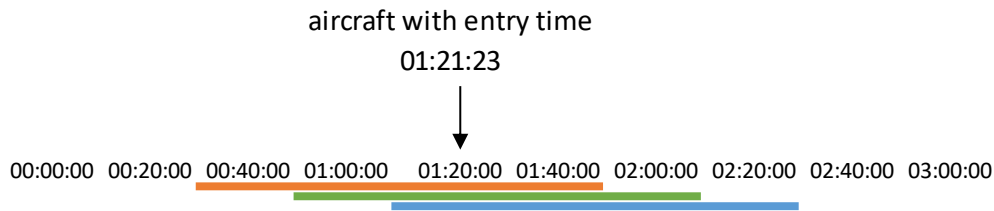


Figure 6. Example counting number of entries

This is executed to obtain more insight into the distribution of the aircraft in an hour. The reason that it is rolling per 20 minutes is that the slots are issued per 20 minutes and this is used often within LVNL. For more detail, the number of entries will also be counted per 20 minutes, which means there are brackets of 20 minutes and every aircraft is only counted once in every bracket.

To count the number of entries arriving and departing on the runway, the entry time on the runway must be calculated. This is not presented in the dataset; therefore, it must be calculated with an offset. The offset is the time it takes from an entry point to the runway or vice versa and is depending on which sector the aircraft comes from or goes to. For the EHAM Arrival (arrivals on the runway) the entry time in the EHFIRAM is used plus the offset time that corresponds with the sector flown through. For EHAM Departure (departures on the runway) the off blocks time in the sector plus the offset time that corresponds with the sector is used. The offset time is depending on the runway used. This is simplified as north or south runway use. The number of entries for both north and south runway use will be calculated. The number of entries will be calculated in the same way for the D-1 data as for the D0 data.

The difference between the number of entries of D-1 and D0 will be calculated with Equation 1.

Equation 1

$$Difference = (number\ of\ entries\ D - 1) - (number\ of\ entries\ D0)$$

When the difference becomes negative, there is more demand at D0 than predicted and when the differences become positive, there is more demand predicted than at D0.

When this difference is visualised in graphs and outlying days appear, these will be filtered if there is a reason for the considerable deviations, which are mentioned in the D-1 plans. Reasons for these deviations will be special conditions such as weather conditions and special events such as a strike.

Another analysis will be performed to the inbound peak hours. These are the most limiting and important moments of the day, which is of importance that it is well predicted. The flights in the EHFIRAM are all the inbound flights to Schiphol in the Netherlands, which is the

airspace segment that the air traffic controllers mostly observe for implementing regulations. The stacks are of great importance, but these are included in the EHFIRAM.

Another analysis will be performed by analysing the differences in entry times. There will be researched what the height of the deviations are in the entry times. When there are deviations in the entry times, there will be researched what happened to those flights. It might be that a flight is visible in the D-1 prediction, this flight disappeared in the D0 data or vice versa. But it is also possible that a flight is still visible but moved to another airspace segment.

### 2.5.3 Validating the D-1 demand prediction

The output of the comparison will be some commonalities and differences between the D-1 demand prediction and the D0 demand. The height of these differences and the accuracy of the D-1 prediction will be validated with statistical analysis. This statistical analysis will be performed for all the airspace segments, but also for the peak hours of EHFIRAM.

The difference calculated will be visualised in a distribution. The average, standard deviation and 95% interval will be calculated.

Predictions are validated in multiple ways. Different methods are found by performing a literature review (3.4). The most suitable method for this prediction is the Mean Forecast Error (MFE). This is the mean of the deviation of the forecast demands for the actual demand. This will be calculated with Equation 2.

Equation 2

$$MFE = \frac{((\text{the sum of the demand at D0}) - (\text{the sum of the demand at D - 1}))}{\text{the total number of values}}$$

A negative MFE means that there are less flights at D0 than predicted and a positive MFE means that there are more flights at D0 than predicted. The other methods mentioned in the literature do not provide extra value to this research or are not suitable for this research.

The demand of D-1 and D0 will be visualised in a distribution as well. If it is a normal distribution, a t-test will be performed. If it is a skewed distribution, a non-parametric test will be performed. This will be the Related-Samples Wilcoxon Signed Rank test which compares the D-1 demand data with the D0 demand data. The result will be a p-value. The hypothesis that is made is that the median of differences between the D-1 data and D0 data equals zero. The p-value will be the chance that random sampling (D-1 prediction) would result in a median change as far from zero as observed (D0). If the p-value is small there is concluded that the population has different medians. If the p-value is large, there is no reason to conclude that the overall medians differ (GraphPad Software, 2017).

The fact that the variables of the prediction have a p-value lower than 10 percent, does not provide the total quality of the prediction. The coefficient of determination or R-square provides a better indication of the quality of the prediction. This provides a percentage of how much of the D0 data is explained by the prediction (Twisk, 2007). A scatterplot with the number of entries of D-1 and D0 with a line through the origin visualises the distribution of the values, where the R-square indicates a percentage that fit to that line.

The validation of the D-1 prediction will be executed for all the airspace segments, as well as for the detailed analysis of the peak hours of EHFIRAM.

## 2.6 Phase 4: Vision of experts

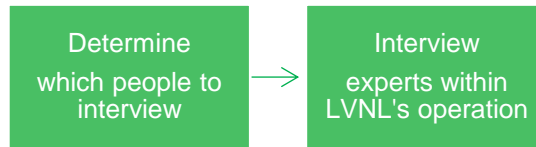


Figure 7. Activities phase 4

The activities of phase 4 are: determine which people in the operation are representative to interview and the accomplishment of these interviews (Figure 7).

The interviews will be semi-structured, where predetermined general questions are formulated, focused on the results of the data analysis. Semi-structured interviews provide the possibility to ask new questions regarding the answers given. Some results obtained with the data analysis will be presented to learn the vision of experts on the reliability of the prediction. The topics of the interview questions are:

- general about their function and activities;
- their influence within the D-1 project;
- their opinion about some results of the data analysis;
- when they think a prediction is usable/reliable enough for the operation.

The interview questions are in Appendix III.

### 3. Desk research

This literature review provides more clarification to understand what is behind the sub-questions. First, the planning phases in general, which are the Eurocontrol planning phases, are explained (see section 3.1) to understand in which phases the D-1 and D0 take place. A benchmark at other ANSPs (see section 3.2) is necessary to get more insight in D-1 planning, that might improve LVNL's D-1 planning. The phases where the D-1 data and D0 data is created in the LVNL planning are explained and at which moments and with what tools there is a collaboration with Eurocontrol (see section 3.3). Finally, to know how a prediction is possible to be validated and to know when it is reliable enough (see section 3.4), accuracy methods of other researches are analysed. In what way the information found with the literature is used during this research is explained (see section 3.5). With the knowledge of the literature review, a stakeholder analysis (see section 3.6) is made.

#### 3.1 Air Traffic Flow Capacity Management (ATFCM) at Eurocontrol

The Network Manager Operations Centre (NMOC) provides ATFCM service to the airspace users for the European Civil Aviation Conference (ECAC) states. The NMOC is the successor of the Central Flow Management Unit (CFMU). ATFCM aims to meet traffic demand with airspace and aerodrome capacity and to make the demand meet the maximum available capacity. This result in flow measures that includes individual aircraft departure times to reduce bottlenecks and safety risks as much as possible. These activities are in combination with all the European ANSPs and aircraft operators (Niarchakou & Simón Selva, 2017).

There are four ATFCM (planning) phases for the day of operation. These are the strategic phase (see section 3.1.1), which takes place twelve months till seven days before the operation, the pre-tactical phase (see section 3.1.2), which is six days till one day before the operation, the tactical phase (see section 3.1.3), which is the day of operation, and the post-operational phase (see section 3.1.4), which is the day after the operation. This research into the D-1 prediction takes place on the last day of the pre-tactical planning and the tactical phase, so these are explained in more detail. At last, the systems used by Eurocontrol within these phases (3.1.5) are explained.

Within the planning phases, the Collaborative Decision Making (CDM) process is used, which allows decisions to be taken by the most comprehensive, accurate information ensuring that all stakeholders can influence the decisions. This facilitates collaboratively agreed decisions to reach performance objectives a dynamically optimised flights to reflect near of real-time events. The structure of this process is designed to ensure that the stakeholders can discuss airspace, capacity, demand and flight efficiency issues on a regular basis. When plans are formulated, all pertinent aspects and points of view of the stakeholders are considered (Niarchakou & Simón Selva, 2017).

##### 3.1.1 Strategic phase

During the strategic phase, the NMOC supports the ANSPs to predict the capacity. The strategic phase includes research, planning and coordination activities that run according to a CDM process. Data is collected for early identification of major demand or capacity imbalances such as major events as well as capacity shortfalls for individual ACCs or airports. The results are ATFCM measures, which contain solutions to be considered for implementation (Niarchakou & Simón Selva, 2017). The Network Manager (NM) is responsible for the coordination and execution of the planning, as well as a routing scheme which includes these events such as large-scale military exercises and sporting events (Eurocontrol, 2017).

##### 3.1.2 Pre-tactical phase

In the pre-tactical planning phase, the demand for the day of operations is compared with the predicted available capacity on the day of operation. The necessary adjustments are made with the plan that was made in the strategic phase, the long-term planning. The goal of this

planning phase is to optimise the efficiency and balance the demand and capacity through resources such as sector configuration management, which means dividing or merging airspace sectors and the use of military sectors, adjustments to the 4D trajectories (considering weather and aircraft performance), and by the implementation of appropriate ATFCM measures. These ATFCM measures are extracted from pre-agreed strategic ATFCM measures or envisaged as ad-hoc measures to respond to a new situation. The work methodology is based on the CDM process between the stakeholders and occurs daily with a daily D-1 briefing e-conferences. This meeting can be more frequently depending on the traffic and capacity situation. The output of these conferences is the ATFCM Daily Plan (ADP) (Niarchakou & Simón Selva, 2017). The NMOC coordinates the definition of this ADP, together with the initial network plan and informs the ANSPs and aircraft operations about the ATFCM measures that will be active in European airspace on the next day (Eurocontrol, 2017).

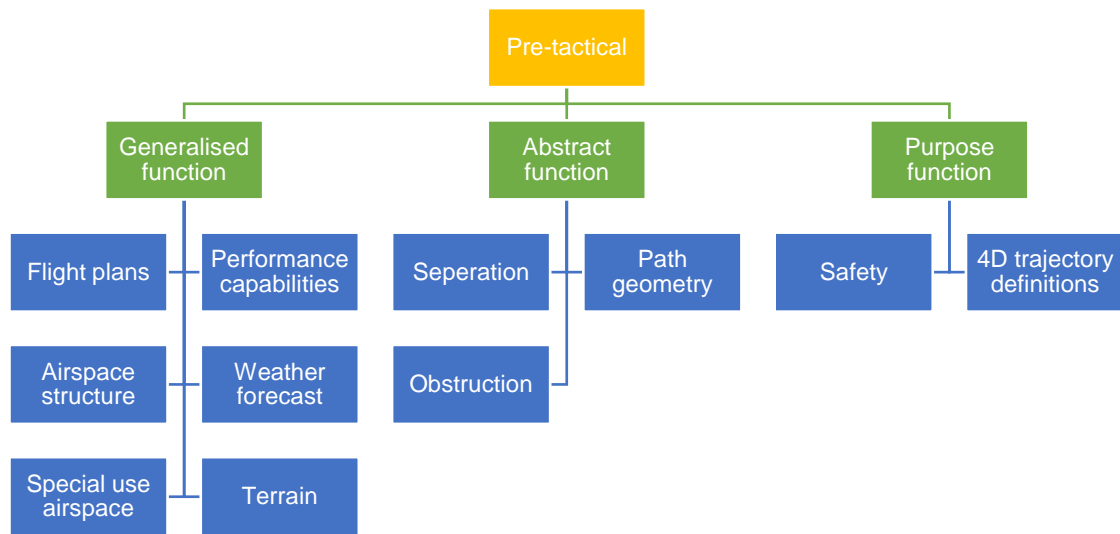


Figure 8. Pre-tactical work domain (van Paasen, et al., 2013)

The work domain analysis is visualised with three divisions, with the corresponding subjects that are considered in the pre-tactical phase (Figure 8). The generalised function are all the subjects that are necessary to consider for the pre-tactical planning. All the information of the subjects in the generalised function will lead to the need of the separation, possible obstruction by terrain, weather, etcetera and geometric constraints of the flight path which are part of the abstract function. The abstract function considers the main subjects within the airspace that is possible to determine in the pre-tactical phase. These abstract functions will finally lead to refined definitions for the 4D trajectories, which is the result of the activities in the pre-tactical planning and is considered as the purpose of the pre-tactical planning, together with safety (van Paasen, et al., 2013).

### 3.1.3 Tactical phase

The tactical planning phase considers the events that affect the ADP and makes the necessary modifications to it. The NMOC updates the ADP based on the current meteorological, technical and human conditions for the operation through further CDM processes. Tactical briefings or conferences are planned to depend on the traffic patterns and their intensity (Eurocontrol, 2017). This phase ensures that the measures taken during the earlier planning phases are the minimum required to solve the demand and capacity imbalances. Adjustments taken in the original plan may result from disturbances such as significant weather phenomena, special events, staffing problems, limitations related to ground or airspace infrastructure. Accurate information is of importance in the phase since it permits short-term forecast which includes the impact of any event and maximises the existing capacity without endangering the safety (Niarchakou & Simón Selva, 2017).

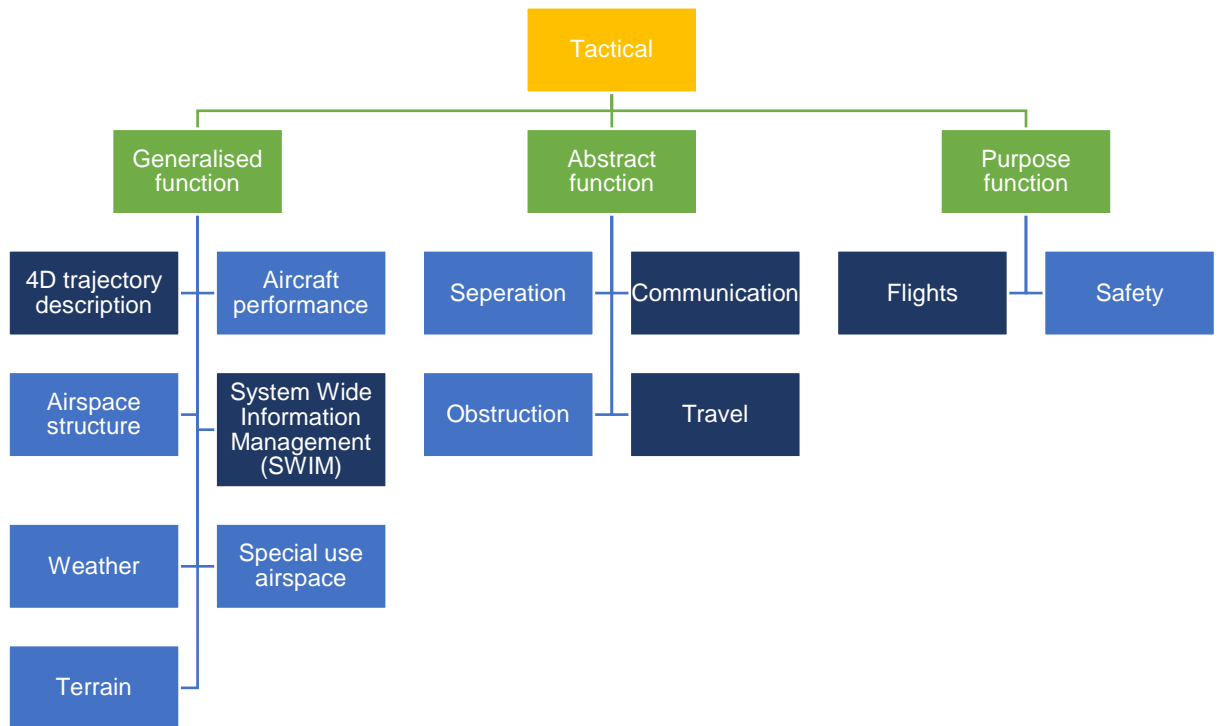


Figure 9. Tactical work domain (van Paasen, et al., 2013)

The work domain analysis is visualised with the same functions as in the pre-tactical planning, with the corresponding subjects that are considered during the tactical planning phase (Figure 9). The subjects mentioned in the pre-tactical planning which are still present in the tactical phase, only updated with more recent information, are marked light blue. The dark blue subjects are new in the tactical phase. The inputs of the generalised function are the planned 4D trajectory descriptions which were the result of the pre-tactical phase. Together with updated weather conditions, airspace and special airspace use, aircraft performance, terrain and SWIM (which is a net-centric and secure environment, based on a globally consistent and unambiguous set of information elements to overcome the existing deficiencies and achieve a 4D trajectory-based globally interoperable ATM system (SKYbrary, 2017)), new communication and travel restrictions are defined, together with updated need of separation and obstruction items. These abstract functions will lead to the results of the tactical phase, which are the actual flights or the operation. Together with safety becomes this the purpose function. The previous ATFCM phases mainly involved planning flights (first globally, resulting in the travel space structure, then in more detail), but in this phase, real-time communication becomes an important function (van Paasen, et al., 2013).

### 3.1.4 Post-operational phase

The post-operational phase is the final phase in the ATFCM process. An analysis is carried out to measure, investigate and report on operational processes and activities throughout all domains and stakeholders (Eurocontrol, 2017). All the stakeholders should provide feedback on the ADP, flight planning and airspace issues. This phase compares the predicted with the actual outcome, in terms of delay and route extension. The goal of this phase is the development of best practices and improving the operational processes and activities (Niarchakou & Simón Selva, 2017).

### 3.1.5 Eurocontrol systems

To provide information about current and predicted air traffic demand and capacity, flow and capacity management systems are used. These systems receive data of the Integrated Initial Flight Plan Processing System (IFPS), Repetitive Flight Plan (RPL), the Central Airspace and

Capacity Database system (CACD), live ATC data of the ANSPs, Aircraft operator Position Reports (APRs) message and meteorological data (Niarchakou & Simón Selva, 2017). The data of the ANSPs, which is provided by the FMPCs, is information without a standard format and can be diverse. It are concrete capacity adjustments, demand adjustments or small events that expect regulations at the day of operation. The usability of the information depends on the amount of information that is received, but this information always supports to provide a better reflection of the day of operation. The output of this information is the ADP and sometimes a recommendation for the ANSPs on behalf of airspace management (NM Eurocontrol, 2017). All the information is archived by the flow and capacity management systems in the historical information management system, the Data Warehouse (DWH).

The most important flow and capacity management systems or tools used during the ATFCM phases are:

- The Enhanced Tactical Flow Management System (ETFMS), which compares traffic demand, regulated demand a load towards capacity, to assess possible imbalances in the European airspace. The imbalances can be resolved by the implementation of measures, such as regulations or rerouting (Eurocontrol, 2019).
- The PREDICT system, this compares forecasted traffic and capacity to evaluate the load situation for the following days. To assess the impact of the ATFCM measures, these are implemented in the systems before being applied in ETFMS. It uses the Demand Data Repository (DDR) to enrich historical data with expected demand (NM Eurocontrol, 2017).
- The Data Distribution System (DDS), is used to distribute real-time ETFMS flight data to NM operational stakeholders, which are the ANSPs, aircraft operators and airports. DDS functionality is provided by the ETFMS (Eurocontrol, 2019).
- The Network Operations Portal (NOP), is a website that provides operational information and dynamic data of the NM. The goal is to facilitate decision making by sharing the most up to date view of the network operations situations along the ATFCM cycle (plans, scenarios, real-time information on flights and measure, events, etcetera). NOP is as well used to reflect the ATFCM decision status, enable a common understanding of the network situation, present disturbances that could impact the Network and that could, therefore, require appropriate actions for risk mitigation, assist airspace users to take their operational decisions and assist in the planning process (Eurocontrol, 2018).
- The Network and Strategy Tool (NEST), is a simulation and modelling tool for network capacity planning and airspace design. This tool is used by the NM of Eurocontrol and the ANSPs. NEST uses datasets of DDR to describe the consolidated pan-European airspace and route network, the traffic demand and distribution as well as the Statistics and Forecasts (STRATFOR) traffic forecasts which are provided by Eurocontrol at the end of each Aeronautical Information Regulation and Control (AIRAC) cycle (Eurocontrol, 2019).

## 3.2 Benchmark D-1 planning at other ANSPs

This benchmark is to learn more about the D-1 planning of other ANSPs. Only ANSPs that do have a kind of D-1 planning that provides input for LVNL is of relevance for LVNL. It appeared that NATS (see section 3.2.1) and Skyguide (see section 3.2.2) do have a D-1 planning (Westerveld, Lieshout, Obbens, Devilee, & Delden, 2017). LVNL visited Skyguide and NATS for information about their D-1 planning in 2017.

### 3.2.1 NATS

Ten years ago, NATS' focus was only on the D-1 planning process, but nowadays the scope is elaborated to longer ahead concerning Airspace Capacity Management (ACM). NATS wants to be transparent to their stakeholders, and the collaboration is established in "partnership agreements", which supports to attain a better capacity management process (Barry, Turner, Borland, & Howard-Allan, 2017).

NATS does have a D-1 process, which is a pre-tactical plan of D-5 till D-1. This is an iterative planning process which includes all stakeholders. This plan is continuously refining prior to

the day of operation. It incorporates airspace management through Flexible Use of Airspace, resources, meteorological information. The plan is published to airline operators and stakeholders (NATS, 2017). Currently, the result of the D-1 preparation is also summarized in a reduced UK/Irish Functional Airspace Block (FAB) D-1 report which is spread every day at 16.00LT to external stakeholders, so they can prepare for the operations. The effectivity variates because the weather and other factors are not updated after 10.00LT (Barry, Turner, Borland, & Howard-Allan, 2017). An example of the pre-tactical D-1 plan of NATS is in Appendix VI. The plan identifies:

- Meteorological outlook;
- Predicted North Atlantic (NAT) track structure;
- Detailed Eastbound NAT track structure;
- (Airport) capacity constraints;
- Danger area activity/airspace utilisation;
- Additional activities that may have an impact on network performance;
- A detailed overview of military activity notified at D-1;
- Pre-tactical regulations;
- Heathrow operational overview;
- General information pertinent to UK – Irish departures, arrivals and en-route traffic;
- Pre-tactical 7-day outlook (NATS, 2017).

### 3.2.2 Skyguide

Skyguide’s importance is to use the airspace as efficiently as possible because they have a high volume of traffic that crosses their airspace (Herda & Mariétan, 2017).

Skyguide has activities that prepare the day of operation. In the pre-tactical phase, they have AUP, scenario analysis and coordination, Short Term ATFCM Measures (STAM) preparation, simulation of traffic demand. Skyguide’s focus is not on D-1 preparation, but on tools used in the long term pre-tactical phase. They developed the tool Crystal, which is the instrument that manages the capacity on the day of operation and before. The objective of Crystal is to improve local traffic situation awareness, choose the best sectorisation, increase capacity, provide reliable complexity indicator, reduce risks of saturation and reduce user’s workload (Herda & Mariétan, 2017). Crystal is used for accurate traffic prediction and to manage the staff’s workload and peaks while ensuring a smooth and efficient traffic flow (skyguide solutions, 2016). Skyguide has long-term planning that is updated every month, instead of every season.

The process to make the roster is made with the traffic forecast and tools (Figure 10). Capacity management and rostering are related to each other.

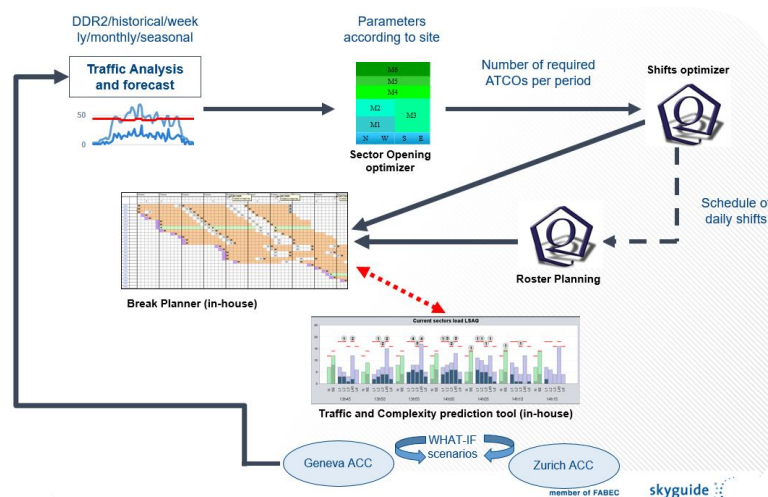


Figure 10. The rostering process at Skyguide (Herda & Mariétan, 2017)

### 3.3 Planning at LVNL

Within LVNL the same planning phases are considered as at Eurocontrol. The activities LVNL performs will be explained for the pre-tactical phase (see section 3.3.1) and for the tactical phase and partly the post-operational phase (see section 3.3.2).

#### 3.3.1 Pre-tactical phase

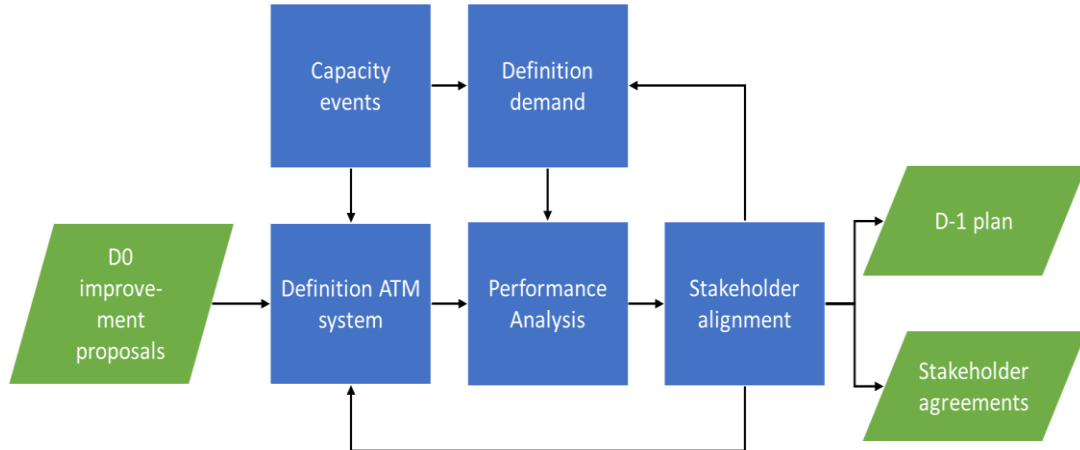


Figure 11. Short term pre-tactical planning, translated by the author (Westerveld, Lieshout, Obbens, Devilee, & Delden, 2017)

The D-1 plan arises of the short term pre-tactical planning (Figure 11), which is seven till one day before the day of operation. In Figure 11 (and Figure 12), the green boxes are information and are the input and the output of the process, while the blue boxes are activities. The black arrows present the order of the activities. The input of the process are improvement proposals for the day of operation. These are defined in the strategic and long term pre-tactical phase. Together with this information and the events that reduce the capacity, the ATM system capacity is defined. The capacity events and the stakeholders define the demand possible with predictions, schedules of airlines and information of the NM. A combination of the possible demand and the capacity provides the performance analysis, which should result in alignment between the stakeholders. If this is not succeeded, the process is done over, so a new definition of the demand and the ATM system should be made. The output will be the D-1 plan and stakeholder agreements. The D-1 plan is the input for the tactical phase. The activities in this phase are performed by the overhead, FMPC and for the performance analysis also a performance expert is concerned.

### 3.3.2 Tactical and post-operational phase

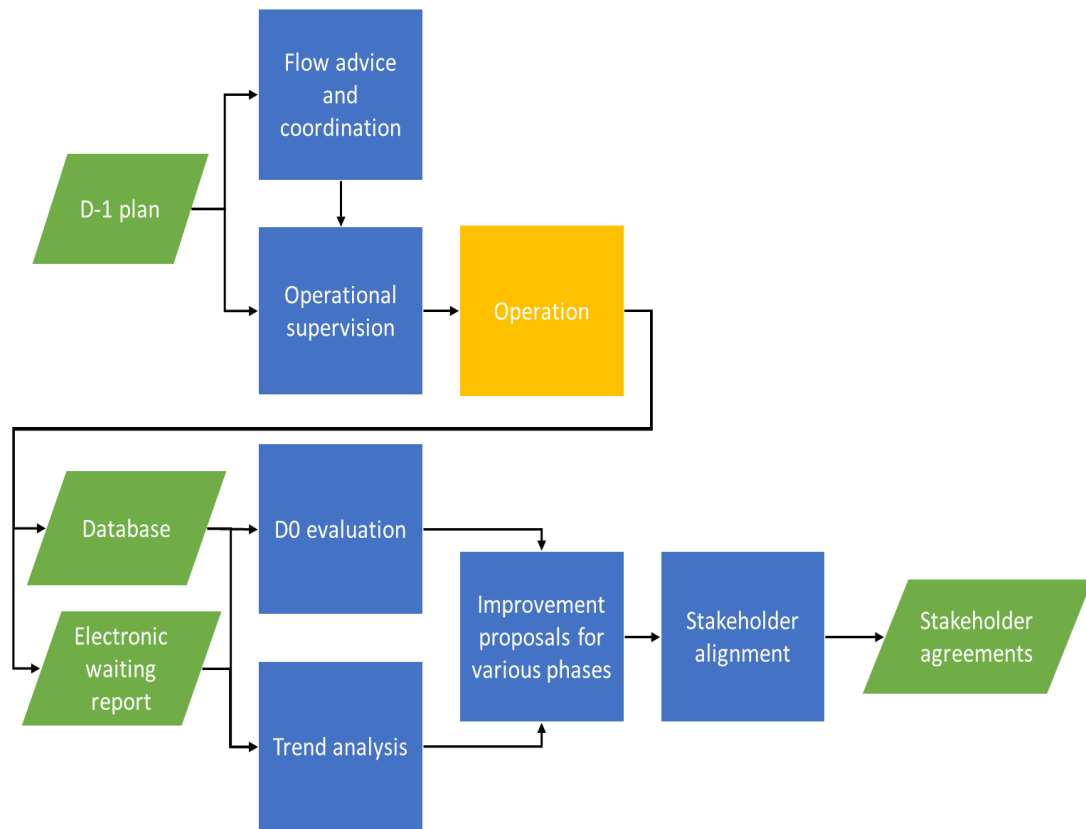


Figure 12. Tactical and post-operational process, translated by the author (Westerveld, Lieshout, Obbens, Devilee, & Delden, 2017)

The tactical phase (Figure 12) starts with the D-1 plan, which is the input for providing information and advice about flow measures and alignment with ANSPs and NM to the supervisor. These together are input for operation supervision carried out by the supervisor, containing decisions based on the advice of FMPC to ensure orderly operation and determine staff deployment. The Collaboration Interface for Flow Management Positions (CIFLO) is the system that the FMPC uses to perceive the traffic demand, to monitor the capacity. This system provides access to all the ATFCM information in the ETFMS, the PREDICT and the archive system data warehouse. The ATFCM information contains flight plan information, combined with environmental data and meteorological information, which are possible to plot on a map. The information that is visible in CIFLO can as well be seen on the NOP, but CIFLO also includes the workload that is visualised with the workload model (WLM) (LVNL, 2012). The WLM is an additional information source for capacity and sector management, which provides a prediction of the required effort of an air traffic controller. The WLM supports to interpret and nuance the demand figures of CIFLO. These are updated figures of the demand and workload of the different sectors, that were in the D-1 plan. The calculated workload is based on nominal circumstances and is a dimensionless number. A flight is integrated into the workload calculation when the flight enters a sector (LVNL, 2012). Together with these systems, the FMPC and the supervisor take care of safe operation. The output of the operation is an electronic waiting report and all the information of the operation is saved in a database. These two outputs are the inputs for the post-operational phase. This information is the source to perform an evaluation of the day of operation and to achieve trend analysis. The results will be improvements for the preparation of the operation. These improvements are discussed with the stakeholders to finally obtain some agreements.

### 3.4 Validating a prediction

To determine the validity and reliability of a prediction or forecast, the results of the forecast are necessary to evaluate. This can be done with different methods.

Sahu and Kumar (2014) discussed different forecasting models to obtain the most applicable one for sales forecasting of sterilized flavoured milk in Chhattisgarh. The accuracy of those forecasting models is measured with the Mean Forecast Error (MFE) (Equation 3), the Mean Absolute Deviation (MAD) (Equation 4), the Mean Square Error (MSE) (Equation 5) and the Root Mean Square Error (RMSE) (Equation 6). The smaller the forecast error is, the more accurate the forecast method. These accurate methods were used to finally define the most accurate forecast method. Finally, the most appropriate forecasting method with the best accuracy had an MFE of -1.6027, MAD of 40.976, MSE of 285162 and an RMSE of 534.005.

Equation 3

$$MFE = \frac{\sum_{t=1}^n (Y_t - F_t)}{n}$$

Equation 4

$$MAD = \frac{\sum_{t=1}^n |Y_t - F_t|}{n}$$

Equation 5

$$MSE = \frac{\sum_{t=1}^n (Y_t - F_t)^2}{n}$$

Equation 6

$$RMSE = \sqrt{\frac{\sum_{t=1}^n (Y_t - F_t)^2}{n}}$$

$Y_t$  is the actual value in time period  $t$ ,  $F_t$  is the forecast value in time period  $t$  and  $n$  is the number of periods.

Abed and BaFail (2001) did research to suitable forecasting demand for air travel at Jeddah International Airport. After the analysis, comparison and cross-checking are performed to validate the forecasting demand model. The performance measures that are used to compare the models with each other to select the best ones are the MAD, Mean Absolute Percentage Error (MAPE), the RMSE and R-square.

Olaniyi, Adedotun and Samuel (2018) did a study to the domestic air passenger demand in the period of 2010 till 2017. Two different forecasting methods were used, and these are compared with the Mean Squared Deviations (MSD), which formula appeared to be the same as the MSE. The study is useful for the planning process an airport, airlines and other stakeholders involved in Nigeria's air transportation. It supports to prevent problems with having the air traffic supply over the demand or vice versa.

BaFail (2004) did a forecast for the number of domestic and international airline passengers in Saudi Arabia. This forecast is then compared to the actual and the forecast error is measured with the MAPE.

### 3.5 Conclusion of the literature

By researching the planning phases of Eurocontrol and the tools used within these phases, the background of the source of the D-1 and D0 data is obtained. Detailed information about the construction of the D-1 prediction data at Eurocontrol is not obtained, therefore, further field research is necessary (see section 4.1). The benchmark at Skyguide and NATS supports LVNL with possible improvements for their D-1 planning. The information of the benchmark is general about a D-1 planning, while more about their traffic forecast would be more useful for improvements to the D-1 prediction data of LVNL. However, this information at NATS and Skyguide is not available in the literature. More knowledge about a D-1 planning at an airline (see section 4.2) might be valuable for the LVNL in their D-1 project. With the insight into the Eurocontrol's and LVNL's planning, a framework for the data analysis is made (see section 5.1) to map in what moment the D-1 and D0 data are extracted. One of the validation methods mentioned will be used for validating the D-1 demand prediction (see section 5.3), which will be the MFE. The MAPE is the absolute difference between forecast and reality in a percentage, but this is unnecessary if the difference itself, together with the average and

standard deviation is calculated. The MAD is the absolute deviation around the median, which is the same as the data visualised in a boxplot, while this also provides a figure with the median and the deviation around it. The MSE and RMSE are suitable for the research but provide the same sort of idea as the MFE. The MFE is more often used for the validation of predictions, so there is chosen to use the MFE for the analysis.

### 3.6 Stakeholder analysis

LVNL and Eurocontrol are continuously involved during the research, LVNL as client and Eurocontrol as a provider of the data. Other ANSPs are involved by providing information for the literature and KLM as a provider of information for possible improvements, but KLM must also keep informed while they will finally use the prediction. AAS is within this research mainly provider of information about their infrastructure, while in the future (when the D-1 project is implemented) they might encounter more influence. The different roles of these stakeholders are clarified with different colours in Figure 13. Red indicates directly involved in this research, green indicates their information provides added value for this research and yellow indicates they might encounter impact but are not directly involved in this research. Still, the information they provide is of importance for this project.

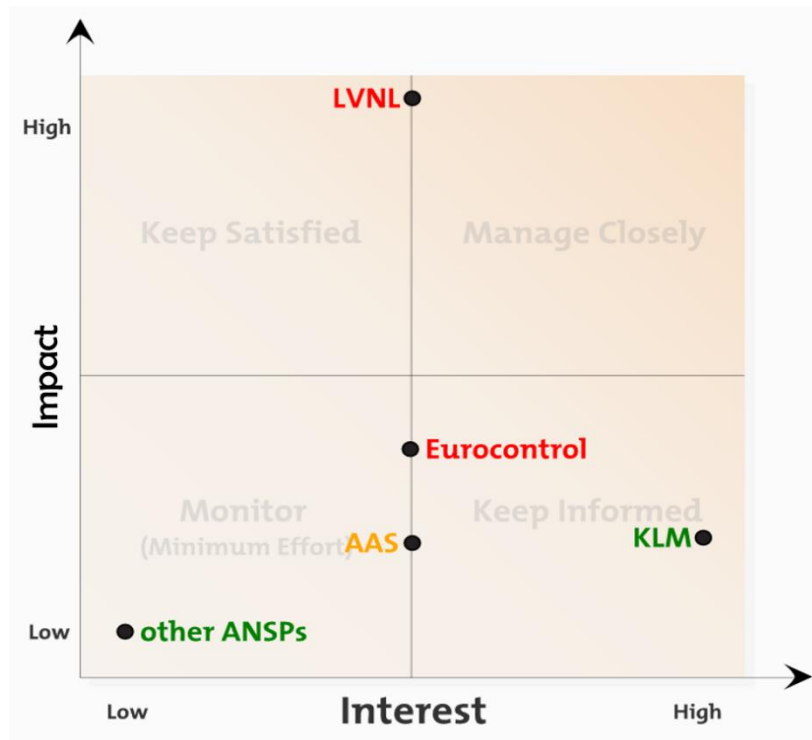


Figure 13. Stakeholder analysis, template retrieved of (Thompson, n.d.)

#### 4. Exploratory research to D-1

Extra research is necessary for the construction of the D-1 data, called within Eurocontrol PREDICT data (see section 4.1), which is used as D-1 demand prediction data for LVNL. Results of the data analysis are understood better if there is awareness of the construction of the data. Additional information about a D-1 planning made at KLM might result in ideas for improvements for LVNL (see section 4.2). KLM is chosen while this is the home carrier at Schiphol and KLM is a stakeholder within the KDC.

##### 4.1 Construction of the D-1 prediction data

The literature acquired of Eurocontrol is an addition to the information explained in the literature review. The presentation with additional information is directly received from Eurocontrol after explaining about this research.

The PREDICT data system was, before the DDR2 system was implemented, fed with only historical traffic demand data. This was the data of the previous week, same day in the week (D-7) if this was a nominal day, or another day in the past when specific conditions affected the previous week (often D-14). After implementing the DDR2 system, the PREDICT data is enriched with early flight intentions. DDR2 means the DDR phase 2, which takes place five years before the operation until one day before the operation. There is also a DDR phase 1, which takes place five years before the operation till six months before the operation and contains historical data with STRATFOR and route & airspace design, strategic evolutions (long term) and seasonal capacity planning. The DDR2 contains this as well, as well as support to route efficiently and a pre-tactical network plan with special events (Eurocontrol, 2017). A timeline of five years before the operation until the operation with the DDR1 and DDR2 included is in Figure 14.

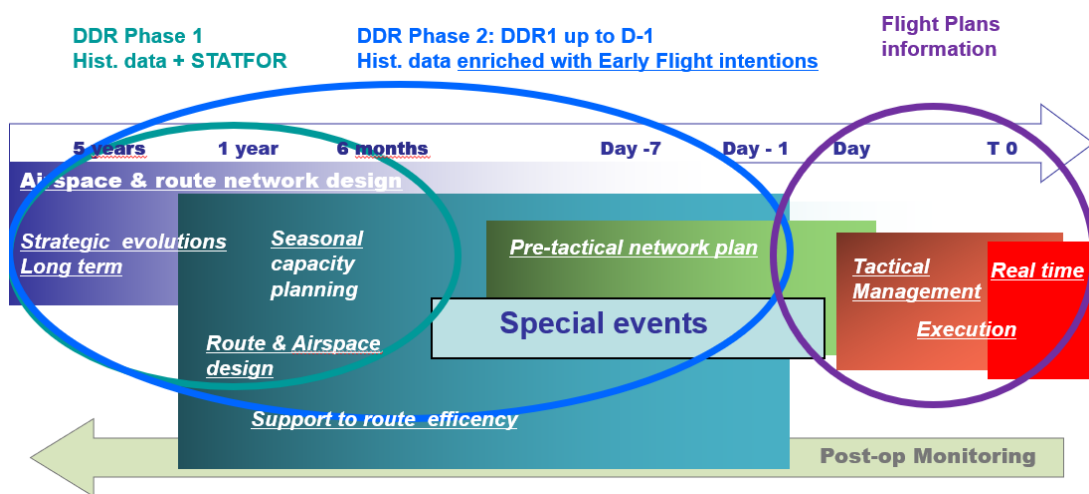


Figure 14. Timeline DDR data (Eurocontrol, 2017)

The DDR2 ensures enrichment, route assignment and North Atlantic (NAT) Traffic flow substitution for the PREDICT data (Eurocontrol, 2019).

Enrichment means that the historical traffic demand data is compared with DDR collected flight intentions to identify the flights operated in the past, which also should be operated in the future and are called 'confirmed flights'. Flight intentions which do not correlate with historical flight data are 'new flights' and past flights which do not correlate with flight intentions are 'deleted flights' (Eurocontrol, 2019).

Route assignment means that past flights which are confirmed by flight intention keep the route as specified in the historical flight plan, so this flight does not deviate too much from the historical route. New flight intentions are assigned to a 4D route with an algorithm, based on the sequential assignment order:

- historical route found in PREDICT between the same airports and operated by the same or another airline if this is not available;
- the route found in the NM route catalogue, if also absent in this;
- the route is generated by the NM pathfinder engine (Eurocontrol, 2019).

NAT flow substitution means that historical NAT flight data in PREDICT is substituted by data of other historical days considered as closer to future forecast, based on instructions received from NATS over the last three days before operation (Eurocontrol, 2019).

The previous steps result in the PREDICT data that is accessible by the ANSPs.

Additionally, an interview is performed to obtain a detailed explanation of the construction, contents and input of the PREDICT data. The questions based on the information mentioned before and the summary of the interview are in Appendix VII.

### **Results**

The information about the construction of the PREDICT data is derived from a presentation about PREDICT data (Eurocontrol, 2017) and an interview (Participant 1, 2019) which is summarized in Appendix VII.

The PREDICT data contains historical traffic demand data, which is enriched with DDR2 data. The historical traffic demand data is the demand of the same day a week before based on the last submitted flight plans of how the route was filed, including the runway use. If this day was disrupted, then another day in the past is used, even though the accuracy becomes less. The enrichment is based on flight intentions. These flight intentions are determined with any information of an airline that intends a future flight. This is based on scheduled data, which is updated every week, airport slot data, which is updated daily and a snapshot of the night before with the last received data (for example already submitted flight plans with Expected Off- or In- Block Time (EOBT/EIBT)). These flight intentions cause confirmed flights or new flights. For confirmed flights, the route is used as specified in the historical flight plan and for new flights, a 4D route is assigned with an algorithm. There are also unconfirmed flights if there is no flight intention, but in historical data, there was a particular flight.

If there are special events which result in a reduction in the demand, this is only considered if this special event results in a reduction of airport slots, while the airport slots are implemented in the PREDICT data. The forecast of the NAT tracks is provided by the NATS for the next three days. The other tracks in Europe are based on historical flight plans and the already submitted flight plans and consider only the wind speed. General aviation is considered in the PREDICT data if possible, with airport slot data because, frequently, there is no schedule data available of general aviation. For non-coordinated airports, historical data is used for the general aviation, but this is unreliable because of considerable variations. Unconfirmed general aviation flights are often removed.

The accuracy of the PREDICT data is researched by Eurocontrol, by comparing this with the reference data of the ETFMS which is based on Filed Technical Flight Model (FTFM) which includes flight plans and slots. This accuracy is compared with the accuracy of only the historical data (not enriched with DDR2). The accuracy of the PREDICT data is more stable during time than only the historical data (Graph 25 in Appendix VII). The accuracy is researched for every airport both departures and arrivals. The departures are more accurate because these are usually aligned with the Scheduled Off-Block Time (SOBT) of the slots (Graph 27 in Appendix VII). The accuracy of the arrivals is lower because the airlines try to have a buffer in the arrival time to ensure the aircraft arrives earlier or on time (Graph 26 in Appendix VII). The accuracy of the PREDICT data for the arrivals at Schiphol is around 93 percent, which means the deviation is around 7 percent for the sum of the hourly counts. The accuracy of the departures at Schiphol is around 97 percent for the sum of the hourly counts.

## 4.2 D-1 planning at KLM

To obtain information about the D-1 planning at KLM, an interview is conducted with a Duty Manager Operation (DMO) of KLM (Rigter, 2019). The DMO is chosen to interview because they are constantly involved in the operation and he determines the impact of the current conditions on the network and if delays or cancellations are necessary. The DMO uses the tool to predict the delays or cancellations with the inbound and outbound capacity. Therefore, the DMO is a suitable person to ask about D-1 planning at KLM.

### **Results**

Next to the information about the D-1 planning of KLM, also problems that KLM faces for creating a plan at D-1 and the relevance of the D-1 project are obtained with an interview (Rigter, 2019), summarized in Appendix VIII.

A flow coordinator of KLM obtains information about the capacity of that day around 09:30LT from the LVNL and an expected capacity of the next day is only received when asked. However, often the LVNL will not provide a capacity for the next day because the weather can still change. When no capacity is provided by the LVNL, the DMO determines together with other colleagues the capacity based on the Schiphol Probability Forecast or with the output of a sector briefing (if there was one). The output of a sector briefing is input for the scenario briefing which is made within KLM. This is a briefing presided by the DMO for the department in the OCC, to make everyone up to date with the same information and announcing the plan for the next day.

The DMO wants the capacity of the next day to make a plan, which includes if it is necessary to cancel or delay some flights. This capacity is imported in the runway tool, which is a tool used by the KLM to determine if it is necessary to delay or cancel flights. The inbound and outbound capacity per hour must be imported. If the capacity is reduced, this can be manually imported. It is possible to load a predicted capacity from AFOS (the AFOS tool will be explained in 5.1). This includes the weather forecast and runway use. The runway tool provides cancellation and delay proposals. If necessary, the tool presents which flight and at what hour these must be cancelled, or how many minutes the delay must be and for which flights. The tool considers KLM as well as Transavia, Air France, Delta and foreign airlines.

If delays are more than 70 minutes, cancellations are necessary. The cancellations will be proposed at the department crew and commerce including the number of flights and within what hours. The DMO can inform Transavia, Air France and Delta about the situation. Often when KLM cancels some flights, the other airlines can continue with their operation. KLM passengers can be transferred to their flights if those flights are not full. KLM prefers the delay not above one hour. If a delay of this magnitude arises, these delays continue throughout the day because there is a strict margin between one flight and the next flight with the same aircraft. Therefore, the problem arises at the end of the day. Intercontinental flights should stay on their schedule as much as possible, while passengers who arrive the next day should not be bothered by the weather of the current day. If there are disruptions at Schiphol, primarily the KLM network is disrupted.

Input for the demand in the runway tool is determined with the timetable of Schiphol. Cargo and general aviation are not included in this, while this are ad-hoc flights. Weather is only included in the capacity imported in the tool but is not considered in the algorithm that determines the necessary flights to cancel or delay. Within the algorithm the special events, the infrastructure of Schiphol, crew connections and working times, commercial information, fleet capacity, reserves and cost model are included. Slot information is not (yet) included in the algorithm.

The DMO wants more proactive steering for the next day and appreciates to receive earlier the expected capacity, preferably in the morning of D-1. This helps them to create a plan earlier and makes it possible to transfer intercontinental (ICA) flights. The current capacity forecast is only three till four hours ahead. The DMO of KLM experience that the provided

capacity of the LVNL is depending on the supervisor of LVNL. They do understand that this capacity might be depending on the team of air traffic controllers, even though this is known in advance. Currently, with the same weather there are different capacities presented by the LVNL. The DMO wants more consistency and hopes that with AFOS, when there is the same weather predicted, also the same capacity will be provided. The effect of a capacity reduction for an airline is challenging, especially when this was not known in advance and there was not yet anticipated to it.

KLM wants more consistency and information about the capacity, and it is up to the LVNL to provide this information. Wrong information is not possible, because the KLM understands that the circumstances are possible to change.

## 5. Data analysis of D-1 demand prediction

Data analysis of the contents and the accuracy of the D-1 demand prediction is necessary to perform. First, the framework for the analysis will be made (see section 5.1) to understand the moment where the data is made and the construction of the data. After this, a comparison between the D-1 demand prediction and the day of operation will be performed (see section 5.2) to find commonalities and differences between these datasets. The accuracy of the D-1 prediction will be validated with some statistics and experts (see section 5.3).

### 5.1 Framework for the analysis

The process starting from the day before the operation to the day after the operation is explained, including the steps necessary to obtain the D-1 and D0 data. For the data analysis, the D-1 prediction dataset will be compared to a dataset of D0, at what moment and by what method the D0 dataset should be constructed is determined. Figure 15 provides an overview of the process starting a day before until the day after the operation. It contains the activities that generate the datasets. The activities (in green) are explained more in detail with a SIPOC. The operation is excluded in the explanation because this is only a moment in time and not the focus of this research.

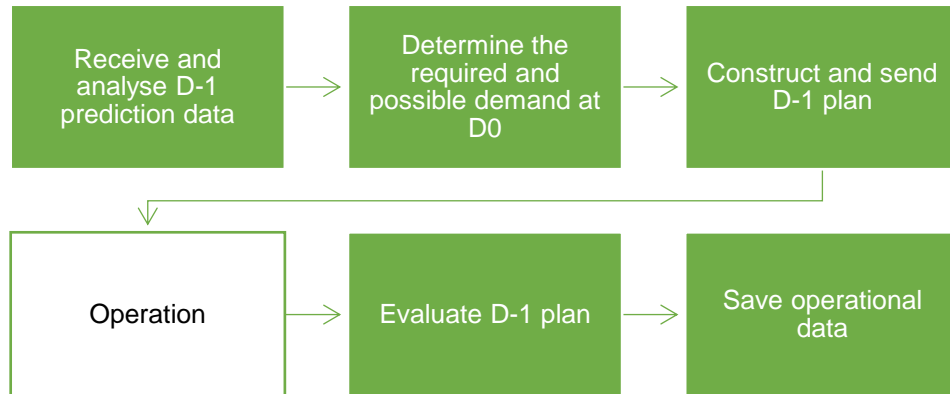


Figure 15. Process data collection

A timeline of the day before the operation and the day of operation, including the moments of retrieving the data and the activities of Figure 15 is visualised (Figure 16).

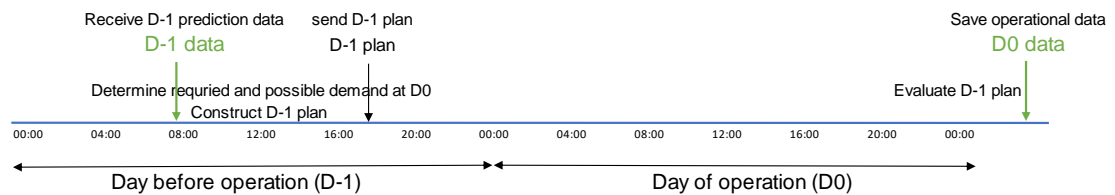


Figure 16. Timeline D-1 and D0 with process data collection

**Receive and analyse D-1 prediction data**

SIPOC D-1 and D0					
	Supplier(s)	Input	Process	Output	Customer(s)
Morning of D-1 (+8:00LT)	Eurocontrol	Historical flight data and DDR2	Receive and analyse D-1 prediction data	PREDICT dataset	LVNL: CMA department D-1 projectteam
	Airlines	Flight intentions			

Figure 17. SIPOC receive and analyse D-1 prediction data

Figure 17 presents the SIPOC of the first activity in the process. The input for the prediction data is historical flight data combined with DDR2 data of Eurocontrol, which includes flight intentions of the airlines. When all this data is received, this data is analysed and cleaned to obtain the PREDICT dataset made by the NM of Eurocontrol. This data is retrieved by the CMA department and the D-1 project team of LVNL with a simulation and modelling tool, for network capacity planning and airspace design and is called NEST.

**Determine the required and possible demand at D0**

SIPOC D-1 and D0					
	Supplier(s)	Input	Process	Output	Customer(s)
Morning of D-1(after 8:00LT)	LVNL: CMA department	PREDICT dataset	Determine the required and possible demand at D0	Demand figures	LVNL: D-1 projectteam
		LVNL tools			

Figure 18. SIPOC determine the required and possible demand at D0

Figure 18 presents the SIPOC of the second activity in the process. The CMA department receives the PREDICT dataset and uses some LVNL tools to clean the data and to determine the required and possible demand to generate the demand figures used in the D-1 plan. This is performed with Toad for Oracle and a tool built in Excel. The demand figures will be the guidelines for the figures for the comparison of D-1 data with D0 data. In these demand figures, the maximum possible capacity is provided and exceeding demand are marked.

**Construct and send D-1 plan**

SIPOC D-1 and D0					
	Supplier(s)	Input	Process	Output	Customer(s)
Afternoon of D-1	KNMI	Probability Forecast Schiphol	Construct and send D-1 plan	D-1 plan	LVNL: Air Traffic Controllers Supervisors FMPCs
	AAS	Infrastructure			
	LVNL: OPS department	Availability Air Traffic Controllers & special events			
	LVNL: D-1 projectteam	D-1 plan template			

Figure 19. SIPOC construct and send D-1 plan

Figure 19 presents the SIPOC of the third activity in the process. To determine a day before operation the weather forecast of the day of operation, the Probability Forecast Schiphol is used (an example in Appendix IV), which is provided by The Royal Dutch Meteorological Institute (KNMI). The AFOS tool combines the weather forecast of the KNMI (The Probability Forecast Schiphol), the demand prediction, NOTAMs and general information of Schiphol about the runways. This tool has an algorithm that determines the probability of the weather condition in combination with the runway use. This probability is input for the D-1 plan. The tool is originating from the KDC and To70. With all the information, the D-1 plan (example in Appendix V) is constructed and send to the operation. Some information of the D-1 plan is used within the analysis to explain deviations. The weather input will be considered to explain major deviations between the D-1 data and the D0 data. The inputs of the D-1 plan are visualised in Figure 20.

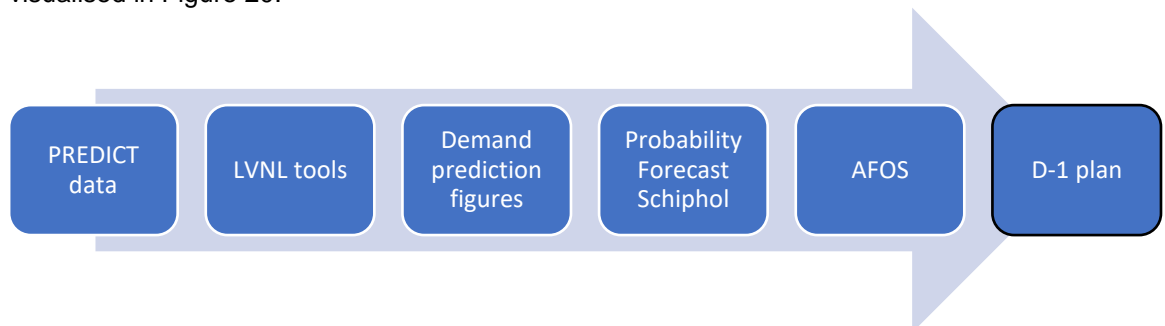


Figure 20. Inputs to obtain the D-1 plan

**Evaluate D-1 plan**

SIPOC D-1 and D0					
	Supplier(s)	Input	Process	Output	Customer(s)
End of D0	LVNL: Supervisors FMPCs	D-1 plan	Evaluate D-1 plan	Feedback	LVNL: D-1 projectteam

Figure 21. SIPOC evaluate D-1 plan

Figure 21 presents the SIPOC of the activity just after the operation. The supervisor or FMPC the D-1 plan receives of the D-1 project team, to use it in their activities and finally provide feedback to the usability and accuracy of the information mentioned in the D-1 plan. The

evaluation of the D-1 plan is the current process step to obtain feedback for the trial, while it is not yet used in the operation to regulate on. If the D-1 project is implemented, this plan will be used for the day of operation to get a more predictable operation.

**Save operational data**

SIPOC D-1 and D0					
	Supplier(s)	Input	Process	Output	Customer(s)
D+1	Airlines	Last submitted flight plans	Save operational data	<u>Dataset of D0</u>	Eurocontrol  LVNL: D-1 projectteam Post-operational evaluation team

Figure 22. SIPOC save operational data

Figure 22 presents the last activity of the process to save the data of the day of operation. There are three options possible to use as a dataset of D0. The three options possible for the D0 traffic demand data are the actual flight execution, a snapshot at the beginning of the day of operation (around 04:30 LT) or the last submitted flight plans at the day of operation.

- The actual flight execution. This data is affected by regulations of air traffic controllers (supervisors or FMPCs), causing changes in the flights at the day of operation. The prediction is made to provide more knowledge in the coming demand and not for the final demand because the prediction will be used by the air traffic controllers to notice if it is necessary to make regulations or not. Hence, the comparison should not be done with the actual operation.
- A snapshot at 04:30LT. In this data, there are no considerable regulations done yet and it is the point where the most important decisions are taken for coming hours, which is just before the morning peak. At this moment the supervisors/FMPCs determine with the expected demand coming if there are regulations necessary. The problem of this point is that not all the flight plans are submitted for the flights later that day, because a flight plan must be submitted at least three hours before departure. When a snapshot is taken, only the first three hours are fixed, while the rest of the day the flights still can change. Another problem of this snapshot is availability. Retrieving this data should be done at the day itself at 04:30LT, but because this research started after the dates where trials are done, it was not possible anymore.
- Last submitted flight plans at the day of operation or initial flight plans. In this data, there are no regulations, neither by LVNL nor by Eurocontrol. The data contains the flight plans submitted by the aircraft operator in the IFPS, which is received by the NMOC. This data is processed in the ETFMS, which calculates with the information of the flight plans (EOBT, route and flight level), the 4D trajectories (Eurocontrol, 2019). The output is the entry times in every airspace segment, which is the same format as the PREDICT data. This data does not have the problems mentioned for the previous two options.

In Figure 23, a timeline is visualised starting from D-1 to D0, including the three possible D0 datasets.

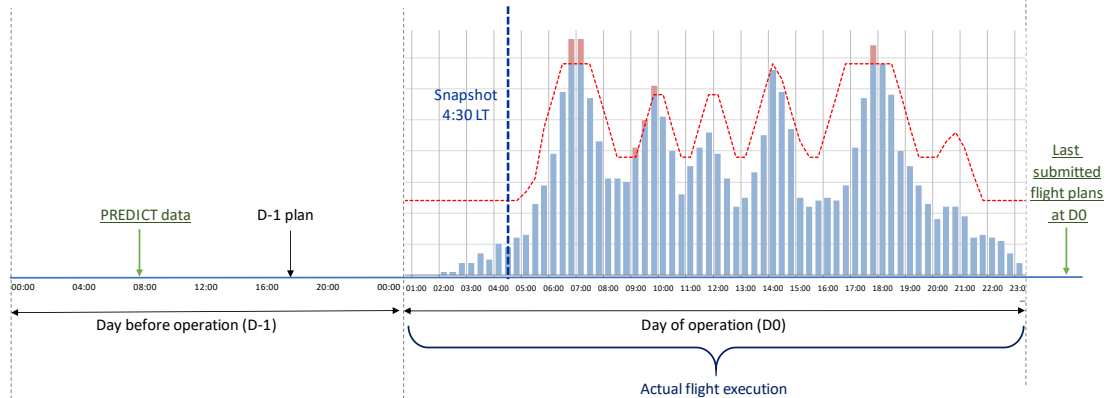


Figure 23. Timeline of D-1 till the end of D0

The best option of the D0 data is the dataset with the last submitted flight plans at D0. This dataset is used by Eurocontrol as input for the PREDICT data, for the D-1 project team to analyse the differences between the dataset of D-1 and D0 and for the post-operational evaluation team to evaluate the day of operations. The D0 data of the day of operation will be retrieved with NEST. This is possible by selecting the corresponding AIRAC cycles, which are AIRAC 1901\_447, 1902\_448 and 1903\_449 for corresponding the months January, February and March.

Finally, the PREDICT data and the last submitted flight plans at the day of operations will be compared to each other (marked green in Figure 23). The PREDICT data will be D-1 and the last submitted flight plans at the day of operations will be D0.

## 5.2 Comparison of the D-1 prediction demand with the D0 demand

The comparison between the D-1 prediction demand with the D0 demand is done in multiple steps. First, the demand must be determined (see section 5.2.1) while this is not yet provided in the dataset. Then the difference between the demand of D-1 and D0 will be calculated (see section 5.2.2). The differences present some outliers and these special days will be filtered (see section 5.2.3). The demand in the peak hours of only the airspace segment of EHFIRAM is analysed in detail (see section 5.2.4), while this airspace sector is the one most used in the operation to regulate on. A detailed analysis of the difference in entry time will be performed (see section 0) to explain some reasons for differences for every airspace segment.

### 5.2.1 Determine demand D-1 and D0

To make the comparison, the number of entries is counted per hour rolling per 20 minutes for every airspace segment. The number of entries can be called demand. The demand is also calculated per 20 minutes (not rolling). A short example of the data that is generated in this way is in

Table 2 per hour rolling per 20 minutes, and the calculation per 20 minutes is executed in almost the same way.

Table 2. Sample data number of entries D-1 and D0 per hour rolling per 20 min

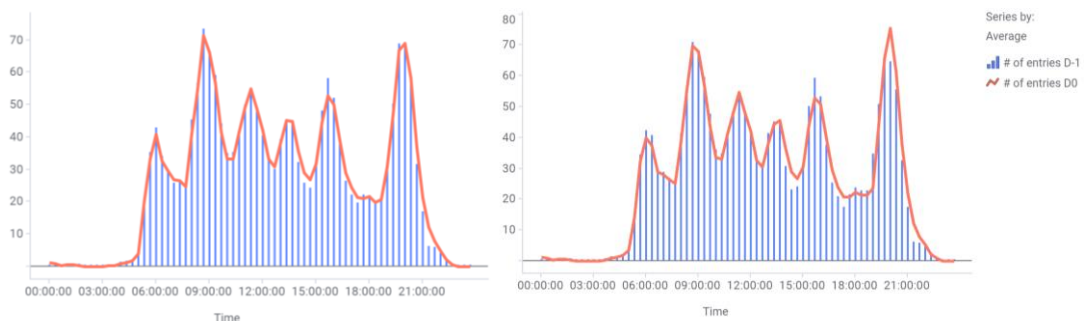
Date	Time	Date/time	Entries D-1 EHFIRAM	Entries D0 EHFIRAM
08/01/2019	03:00:00	8/01/19 3:00	5	4
08/01/2019	03:20:00	8/01/19 3:20	5	10
08/01/2019	03:40:00	8/01/19 3:40	10	12
08/01/2019	04:00:00	8/01/19 4:00	12	14
08/01/2019	04:20:00	8/01/19 4:20	14	12
08/01/2019	04:40:00	8/01/19 4:40	20	24
08/01/2019	05:00:00	8/01/19 5:00	29	35

This is done for all the sectors, the three stacks and arrival and departures at the runway of EHAM. To obtain the entry time of the number of arrivals at the runway and the number of departures at the runway, an offset time is used (Table 3).

Table 3. Offsets

TYPE	RWY use	SECTOR	Offset to RWY (min)
EHFIRAM	North	EHSECT1	26
EHFIRAM	North	EHSECT2	27
EHFIRAM	North	EHSECT3	19
EHFIRAM	North	EHSECT4	23
EHFIRAM	North	EHSECT5	22
EHFIRAM	South	EHSECT1	25
EHFIRAM	South	EHSECT2	26
EHFIRAM	South	EHSECT3	25
EHFIRAM	South	EHSECT4	22
EHFIRAM	South	EHSECT5	21
Scheduled Off-Block Time (SOBT)	North	EHSECT1	15
SOBT	North	EHSECT2	11
SOBT	North	EHSECT3	11
SOBT	North	EHSECT4	15
SOBT	North	EHSECT5	15
SOBT	South	EHSECT1	9
SOBT	South	EHSECT2	10
SOBT	South	EHSECT3	10
SOBT	South	EHSECT4	9
SOBT	South	EHSECT5	9

When the number of entries is calculated for both datasets, these are brought together in one graph per airspace segment. The visualisations are limited to only south runway use for the departures and arrivals because it appeared that the visualisations of north runway use and south runway use are almost the same. There is chosen to visualise only south runway use because this is the most common at Schiphol. The left graph in Graph 1 presents the demand of the departures for north runway use, while the right graph presents the demand of the departures for south runway use. The differences between the two graphs are minimal.

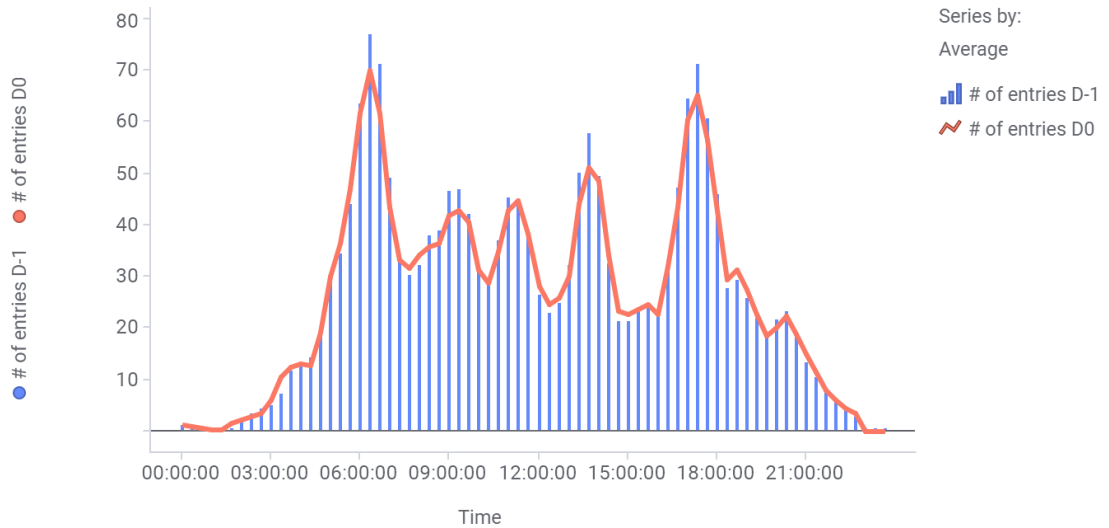


Graph 1. Average demand D-1 and D0 EHAM Departure North (left) versus South (right)

The average demand of D-1 and D0 per hour rolling per 20 minutes of EHFIRAM is presented (Graph 2), as well as the average demand of D-1 and D0 per 20 minutes of EHFIRAM (Graph 3). These two visualisations of the other airspace segments are in Appendix IX. The number

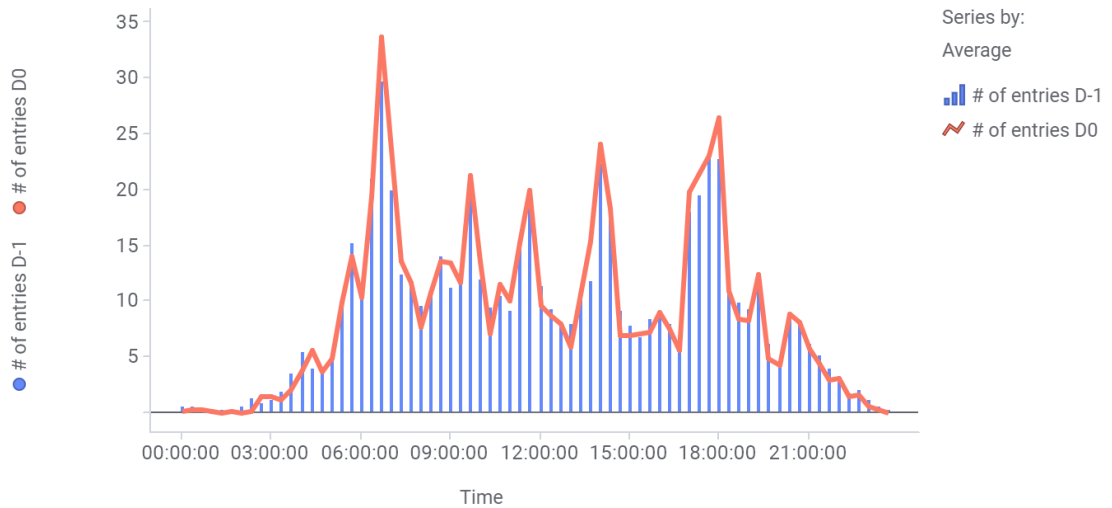
of entries of D-1 are the bars in blue and the number of entries of D0 is the red line. When the blue bar exceeds the red line, it means that there are, on average, more demand predicted than at D0 in that hour.

Average demand per hour rolling per 20 min D-1 & D0 EHFIRAM



Graph 2. Average demand D-1 and D0 per hour rolling per 20 min EHFIRAM

Average demand per 20 min D-1 & D0 EHFIRAM



Graph 3. Average demand D-1 and D0 per 20 min EHFIRAM

**Results**

For the airspace segments, the result is that the average predicted demand is higher than the D0 demand in the peaks during the day. Outside these peaks, it often happened that the predicted demand is lower than the D0 demand. Regularly, the exceeding demand fits within the hours where the demand does not exceed the demand of D0. Therefore, it is possible to spread the expected demand over the whole day.

**5.2.2 Difference demand D-1 and D0**

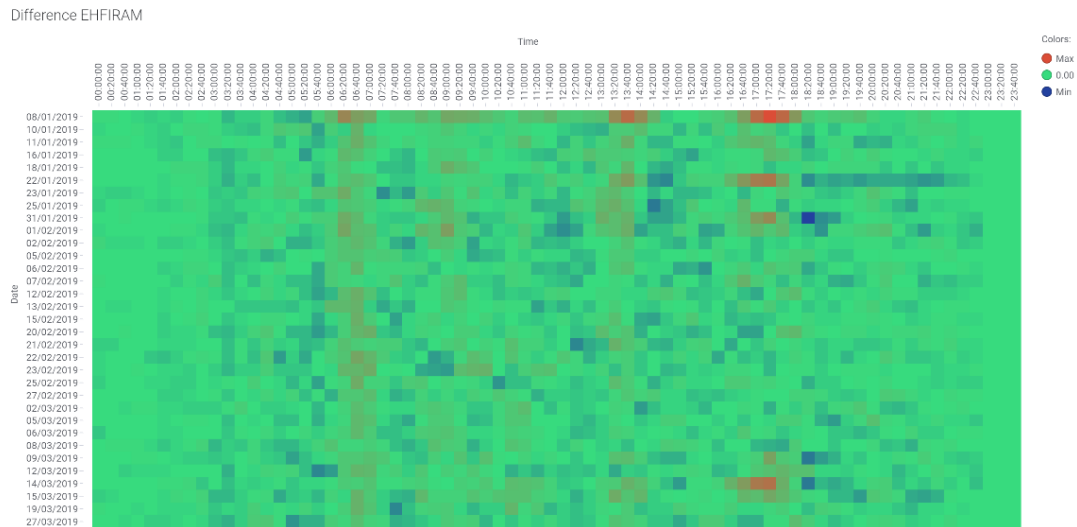
When the number of entries of D0 is subtracted of the number of entries of D-1, the difference is obtained. The average difference per day per airspace segment (Appendix XII) provides an

overview of nominal days and special days where the difference between the demand of D-1 and the demand of D0 is very high. If the difference is negative, it means that there is less aircraft predicted than at D0 and the difference is positive if there are more aircraft predicted than at D0. Long vertical lines indicate that the difference between D-1 and D0 is high on that day, due to disruptions.

**Results**

In the graph in Appendix XII, there are two remarkable days: 13-02-2019 and 08-01-2019. The vertical lines are high for these days, the value of the difference is above 2, on average. For the other days, the difference is on average between 0 and 2. The average difference is at 13-02-2019 in EHSECT3 and EHRIVER is positive, while the average difference in EHSUGOL and EHSECT2 is negative. The traffic demand is still almost the same but moved to other airspace segments. For other days if there is a positive difference in one airspace segment, frequently, there is a negative difference in another airspace segment.

Another way to visualise the difference is per day per hour rolling per 20 minutes, merged in a heatmap (Graph 4 for EHFIRAM). When there is no difference between the D-1 demand and the D0 demand, the difference is zero, which is, in the graph, green. The red colour in the graph is the maximum (Max) height of the difference, so then there is more predicted than there were at D0 and the blue colour is the minimum (Min), which means the highest negative value of the difference, so there was less predicted than at D0. However, the values between the zero and the minimum change colour from bright green to light blue to dark blue. The values between zero and the maximum change colour from bright green to light red to bright red.



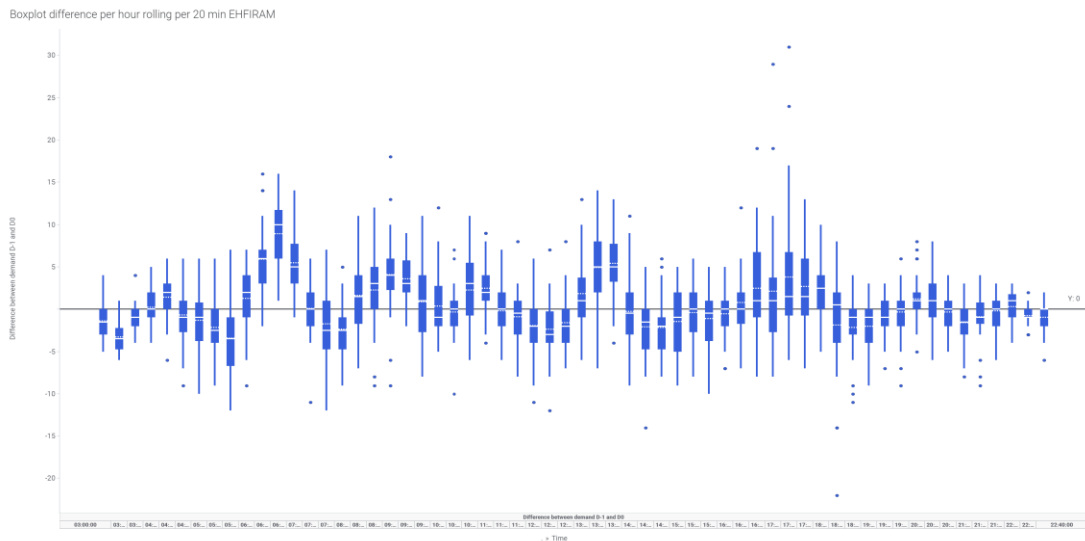
Graph 4. Heatmap EHFIRAM

The heatmaps of the other airspace segments are in Appendix X.

**Results**

The findings of the difference per date in the demand and the findings of the demand per hour are both visible in the heatmaps. The extra predicted demand in the peaks and the lower predicted demand outside of the peaks are visualised as red and blue strips clearly for EHFIRAM, EHSUGOL, EHSECT2 and EHAM Arrival South. The outstanding day of 13-02-2019 is a blue or red line for EHARTIP, EHSECT2, EHSECT3, EHSUGOL and EHRIVER. When there is more predicted than at D0 (red) for one airspace segment, there is less predicted than at D0 (blue) for another airspace segment.

Next to the average difference, it is also of importance to know how the data is organized by visualising the minimum, maximum and median of the data. This is presented in boxplots per hour rolling per 20 minutes. This provides information about in what hours there is more deviation in the prediction compared to other hours. The boxplot of the difference per hour rolling per 20 min for EHFIRAM are visualised in Graph 5. The boxplots of the other airspace segments are in Appendix XI including a statistics table. The dots present outlying values, the top of vertical line presents the maximum, the bottom of the vertical line presents the minimum, the length of the line indicate the distribution of the values, the box present the interquartile range, the white horizontal line in the box is the median and the white dotted line in the box is the average. Important in the graph is the length of the vertical line and the place of the box, to determine the distribution of the values is and what the difference is at in that hour.



Graph 5. Boxplot difference per hour rolling per 20 min EHFIRAM

**Results**

The boxplot difference per hour rolling per 20 minutes visualises the fluctuation of the data during the time. For most of the airspace segments, the amount of fluctuation of the values is almost equivalent during the day. Still, the variation is a bit more around peak hours. For EHSUGOL it is remarkable that the difference is very high (positive) around 06:40, while at 05:40 very high negative difference is seen. The fluctuation in the first hours of EHSUGOL is higher than later the day. In comparison to the other airspace segments is the fluctuation of the difference for EHAM Departure South very low. The extreme values are often around the first or fifth peak hour for every airspace segment (around 6:20 and 17:20).

**5.2.3 Filter special condition days**

When the difference was calculated, there arise outstanding days, which were visible in the average difference per day and the heatmaps. Research is performed to the days with special conditions, that have a valid reason to be removed from the data. Those special conditions should have been mentioned in the D-1 plan made for those days. It appeared that not for every day where a D-1 prediction is retrieved a D-1 plan is made. For those days there is researched if there was a sector briefing for that day or if there were special weather conditions. It appeared that for three days there were special conditions, which are 08-01-2019, 22-01-2019 and 13-02-2019.

- For 08-01-2019, the special weather condition was a high crosswind component which reduces the maximum inbound capacity because the crosswind component exceeds the use of every runway combination. The wind direction was 310 and a speed of 27 knots with outliers of 41 knots (LVNL, 2019).

- For 22-01-2019, the special weather condition was hard wind (outliers of 19 knots), low temperature (-2 degrees Celsius) and snow that becomes rain. This makes the runway 09/27 not usable, which provides a reduction in capacity. This reduction of the capacity is also mentioned with a sector briefing (LVNL, 2019).
- For 13-02-2019, the special conditions were that the Belgian ATC (Skeyes) had a strike, causing a reduction of the capacity of 50 percent of en-route sectors (LVNL, 2019).

After filtering those days, a new graph is created with the average difference per date per airspace segment which provides a more representative graph (Appendix XII).

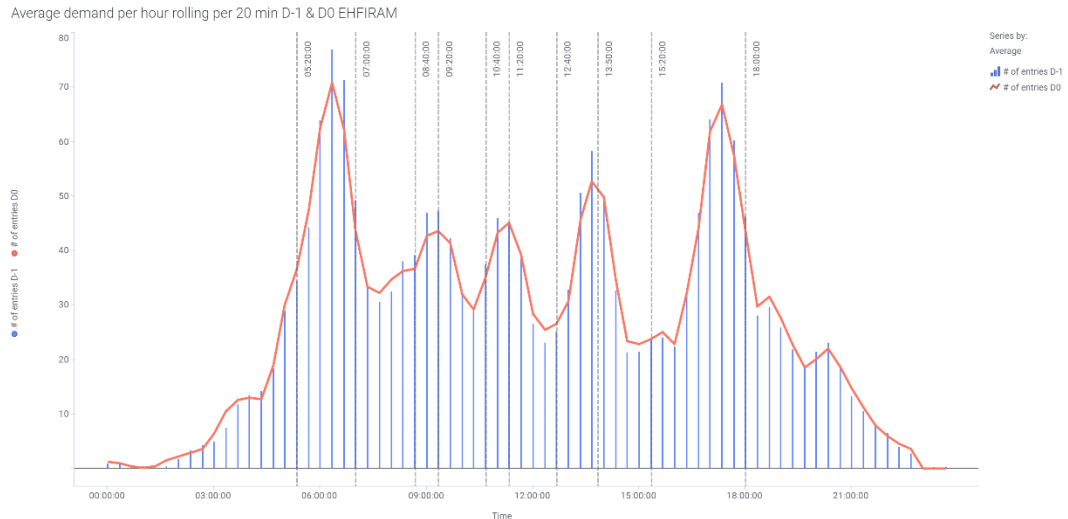
The following analyses will only consider the 30 days of data, which are the number of days left after filtering.

**Results**

After filtering the special days, there are still some remarkable days with outliers. The most extreme day is 20-02-2019 and the last four days in March (14, 15, 19 and 27 March). For these days there is no explanation found for the differences. Therefore, these are left in the data.

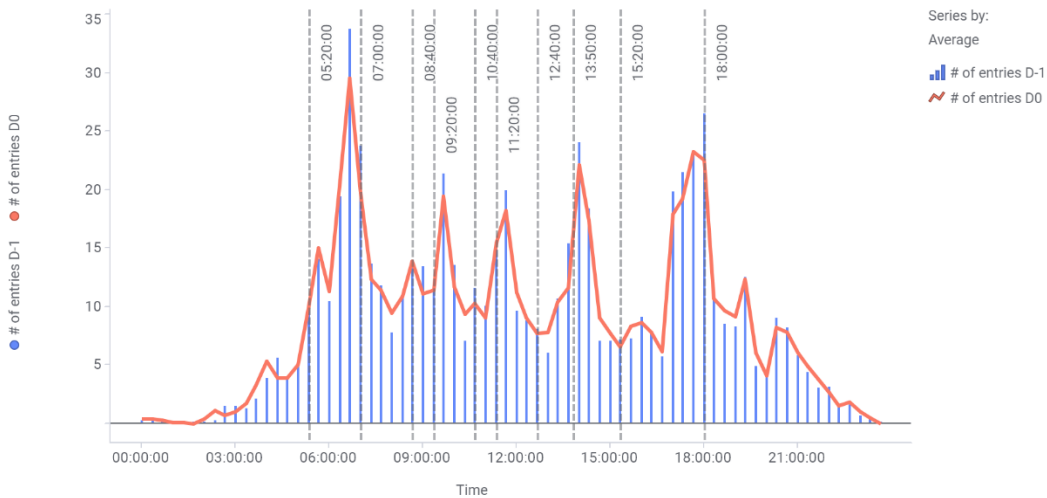
**5.2.4 EHFIRAM peak hours**

The same analysis performed before to determine the demand and the difference is performed again but focusing on the peak hours within the EHFIRAM. The peak hours in the EHFIRAM are between 05:20 and 07:00, between 08:40 and 09:20, between 10:40 and 11:20, between 12:40 and 13:50 and between 15:20 and 18:00. All the times are in Universal Time Coordinated (UTC) (LVNL, 2019). The average demand per hour rolling per 20 min is visualised together with the peak hours (Graph 6), to notice if the peaks in demand fall within the peak hours. The average demand per 20 minutes is also visualised together with the peak hours (Graph 7). These graphs are the same as Graph 2 and Graph 3 only with grey vertical dotted lines that indicate the start and the end of a peak hour.



Graph 6. Average demand per hour rolling per 20 min D-1 and D0 EHFIRAM with peak hours

Average demand per 20 min D-1 & D0 EHFIRAM



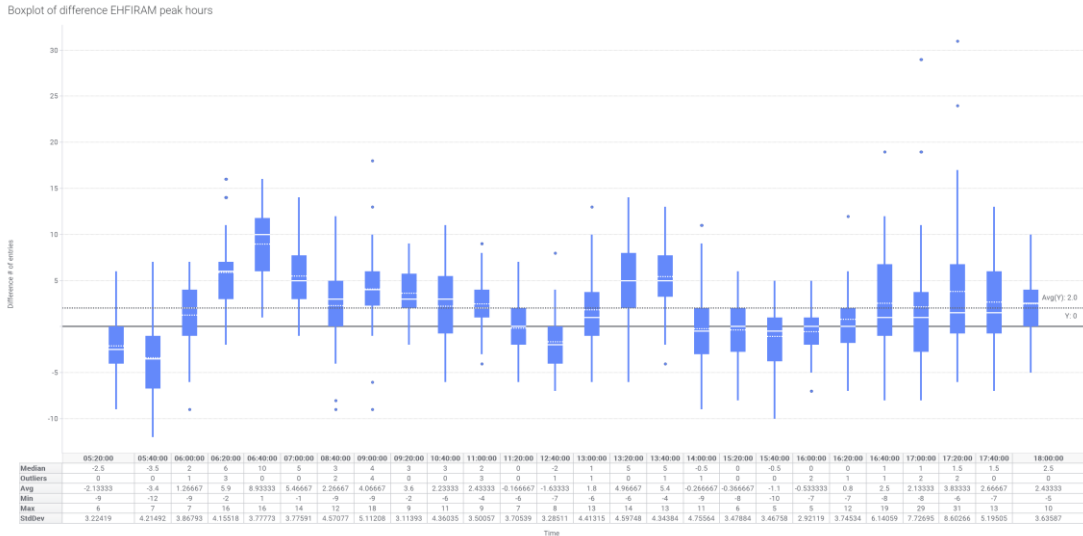
Graph 7. Average demand per 20 min D-1 and D0 EHFIRAM with peak hours

The graphs visualise that the peaks in the demand per hour rolling per 20 min fall better within the peak hours than the demand per 20 minutes. Therefore, the rest of the analysis will be performed with the demand per hour rolling per 20 min. Still, the demand falls not perfectly within the peak hours. An assumption is made that the expected highest value of the demand should fall exactly in the middle of the peak hour. The measured highest value does not match with this. The height of the difference between the highest values of the expected and the measured is calculated (Table 4). This difference is the number of minutes that the measured highest peak is later than the expected highest value.

Table 4. The difference in peak hour time provided versus measured

Expected highest value in peak hour	Average measured highest value peak hour	Difference between expected and measured highest value (minutes)
06:10:00	06:20:00	10
09:00:00	09:10:00	10
11:00:00	11:10:00	10
13:15:00	13:40:00	25
16:40:00	17:20:00	40

For this analysis, it is also important to know how the data is organized by visualising the minimum, maximum and median of the difference in demand data with a boxplot. The distribution of the data during the time, which provides information about in what hours there is more deviation in the prediction compared to other hours, is visualised per hour rolling per 20 min for the EHFIRAM peak hours in Graph 8. Again, important in the graph is the length of the vertical line and the place of the box, to determine the distribution of the values is and what the difference is at in that hour.



Graph 8. Boxplot of difference EHFIRAM peak hours

**Results**

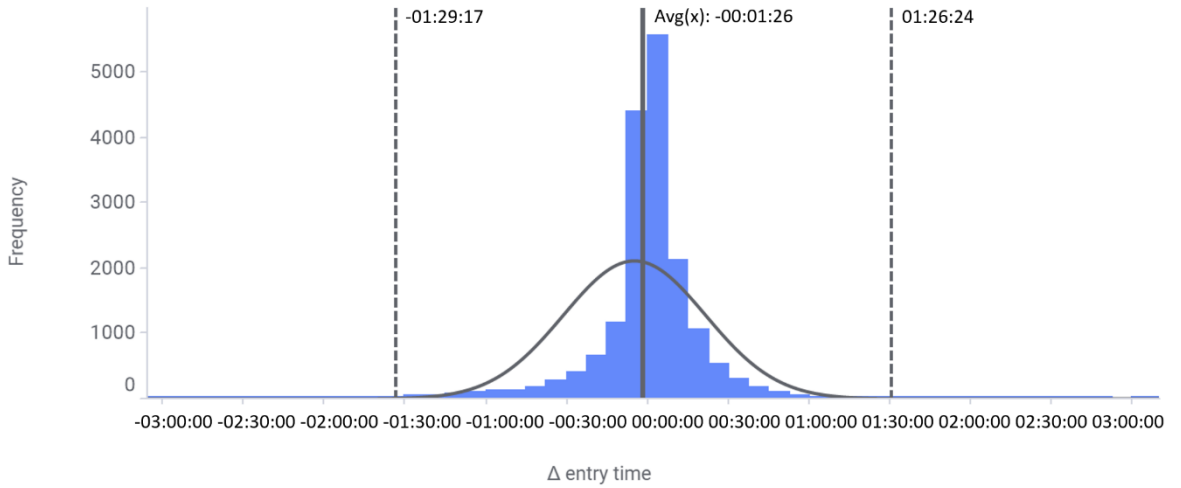
The peak hours provided by LVNL do not correspond precisely with the measured demand peak hours. If focused on the measured demand per hour rolling per 20 minutes, the first and the last peak are within the provided peak of LVNL, but the highest value of the second, third and fourth peak fall at the end of the provided peak. Therefore, the provided peaks are approximately 20 minutes too early. When analysing the demand per 20 minutes, the peaks of the second, third and fourth do not fall at all in the provided peak. The highest value of the first and fifth peak is at the end of the peak. When only focussing on the expected and measured highest value, the difference for the fifth and fourth peak is the highest.

Compared to the distribution of the difference between D0 and D-1 of EHFIRAM, the distribution of the difference between D0 and D-1 of the EHFIRAM focused on the peak hours has a higher (more positive) average and median in general. In the highest point of the first peak, there is never less predicted than at D0, while at the start of the first peak there is more often less predicted than at D0. The most deviation and outliers occur in the fifth peak. When there is more demand, there is often a positive difference, which means there is more predicted than at D0.

**5.2.5 Differences in entry time**

The entry time at D0 of one flight is compared to the extra time at D-1 of that same flight for every airspace segment. The difference between those entry times might be positive, which means the flight came earlier than predicted, negative, which means the flight came later than predicted, or a flight is precisely on time. The distribution of the differences in entry time of EHFIRAM is visualised (Graph 9). A line for the average is provided and the lines for the average plus or minus two times the standard deviation. Everything between those lines is 95 percent of the values. The distribution of the other segments is in Appendix XIII.

Distribution difference in entry time D0 with D-1 EHFIRAM



Graph 9. Distribution difference in entry time D0 with D-1 EHFIRAM

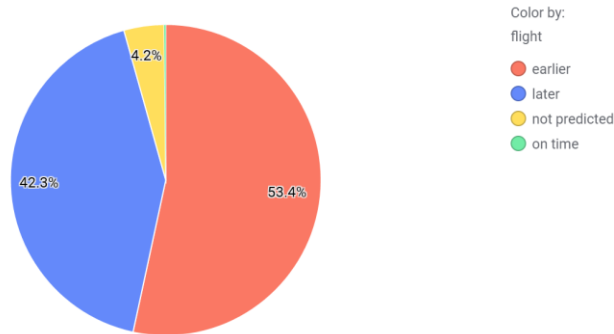
The average and standard deviation of the difference in entry time for all the airspace segments are in Table 5.

Table 5. Statistics of difference in entry time D0 with D-1

Airspace segment	Standard deviation	Average
EHFIRAM	00:43:55	-00:01:26
EHARTIP	00:51:07	-00:02:53
EHRIVER	00:36:43	-00:02:53
EHSUGOL	00:39:36	00:00:00
EHSECT2	00:46:05	-00:05:46
EHSECT3	00:49:41	-00:05:46
EHAM Arrival South	00:59:02	-00:01:26
EHAM Departure South	00:58:19	-00:05:46

The percentage of flights that are later than predicted, earlier than predicted, on time or not predicted in that airspace segment is calculated (for EHFIRAM in Graph 10). Also, the other way around, the percentage of flights that are later, earlier than predicted, on time or not present in the D0 data in that airspace segment is calculated (Appendix XIV). However, when a flight is counted on time, it must have the exact same entry time in D-1 as in D0.

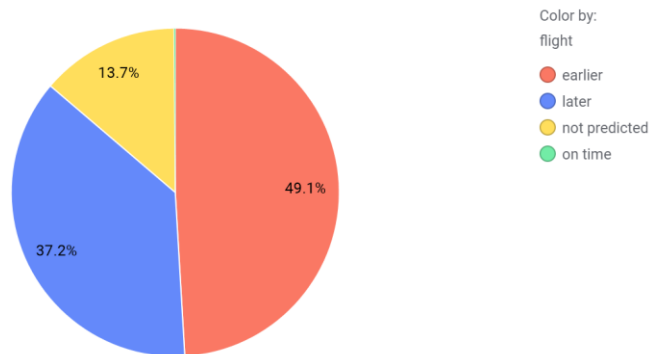
D0 versus D-1 entry time EHFIRAM



Graph 10. D0 versus D-1 entry time EHFIRAM

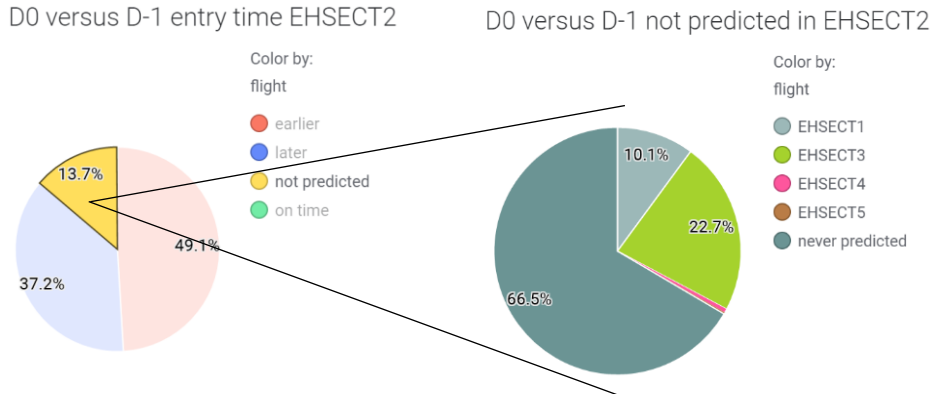
These percentages are calculated for every airspace segment, but in some airspace segments, it is possible that when a flight is not predicted in that segment, it might be that the flight is still present in another segment in the prediction data. This means that a flight changed its route. This is possible for the sectors and the stacks. The sectors and the stacks are small parts in the Dutch airspace. Therefore, it is possible that a flight flew through another part of the Dutch airspace instead of through the particular sector or stack. The percentages for sector 2 of the difference between D0 and D-1 in entry time is in Graph 11.

D0 versus D-1 entry time EHSECT2



Graph 11. D0 versus D-1 entry time EHSECT2

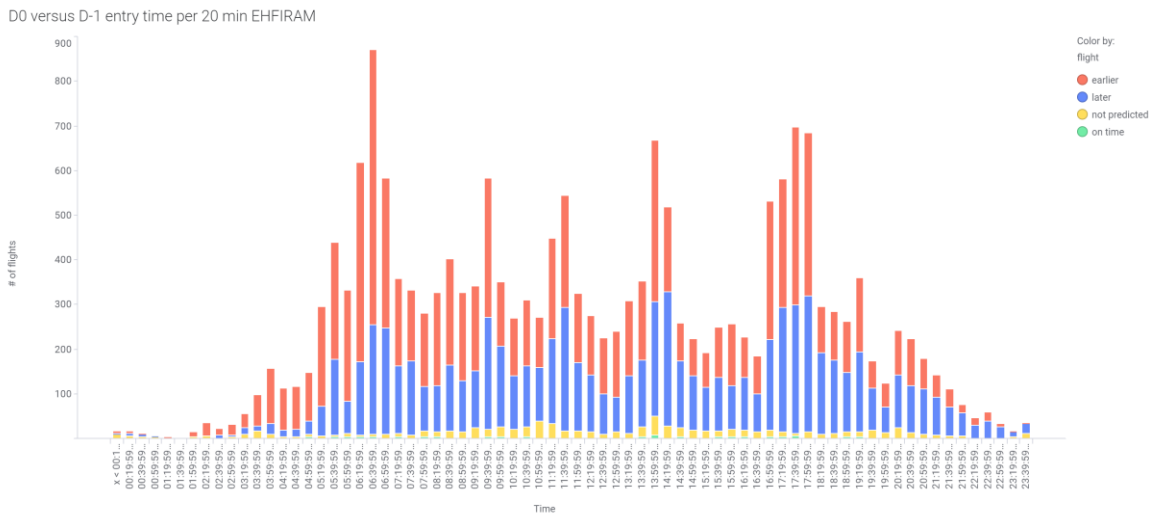
Of the 13.7 percent flights that are not predicted in sector 2, 10.1 percent of the flights are present in Sector 1, 22.7 percent in sector 3 and 0.7 percent spread over sector 4 and sector 5. Still, 66.5 percent is never predicted, which means those flight appearing in the D0 data do not appear in the D-1 data (Graph 12).



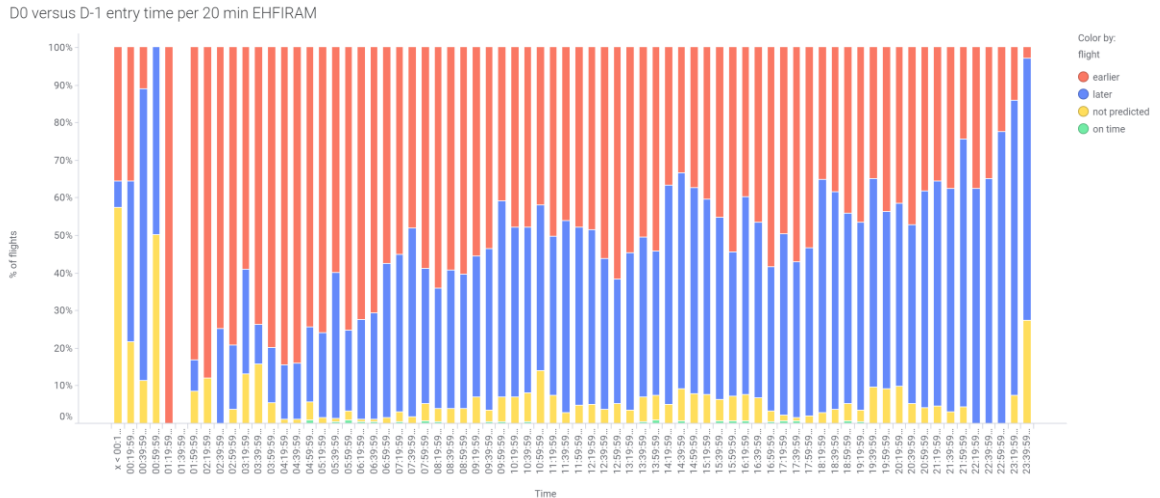
Graph 12. D0 versus D-1 not predicted in EHSECT2

Again, the other way around, in some airspace segments it is possible that a flight is not available in the D0 data of that segment, but it is present in another segment in the D0 data. The calculated percentages for D0 versus D-1 and D-1 versus D0 of the other airspace segments are in Appendix XIV.

The difference in entry time is not only for the whole dataset calculated but also per 20 minutes. This is of importance to obtain a better view of the flights during peak hours. The number of flights that arrive earlier, later, on time or the flights that are not predicted per 20 minutes for EHFIRAM is visualised in Graph 13. The same visualisation, only now the percentage of the total flights that are earlier, later, on time or not predicted is visualised in Graph 14 for EHFIRAM.



Graph 13. D0 versus D-1 entry time per 20 min EHFIRAM number of flights



Graph 14. D0 versus D-1 entry time per 20 min EHFIRAM percentage of flights

This is also visualised for D-1 versus D0, which present the number and percentage of flights that are not in D0. These graphs, together with the graphs of the other airspace segments, for both D0 versus D-1 and D-1 versus D0, are in Appendix XV.

**Results**

When the difference in entry time is analysed it resulted that for roughly all the airspace segments, the average is negative. Only for EHSUGOL, the average is exactly 0 minutes. The standard deviation of EHSUGOL and EHRIVER are the smallest, accordingly, there are fewer extreme late flights or extreme early flights. The reasons for the differences in entry time are a flight at the day of operation that is later than predicted, a flight that is earlier than predicted, a flight that is exactly on time or that the flight is not predicted or not in the D0 at all. A summary of this is provided for every airspace segment (Table 6).

Table 6. Summary difference in entry time for every airspace segment

Airspace segment	D0 versus D-1 (percentage)				D-1 versus D0 (percentage)			
	Later	Earlier	Not predicted	On time	Later	Earlier	Not in D0	On time
<b>EHSECT2</b>	37.2	49.1	13.7	0	37.6	50.0	12.3	0.1
<b>EHSECT3</b>	41.3	44.1	14.1	0.6	41.7	44.8	12.9	0.6
<b>EHARTIP</b>	44.9	47.2	7.8	0.1	44.7	47.6	7.6	0.1
<b>EHSUGOL</b>	34.8	58.9	6.1	0.2	34.3	58.4	7.1	0.2
<b>EHRIVER</b>	42.2	46.1	11.5	0.2	41.9	46.1	11.8	0.2
<b>EHFIRAM</b>	42.3	53.4	4.2	0.1	40.5	51.3	8.0	0.2
<b>EHAM Departure South</b>	25.6	6.1	5.6	62.7	6.4	25.9	4.1	63.5
<b>EHAM Arrival South</b>	42.6	52.9	4.3	0.2	52.8	42.2	4.8	0.2

It results that even though the average difference in entry time is almost always negative, the percentage of the aircraft later than predicted is most of the time not the highest. EHAM Departure South is very remarkable because of the percentage on time and the small percentage of later than predicted flights. This is explained by the fact that departing flights operate on scheduled times, while an arriving flight is not exactly on the minute in the airspace segment because these flights are more influenced by other factors, for example route, wind, etcetera. The most important result of Table 6 is the percentage of the flights which were not found in the predicted or D0 data of the corresponding airspace segment (marked in green). This percentage is divided in never predicted/disappeared in D0 or the airspace segment where the flight is found (Table 7). If this flight is found in another airspace segment, the flight

changed in route. If the flight completely disappeared, the flight may be cancelled, or the flight is added at the day of operation if it is never predicted. The exact reason why a flight is later, earlier, changed its route or disappeared is not investigated because this must be performed for every unique flight which is not part of this research.

Table 7. Causes of not predicted or not in D0 in the corresponding airspace segment

Airspace segment	Not predicted	Not in D0
<b>EHSECT2</b>	66.5% never predicted 22.7 % EHSECT3 10.1% EHSECT1 0.5% EHSECT4 0.2% EHSECT5	85.9% disappeared in D0 8.0% EHSECT 3 5.6% EHSECT1 0.1% EHSECT4 0.4% EHSECT5
<b>EHSECT3</b>	71.4% never predicted 20.9% EHSECT2 6.9% EHSECT4 0.5%EHSECT1 0.4%EHSECT5	87.9% disappeared in D0 6.3% EHSECT2 5.5% EHSECT4 0.2%EHSECT5 0.1%EHSECT1
<b>EHARTIP</b>	49.4% never predicted 44.8% EHRIVER 5.8% EHSUGOL	53.1% disappeared in D0 43.1% EHRIVER 3.8% EHSUGOL
<b>EHSUGOL</b>	71.5% never predicted 22.5% EHRIVER 6.0% EHARTIP	77.5% disappeared in D0 14.6% EHRIVER 7.9% EHARTIP
<b>EHRIVER</b>	44.4% EHARTIP 44.2% never predicted 11.4% EHSUGOL	47.2% EHARTIP 38.2% disappeared in D0 14.6% EHSUGOL

The flights that are not predicted or not in D0 in the airspace segments is during the day almost constant. The number and percentage of flights earlier or later deviates more during the day and differs for the airspace segments. For some airspace segments, the percentage of earlier flights is the highest at the beginning of the day, while during the day this percentage becomes less and the percentage of flights that arrive later becomes more. For the EHFIRAM the earlier flights start with 80 percent while in the afternoon the early and later flights are both around 40 percent of the flights. For EHARTIP and EHSUGOL the early flights in the morning are around 70 percent, while in the afternoon the early and later flights are both around 45 percent For the arrivals at EHAM the early flights in the morning are around 80 percent, while the later flights are in the afternoon almost 70 percent. The early and later flights for EHSECT3 and EHRIVER deviates during the day, however, in the peak hours there are more early flights. EHSECT2 is more constant during the day, although there are still some more early outliers during the peak hours. For the departures at EHAM, the percentage of on time flights is the highest in the morning, around 80 percent, while during the day this percentage becomes lower.

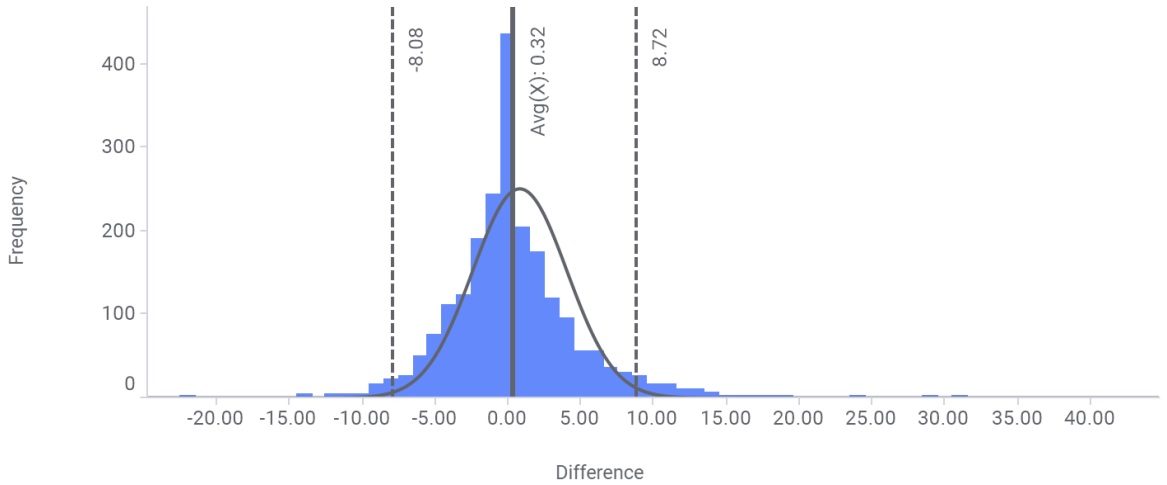
### 5.3 Validating the D-1 demand prediction

To validate the D-1 prediction, the accuracy of this prediction is analysed. This is performed for all the airspace segments (see section 5.3.1) and the EHFIRAM peak hours (see section 5.3.2). First, the difference that is calculated before visualised in a distribution. Secondly, the MFE is calculated, after this the R-square is calculated and at last a significance test is done. Finally, the accuracy is validated for the operation by interviewing experts (see section 5.3.3).

#### 5.3.1 Statistics on all segments

The frequency of the values of the difference presents a normal distribution. This normal distribution of EHFIRAM is visualised (Graph 15). The other distributions of the airspace segments are in Appendix XVI.

Distribution difference EHFIRAM



Graph 15. Distribution difference EHFIRAM

The average difference is 0.32 for EHFIRAM. The two dotted lines are the average plus two times the standard deviation. A summary of the averages and standard deviations of the airspace segments are in

Table 8.

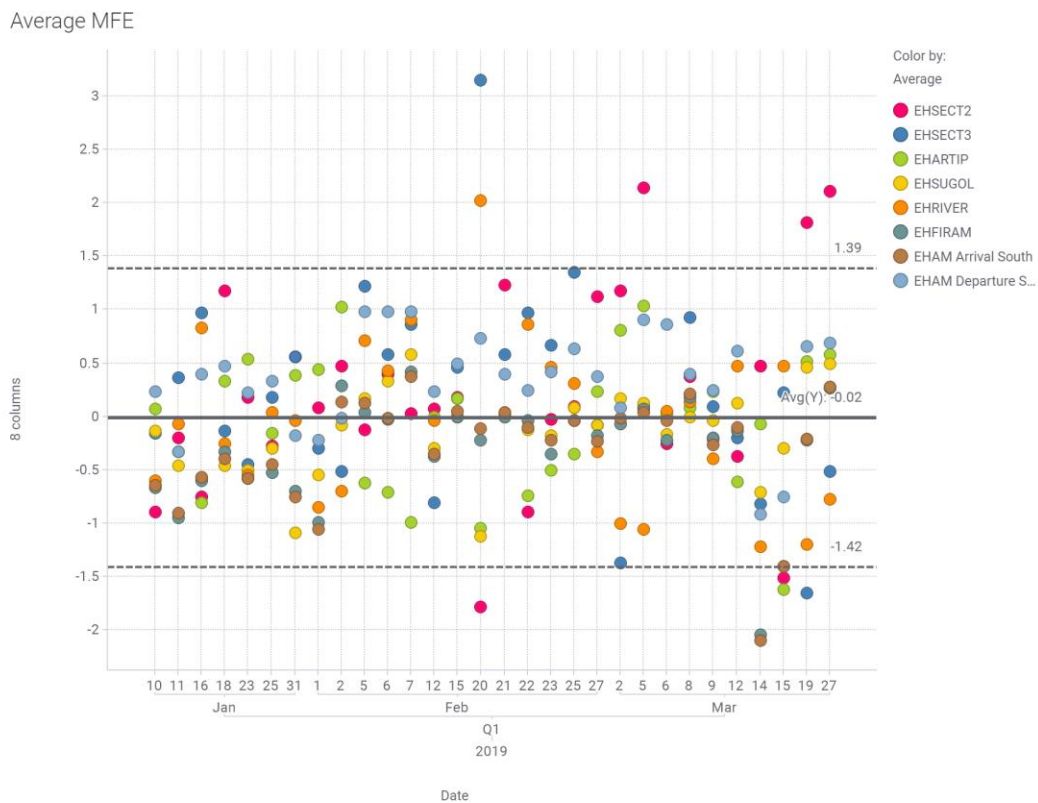
Table 8. Average and standard deviation difference of all airspace segments

Airspace segment	Average difference	Average difference in aircraft per hour	Standard deviation	Average total a/c per hour	% standard deviation of total
<b>EHSECT2</b>	-0.21	1 aircraft per 5 hours more in D0 than predicted	3.66	18.7	19.6
<b>EHSECT3</b>	-0.21	1 aircraft per 5 hours more in D0 than predicted	3.62	19.2	18.9
<b>EHARTIP</b>	0.07	1 aircraft per 14.5 hour less in D0 than predicted	2.62	11.0	23.8
<b>EHSUGOL</b>	0.15	1 aircraft per 7 hours less in D0 than predicted	2.50	8.8	28.4
<b>EHRIVER</b>	0.04	1 aircraft per 25 hours less in D0 than predicted	2.27	6.9	32.9
<b>EHFIRAM</b>	0.32	1 aircraft per 3 hours less in D0 than predicted	4.20	26.7	15.7
<b>EHAM Arrival South</b>	0.31	1 aircraft per 3 hours less in D0 than predicted	4.26	26.7	16.0
<b>EHAM Arrival North</b>	0.30	1 aircraft per 3.5 hours less in D0 than predicted	4.26	26.7	16.0
<b>EHAM Departure South</b>	-0.34	1 aircraft per 3 hours more in D0 than predicted	4.49	26.7	16.8
<b>EHAM Departure North</b>	-0.34	1 aircraft per 3 hours more in D0 than predicted	3.83	26.7	14.3

The average of the difference is translated into aircraft per how many hours, which provides a more accessible view which will be presented to the supervisors and FMPCs during the interviews. The total number of aircraft per (rolling) hour is presented as well, to understand that the average number of aircraft per hour can fluctuate between this value plus or minus

the standard deviation. Also, the percentage of the standard deviation of the average number of aircraft per hour is provided.

The MFE is calculated for every airspace segment per day (Appendix XVII) and for the whole period. The MFE per day for every sector is visualised together in one graph (Graph 16). A negative MFE means that there is less aircraft at D0 than predicted and a positive MFE means that there are more aircraft at D0 than predicted. The two horizontal dotted lines are the average plus or minus two times the standard deviation. Everything between these lines is within the 95 percent interval. Some outliers are on the 22<sup>nd</sup> of February, the 5<sup>th</sup>, 14<sup>th</sup>, 15<sup>th</sup>, 19<sup>th</sup> and the 27<sup>th</sup> of March. When there is a positive MFE in several airspace segments, often in the other airspace segments there is a negative MFE. These values weigh against each other making the average almost zero. The same graph only separately for the stacks, arrival and departure and sectors are in Appendix XVII.



Graph 16. Average MFE per airspace segment per date

The average of the MFE of all the sectors is -0.02. The average of every airspace segment for the whole period is in Table 9.

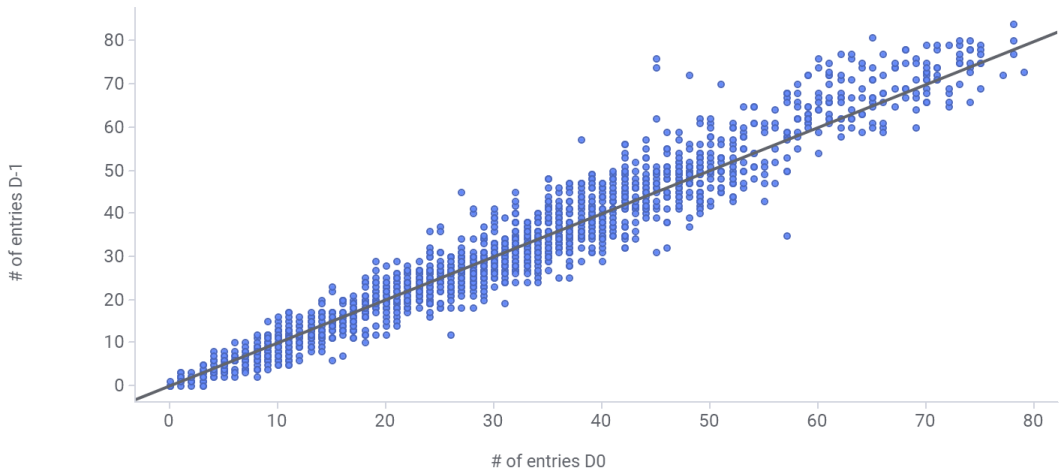
Table 9. Average MFE per airspace segment

Airspace segment	MFE
EHSECT2	0.214
EHSECT3	0.210
EHARTIP	-0.068
EHSUGOL	-0.153
EHRIVER	-0.045
EHFIRAM	-0.320
EHAM Arrival South	-0.309
EHAM Arrival North	-0.309
EHAM Departure South	0.341

<b>EHAM Departure North</b>	0.341
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The number of entries of D-1 and the number of entries of D0 is set against each other which creates a scatterplot (Graph 17 of EHFIRAM, rest in Appendix XVIII). The line in the graph is the line when the demand of D0 and the demand of D-1 are the same, so when the difference is zero. The most ideal would be to have all the dots on this line.

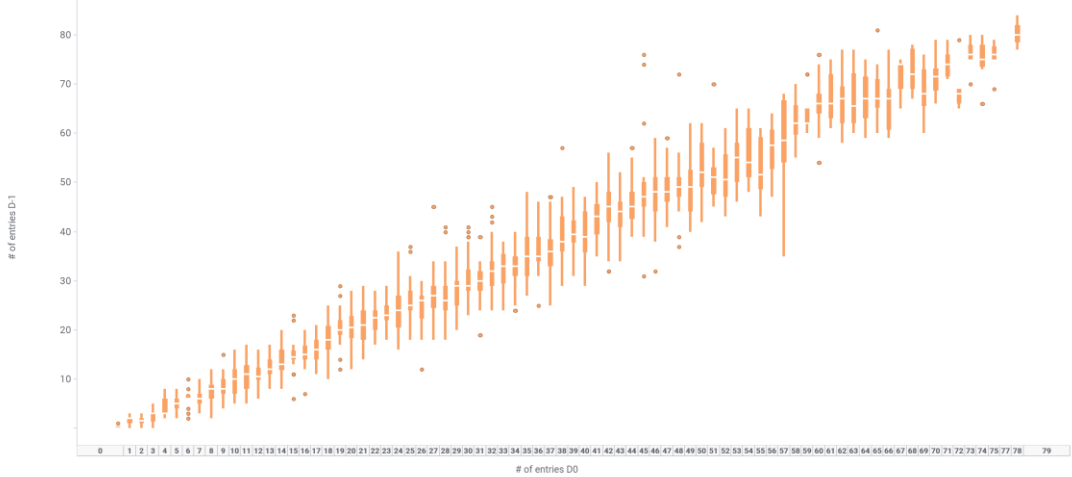
Scatterplot EHFIRAM



Graph 17. Scatterplot EHFIRAM

The scatterplot is also visualised with boxplots, to obtain more overview of the distribution of the dots in the scatterplot (Graph 18 of EHFIRAM, rest in Appendix XVIII). The dots overlying each other in Graph 17 are visualised in Graph 18 as a box. Even in this graph the outliers, presented as dots, are more clearly.

Boxplot of scatterplot EHFIRAM



Graph 18. Boxplot of scatterplot number of entries EHFIRAM

The deviation of the dots in the scatterplot compared to the line are expressed with the R-square (Table 10).

Table 10. R-square per airspace segment

Airspace segment	R-square	Percentage
EHSECT2	0.923	92.3
EHSECT3	0.926	92.6
EHARTIP	0.908	90.8
EHSUGOL	0.903	90.3
EHRIVER	0.838	83.8
EHFIRAM	0.958	95.8
EHAM Arrival South	0.958	95.8
EHAM Arrival North	0.958	95.8
EHAM Departure South	0.958	95.8
EHAM Departure North	0.969	96.9

This R-square is converted to a percentage which presents how much percent of the values are well predicted. The other percentage ( $100 - R^2 \cdot 100$ ) is the percentage of outlying values.

Another way to research the accuracy of a prediction is to perform a significance test. First, the demand of D0 and the demand of D-1 are visualised in a histogram to describe if the distribution is normal, which appeared this was not normally distributed. The demand is converted with a log-transformation to determine if it then normally distributed (Appendix XIX). This was still not the case, so a t-test is not allowed to perform. The other option is then to perform a non-parametric test. A best option is the Related-Samples Wilcoxon Signed Rank Test (Table 11). A null hypothesis is checked, and a recommendation is provided to reject or retain the null hypothesis and the significance is displayed. The null hypothesis is: The median of differences between the number of entries of D-1 and the number of entries of D0 equals zero. The significance level is 0.05, which means if the significance is above this value, the hypothesis must be retained, but if the significance is below this value, the null hypothesis must be rejected.

Table 11. Related-Samples Wilcoxon Signed Rank Test per airspace segment

Airspace segment	Significance	Decision to hypothesis
EHSECT2	0.000	Reject
EHSECT3	0.000	Reject
EHARTIP	0.819	Retain
EHSUGOL	0.105	Retain
EHRIVER	0.756	Retain
EHFIRAM	0.079	Retain
EHAM Arrival South	0.161	Retain
EHAM Arrival North	0.241	Retain
EHAM Departure South	0.000	Reject
EHAM Departure North	0.000	Reject

### Results

Sector 2, sector 3 and the number of departures at the runway have a negative average for the difference. This indicates that, on average, the other airspace segments have a higher demand prediction than the demand is at D0. The sectors with a higher average number of aircraft per hour have a higher standard deviation, so in proportion, they are almost the same.

A summary of all the statistic per airspace segment is provided in

Table 12. This visualises the differences in accuracy for the airspace segments and which airspace segment is the most accurate predicted. The three stacks have the most optimal average for the difference, while the R-square of EHRIVER is the lowest of the airspace segments. The MFE is for all the segments between -0.5 and 0.5, so there is not an extreme

forecast error. Again, the stacks have the best MFE while these are the closest to zero. The airspace segments with a negative average difference and a positive MFE do have a that the hypothesis of the Wilcoxon test must be rejected. The accuracy of the airspace segments differs and there are possibilities to improve.

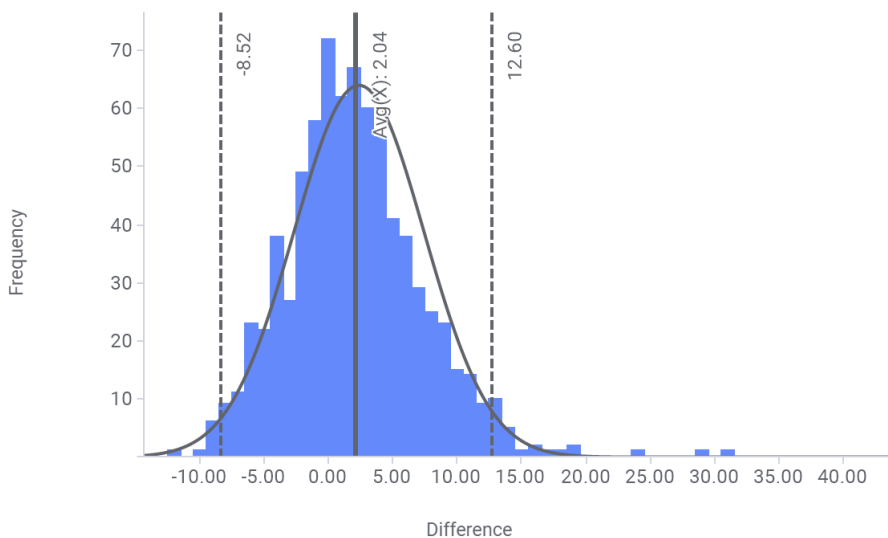
Table 12. Summary of statistics all airspace segments

Airspace segment	Average difference	Standard deviation	% standard deviation of total	MFE	Percentage (R-square)	Decision to hypothesis of Wilcoxon test
EHSECT2	-0.21	3.66	19.6	0.214	92.3	Reject
EHSECT3	-0.21	3.62	18.9	0.210	92.6	Reject
EHARTIP	0.07	2.62	23.8	-0.068	90.8	Retain
EHSUGOL	0.15	2.50	28.4	-0.153	90.3	Retain
EHRIVER	0.04	2.27	32.9	-0.045	83.8	Retain
EHFIRAM	0.32	4.20	15.7	-0.320	95.8	Retain
EHAM Arrival South	0.31	4.26	16.0	-0.309	95.8	Retain
EHAM Arrival North	0.30	4.26	16.0	-0.309	95.8	Retain
EHAM Departure South	-0.34	4.49	16.8	0.341	95.8	Reject
EHAM Departure North	-0.34	3.83	14.3	0.341	96.9	Reject

### 5.3.2 Statistics on peak hours of EHFIRAM

The distribution of the difference of all the peak hours together of EHFIRAM (Graph 19) appears to be a normal distribution. When only the first or the last peak is visualised in a distribution (Appendix XX), the distribution is still normal and has more extreme values. This is probably because there is a lower amount of values in that dataset.

Distribution difference peak hours EHFIRAM



Graph 19. Distribution difference peak hours EHFIRAM

The average difference is 2.04 for the EHFIRAM peak hours. The two dotted lines are the average plus two times the standard deviation. A summary of the averages and standard deviations of the EHFIRAM peak hours, including the first and fifth peak hour are in Table 13.

Table 13. Average and standard deviation EHFIRAM peak hour

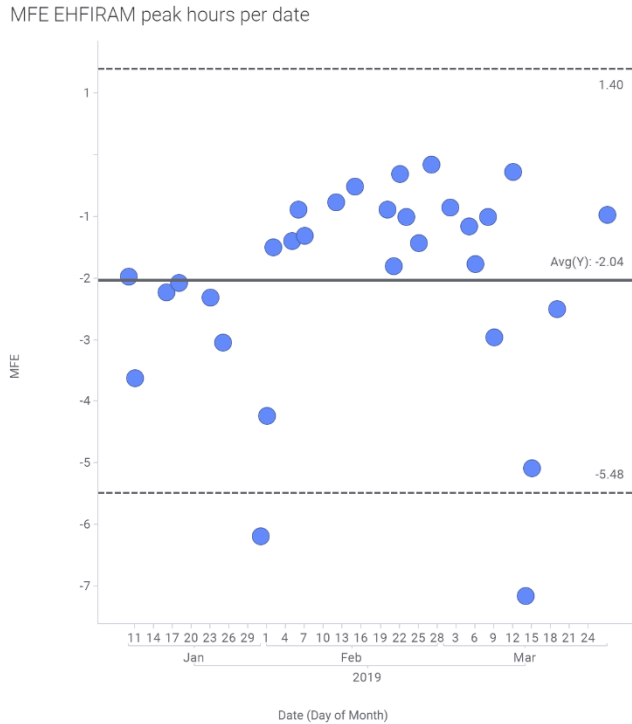
Airspace segment	Average difference	Average difference in aircraft per hour	Standard deviation	Average total a/c per hour	% standard deviation of total
EHFIRAM peak hours	2.04	1 aircraft per half hour less in D0 than predicted	5.28	44.4	11.9
EHFIRAM 1th peak hour	2.67	1 aircraft per 20 minutes less in D0 than predicted	5.87	53.9	10.9
EHFIRAM 5th peak hour	1.37	1 aircraft per 45 minutes less in D0 than predicted	5.52	42.0	13.1

The standard deviation is also calculated per hour rolling per 20 minutes to obtain more insight into the accuracy during the day. The percentage standard deviation of the average total aircraft per hour presents the percentage of deviation per hour (Table 14).

Table 14. Standard deviation and percentage standard deviation of average a/c per hour

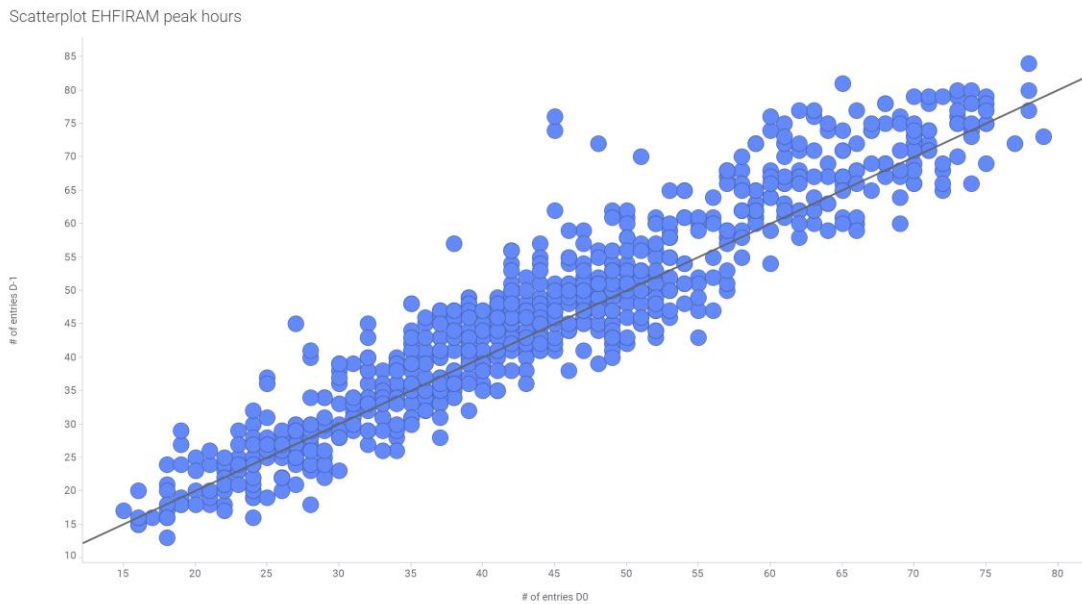
Time	00:00:00	00:20:00	00:40:00	01:00:00	01:20:00	01:40:00	02:00:00	02:20:00	02:40:00	03:00:00
Average a/c per hour	1.23	0.93	0.47	0.17	0.43	1.57	2.27	2.93	3.60	6.30
Standard deviation	1.07	0.63	0.74	0.58	0.79	1.04	1.18	1.30	1.54	2.18
%	86.5	67.4	158.5	350.0	183.3	66.4	52.2	44.2	42.9	34.5
Time	03:20:00	03:40:00	04:00:00	04:20:00	04:40:00	05:00:00	05:20:00	05:40:00	06:00:00	06:20:00
Average a/c per hour	10.57	12.60	13.03	12.77	18.97	30.10	36.50	47.50	62.50	70.93
Standard deviation	1.82	1.77	2.50	2.80	3.39	3.64	3.22	4.21	3.87	4.16
%	17.21	14.06	19.16	21.92	17.86	12.09	8.83	8.87	6.2	5.9
Time	06:40:00	07:00:00	07:20:00	07:40:00	08:00:00	08:20:00	08:40:00	09:00:00	09:20:00	09:40:00
Average a/c per hour	62.20	43.73	33.40	32.27	34.70	36.30	36.73	42.77	43.67	41.40
Standard deviation	3.78	3.78	3.41	4.18	3.44	4.47	4.57	5.11	3.11	4.90
%	6.07	8.63	10.22	12.96	9.91	12.31	12.44	11.95	7.13	11.83
Time	10:00:00	10:20:00	10:40:00	11:00:00	11:20:00	11:40:00	12:00:00	12:20:00	12:40:00	13:00:00
Average a/c per hour	31.93	29.17	35.20	43.33	45.20	39.27	28.43	25.43	26.63	30.80
Standard deviation	4.01	3.13	4.36	3.50	3.71	3.26	3.62	3.82	3.29	4.45
%	12.56	10.75	12.39	8.08	8.20	8.31	12.7	15.0	12.3	14.4
Time	13:20:00	13:40:00	14:00:00	14:20:00	14:40:00	15:00:00	15:20:00	15:40:00	16:00:00	16:20:00
Average a/c per hour	45.67	52.80	49.83	34.57	23.33	22.80	23.83	25.03	22.80	32.17
Standard deviation	4.65	4.34	4.76	4.04	3.56	4.00	3.45	3.47	2.92	3.75
%	10.18	8.23	9.54	11.68	15.27	17.53	14.48	13.85	12.81	11.64
Time	16:40:00	17:00:00	17:20:00	17:40:00	18:00:00	18:20:00	18:40:00	19:00:00	19:20:00	19:40:00
Average a/c per hour	44.30	61.83	66.87	57.47	43.70	29.77	31.60	27.73	22.70	18.60
Standard deviation	6.14	7.73	8.60	5.20	3.64	6.30	3.37	3.02	2.53	3.06
%	13.86	12.50	12.87	9.04	8.3	21.2	10.7	10.9	11.2	16.4
Time	20:00:00	20:20:00	20:40:00	21:00:00	21:20:00	21:40:00	22:00:00	22:20:00	22:40:00	23:00:00
Average a/c per hour	20.13	21.97	18.67	14.80	11.23	7.83	6.00	4.60	3.57	0.00
Standard deviation	2.97	3.17	2.44	2.67	2.96	2.09	1.68	1.28	1.70	0.00
%	14.74	14.45	13.08	18.06	26.32	26.69	28.08	27.93	47.68	-

The MFE is calculated for all the peak hours together and is visualised per date in a graph (Graph 20). The values of the MFE per date are in Appendix XX. The average the MFE of the EHFIRAM peak hours is -2.04, which indicates there is often less aircraft at D0 than predicted. There are two dates were the MFE lower than the line for the average minus two times the standard deviation.



Graph 20. Average MFE EHFIRAM peak hours per date

The number of entries of D-1 and D0 are set to each other to create a scatterplot. This is performed for all the EHFIRAM peak hours (Graph 21) and the first and fifth peak hour of EHFIRAM (Appendix XX).



Graph 21. Scatterplot EHFIRAM peak hours

The deviation of the dots compared to the grey line in is expressed in the R-square (Table 15). This provides the percentage of accurately predicted values.

Table 15. R-square EHFIRAM peak hour

Sector	R-square	Percentage
EHFIRAM peak hours	0.887	88.7
EHFIRAM 1th peak hour	0.871	87.1
EHFIRAM 5th peak hour	0.912	91.2

The accuracy of the prediction is again checked with a significance test. The demand of D0 and the demand of D-1 are visualised in a histogram to determine if the distribution is normal, which appeared this was not normally distributed. The demand is converted with a log-transformation, to see if it then is normal distributed (both histograms in Appendix XX). This was still not the case, so again a t-test is not allowed to perform. The Related-Samples Wilcoxon Signed Rank Test is performed (Table 16). The significance is still 0.05, which means above this value, the hypothesis must be retained and below this value, the null hypothesis must be rejected.

Table 16. Related-Samples Wilcoxon Signed Rank test EHFIRAM peak hour

Sector	Significance	Decision to hypothesis
EHFIRAM peak hours	0.000	Reject
EHFIRAM 1th peak hour	0.000	Reject
EHFIRAM 5th peak hour	0.001	Reject

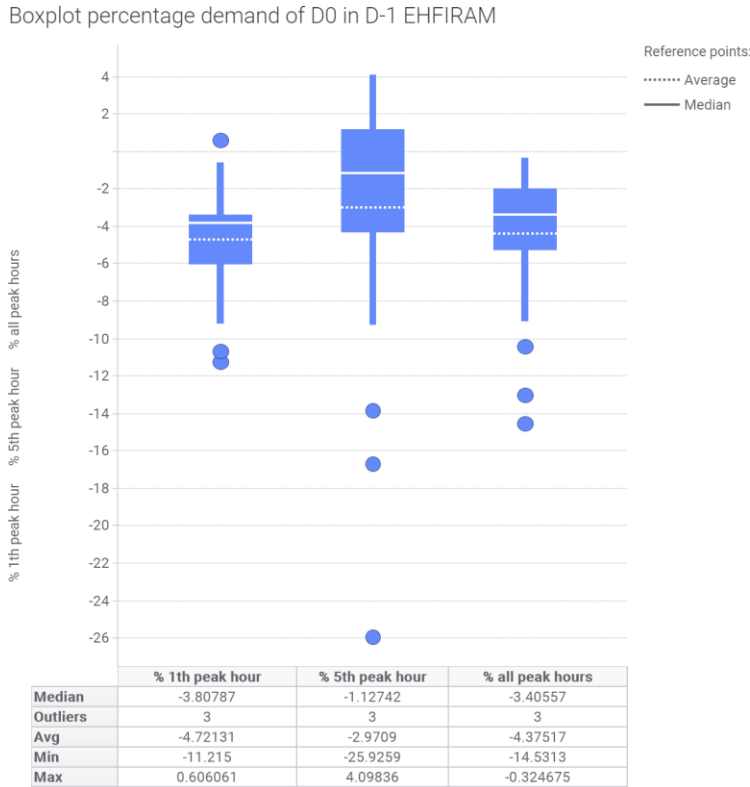
To obtain a more detailed view of the accuracy between the peak hours, there is researched what the percentage more or less demand provided in D0 is compared to the demand predicted in D-1. If the percentage is negative, there is less demand at D0 than D-1 and vice versa. The percentages per date for all the EHFIRAM peak hours, the first and the fifth peak hour are provided (Graph 22). It is important to identify if the percentage is above or below zero (black horizontal line). If the percentage is close to zero, it means that the same amount of flights enters the airspace segment at D0 as at D-1, which is optimal.

Percentage demand of D0 in D-1 per date EHFIRAM



Graph 22. Percentage more or less demand of D0 compared to D-1 per date EHFIRAM peak hours

To summarize the graph in Graph 22, a boxplot is made for the EHFIRAM peak hours, first and fifth peak hour (Graph 23). To visualise them next to each other, the differences in the accuracy of the first and the fifth peak hour is clarified. The percentages of all the peak hours together are between the values of the first and fifth peak hour.



Graph 23. Boxplots percentage demand of D0 compared to D-1 EHFIRAM peak hours

### Results

The analysis of the EHFIRAM peak hours is performed to provide more detail in the accuracy in the peak hours and if this is better or worse compared to when all the hours of EHFIRAM are used. Therefore, the statistics of EHFIRAM peak hours are set next to the statistics of EHFIRAM (Table 17). Focussed on the peak hours the statistics are significantly less compared to the general EHFIRAM. The more significant positive difference and higher negative MFE indicate that there is often more predicted than the demand is at D0. The value of the R-square is lower but still representative. Therefore, the hypothesis of the Wilcoxon test must be rejected. Overall the fifth peak hour has better statistics compared to the first peak hour. The values are worse compared to EHFIRAM in general because the dataset is smaller.

Table 17. Summary of statics of EHFIRAM peak hours

Airspace segment	Average difference	Standard deviation	% standard deviation of total	MFE	Percentage (R-square)	Decision to hypothesis of Wilcoxon test
EHFIRAM	0.32	4.20	15.7	-0.320	95.8	Retain
EHFIRAM all peak hours	2.04	5.28	11.9	-2.04	88.7	Reject
EHFIRAM 1th peak hour	2.67	5.87	10.9	n/a	87.1	Reject
EHFIRAM 5th peak hour	1.37	5.52	13.1	n/a	91.2	Reject

When focusing on the standard deviation per peak hour, this standard deviation is smaller for every hour in the first peak, compared to the standard deviation of the whole first peak hour. This is because in the first hours (around 05:40) there is often less predicted than at D0, while in the later hours (around 6:40) there is often more predicted than at D0 (Graph 5). The standard deviation of the first peak hour together higher while this includes more deviation because of a more significant difference between the first hours and the last hours of the first peak hour. It is of importance for determining the accuracy, this is also dependent on the time of the day. During the peak hours, the standard deviation together with the percentage deviation is smaller than outside the peak hours.

The D0 demand more or less of D-1 demand within the peak hours provides the accuracy of the prediction with a value for the percentage of flights not corresponding with D-1. For the first peak hour, this is for approximately the whole period a negative percentage between -3 and -6 percent, with outliers till -11 percent. This indicates less flight in D0 than predicted. For all the peak hours together, this percentage is almost the entire period negative. The fifth peak hour has higher deviations in the percentage, both positive and negative between 3 and -4 percent and high negative outliers (maximum of -26 percent). The maximum positive value is 4 percent.

### 5.3.3 Vision of experts

With the desk research, it is learned that the FMPCs and the supervisor are working in the operation and some of them are involved in the D-1 project. Within the operation, air traffic controllers, but mostly the supervisors and the FMPCs use the demand and capacity prediction. Their vision is representative for the influence of the D-1 prediction on the operation. The supervisors and the FMPCs regulate the capacity regarding the demand. The supervisors and FMPCs who are involved within the D-1 project, have seen some D-1 plans. These plans were not yet used for the operation to regulate because not everyone in the operation is familiar with it. Two FMPCs and one supervisor who are involved in the D-1 project will be interviewed. These people will have an idea of how the operation will be with the D-1 prediction and without. Currently, four supervisors and four FMPCs are involved in the D-1 project. There is chosen for only supervisors and FMPCs because the air traffic controllers do not use the predicted demand data for the rest of the day. Only the supervisor and FMPC use the figures where the future demand is visualised and regulate on this.

Three interviews are performed with one supervisor ACC and two FMPC ACC. The questions in Appendix III are asked, providing some statistics (

Table 8) and demand graphs (Appendix IX). These interviews are transcribed and provided in Appendix XXI.

#### Results

One supervisor (Nieuwenhuijs, 2019) and two FMPCs (Lautenbach, 2019) (Geurten, 2019) are interviewed about the D-1 plan within the operation and about the accuracy of the prediction and if this reliable enough to use for the operation. The FMPC and the supervisor monitors the demand and capacity for the Dutch civil airspace and for the airports with civil aviation. The supervisor has the main responsibility. The FMPC has more knowledge about the system and must notice overloads and provides advice to the supervisor. The FMPC is also Flight Information Service Officer (FISO) for the Visual Flight Rules (VFR) traffic. In the night the FMPC is only FISO. The findings of the interviews are split into information about the D-1 plan within the operation and about the accuracy of the D-1 prediction. The information of these subjects is divided into primary results and secondary results.

#### **D-1 plan within the operation**

Primary results:

- The D-1 plan should be the start for pre-tactical regulations, which is important to perform. If the D-1 plan is received a day before the operation, the LVNL can proactively set some restrictions for the next day till 12:00LT, instead of every morning

at 4:30LT. It would be useful if this D-1 plan is received in the morning of D-1, to regulate in the evening of D-1. This creates a more predictable process. It is preferred to regulate in forehand than last minute. If more information is received at D-1 the enormous restrictions will be less, and the prediction will provide more tranquillity because only fine-tuning is necessary. For the FMPC it would be an improvement to know the capacity and demand earlier while in the night it is often not possible to perform FMP activities. D-1 plan indicates the expected demand but that are no exact numbers.

- The D-1 plans the supervisor and FMPCs received to provide feedback on, were sometimes correct and sometimes not at all because of significant weather disruptions. With these disruptions, there is less accurately predicted. Nevertheless, the quality of the D-1 plans is improving during the time.

#### Secondary results:

- All the relevant information joined in one document is very useful, which includes at least: the demand, accurate weather conditions with the expected runway combinations, maintenance activities at Schiphol, special flights, activity in the military sectors and if these are available to use by LVNL and system degradations. In general, activities which reduce the capacity and maybe an estimation of the percentage of reduction and the probability for large deviations. The graphs with the demand should be adjusted with the expected reduction and should be more specific.
- The supervisors and FMPCs are sometimes uninformed because the information is in different places or there is not well communicated.
- If the D-1 project is implemented there might be training necessary because a different way of managing is implemented. The people within the operation are open for the chances. The air traffic controllers will appreciate if there will be a small graph with the expected operation of the day regarding capacity and the reason for possible disruptions. The stability of the total network will improve, which is important. It might be useful to send the expected capacity of the LVNL to the stakeholders in the afternoon at the day before operation, so they are more prepared.
- The current demand predictions used in the operation are based on flight plans and up-to-date position in the air if airborne, focused on the demand hourly demand rolling, demand per 20 minutes and the workload. The FMPC monitors 3 to 4 hours ahead while the supervisor monitors 4 till 6 hours ahead to create a plan with the expected demand. The nominal capacity is a monitoring value, it determines where the peaks are and where too much demand is. Depending on the configuration of the traffic, it is necessary to regulate which is performed by the supervisor of tower and ACC. The current moment to regulate is too late which is something that must change. There must come more alignment with the network manager of Eurocontrol.
- Occupation of the air traffic controller is not determined with the predicted demand for the next day but is a standard for the day of the week based on the expected demand. 98 percent of the days there is a pleasing occupation. Although, often there are too many people, however, this is to have a buffer for unforeseen event.

#### Accuracy of the D-1 demand prediction

##### Primary results:

- There are three different opinions about the usability of the D-1 prediction. The supervisor considers the D-1 prediction as useful for the operation. Although it is sometimes difficult if there are more aircraft than predicted, however, this depends on the distribution over the hour. The deviation is acceptable because it is never possible to obtain zero deviation. Still, the supervisor and FMPC must always be aware of the demand for the next 4 to 6 hours. One FMPC doubts if the PREDICT data used of Eurocontrol is even the best option. He considers the standard deviation as high, while it is more than 10 percent, which is not accurate enough to use for regulations. An option might be to create a PREDICT within LVNL, instead of using the data of the network manager. It is not always positive to be dependent on others. An acceptable deviation would be 10 percent of the traffic. The other FMPC agrees

with the 10 percent deviation if it is 5 percent above or 5 percent less. The standard deviation of sector 3 is high, a maximum of 2 would be better. But it depends on the traffic, regional traffic requires more workload than mainport traffic.

- It is preferred to have a higher demand predicted than more demand at the day of operation, and to remove a regulation than make a new regulation last minute. A risk will be that the people might think there is always less demand at D0 than predicted, which might result in risky assumptions and undesirable situations.

#### Secondary results:

- The stacks are the most important airspace segments because these are the most limiting in traffic demand, therefore, the airspace segment that has the most regulations. These together create the EHFIRAM. If there are high peaks in the demand of EHFIRAM, it is possible that this demand is evenly distributed between the stacks and therefore the workload is still acceptable. If there is an overload in the demand of EHFIRAM, the stacks are researched to find the problem, if there is one stack that has the most limiting demand. Principally the inbounds are monitored. Sector 3 is a complex sector which causes pressure, although this sector is possible to divide by different controllers. Also, sector 2 is a crowded sector.
- There is a buffer in the capacity because of bunches. The bunches in the peaks are because of the deviation of 15 minutes in the slot time.

## 6. Conclusions

This research aimed to identify *the reliability of the traffic demand prediction for the day of operation on the day before operation at Schiphol and LVNL controlled airspace*. The conclusion is based on the findings of the qualitative and quantitative analysis of the D-1 prediction with the last submitted flight plans at D0, together with the assumptions and scope made. The D-1 demand prediction of the first three months of the D-1 trial, containing January, February and March, is not usable enough in the operation to make regulations for the day before the operation. There is no unambiguous answer to the reliability of the D-1 prediction, while further research is necessary with more factors. However, some parts of the D-1 prediction are reliable enough for the operation, while the accuracy varies during the day. The answers provided on the sub-research questions are based on the scope and assumptions made.

To answer *what the differences between the D-1 traffic demand prediction and the demand at the day of operation are and what causes can be for these differences* two types of differences are analysed: the difference in the number of entries (demand) and the difference in entry time. First, it was necessary to determine the D-1 traffic demand dataset and the dataset used for the demand at D0. The D-1 traffic demand prediction is the PREDICT data received from Eurocontrol which contains historical flight data that is enriched with flight intentions based on schedule data of airlines, airport slot data and a snapshot of the night before with the last received data such of submitted flight plans. The D0 demand data is the data with the last submitted flight plans of the aircraft operation in the IFPS. This data is processed in the ETFMS to calculate the 4D trajectories to obtain a dataset with entry times.

For every airspace segment, the average demand of D-1 is higher during peak hours compared to D0 when visualized in a graph per hour rolling per 20 minutes. Outside the peaks, there is often less demand in D-1 than D0. The distribution of the difference per hour rolling per 20 minutes provides that there is often more variation in the difference around the first and last peak hour. The variation of the difference over the day for sector 2 and the arrivals at Schiphol is the highest, while for the departures at Schiphol this variation is the lowest. When the difference is visualised per date, the days with the highest difference value are related to the days with special conditions. For the other days, if there is a positive difference for two till four airspace segments, there is often a negative difference for the other airspace segments. The average difference for all the airspace segments is between -0.34 and 0.30, while focused on the peak hours of the EHFIRAM the average difference is in the first peak hour is 2.67 and the fifth peak hour 1.37, which confirms that there is more predicted compared to the demand of D0 in the peak hours.

The difference in entry time for a flight is on average negative or null for all the airspace segments, even though the percentage of flights that arrive earlier is often higher. This is because there are more extreme values in aircraft that arrive later than aircraft that arrive early. The reasons for the difference in entry time are because a flight is:

- later than predicted;
- earlier than predicted;
- not predicted or not present in D0, depending on which dataset is compared to which dataset.

For sector 2, sector 3, the three stacks and the EHFIRAM is the most flights arrive earlier than predicted. For the departures at Schiphol, the highest percentage of flights are on time and for the arrivals at Schiphol, the highest percentage of flights earlier or later depends on the comparison, D-1 with D0 or D0 with D-1. If a flight is not predicted in the same sector or the same stack, it is possible that the route of a flight changed between the prediction and the filed flight plan. For sector 2 the most flights moved to sector 3, for sector 3 the most flights moved to sector 2, for the stack ARTIP the most flights moved to RIVER, for SUGOL the most flights moved to RIVER and for RIVER the most flights moved to ARTIP.

For EHFIRAM, EHARTIP, EHSUGOL and the arrivals at EHAM the percentage of flights earlier are the most in the morning, while later in the day the earlier flights become less and the flights later become more. This is because, in the data of D0, which is the last filed flight

plan, the delays during the day are implemented. The flight plan of the next flight is influenced by the delays the aircraft obtained during the day. The number of early or late arriving aircraft deviates during the day for EHSECT3 and EHRIVER. For EHSECT2 this is more constant during the day.

*The accuracy of the D-1 demand* differs per airspace segment. The airspace segments are ranked for per statistical analysis, which is visualised in Appendix XXII. For some statistical analysis, the airspace segments score high, while another analysis contradicts this. There is no uniform answer of which airspace segment has the best accuracy or if the airspace segments are accurate enough.

Based on the average difference, standard deviation, MFE and the Wilcoxon test, the three stacks score the best. However, when the standard deviation is compared to the average number of flights per hour, this value is high. The best standard deviation value of the total has the departures at Schiphol, the EHFIRAM and the arrivals at Schiphol. These three do all have high a percentage for the R-square. Only for the departures the result of the Wilcoxon test is inadequate. The percentage of the standard deviation of the average flights per hour of the first peak of the EHFIRAM is the finest compared to the others, because of the average total flight per hour is more accurate because there is less deviation in the values. The standard deviation and percentage are more accurate if focused per hour instead of the standard deviation of the whole first peak hour. The standard deviation deviates during the day and is the most accurate between 05:20 and 07:00, between 11:00 and 11:40, between 13:40 and 14:0 and between 17:40 and 18:00 if focused per hour. The standard deviation is high (above 10 percent of the average aircraft per hour) at the start of the day till 05:00 and at the end of the day starting from 18:40.

*The quality of the D-1 prediction influences the day of operation and the prediction might not be reliable enough for the day of operation*, which is based on the vision of a supervisor and two FMPCs. If the D-1 demand prediction of the first three months of the D-1 trail reliable enough is for the day of operation is questionable because of different opinions. The supervisor was positive about this accuracy, however, mentions that it is difficult if there are more aircraft at the day of operation than predicted if these are not nicely distributed over the hour. The two FMPC consider the accuracy as insufficient because the deviation of the standard deviation is more than 10 percent of the total flight in the hour. This accuracy should not exceed 10 percent. The most crucial airspace segments for the operation are primarily the stacks (because of the traffic distribution between those) and the EHFIRAM. Secondly, sector 3 while it is a complex sector with different traffic flows. The EHFIRAM is the airspace segment that requires the most attention to regulate and is the most limiting airspace segment. These airspace segments should be predicted the most accurate.

When the D-1 plan is received, including the D-1 demand prediction, it is possible to start earlier with setting restrictions and making regulations. This creates a more predictable process and more stability. It is preferred to regulate more in advance than last minute. The large adjustments will be less, so only some fine-tuning is necessary. Currently, the FMPC monitors only 3 till 4 hours ahead and the supervisor 4 till 6 hours ahead. To set a restriction earlier, a reliable and consistent prediction is of importance. This importance is visible as well at KLM. The DMO of KLM prefers more proactive steering for the next day and wants the expected capacity at the morning of D-1. KLM uses this capacity for determining if they have to cancel or delay flights, which is important to determine early to prevent circumstances whereas KLM has to pay compensation. When the plan is early made, it is possible to transfer passengers, even from ICA flights. The effect of a capacity reduction for an airline is challenging, especially when this was not known in advance and there was not anticipated to it, while a delay continues throughout the day. KLM desires that LVNL provides a substantiated capacity on the morning of D-1. Therefore, it is relevant to have this capacity well predicted, which presents the relevance of an accurate D-1 prediction within LVNL.

*The reliability of the D-1 prediction can be improved*, mainly focusing on the accuracy of the D-1 prediction. This is necessary to make the D-1 prediction usable enough for the operation, which supports the supervisors and FMPCs in their work. Improvements are possible in

different areas. If focused on the D-1 prediction data, the PREDICT data created by Eurocontrol, more inputs should be implemented in the data such as weather conditions or special conditions such as a strike. Eurocontrol receives less information or feedback of the ANSPs, which is necessary to improve the PREDICT data. Another option is to create the D-1 prediction data within LVNL, based on the information of their operation. Other improvements will be found by performing further research, which will be mentioned in the discussion (see chapter 7).

#### **Retain or reject the hypotheses**

Hypothesis 1: The D-1 demand prediction deviates not significant compared to D0 demand.

This differs per airspace segment, while the statistical values differ per airspace segment. The prediction is per airspace segment for some statistics and at some moments of the day accurate. Nevertheless, based on the assumptions and scope, the D-1 demand prediction of the first three months is not reliable enough to use in the operation, due to the differences in predictions, which make it difficult to regulate on. There is no unambiguous answer to the reliability of the D-1 prediction. This hypothesis must be rejected while is not confirmed on every part of the D-1 demand prediction. This supports the answer to the main research question, while there is no uniform answer.

Hypothesis 2: The D-1 demand prediction part of the D-1 plan and has a positive effect on the day of operation.

This hypothesis is retained, which is supported by the supervisor, FMPC and the DMO of KLM, even though the accuracy might still be improved.

## 7. Discussion

This research was to provide more insight into the D-1 demand prediction used within the D-1 plan for the operation. This resulted in the main research question: *How reliable is the traffic demand prediction for the day of operation (D0) on the day before operation (D-1) at Schiphol and LVNL controlled airspace?* The conclusion is that most of the parts of the D-1 demand prediction researched are not usable enough for the operation for making regulations on the day before the operation. To develop this answer, different research methods were executed, assumptions and interpretations are made for the analysis (see section 7.1) and there were some limitations which appeared during the analysis (see section 7.2). Some of these choices are worth to discuss, because other choices, assumptions and scope might result in another conclusion. The results and conclusions of this research provide new insights into further researches (see section 7.3), which will provide more improvements for this research.

### 7.1 Research methods and interpretations

For the analysis, the choice was made to compare the PREDICT data of Eurocontrol with the last submitted flight plans of the aircraft operations. To use the PREDICT data as D-1 data is coherent because this data is used to produce the graphs in the D-1 plans which should be validated. For the D0 data, there were other options, such as the actual operation or a snapshot in the morning of the expected demand for that day. If the PREDICT data is compared to one of these, there might be different results.

During the analysis of the difference in entry time, there is no margin used for flights 'on time'. In this research, the difference in entry time between D-1 and D0 must be zero exactly to consider a flight on time. This might be too restrictive because, for most of the airspace sectors, almost no flights are on time.

There are other statistical methods possible to measure the accuracy of a prediction. Five methods were chosen for analysing the accuracy. However, other statistical methods might provide another ranking for the conclusion of the most accurate airspace segment. Nevertheless, the methods used provide a representative result.

Due to the scope, during this research, there is mostly focused on the differences between the two datasets. There was no research that concentrated on the causes of these differences for particular flights or during moments of the day.

The choice was made to interview three people working within the operation of LVNL, however, with the opinion of these three, it is not possible to provide a final answer about the reliability of the prediction for the operation. To provide a more decisive answer, more experts should be interviewed about their opinion about the accuracy of the D-1 prediction. The approach to determine the accuracy of the D-1 prediction is valuable, so the statistics measured are usable to present the next experts. The opinion the experts provided about the maximum deviation, there must be considered that they compare their operational margins of deviation with the deviation of a prediction. The 10 percent they are used now in the operation is a buffer of the reality, based on that there is no insight into the expected demand. The calculated value in this research is a margin for the prediction. Nevertheless, the uncertainty of the prediction is more than 10 percent, this does not mean that the prediction is not usable at all.

### 7.2 Limitations

Eurocontrol did not implement the strike of Skeyes in their data, even though it was already known at the day of retrieving this PREDICT data. The aftermath of this strike was not traceable because there is no D-1 data of the day after the strike, because there was no D-1 plan made for this day.

There were three months of data available for this research, containing 33 trial days with data. After filtering, there were 30 days left to perform the analysis on. These days were necessary

to filter to obtain a more representative view about the accuracy of the prediction. However, there must be kept in mind that when the prediction will be used in the operation, special days can always occur, and it must be possible to anticipate this. During the data analysis, when focusing on smaller parts of the data, it appeared that when the number of values becomes less, the accuracy also becomes less. It is possible that if more data is available and the same analysis is performed, the accuracy becomes better.

The peak hours provided by the LVNL do not match exactly with the peaks of the demand measured in the data. The measured demand per hour rolling per 20 minutes fit better in the peak hours than the demand per 20 minutes, therefore, the analysis of the EHFIRAM peak hours are performed with the demand per hour rolling per 20 minutes. The results might differ from the demand per 20 minutes will be used. Still, the analysis might not provide a representative accuracy of the peak hour.

### 7.3 Further research

The accuracy may be different if the research is performed in a different way when other parts are considered. To make it possible to provide a definitive answer to the reliability of the D-1 prediction, further research is necessary, considering other elements. To improve or obtain more knowledge about the accuracy and reliability of the D-1 prediction, there are further research options:

- Use another D0 dataset.  
There are other options for the dataset of D0 to compare with the PREDICT data, most suitably a snapshot of the operation. This data of the snapshots should first be captured before the research is possible to perform. This research might present other results about the accuracy and together with the research performed in this thesis, it would provide extra quality and importance. However, within a snapshot in the morning, not all the flight plans are received of flight in the evening causing the analysis not representative for the whole day.
- An extended period of data for the analysis.  
To acquire more insight into the D-1 demand prediction, the same data analysis should be performed again with data of a more extended period for a more representative view on the accuracy of the D-1 prediction.
- Improve D-1 dataset.  
Further investigating into the PREDICT data is necessary to improve the current dataset, which should improve the accuracy of the D-1 demand prediction. Other options for the D-1 are possible, therefore, investigation to options to create a prediction within LVNL is necessary.
- Analysis of the causes of differences for particular flights or moments during the day.  
More detailed research, with the knowledge of this research, should be performed to obtain more insight into the causes for the differences. During this research there is only focused to explain high deviations by causes already known at D-1, or reasons for differences in general. If the causes for the other differences will be prevented, the prediction will improve.
- Consult more experts within LVNL.  
The opinion about the reliability of the D-1 demand prediction for the operation by the experts was not decisive. To obtain a decisive opinion about this reliability and usability, this research must be extended to consult more experts, presenting the same results as found within this research.

When the assignment was provided six months ago, at the start of this graduation internship, different research was expected. The main research question was then: *Is the D-1 project the most effective way to provide all information to all relevant stakeholders about the day of operation with regards to the capacity at Schiphol Airport and the surrounding airspace?* This question was impossible to answer within five months, while it was not specific enough. With all the results and conclusions found with this research, as performed, together with further research, it is possible to answer this broad question.

## 8. Recommendations

The main conclusion is that the D-1 demand prediction of the first three months of the trial is not usable enough for the operation, which is based on the findings of the qualitative and quantitative analysis of the D-1 demand prediction of Eurocontrol with the last submitted flight plans at D0, together with the assumptions and scope made. To provide a definitive answer to the reliability of the D-1 prediction, further research is necessary with more factors included. A more detailed analysis will obtain more insight into the D-1 prediction. Based on the conclusion of this research, the accuracy must be improved to obtain a safe and reliable D-1 demand prediction to be used in operation. There are different possibilities to improve the accuracy, explained in the conclusion and discussion. These additional research or analysis activities should be performed to finally create an accuracy with a maximum of 10 percent deviation of the average total aircraft per hour. This is a maximum of 5 percent more predicted or 5 percent less predicted. Preferably, the prediction should be a bit higher than the demand at D0, to be safe.

It must be kept in mind that this research showed that the accuracy varies during the day and that at some moments of the day the accuracy is acceptable. Some statistics present that the prediction is accurate while the other statistics contradict this. Some parts of the prediction might already be useful for the operation, as long as it is anticipated that the prediction might deviate.

The information mentioned in the D-1 plans, next to the demand figures, are of extra value for the operation and support the supervisor and FMPC to be more prepared for the day of operation. If there is more relevant information that reduces the capacity, this must be added in these plans. This should be a process of continuous improvement.

The D-1 project should be continued because it will decrease the workload, predictability for the day of operation. If more data is available, a more detailed evaluation should be done about the whole D-1 project. Also, the accuracy of the D-1 demand prediction should be improved. When this is all finished, the D-1 project is ready to be implemented.

The relevance of D-1 project is visible at KLM. An expected capacity at the morning of D-1, based on the expected demand, supports the KLM a lot to prevent last-minute restrictions. A last-minute reduction in the capacity is expensive for the KLM because it is then not possible anymore to transfer the passengers, which means KLM has to pay compensation. Wrong capacity information provided by the LVNL is not possible, because the KLM understands that the circumstances are possible to change. The recommendation would be to have more communication between the KLM and the LVNL, and for LVNL to provide earlier the capacity based on the D-1 prediction. KLM would rather receive something than nothing, even when the D-1 prediction is not accurate, when it is at least substantiated. The DMO wants more consistency and information about the capacity and it is up to the LVNL to provide this information. In the runway tool KLM uses to determine if flights are necessary to delay or cancel, it is possible to load the capacity with the AFOS tool, when no capacity is received of LVNL. LVNL uses the AFOS tool as well in the trial of D-1, for the D-1 plan. If the AFOS tool is going to be used in the operation by the LVNL, it might be that it helps the LVNL to provide a more consistent capacity. KLM currently experiences that there is often a different capacity provided, even when the weather conditions are the same. KLM hopes that with AFOS, when there is the same weather predicted, also the same capacity will be provided. A recommendation for the LVNL will be to make more use of the tool AFOS for providing a more consistent capacity.

The focus of this research was on the demand of Schiphol. Also, the traffic of Rotterdam, Eindhoven and Lelystad is important to research in detail, because the traffic of these airports is also part of the sectors. To obtain insight into the whole system and the complete accuracy of the D-1 prediction, more research should be executed with the focus on the sectors and inbound and outbound traffic of Rotterdam, Eindhoven and Lelystad. Another

recommendation will be to obtain more insight into the D-1 traffic demand prediction, by performing more detailed research towards the causes of the differences.

For the analysis of the difference in entry time, no margin is used to consider a flight on time. With a margin, more flights will be considered on time, causing a different distribution. The value of this margin is debatable and could be up to 30 seconds, 1 minute, 5 minutes or minus 5 and plus 10 minutes, depending on how strict the margin is measured. Within the analysis of the difference in entry time, further research, which provides insight into the origin of the traffic that arrives earlier, later or on time will be valuable. Origin of the traffic, departure airport or aircraft type might influence the entry time of an aircraft.

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## D-1 prediction

### *Validating and improving the prediction of the demand at the day before operation*

Thesis

## Appendices

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## Appendix I. Reflection

This research is the result of the graduation internship at the Knowledge and Development Centre – Centre of Excellence. The personal reflection of this internship is divided in two parts. The first part is the reflection about the assignment, what skills and knowledge were developed and what challenges there were. The second part is about the support and working methods of the KDC and LVNL.

### The assignment

When I started the internship in February 2019, I had not much knowledge about Air Traffic Management (ATM). I had to learn more about the ATM, as this was necessary to understand the assignment. The subjects during this internship are not technical, however, during my study I learned more about engineering. Therefore, the start was very challenging, because I had to understand the assignment, the operational process and how the ATM works. I gladly accepted this challenge because I really wanted to learn more about these subjects.

Defining a problem that was realistic to research and answer within five months was challenging. Not only did I had to learn a lot before understanding the problem, but also because the assignment was vague and there were different opinions about how the assignment should be approached. Two people within the LVNL were directly involved in my research and helped me to scope the problem. However, a lot of stakeholders are involved in the research, for example other people of the LVNL, people within the KDC and the HVA. They all had an opinion about the research, so to really define the exact assignment was challenging.

For analysing the problem, the main focus was data analysis. Before this internship I had never analysed datasets of this size. Therefore, when I started, I was doubting if I could do all the analysis expected of me. For the data analysis I tried multiple programs I had not used before, such as: Tableau, TIBCO Spotfire and Python. I decided to continue with TIBCO Spotfire and I am gladfully that I was able to learn a lot about this program and that the data analysis succeeded with this program. Also, other programs I already used before, such as Microsoft Excel and Visio, were used again during this internship and therefore I became more experienced with these.

To obtain information for the research, I had to talk to a lot of experts. By doing this, I developed the competence to approach people and to not be afraid of this communication.

I am delighted about the challenges. I appreciate the knowledge and skills I developed by doing this assignment.

### Support within KDC

The KDC work with the agile or scrum method to guide the students. This means there were weekly stand-ups, guided by a manager who asked what I had done last week, what I will do next week and if I identified any problems. These meetings helped me to keep working to make sure I could always present results. I found these meetings mostly helpful when I encountered a problem (or challenges) and by discussing the problem a workable solution could be found.

Next to the stand-ups, the agile method had also a SPRINT session once in the two weeks, where I had to present our results in five minutes. Different people of Schiphol, KLM, LVNL and HVA attended these sessions to ask questions afterward and provide feedback. These sessions motivated me to work hard so I would be able to present new results. With these SPRINT sessions I developed my presentation skill. This skill was developed even more because this presentation was in English, which I was not used to when I started this internship. I appreciate that I had to opportunity to do this, because I was aware that presenting was not my best skill and therefore, I am delighted that I developed this skill. This will also help me for presenting in the future, for example for my defence.

By doing this internship, together with the four years of study within The Netherlands, I learned that I want to experience a bit more of the working sector abroad. I am still eager to learn new things and like to study more in the future.

## Appendix II. Data Management Plan

The Data Management Plan (DMP) describes which data is used during this research, how this is retrieved, how this is saved and what happens with the data afterward. This plan makes the data analyse concrete and feasible. It supports to prevent unexpected surprises during the research (UvA, 2019).

D-1 prediction data set		D0 data set		
<b>Company</b>	LVNL			
<b>Role</b>	Use the data for determining the capacity and demand of the day of operation. This data will be used to research the reliability of the D-1 prediction versus D0 commissioned by LVNL.			
<b>Description data</b>	Contains every flight in the Dutch airspace, with the corresponding information about this flight. This is information that comes from the submitted flight plans at the day before operation	Contains every flight in the Dutch airspace, with the corresponding information about this flight. This is information that comes from the last submitted flight plans at the day of operation (no later than three hours before departure)		
<b>Period</b>	Selected dates between 08-01-2019 and 31-03-2019	01-01-2019 till 31-03-2019		
<b>Columns</b>	<b>Date</b>	Of the day of operation	<b>Date</b>	Of the day of operation
	<b>D-1 date</b>	Day before the day of operation	<b>TV</b>	Traffic Volume → airspace segment
	<b>TV</b>	Traffic Volume → airspace segment	<b>Flight ID</b>	Flight identification number
	<b>Flight ID</b>	Flight identification number	<b>Call Sign</b>	Identification of aircraft in air-ground communications
	<b>Call Sign</b>	Identification of aircraft in air-ground communications	<b>Aircraft Type</b>	Aircraft Type
	<b>Aircraft Type</b>	Aircraft type	<b>ADEP</b>	Departure airport
	<b>ADEP</b>	Departure airport	<b>Destination</b>	Destination airport
	<b>Destination</b>	Destination airport	<b>Take Off Date</b>	Date of departure at ADEP
	<b>ENTRY</b>	Entry time in the airspace segment	<b>Off Block Time</b>	Time off blocks at departure airport
	<b>EXIT</b>	Exit time in the airspace segment	<b>Entry time</b>	Entry time in the airspace segment
	<b>Delay</b>	Delay time in minutes	<b>Exit time</b>	Exit time in the airspace segment
			<b>Entry FL</b>	Flight Level where TV is entered
			<b>Exit FL</b>	Flight level where TV is left
			<b>Crossed duration</b>	Seconds that is takes to cross the airspace segment
		<b>Cross length</b>	Distances crossed through the sector in NM	
		<b>Delay</b>	Delay time in minutes	

<b>Rows</b>	311324	285180
<b>Supplier</b>	Eurocontrol and airlines	
<b>User</b>	Flore Wassenberg	
<b>Data usage</b>	All the data within this dataset will be analysed.	Of this dataset, the period that will be used are the same dates that are present in the D-1 prediction dataset because only those will be compared to each other. Also, only the columns that appear in the D-1 prediction will be used.
<b>Analysis</b>	The analysis will be done in Excel, Spotfire and SPSS. The analysis will only be done on the computer at the LVNL and the laptop of Flore Wassenberg, while LVNL does not have all the programs. The data will be the responsibility of Flore Wassenberg and will not be shared with someone else without permission.	
<b>Archive</b>	After the analysis is done, the data will be removed from the laptop of Flore Wassenberg and will only be available at an LVNL computer.	

## Appendix III. Interview questions LVNL and ethical guidelines

Interview questions for the FMPCs and a supervisor of LVNL.

- Can you explain your day if you take the D-1 prediction into account?
  - What is the influence on your activities?
  - What is the influence on the day of operation?
- What will you do differently with the prediction relative to when you do not consider the prediction?
- What is important for you that is included in the D-1 plan?
- What has your influence already been within the D-1 project?

Some results of the data analysis, such as the average of the difference, graphs of the demand and the standard deviation will be presented to the supervisor or FMPC. This will be translated into aircraft per how many hours more or less predicted, which is easier to understand for them. The next questions are about the presented results.

- What would be the consequence of the prediction with this accuracy being used for the operation?
- Is this usable for your activities?
- Is this usable to determine the occupation of the air traffic controllers?
- Which sectors are the most important to be well predicted?
- How much deviation do you think is acceptable? Do you prefer too much or too little predicted?
- What is the current procedure considering occupancy and estimation of the demand?
- What capacity is provided to the stakeholders? Is there a buffer in this capacity?
- Do you think that other air traffic controllers/Supervisors/FMPCs are being open for the D-1 prediction?

Ethical guidelines that will be applied during the research.

1. Research participants should not be subjected to harm in any ways whatsoever.
2. Respect for the dignity of research participants should be prioritized.
3. Full consent should be obtained from the participants prior to the study.
4. The protection of the privacy of research participants has to be ensured.
5. An adequate level of confidentiality of the research data should be ensured.
6. The anonymity of individuals and organizations participating in the research has to be ensured.
7. Any deception or exaggeration about the aims and objectives of the research must be avoided.
8. Affiliations in any forms, sources of funding, as well as any possible conflicts of interests have to be declared.
9. Any type of communication in relation to the research should be done with honesty and transparency. For interviews, this means that the person that is interviewed must give permission that their opinion may be used in the research. This is guaranteed with an overview of the information generated by the interview, which will be sent to the person that is interviewed, and that person must give permission that the information may be used.
10. Any type of misleading information, as well as the representation of primary data findings in a biased way, must be avoided.

## Appendix IV. Probability Forecast Schiphol (KNMI, 2019)

Wednesday 20 March 11 UTC till Thursday 21 March 18 UTC

Last update: Short term: 09:43 UTC Long term: 05:04 UTC

	11	12	13	14	15	16	17	18	21	00	03	06	09	12	15	18
Visibility < 5 km and/or ceiling ≤ 2000 ft (%)	70	60	60	60	60	50	40	30	40	70	80	90	70	40	25	25
Visibility < 5 km and/or ceiling < 1000 ft (%)	20	15	10	5	5	5	5	5	30	60	70	70	50	20	15	15
RVR < 1500 m and/or ceiling ≤ 300 ft (%)	0	0	0	0	0	0	0	0	10	20	25	30	10	5	5	5
RVR < 550 m and/or ceiling < 200 ft (%)	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0
RVR < 350 m (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winddirection (deg)	↗ 230	↗ 230	↗ 240	↗ 240	↗ 250	↗ 240	↗ 240	↗ 240	↗ 230	↗ 220	↗ 210	↗ 220	↗ 220	↗ 240	↗ 260	↗ 250
Windspeed (kt)	10	11	12	12	12	10	9	8	6	6	6	7	8	10	8	6
Gusts (kt)	15	16	17	17	17	15	14	13						15	13	
Standarddeviation winddirection (deg)	10	10	15	15	20	20	25	25	30	30	20	15	15	15	25	30
Standarddeviation windspeed (kt)	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2
CB (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorm (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aircraft Induced Lightning (AIL)																
Temperature (C)	11	12	12	13	12	11	10	9	8	7	7	8	10	12	13	10
Dewpoint (C)	9	9	9	9	9	9	8	8	8	6	7	8	8	9	8	7
Relative humidity (%)	87	82	82	77	82	87	87	93	100	93	100	100	87	82	72	82
Windchill							8	7	6	5	5	6	8			8
Snow (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moderate or heavy snow (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Freezing precipitation (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pressure (hPa) (modeloutput)	1032	1033	1033	1033	1033	1033	1033	1033	1033	1034	1033	1034	1034	1035	1034	1033

## Appendix V. D-1 plan example

— common ATC boundary

Situatie **0000-2359** UTC

### Weersverwachting Nederland

#### Algemeen beeld

0600-0900: Wind 200-210/6kts,

Ruimend naar 250-270/10kts

#### Airport

Tot 0700-0800 temperaturen < 3C i.c.m. hoge  
luchtvochtigheid

#### FIRAM:

Overaanbod tussen 0620-  
0720

SECTOR 4

#### SECTOR 3:

Overaanbod tussen: 0600-  
0740 i.c.m. werklaspieken

**Samenvatting & knelpunten**

Geen capaciteitsbeperkingen verwacht.  
Regulatie voor inboundpiek vanaf 0620 verwacht als gevolg van overaanbod.

**Amsterdam Airport Schiphol**

<u>Banen</u>	18C/36C n/a (M19-0179)
<u>Rijbanen</u>	Werkzaamheden baan 18C/36C en omliggende rijbanen (M19-0179)
<u>De-icing</u>	De-icing condities tot maximaal 0800

**Overige vliegvelden**

Geen bijzonderheden.

**Relevante NOTAMs**

A0004/19 & A0005/19: PJE Echten & Spier. Beide gebieden tijdelijk verhoogd naar FL150

**Evenementen**

Geen bijzonderheden.

**Militair luchtruimgebruik**

Geen bijzonderheden.

**Systemen**

**Onderhoud**

Testnacht CCIS (BUP400) 19 op 20 maart

Nachtoperatie vanaf TWR-E

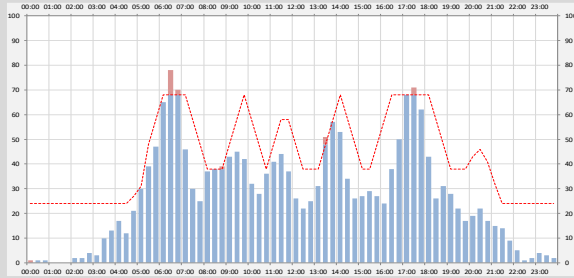
**Releases**

Geen bijzonderheden

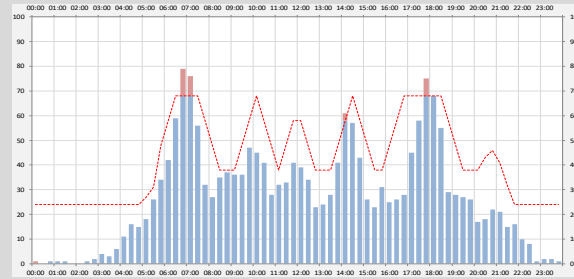
# D-1 Verkeersaanbod en Werklast

di 19 maart 2019  
(bron: ma 18 mrt 2019)

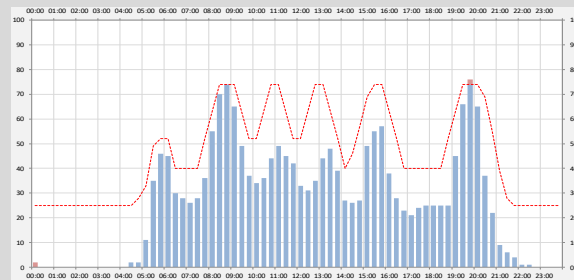
EHFIRAM



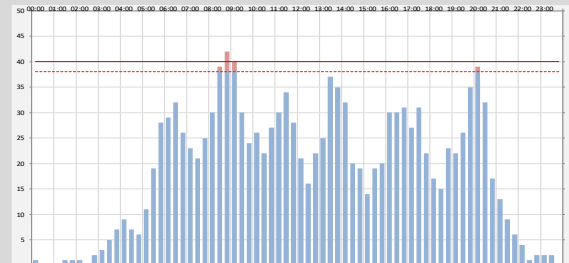
EHAMARR



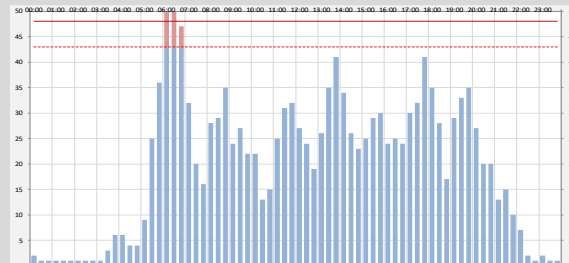
EHAMDEP



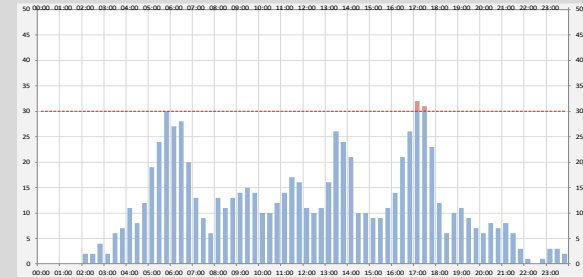
EHSECT2



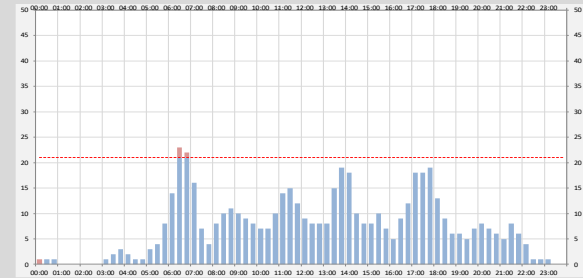
EHSECT3



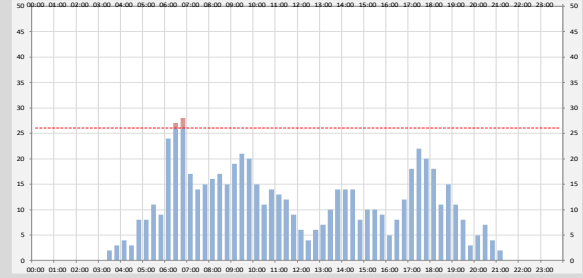
EHARTIP



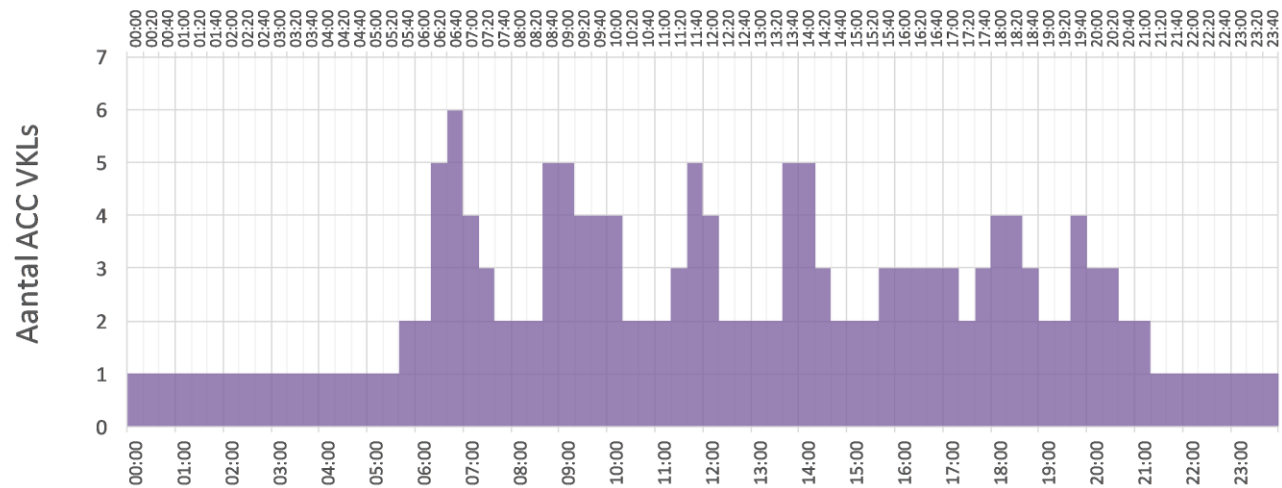
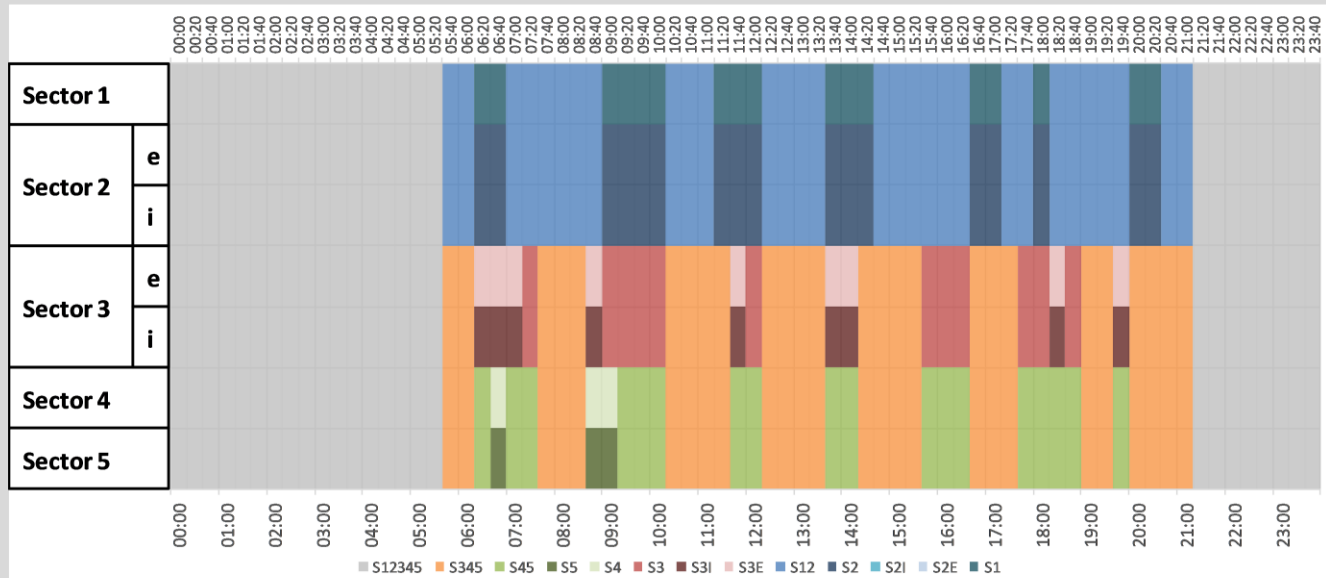
EHRIVER



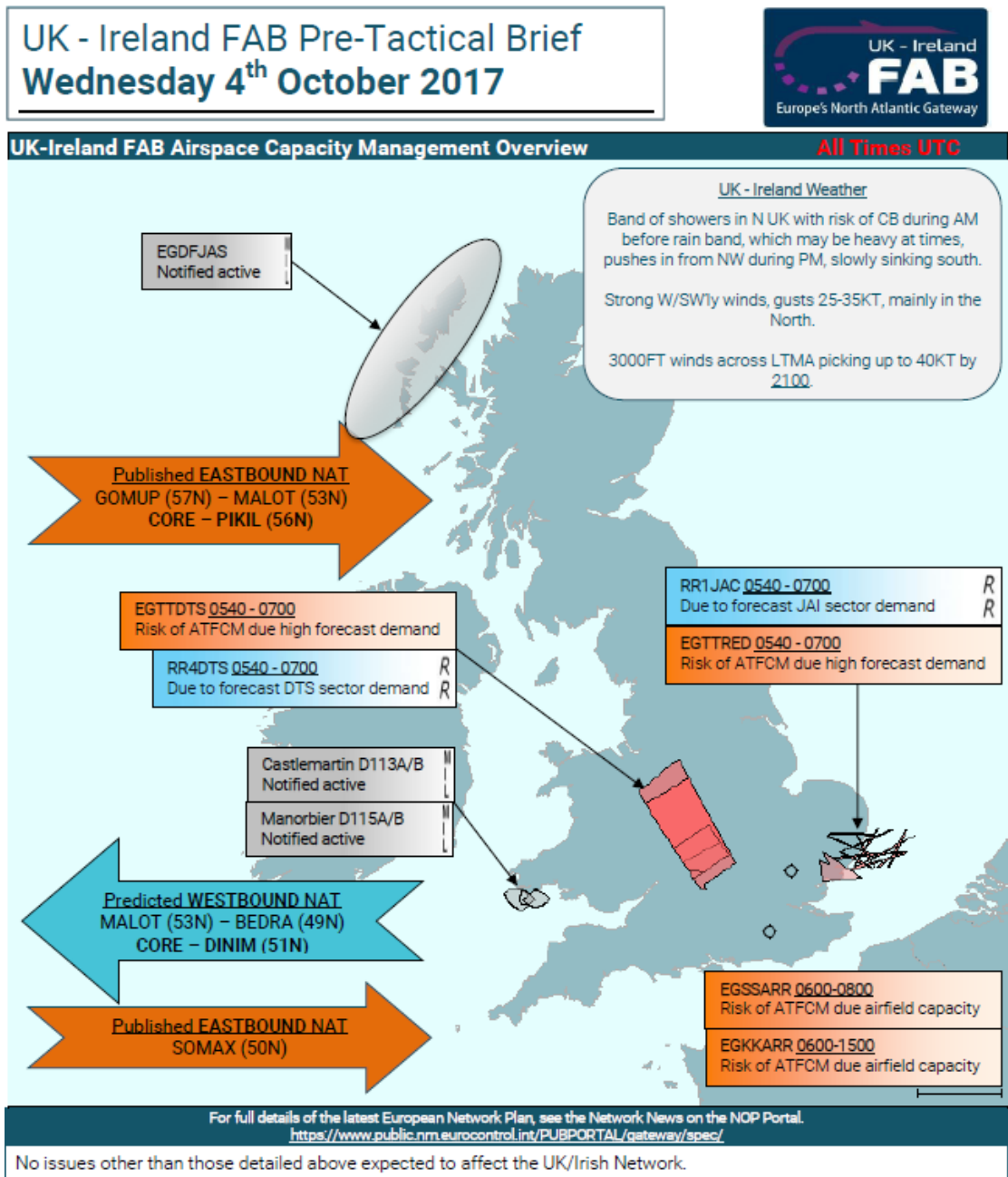
EHUGOL



# ACC sectorconfiguratie



# Appendix VI. NATS D-1 pre-tactical plan example



### FUA information and Planned Military Activity

Area	Potential Impact?	Impact / Resolution	Advice / Notes
Hebrides D701A	No		
High Seas Firing	No		
Portland	No		
Portsmouth	No		
SWMDA	No		
Shoeburyness	No		
Major Exercises	Yes	Formidable Shield 17 runs until 19 <sup>th</sup> October Impact to NAT traffic possible 05 <sup>th</sup> -09 <sup>th</sup> October Joint Warrior 172 runs 02 <sup>nd</sup> October – 12 <sup>th</sup> October – No significant impact expected	Check AUP/UUP for details
Irish Activity	No		
CBA1	No		
Aberporth	No		
Manorbier	Yes	EGD115A/B notified active	Check AUP/UUP for details
Castlemartin	Yes	EGD113A/B notified active	Check AUP/UUP for details
* Military activity predicted at time of publication and is subject to change * This is a briefing document – Refer to NOTAM/AUP/UUP for definitive activity.			

Area	Time	Issue	Impact / Resolution	Advice / Notes
RR1JAC	<u>0540-0700</u>	EGTTJAI / REDFA High forecast demand	Captures Deps from LDDU/PL/ZD/LF*/LI*/LS* to EGSS/GW. Refile via LYD	Off-loads 4 flights inbound to EGSS/GW from JACKO to LYD sector
RR4DTS	<u>0540-0700</u>	DTS/LUW High forecast demand	Captures Deps from EGCC/GP/NH/NR/EGP* to GC**/LE**/LFBD/BP/BT/BZ/LP** (except LEBL/GE/RS/LL/IB/MH/PA/SB/SJ/SL). Refile via SALCO/west of	Off-loads 5 flights from DTS/LUS/LMS to West and Brest V/ K sectors

### Heathrow Operational Overview Section

Landing Rate Predictor	Impact / Resolution			Advice / Notes
	0600	1200	1800	
	40	39	38	Low risk of ATFCM measures Check during tactical phase
Predicted Westbound NAT Traffic SID	CPT			Due to forecast NAT tracks a CPT SID bias is forecast for Oceanic departures Check during tactical phase

### Airport Section

Airport	Issue	Impact / Resolution	Advice / Notes
EIDW	Runway Configuration	Dual runway operations are possible for the first rotation subject to weather	Check during tactical phase
	Runway closure due scheduled maintenance	Runway 10/28 unavailable <u>2200-0400</u> Mon – Friday on an ad-hoc basis until April 2018	
EGAA	Runway scheduled maintenance	Runway 07/25 closed, but subject to 40 minute availability notice <u>2200-0400</u> until 30 <sup>th</sup> November	Check during tactical phase
EGCC	Runway closure due scheduled maintenance	Runway 05R/23L closed overnight <u>2130-0500</u> until 05 <sup>th</sup> October	Check during tactical phase
EGGW	Runway scheduled maintenance	Runway 08/26 subject to 20 minute availability notice <u>0200-0430</u> Sunday and Monday mornings from 13 <sup>th</sup> August until 5 <sup>th</sup> November ATFCM may be applied tactically	Check during tactical phase NOTAM A2582/17
EGKK	Runway closure due scheduled maintenance	Runway 08R/26L closed overnight 06 Sep – 28 Oct <u>2200-0430</u> 29 Oct – 05 Nov <u>2300-0530</u> 06 -10 Nov <u>2230-0600</u> 11 - 12 Nov <u>2300-0530</u> 13 -17 Nov <u>2230-0600</u> 18 Nov – 22 Dec <u>2300-0530</u> Runway 26R/08L in operation during closures	Check during tactical phase
EGPH	Runway closure due scheduled maintenance	Runway 06/24 closed overnight 07 - 09 Oct <u>2215-0430</u> 14 - 16 Oct <u>2215-0430</u> 21 – 23 Oct <u>2215-0430</u> (Spare)	Check during tactical phase
EGSS	Runway closure due scheduled maintenance	Runway 04/22 unavailable <u>2345-0445</u> Sunday and Monday mornings from 01-17 October	Check during tactical phase

### NAT Tracks

**FAA**  
Strong Atlantic jet stream may result in early arrivals

**NTFSR (Fuel Saving Route) Closures:**  
Nil

**Jet plan Track Images:**

**Eastbound:**  
<http://www.jetplan.com/tda/east.html>

**Westbound:**  
<http://www.jetplan.com/tda/west.html>

### General Information

**UK/Ireland:**

**Europe:**

**Brest:**  
FL7RVK has been applied 0630-0730 capturing flights departing EGFF, EGGD, EGTE, EGHH, EGHI, EGKK, EGLL not allowed via sector LFRRVKU. File below FL355 until KEREB/ERWAN/NOVAN/KORER.

FL1RQXU has been applied 0540-0700 capturing traffic departing EGGW, EGHL, EGKB, EGKK, EGLC, EGLF, EGLK, EGLL, EGMC, EGTD, EGTF, EGTO, EGVO & EGWU not to route via QXU sector. Refile below FL365 until clear of the sector.

**Bordeaux:**  
FL3BL4 has been applied 0600-0720 capturing traffic departing EGGW, EGHL, EGKB, EGKK, EGLC, EGLF, EGLK, EGLL, EGMC, EGTD, EGTF, EGTO, EGVO & EGWU. Refile below FL365 until clear of Bordeaux L4 sector.

For full details of the latest European Network Plan, see the Network News on the NOP Portal:  
<https://www.public.nm.eurocontrol.int/PUBPORTAL/gateway/spec/index.html>

### 7 Day Outlook

Thu 05 Oct	Nil
Fri 06 Oct	Western Radar closure – 1315-1715 - NOTAM B1723 refers
Sat 07 Oct	EGLC ILS Calibration
Sun 08 Oct	EGLC ILS Calibration
Mon 09 Oct	Western Radar closure – 0730-1145 - NOTAM B1724 refers
Tue 10 Oct	Possible French Industrial Action
Wed 11 Oct	Nil

### UK FMP Contact Information

Airspace Capacity Management Specialist [+44 \(0\)1489 612428](tel:+44201489612428) or email [pretact.fmp@nats.co.uk](mailto:pretact.fmp@nats.co.uk)  
 UK FMP Tactical team: [+44 \(0\)1489 588150](tel:+44201489588150)  
 Operational Customer Interface Gateway (OCIG) [02380 401555](tel:+4420380401555)  
 Dublin ACC Station Manager: [+353 18 144601](tel:+35318144601) / Shannon ACC Station Manager: [+353 61 770700](tel:+35361770700)  
 NATS Customer Website use <http://www.customer.nats.co.uk/> for the FAB website use <http://www.ukirelandfab.eu/>

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## **Appendix VII. Summarized Interview Eurocontrol PREDICT**

Interviewee: Participant 1

Interviewers: Leo Hoogerbrugge and Flore Wassenberg

Interview date: 16-05-2019

Verified by Participant 1 on: 06-06-2019

### **What is your function and what are your activities regarding constructing the PREDICT data?**

Multiple activities:

- Manage the DDR process in charge of collecting & processing flight intention data.
- Monitor the quality of flight intentions and their consistency between multiple sources: departure and arrival airport slots, schedule data. Investigate inconsistencies and propose corrective measures
- Monitor the accuracy of the PREDICT counts.
- Liaise with data providers sharing flight intentions with DDR

### **What are the main differences between the DDR2 prediction process and the PREDICT prediction process?**

DDR is general concept which is develop years ago, with introducing SESAR. The problem was that they only had real time data for next day, and flight plans are only uploaded a couple of hours before take-off, so these are not available for earlier planning. So their initial concept is to use another traffic flow. The establishment of this process was quite long. They started collecting 'early flight intention' which is any information of an airline which gives the intention that a future flight could be conducted. They had not many choices for the data they could use for this. Either airport slots data or schedule data.

They also receive addition data of airlines. This together is available as flight intentions. For this flight intentions they use airport slot data (departure and arrival slots collected of more than 175 coordinated airports in Europe) which are compared to schedules. The airport slot data should be consistent with flight schedule data. But they experience inconsistency within this. PREDICT is historical data, which is enriched with route of repetitive flight plan. Sometimes there are airlines that do not work with repetitive flight plan such as Ryanair. Then they compare historical data with the flight intention based on airport slot of given airport.

Therefore, PREDICT is customer of DDR flight intentions. The PREDICT traffic demand is available from the DDR web portal from D-6 to D-1 and from the CHMI/PREDICT. Traffic demand forecast for a longer-term horizon (D-7 till 18 months ahead) are generated from the DDR2 strategic planning system. It is based on different algorithmic and simulation capabilities.

### **How do you determine that there are flight intentions (a flight that will be performed in the future)? How are you dealing with the unconfirmed flights?**

Any information of an airline which gives the intention that a future flight could be conducted can be a flight intention. This is based on scheduled data, airport slot data, EOBT and EIBT and a snapshot of the night before with the last received data. For example, if the day of operation is Thursday, a snapshot of the night of Tuesday is used for the D-1 predict that is made Wednesday. Scheduled data is updated on weekly basis, while airport slot data is updated on daily basis. DDR monitors the coverage of the collected flight intention, through regular comparisons between PREDICT counts derived from flight intentions and ETFMS counts computed from the FTFM.

Unconfirmed flights (historical flights not correlating with an airport slot) are removed from the PREDICT flight data, when operating from/to coordinated airports where the coverage of their airports slots is sufficient (above 90% on average). This is the case for Amsterdam Schiphol. Unconfirmed flights from/to Eindhoven Airport and from/to Rotterdam Airport are kept in the PREDICT.

### **Which historical flight data do you use?**

Historical data of the demand of the same day a week before based on the last submitted flight plans (not the actual operation) of how the route was filed. But if this day a week before is disrupted which affect the nominal routes of a large proportion of flights, then there is a procedure executed by the pre-tactical team. Then they will use instead of using the day a week before, another day in the past is used (often D-14). But when there is gone more in the past is becomes more challenging to have it accurate. For example, that the AIRAC cycle is already changed.

### **Within the PREDICT data, how do you consider special events? For example, if there is already a reduction in the demand because of an event, how do you consider this for making the PREDICT for the next day?**

Only special events are considered if they have results in a reduction of airport slots. So it might happen that special events are reflected in airport slot data. Airports slots are provided to manage demand of the airport. Every September the slots are provided for the summer season, while every January they are updated for the winter season. Each day they receive full picture of the whole season regarding slots, if there is data changed, this is implemented, and the information is updated to keep consistent. However, special events affecting coordinated airports operation at short notice (e.g. bad meteo conditions) or affecting not coordinated airports are not reflected in PREDICT (or only partially through ad hoc manual interventions).

If there are repetitive slots, it means a flight intention. The slot times for Arrival is the SOBT, and for the Departure it is the SIBT.

**Within the PREDICT data, how do you consider the weather forecast (apart of the NAT forecast)?**

The impact of the weather forecast is only partially reflected in the PREDICT flight data: only the forecasts of wind speed is used to adjust the time dimension of the historical 4D trajectories in PREDICT. Exception, the routes of North Transatlantic traffic are substituted routes best reflecting the UK NATS forecasts for the upcoming 3 days, respectively for westbound and eastbound flows. When this information is received, some days are replaced with the new and better information. So, they replace historical routes used in the past by new ones. This substitution procedure is not applied for other tracks in Europe yet. For other tracks in Europe only windspeed is considered, not wind direction. This trajectory prediction is based on the historical flight plans and the already submitted flight plans. Improvements for meteorological data is limited because of the use of historical data.

**Within the PREDICT data, how do you consider general aviation?**

General aviation is considered in the PREDICT data if possible with airport slot data, while there is no scheduled data made for general aviation. For non-coordinated airports (airports that do not work with slots) they use historical data, but this is often very unreliable because of big variations. They try to remove all the flights that are not confirmed, unless they are found in DDR slot data. The cleaning of the non-correlating historical general aviation traffic is applied only to flights liaising fully coordinated airports (Level 3) for which general aviation airport slots are mandatory. This is the case for Amsterdam Schiphol, however not for Rotterdam and Eindhoven. For Eindhoven they use scheduled data for the general aviation, for Rotterdam they take scheduled data as well but do not remove if not confirmed. Additional flights are added if new found.

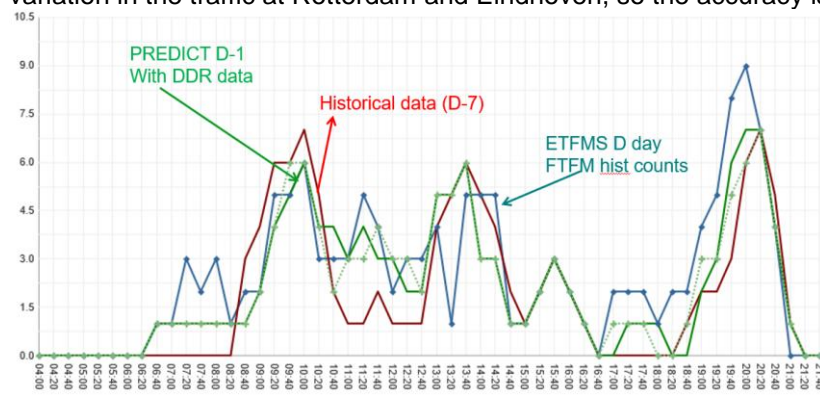
**Within the PREDICT data, how do you consider runway use?**

The runway use is included in planned trajectory of the historical data.

**Do you have statistics of the accuracy of the PREDICT data?**

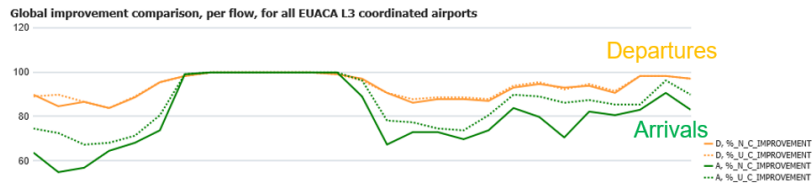
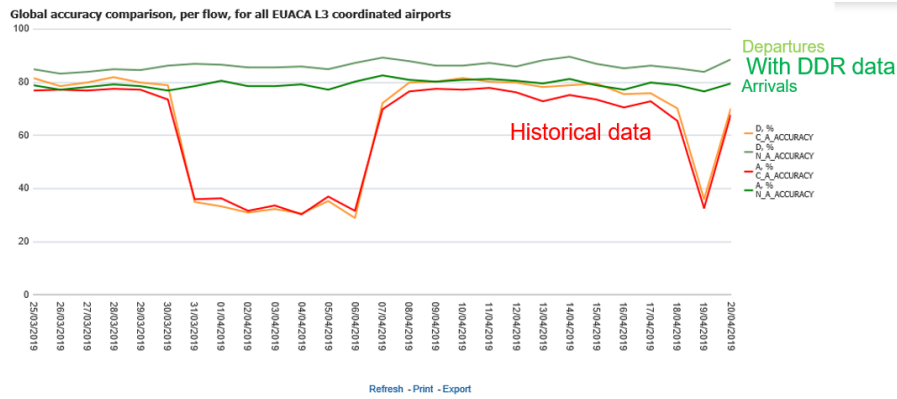
The accuracy they give in the presentation is just a global indicator. In the presentation they compare if the historical data is used pure, compared to historical data that is enriched (the PREDICT data). They did the analysis for each airport, both departures as arrivals. They use the hourly count per 20 min.

They use the data of the ETFMS, which is based on the FTFM, as the reference. The accuracy is based on which of the historical data of historical data enriched is closer to this reference. If the accuracy is 90 percent, it means that the absolute deviation is 10 percent on average between the reference hourly traffic counts and the PREDICT hourly counts, computed for the sum of the hourly counts. There is a lot of variation in the traffic at Rotterdam and Eindhoven, so the accuracy is lower (Graph 24).



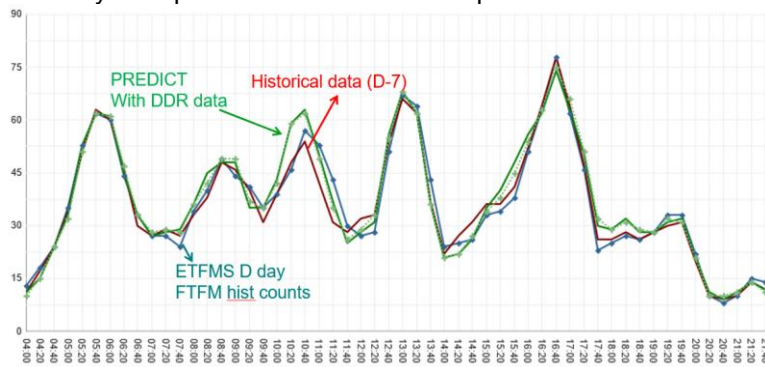
Graph 24. Hourly count comparison Rotterdam Airport arrivals of 26-04-2019 (Eurocontrol, 2017)

When the historical data is enriched with DDR data, this data keeps more stable during the time, while historical data only has some drops during the time (Graph 25).

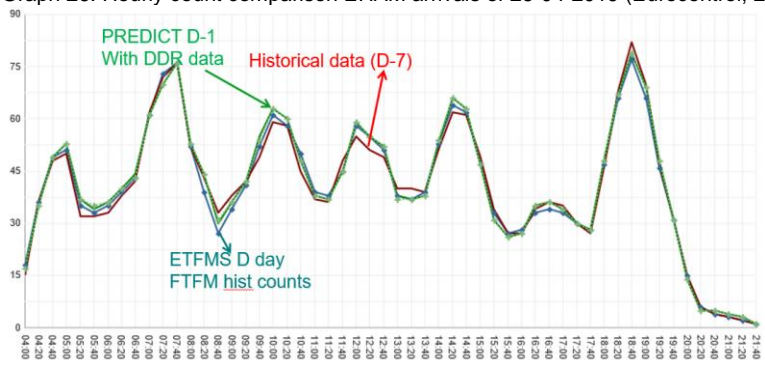


Graph 25. Stability of the accuracy during time (Eurocontrol, 2017)

The accuracy of the hourly count for the departure is better than arrivals, because departures are mostly aligned with the Scheduled Off Block Time of the slots, while the within the arrival time because the airlines try to use a buffer to ensure the aircraft arrives on time. Accuracy of arrivals visualised in Graph 26 and accuracy of departures visualised in Graph 27.



Graph 26. Hourly count comparison EHAM arrivals of 26-04-2019 (Eurocontrol, 2017)



Graph 27. Hourly count comparison EHAM departures of 26-04-2019 (Eurocontrol, 2017)

The graphs given in the presentation are not available anymore for the days analysed in the D-1 trail, because they don't have the data of days earlier than 30 days.

**In what way are you using the PREDICT data yourself?**

The main goal for them is to monitor the quality of the forecast. They are doing this because they are involved in a SESAR project, where it became important to have pre-tactical planning. Currently they are trying to develop this and find partners because they are aware that there is room to improve, but the need specific elements to improve. This input should come of local institutions. Expectations of the local institutions are that is keeps better, but therefore everyone should align their planning with each other. Preliminary flight plans should be a good idea for improving the PREDICT data. Eurocontrol want to develop more cooperation, Eurocontrol likes to know what the results are of the D-1 prediction thesis. They like to

have a good evolution of the concept, but nobody seems very keen for providing new information/algorithms, etcetera. However, a better forecast would help the coordination/operation. Eurocontrol wants to be sure to be consistent because of the different airports they work with.

Some challenges and areas for improvement Eurocontrol faces regarding the quality of the flight intentions are:

- Information consistency between sources.  
The consolidation per flight of different data sources (departure and/or arrival airports slots and schedule flight data) may reveals some inconsistencies and contradictive timing information. The goal is to develop and automate processes to detect and correct such inconsistencies. This process still requires manual corrections for the most complex cases. Inconsistent data has a direct input on the quality of the generated traffic forecast.
- Accuracy, coverage and updates of the flight intentions.  
Another challenge is the coverage of collected flight intentions. The current coverage is around 80 percent of the traffic, on average. However, specific traffic flows liaising non coordinated airports are missing and the anticipation of the general and business aviation traffic remains limited to flights liaising fully coordinated airports. The goal is to expand the coverage and the update cycle of collected flight intentions, to increase the network awareness traffic demand changes in the last two day prior to departure.
- Improve the accuracy of the forecast trajectory & en-route demand.  
Early submission of flight plans is encouraged to solve limitations of using historical route data in PREDICT. Concepts of preliminary flight plans (FPL's received at least 48 hours prior to departures) and Shared Business Trajectory (currently under development in the SESAR context) are expected to improve the predictability of traffic demand forecasts during the pre-tactical phase.

## Appendix VIII. Interview KLM

### Pre-determined questions

How do you make a prediction a day before the operation and what is the input for this?

What are you doing with the prediction?

What is within this prediction, capacity, demand, or more?

What are the inputs for this prediction? Weather, capacity of LVNL, special events, infrastructure Schiphol Airport?

What are the benefits for making this prediction?

What is already known of the D-1 project within LVNL at KLM and what might be the influence of D-1 prediction on the KLM operation?

### Summarized interview KLM

Interviewee: Menno Rigter, Duty Manager Operations

Interviewer: Flore Wassenberg

Interview date: 05-06-2019

Verified by Menno Rigter on: 06-06-2019

### Current situation

De Duty Manager Operations (DMO) geeft 's ochtends aan of ze ergens tegen aan lopen, of er vluchten geannuleerd moeten worden en welke vluchten dat dan zijn. Om 09:30LT gaat de flow coördinator van KLM naar de luchtverkeersleiding, om informatie over de capaciteit van die dag te verkrijgen. Alleen als er echt naar gevraagd wordt, dan wordt er iets aangegeven van wat de luchtverkeersleiding verwacht voor de capaciteit van morgen. DMO hoort dan vaak: "Het is nog veel te vroeg, de capaciteit en het weer kan nog veranderen", waardoor KLM weinig informatie verkrijgt. De DMO kan wel op die informatie inspelen want dat het nog kan veranderen dat weet KLM ook. KLM kijkt LVNL er echt niet op aan als het net iets anders wordt.

Met de normale capaciteit doet de DMO niet veel. DMO is voornamelijk geïnteresseerd in gereduceerde capaciteit, want dat heeft invloed op hun operatie. Als capaciteit significant gereduceerd wordt, zoals inbound onder de 44 dan wordt de operatie minder haalbaar en dient er een plan te komen om het weer haalbaar te maken. Er zijn een aantal situaties mogelijk om een sectorbriefing aan te vragen (met KNMI, AAS, LVNL en KLM). Hierin wordt het weer en capaciteit van de verstoorde dag (meestal morgen) besproken. Het aanbod wordt dan nog niet besproken. Wat er in een sectorbriefing besproken wordt en de manier waarop er gesproken wordt, zou KLM eigenlijk elke dag willen zien. De output van de sectorbriefing is input voor de scenario briefing die gemaakt wordt binnen KLM. De scenariobriefing is een briefing voorgezeten door de DMO voor de afdelingen in het OCC zodat iedereen dezelfde info heeft en bekend is met het te maken plan. Men heeft daarbij ook invloed op het te maken plan. De DMO maakt op basis hiervan het plan finaal. De informatie van de sectorbriefing wordt ingevuld in een tool die dan aangeeft of de operatie nog haalbaar is voor KLM of dat er gesneden moet worden in het netwerk.

KLM wil de vertragingen gemiddeld genomen liever niet boven het uur. Indien er een vertraging van dergelijke omvang ontstaat dan loopt dit nog de hele dag door, omdat er weinig marge zit tussen de ene vlucht en de volgende vlucht met hetzelfde vliegtuig. Het probleem schuift op en komt aan het eind van de dag. Intercontinentale (ICA) vluchten laten ze zo veel mogelijk op hun schema staan. De passagiers die morgen landen op Schiphol mogen geen last hebben van het weer van vandaag. Voornamelijk Europese vluchten worden vertraagd of geannuleerd. Als er verstoringen zijn op Schiphol, dan verstoord dat voornamelijk het netwerk van KLM.

De flow coördinator heeft de data van Eurocontrol wat is gebaseerd op een week geleden. Het aanbod van de volgende dag kan hij nog niet zien. Meestal kijken ze dan een week terug op dezelfde dag voor een verwachting. KLM-aanbod weten ze precies.

### Runway tool

De DMO gebruikt de tool: Runway, om een dag van tevoren te bepalen of er vluchten vertraagd of geannuleerd moeten worden. In de tool moet de inbound en outbound capaciteit per uur ingevoerd worden. Als de capaciteit gereduceerd wordt, kan deze handmatig ingevoerd worden. Ook is het mogelijk om de voorspelde capaciteit te laden vanuit de AFOS-tool. Door middel van Load from AFOS wordt de verwachte capaciteit in de tool geladen, inclusief de weersverwachting met het baangebruik. Deze hoeft je dan niet handmatig in te voeren. De DMO maakt naar aanleiding van de Schiphol Kans Verwachting voorspellingen van de capaciteit indien er geen capaciteit bekend is van de LVNL. Deze capaciteit wordt dan met meerdere mensen gedeeld en afgestemd. Na het invoeren van de capaciteit in de tool, kan de tool gerund worden en

dan komt het systeem met annulerings- en vertragingen voorstellen. De tool houdt rekening met KLM en buitenlandse maatschappijen (BM). Er zit een algoritme achter wat de vertragingen en annuleringen voorspellen. BM gaan pas heel laat annuleren. De output van de tool zijn mogelijke annuleringen in aankomst en vertrek met daarbij om welke vluchten het gaat en in welk uur deze annuleringen moeten zijn. Ook mogelijke vertragingen (in minuten) worden aangegeven en in welk uur deze nodig zijn. Als de vertragingen hoger zijn dan 70 minuten, dan komen er annuleringen. Annuleringen, met daarin het aantal vluchten, tussen welke tijden en welke vluchten, worden voorgelegd bij de afdeling crew en commercie. Transavia, Air France en Delta kunnen ze ook in de tool zien. Transavia kan geïnformeerd worden door de DMO van KLM. Ook de DMOs van AirFrance en Delta worden door de DMO geïnformeerd. Vaak als KLM gaat annuleren, kunnen de andere vluchten doorgaan. Indien deze vluchten niet vol zitten kunnen KLM-passagiers overgeboekt worden op een van deze maatschappijen.

Input over het aanbod komt van het spoorboekje van Schiphol. Hier zitten geen cargo en zakenjets in, omdat dit allemaal ad hoc is. Weer zit alleen in de capaciteit die wordt ingevoerd maar niet in het algoritme, verder zitten special events en infrastructuur van Schiphol er allemaal in. Indien LVNL geen capaciteit afgeeft, dan zal de DMO zelf op basis van de aanwezige informatie de capaciteitsverwachting maken. Verder zit voornamelijk in het algoritme van de tool de crewconnecties en werktijden en commerciële informatie, maar ook vlootcapaciteit, reserves, kostenmodel. Slot informatie is (nog) niet meegenomen.

### ***Relevance of D-1 for KLM***

De DMO wil eerder de capaciteit weten en ze merken dat deze capaciteit heel erg afhankelijk kan zijn van de luchtverkeersleider (supervisor) op dienst. KLM snapt dat het afhankelijk is van het team luchtverkeersleiders waar je mee zit, maar ook dat is van tevoren al bekend. Met hetzelfde weersbeeld worden er nu verschillende capaciteiten aangeboden door de LVNL. Door middel van AFOS hoopt de DMO op meer consistentie doordat bij dezelfde weersbeelden dezelfde capaciteit wordt afgegeven. Als ditzelfde weerbeeld dan voorkomt dan zou er ook dezelfde capaciteit als de vorige keer afgegeven moeten worden. Dit zou moeten zorgen in meer consistentie in de afgifte van capaciteit.

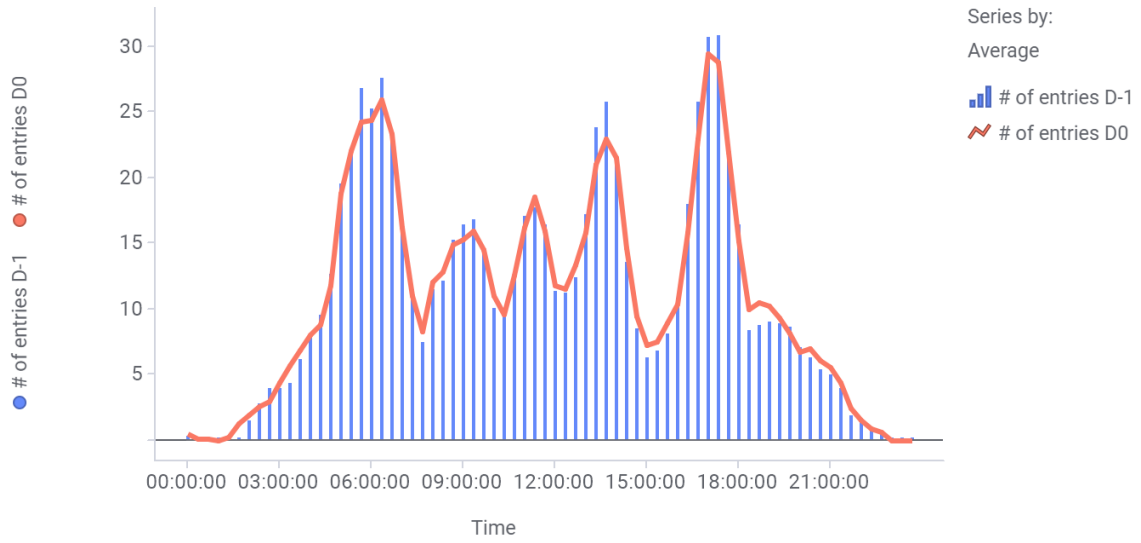
De DMO is op zoek naar meer proactieve sturing voor de dag van morgen. Het liefste willen ze in de ochtend van D-1 weten wat de capaciteit wordt, omdat ze dan een plan kunnen maken. Om vluchten te annuleren moet je dan op tijd weten, want als je ICA vluchten nog wilt kunnen omboeken, dan moet je vroeg zijn. De huidige capaciteitsforecast gaat niet zo ver, namelijk maar 3 tot 4 uur vooruit.

De DMO heeft het idee dat het beeld van het effect van capaciteitsreductie voor een airline bij LVNL niet altijd hetzelfde is. Het is belangrijk dat er meer als sector geopereerd wordt. KLM is op zoek naar consistentie en informatie over de capaciteit en het is LVNL als enige die deze informatie kan verstrekken. Verkeerde informatie kan niet, want ze snappen dat omstandigheden nog kunnen wijzigen. Het is wel vervelend als er vluchten geannuleerd zijn, terwijl het weer uiteindelijk helemaal niet zo slecht is maar ook dat is het weer. Bijvoorbeeld bij onweer, dan kan het zijn dat het net langs Schiphol gaat en je er toch geen last van had, alhoewel dat niet altijd iets zegt over aan en uitvliegroutes. Maar dat begrijpt de DMO ook en ze hebben 'Just Culture'. Dat wil zeggen dat er ruimte is om fouten te maken, mits ze niet expres of ondoordacht zijn gemaakt. Ze moeten er ook van leren. Ze willen liever iets wat met goede argumenten is afgegeven en wat later anders wordt, dan niets. Het zou fijn zijn als de kans aangegeven wordt van de gereduceerde capaciteit.

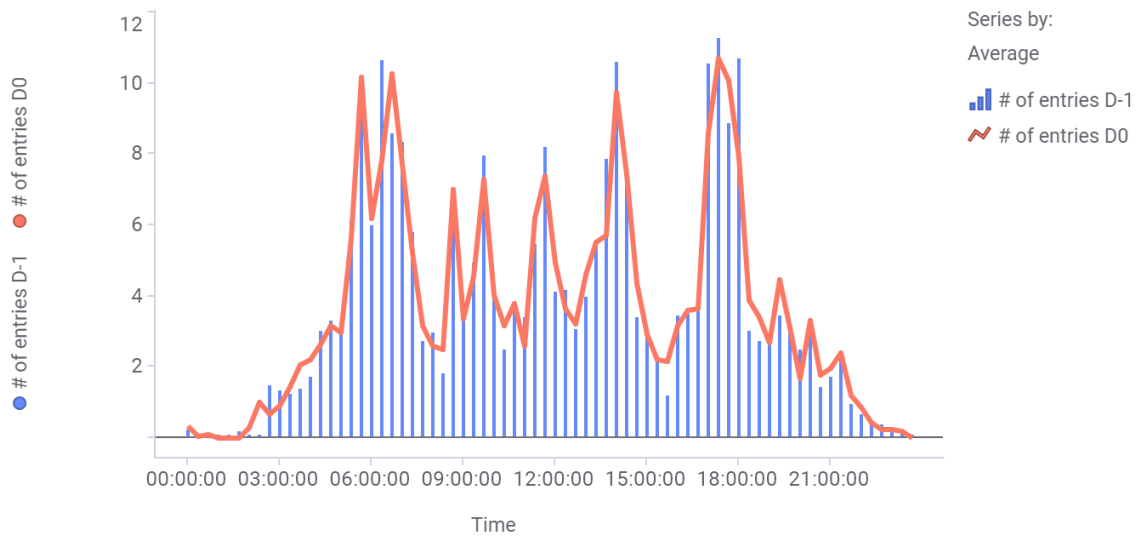
De DMO is bekend met het D-1 project wat loopt binnen LVNL en zijn daar blij mee. Ze hopen dat hiermee LVNL eerder met de informatie komt dan wel het mogelijk wordt om gezamenlijk de dag van uitvoering aan te vliegen.

# Appendix IX. Average demand graphs

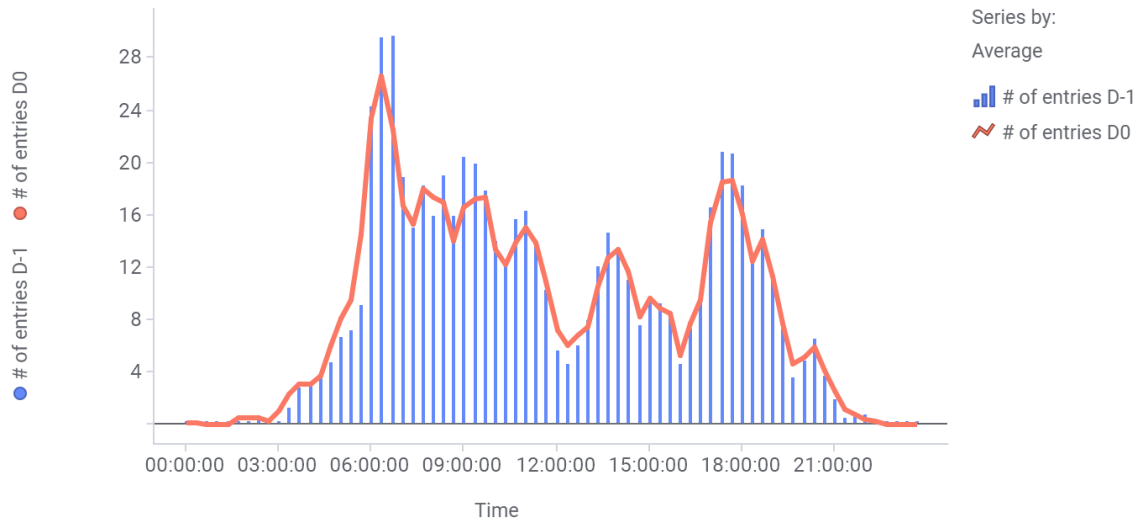
Average demand per hour rolling per 20 min D-1 & D0 EHARTIP



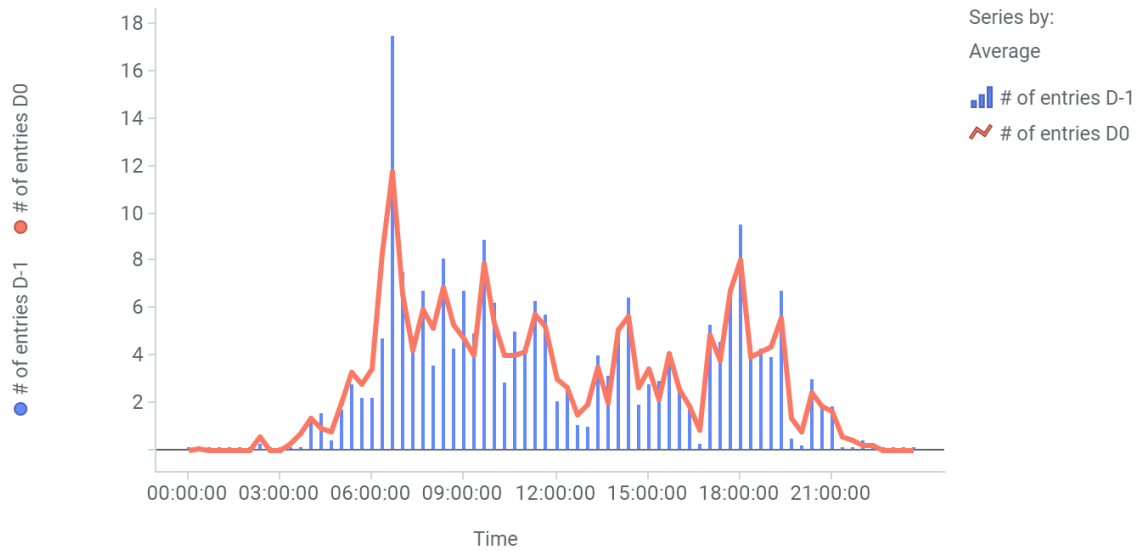
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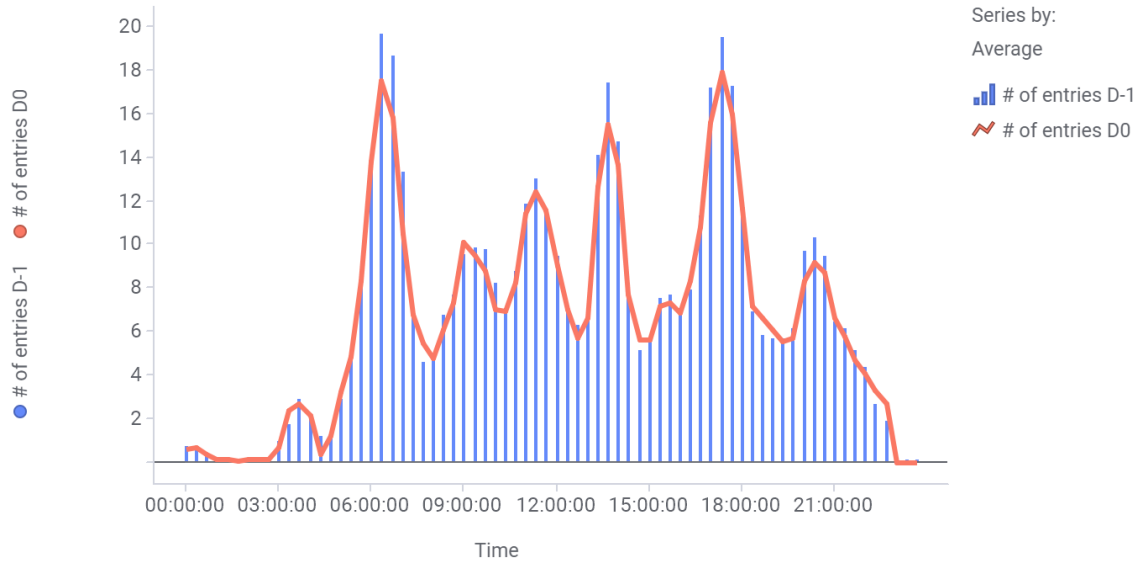
Average demand per hour rolling per 20 min D-1 & D0 EHSUGOL



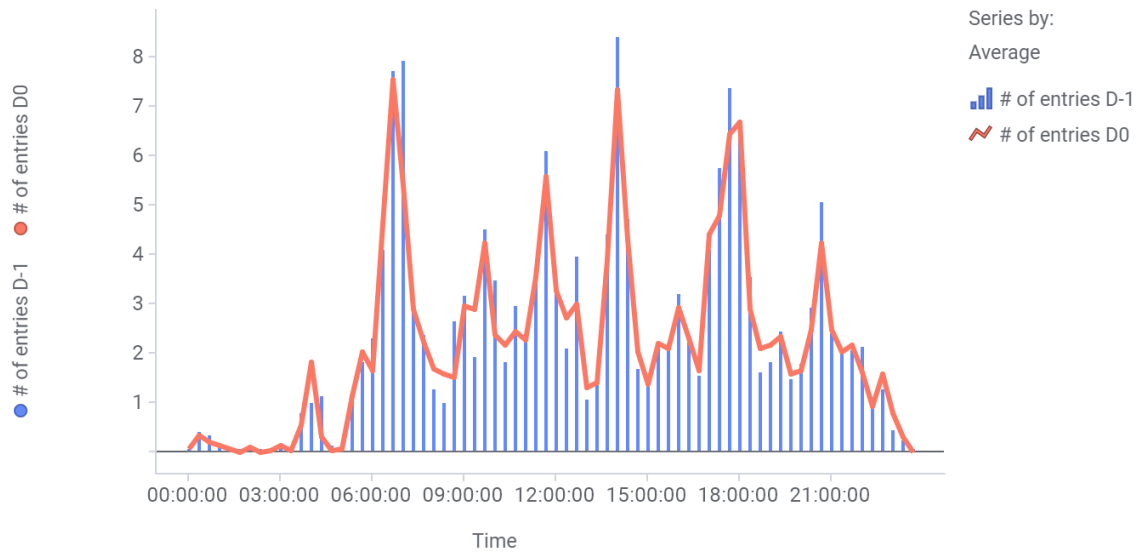
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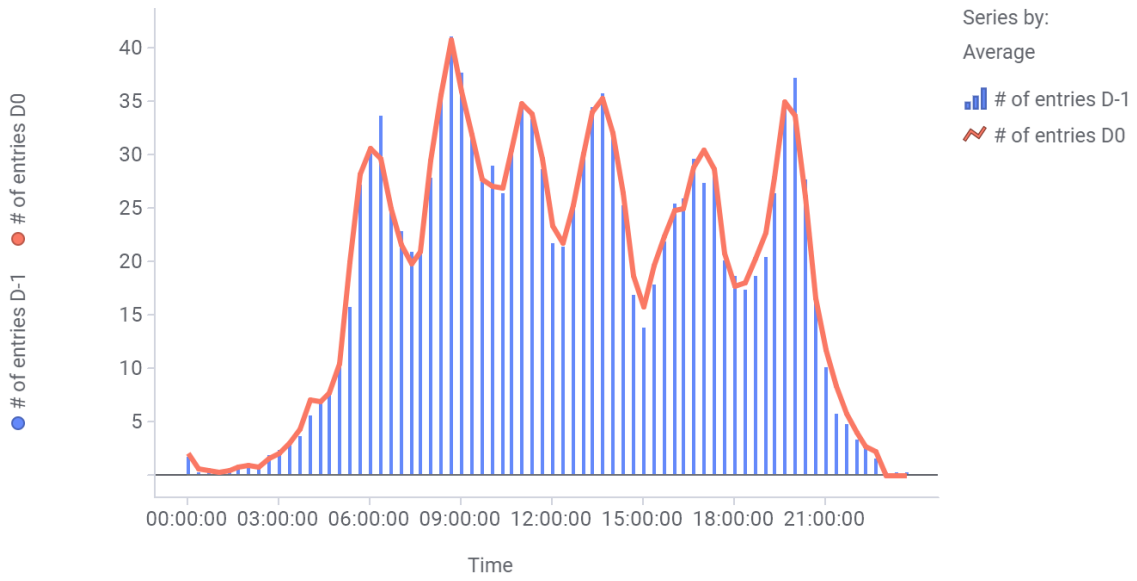
Average demand per hour rolling per 20 min D-1 & D0 EHRIVER



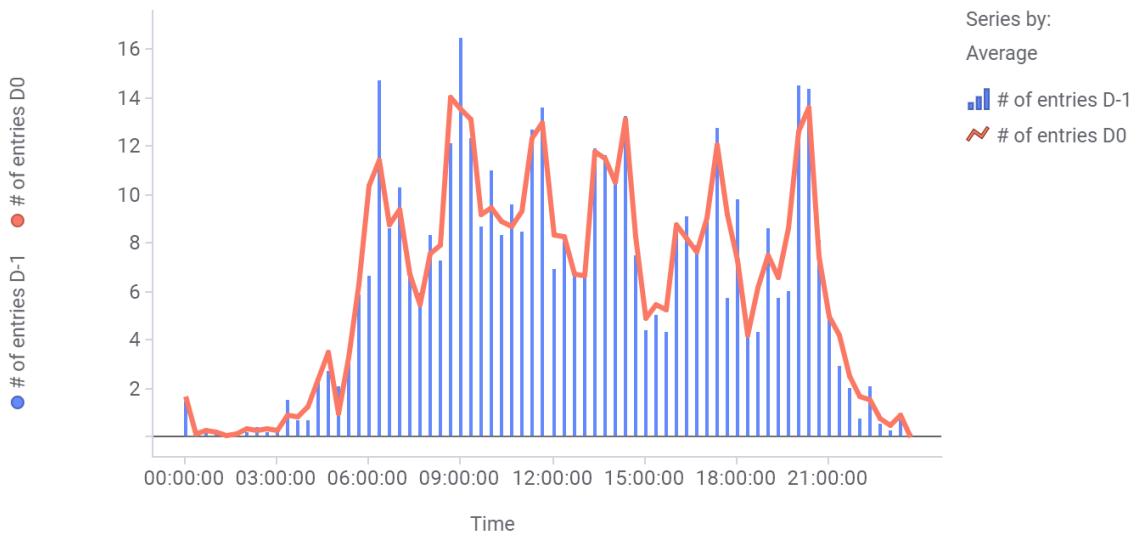
Average demand per 20 min D-1 & D0 EHRIVER



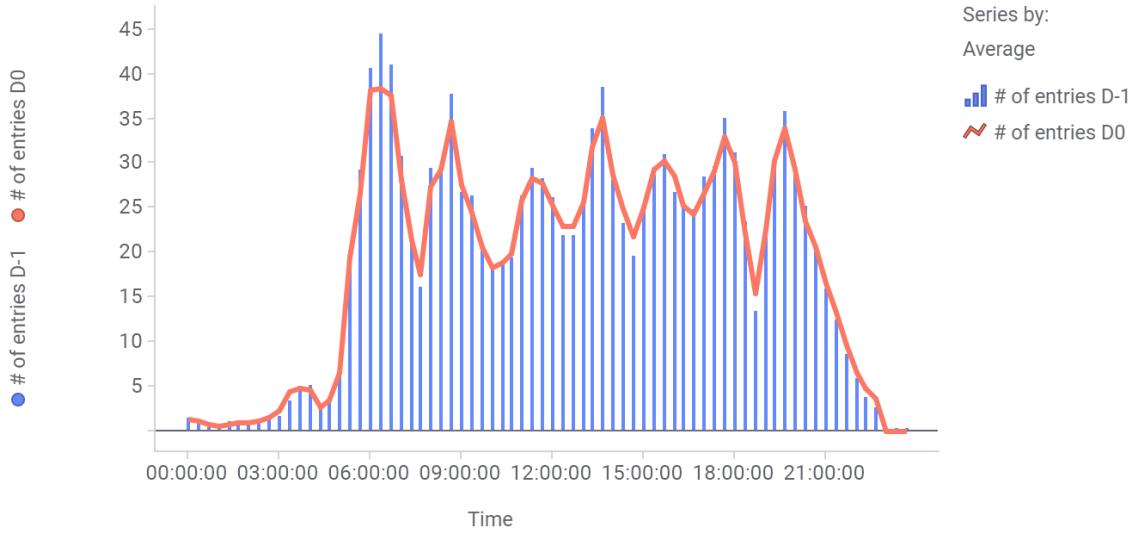
Average demand per hour rolling per 20 min D-1 & D0 EHSECT2



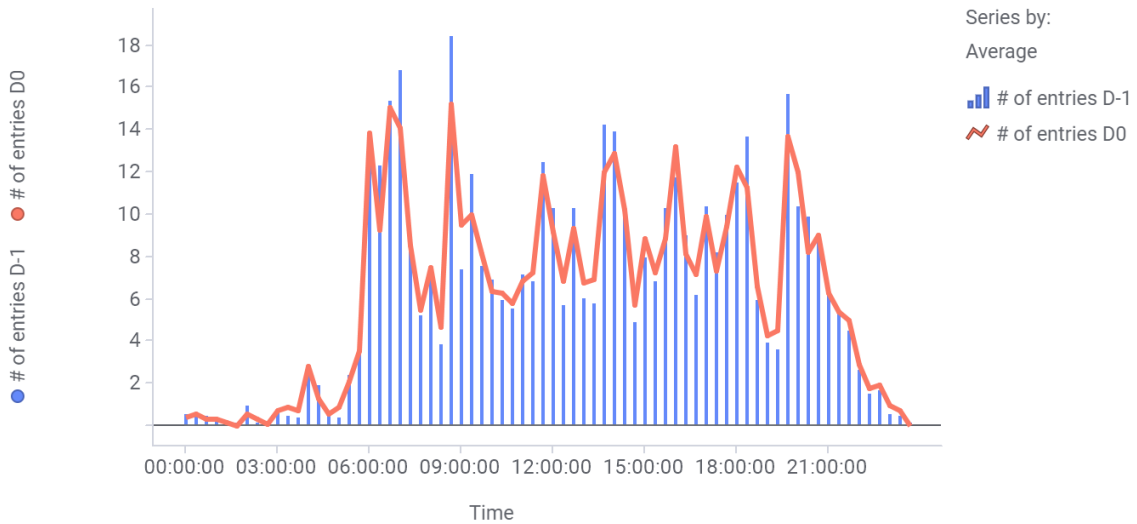
Average demand per 20 min D-1 & D0 EHSECT2



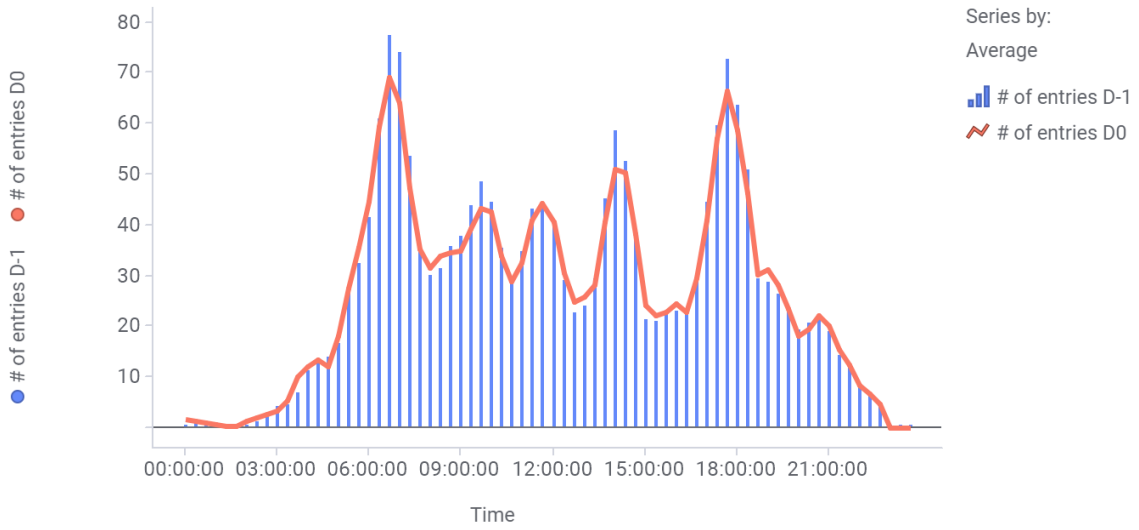
Average demand per hour rolling per 20 min D-1 & D0 EHSECT3



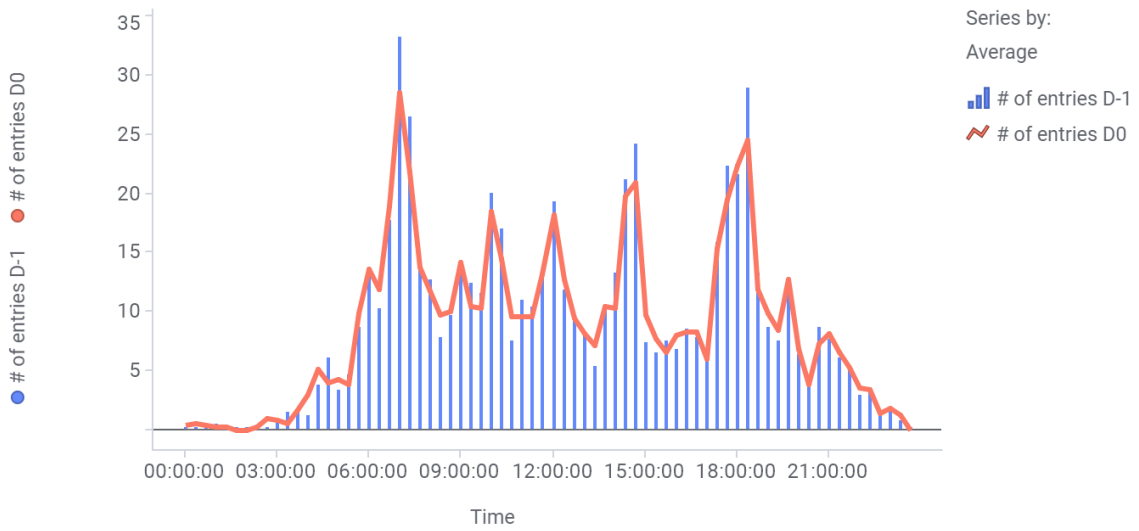
Average demand per 20 min D-1 & D0 EHSECT3



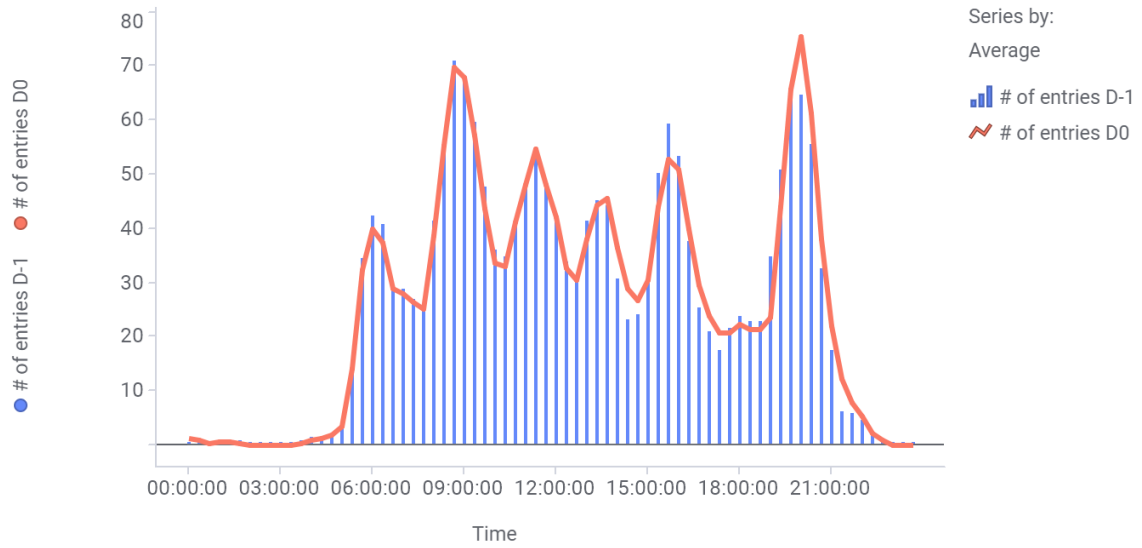
Average demand per hour rolling per 20 min D-1 & D0 EHAM Arrival South



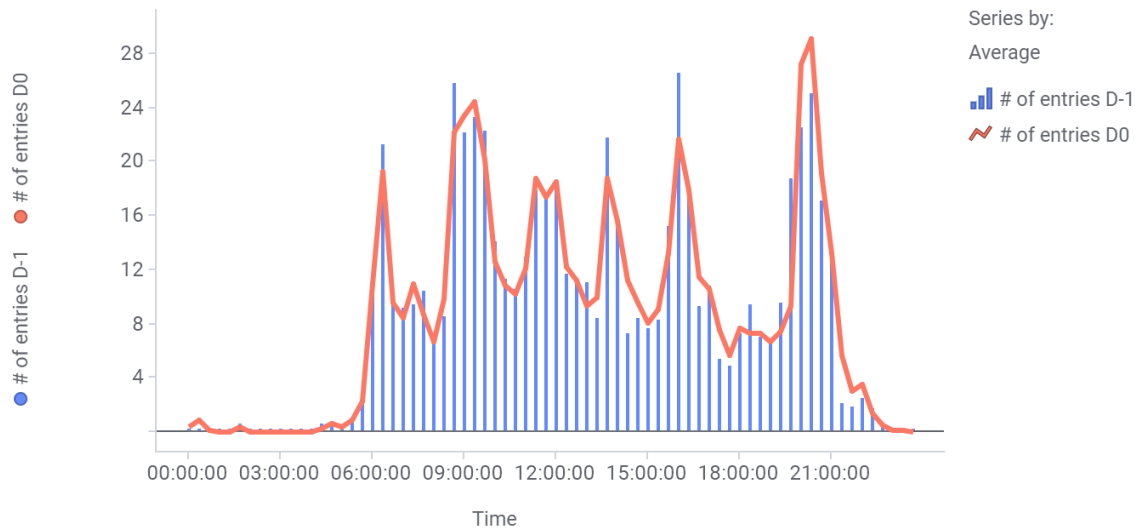
Average demand per 20 min D-1 & D0 EHAM Arrival South



Average demand per hour rolling per 20 min D-1 & D0 EHAM Departure South

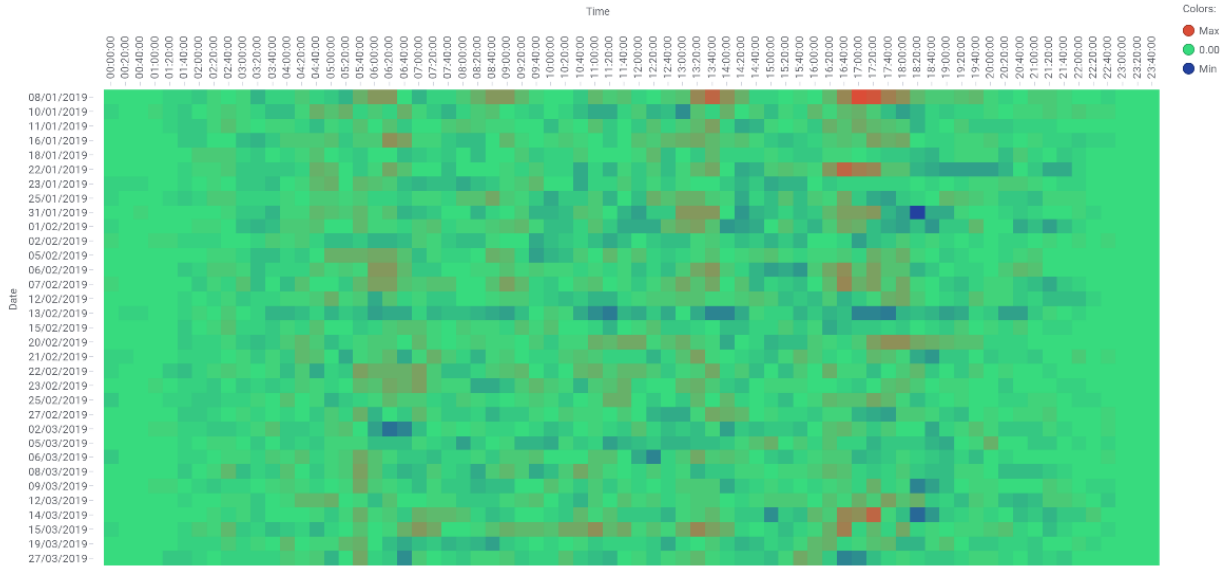


Average demand per 20 min D-1 & D0 EHAM Departure South

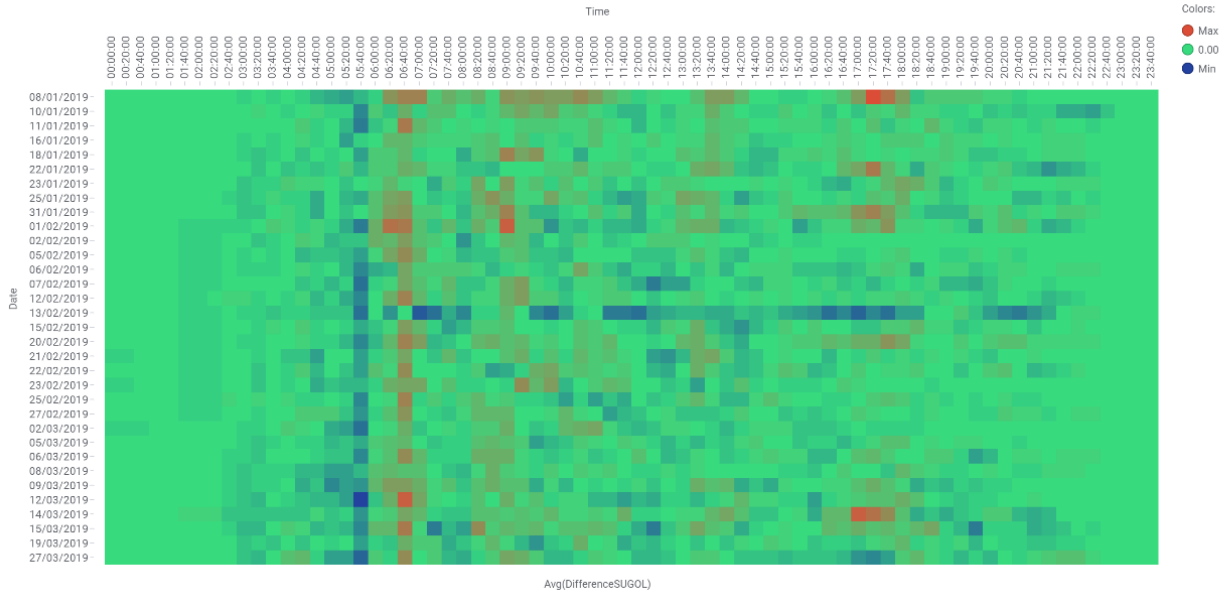


# Appendix X. Heatmaps

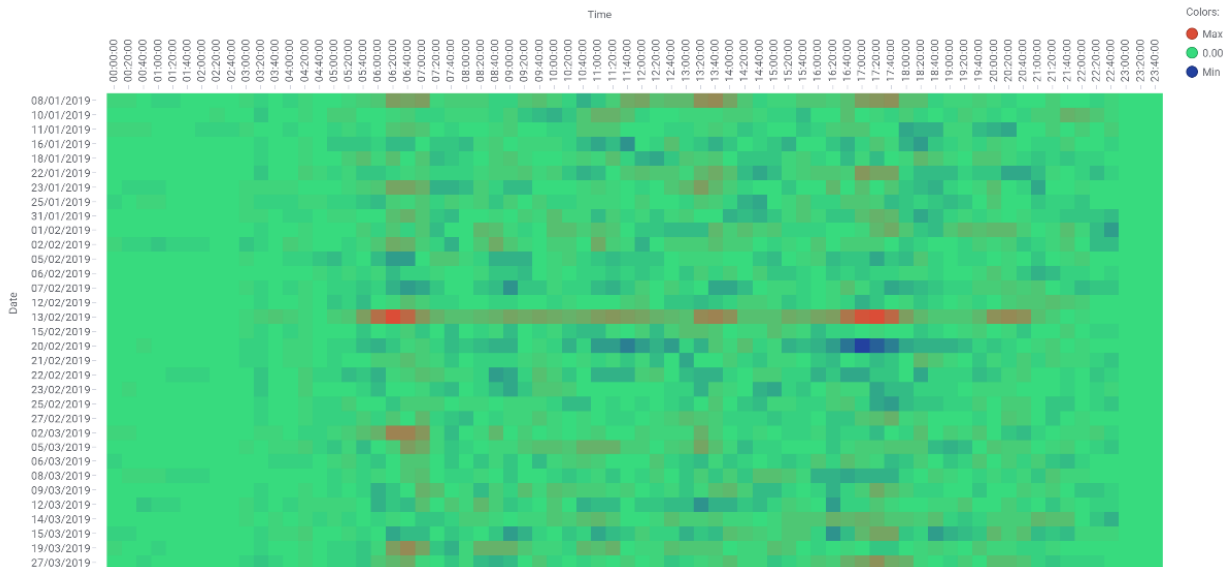
Difference EHARTIP



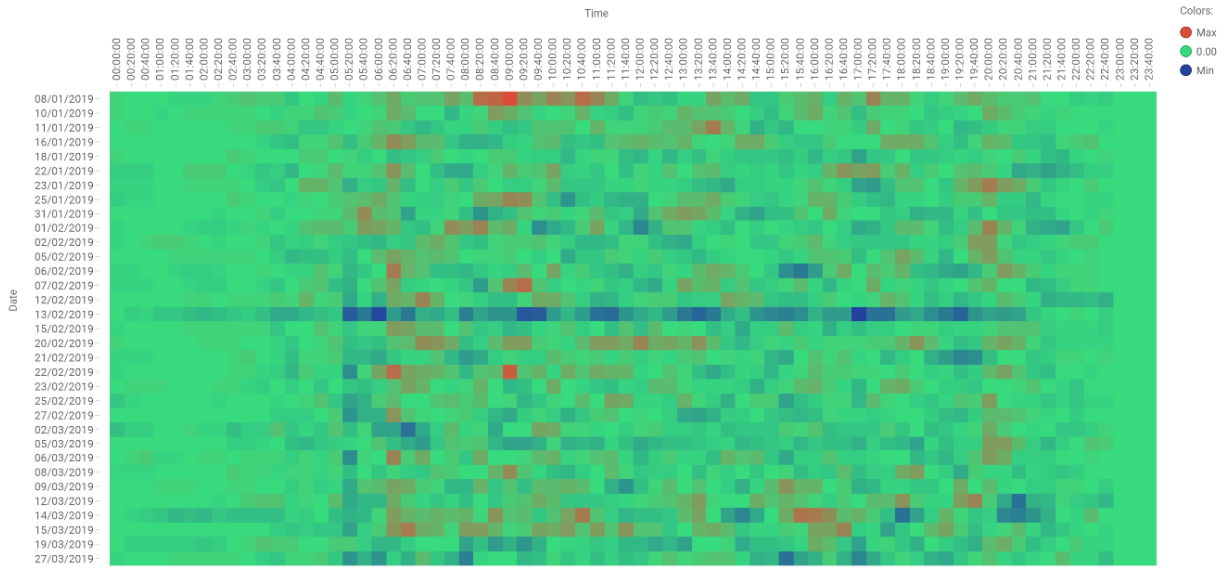
Difference EHSUGOL



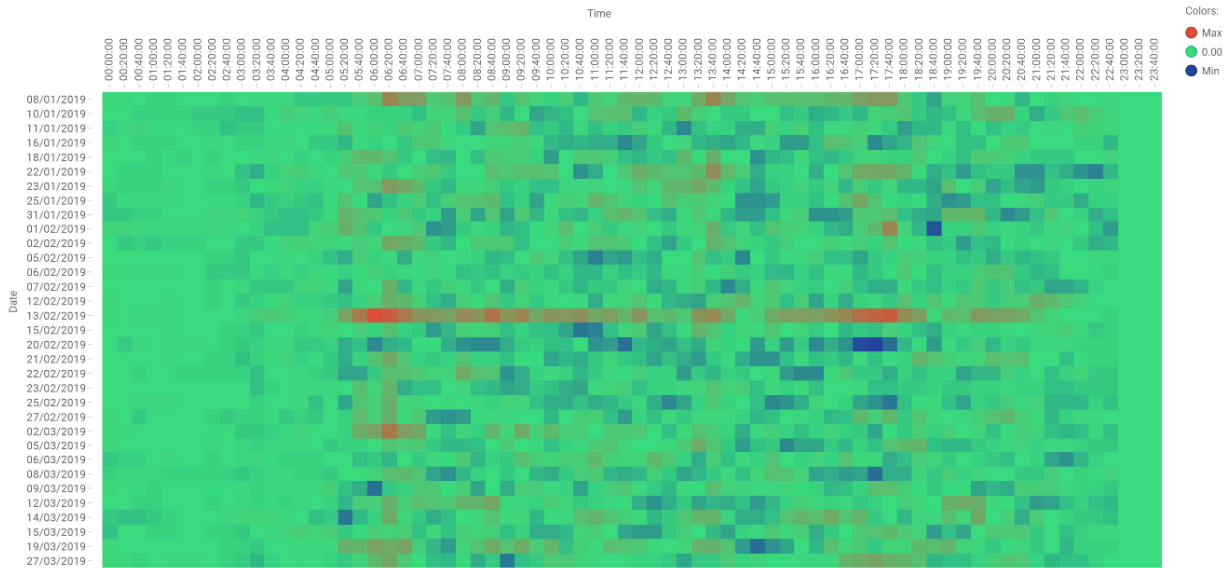
Difference EHRIVER



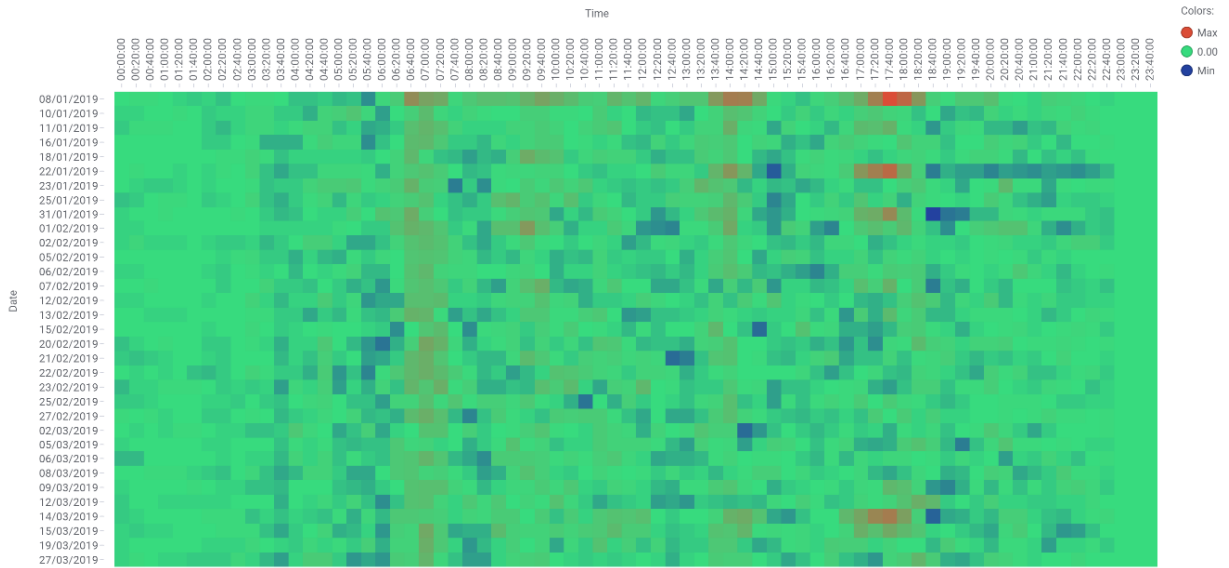
Difference EHSECT2



Difference EHSECT3



Difference EHAM Arrival South

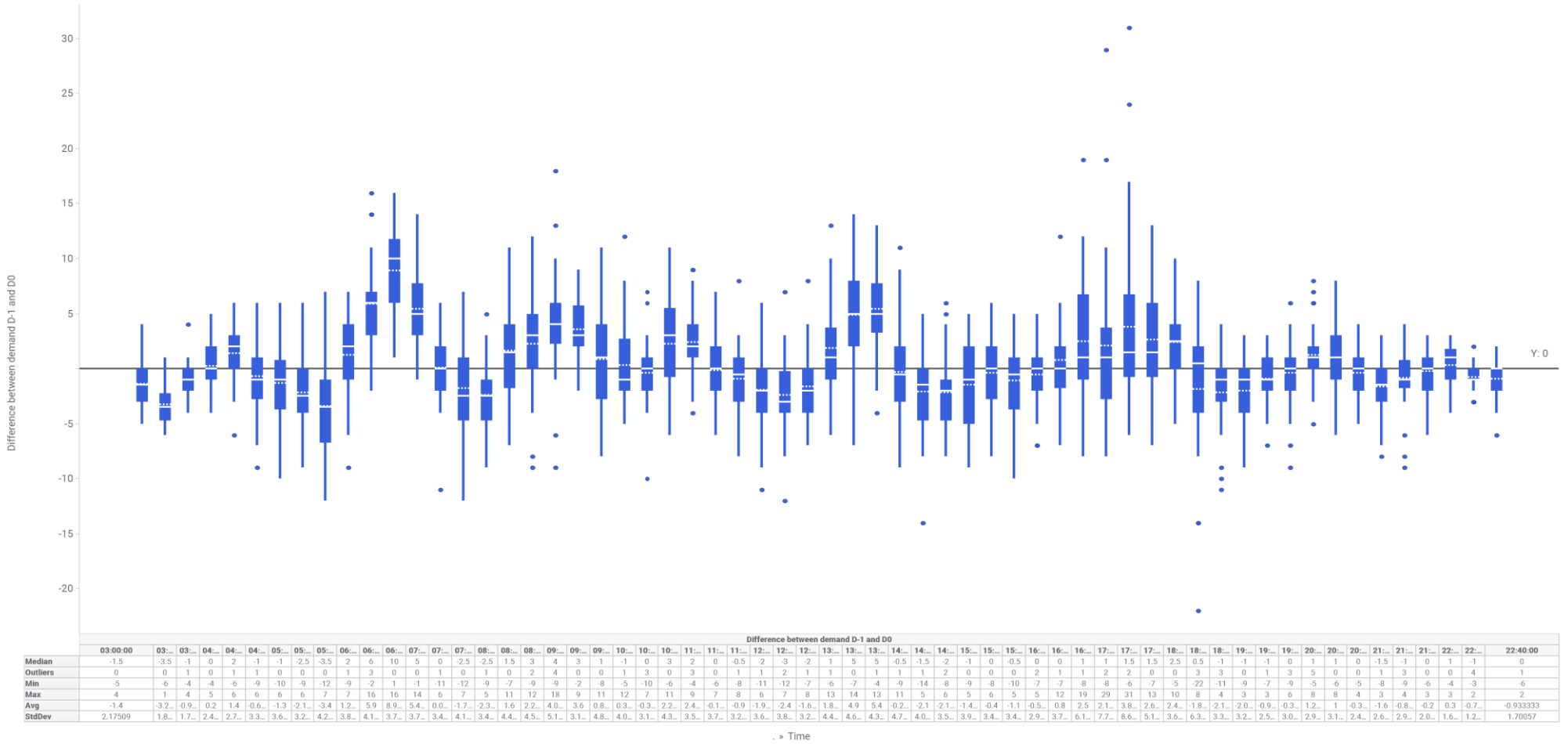


Difference EHAM Departure South

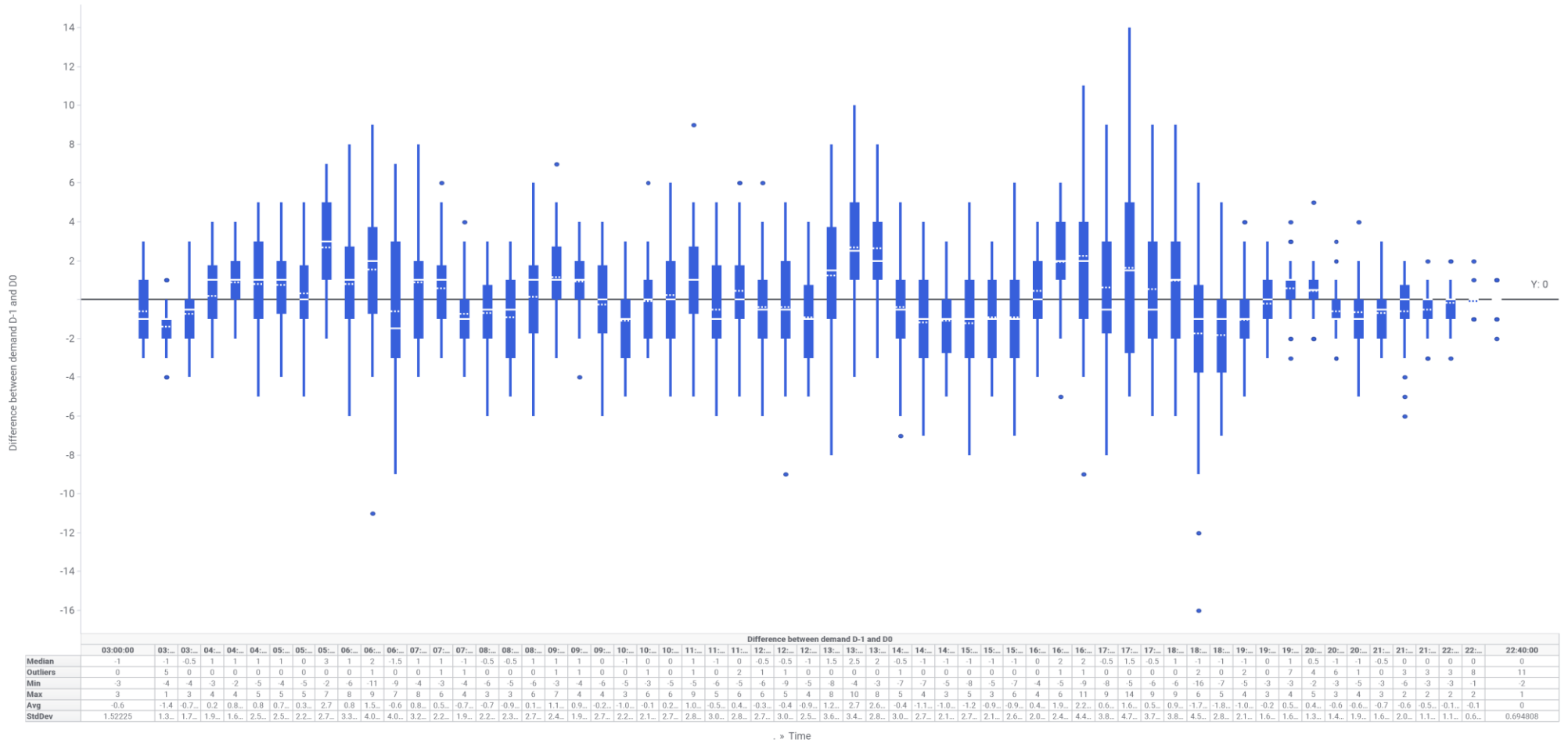


# Appendix XI. Boxplots of difference

Boxplot difference per hour rolling per 20 min EHFIRAM

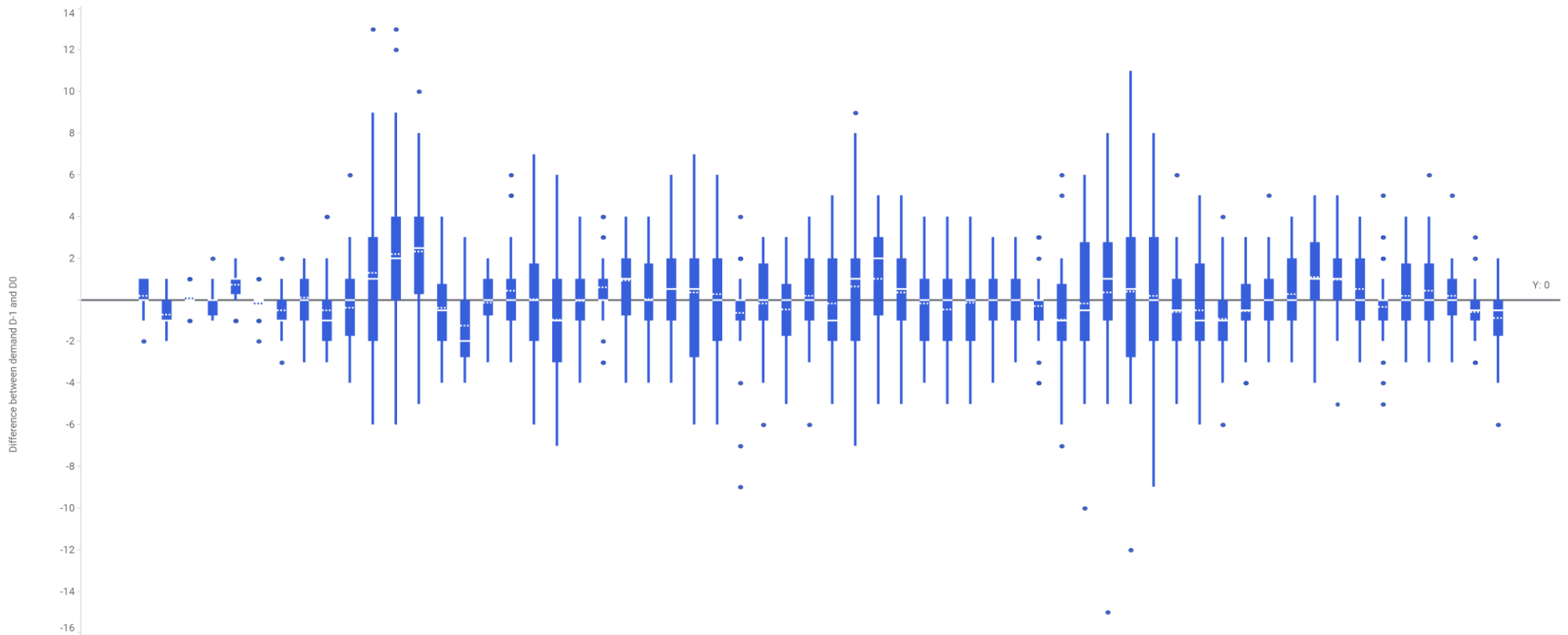


Boxplot difference per hour rolling per 20 min EHARTIP





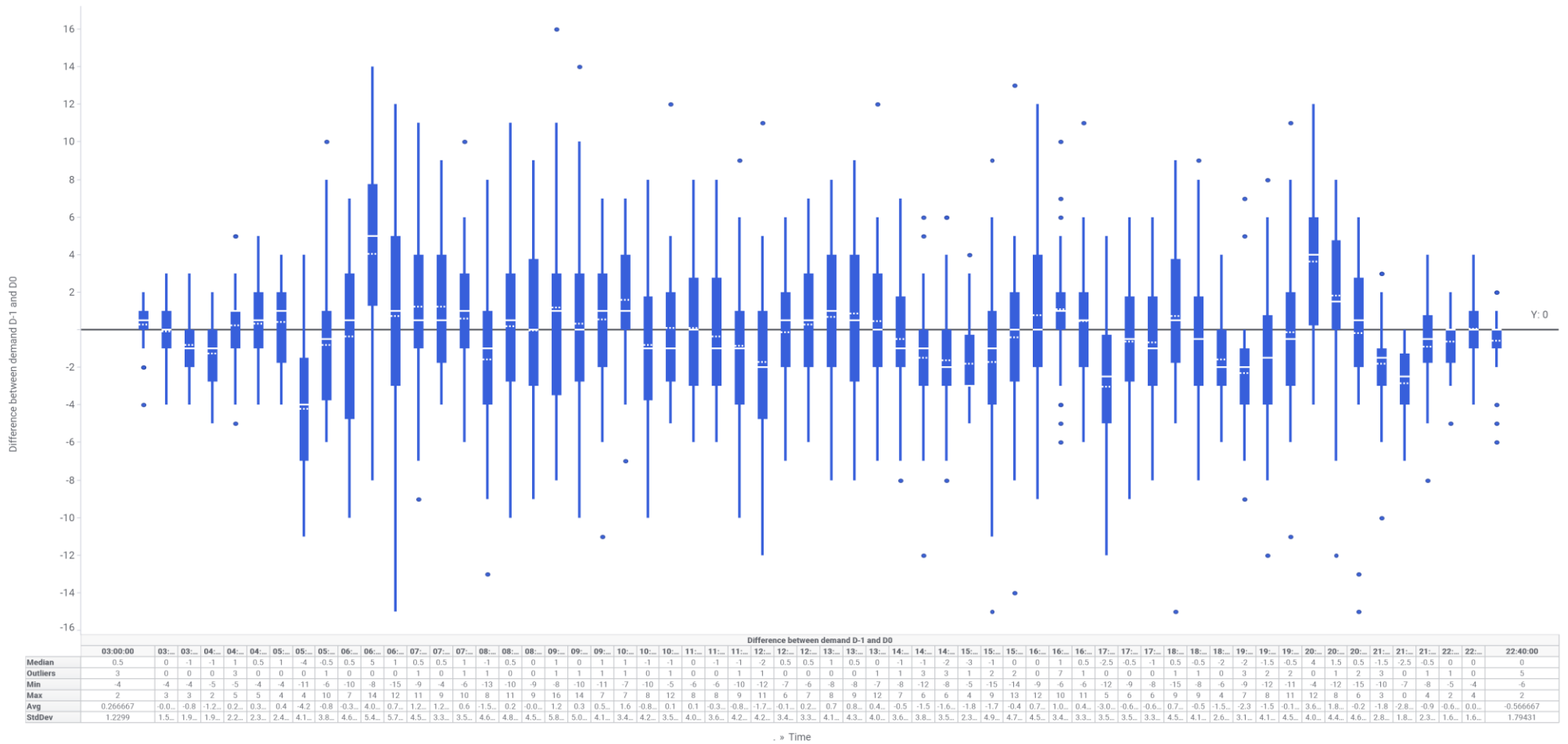
Boxplot difference per hour rolling per 20 min EHRIVER



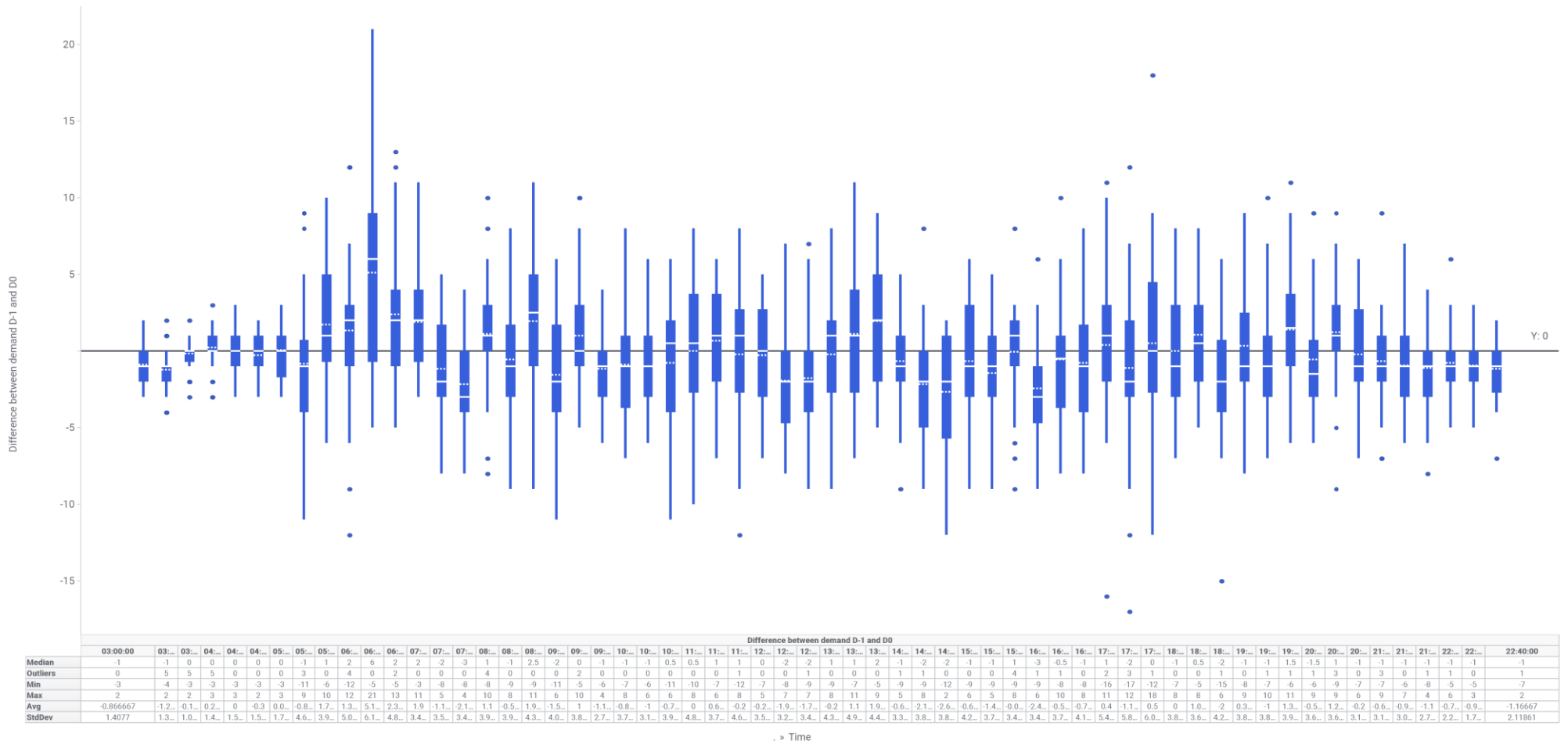
	Difference between demand D-1 and D0																																																															
	03:00:00	03:00:00	03:00:00	04:00:00	04:00:00	04:00:00	05:00:00	05:00:00	05:00:00	06:00:00	06:00:00	06:00:00	07:00:00	07:00:00	07:00:00	08:00:00	08:00:00	08:00:00	09:00:00	09:00:00	09:00:00	10:00:00	10:00:00	10:00:00	10:00:00	11:00:00	11:00:00	11:00:00	12:00:00	12:00:00	12:00:00	13:00:00	13:00:00	13:00:00	14:00:00	14:00:00	14:00:00	15:00:00	15:00:00	15:00:00	16:00:00	16:00:00	17:00:00	17:00:00	17:00:00	18:00:00	18:00:00	18:00:00	19:00:00	19:00:00	19:00:00	20:00:00	20:00:00	20:00:00	21:00:00	21:00:00	21:00:00	22:00:00	22:00:00	22:00:00	22:40:00			
Median	0	-1	0	0	1	0	-1	0	-1	0	1	2	2.5	-0.5	-2	0	0	0	-1	0	0	1	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-0.5	1	0.5	0	-0.5	-1	-1	-0.5	0	0	1	1	0	0	0	0	0	0	0	0	-0.5
Outliers	1	0	8	1	4	10	2	0	2	1	1	2	1	0	0	0	3	0	0	0	8	0	0	0	0	0	8	1	0	1	0	1	0	0	0	0	0	0	0	0	9	3	1	1	1	0	1	0	2	3	1	0	0	1	0	8	0	1	1	4	1			
Min	-2	-2	-1	-1	-1	-2	-3	-3	-4	-6	-6	-5	-4	-4	-3	-3	-6	-7	-4	-3	-4	-4	-4	-4	-6	-6	-9	-6	-5	-6	-5	-7	-5	-5	-4	-5	-4	-3	-4	-7	-10	-15	-12	-9	-5	-6	-6	-4	-3	-3	-4	-5	-3	-5	-3	-3	-3	-3	-6					
Max	1	-1	1	2	2	1	2	2	4	6	13	13	10	4	3	2	6	7	6	4	4	4	4	6	7	6	4	3	3	4	5	9	5	5	4	4	4	3	3	3	6	6	8	11	8	6	5	4	3	5	4	5	5	4	5	4	6	5	3	2				
Avg	0.166667	-0.7	0.0	-0.0	0.7	-0.1	-0.5	0.1	-0.5	-0.3	1.3	2.2	2.3	-0.4	-1.2	-0.1	0.4	0.0	-0.9	-0.0	0.6	0.9	0.0	0.5	0.3	0.2	-0.6	-0.2	-0.4	0.1	-0.2	0.6	1	0.3	-0.1	-0.4	-0.1	0.0	0	-0.3	-0.9	-0.1	0.3	0.4	0.1	-0.6	-0.5	-0.9	-0.5	-0.0	0.2	1.1	0.9	0.5	-0.3	0.2	0.4	0.2	-0.6	-0.866667				
StdDev	0.74664	0.8	0.5	0.7	0.8	0.6	1.1	1.3	1.8	2.3	4.2	4.6	3.2	1.8	1.9	1.2	2.2	3.0	2.9	1.9	1.7	1.9	1.9	2.3	3.4	3.0	2.5	2.0	1.8	2.2	2.6	3.5	2.8	2.3	2.1	2.1	2.1	1.9	1.6	1.9	2.9	3.4	4.1	4.7	4.0	2.6	2.9	2.2	1.6	1.7	1.9	2.0	1.8	1.7	2.0	1.8	2.1	1.5	1.3	1.6344				

. > Time

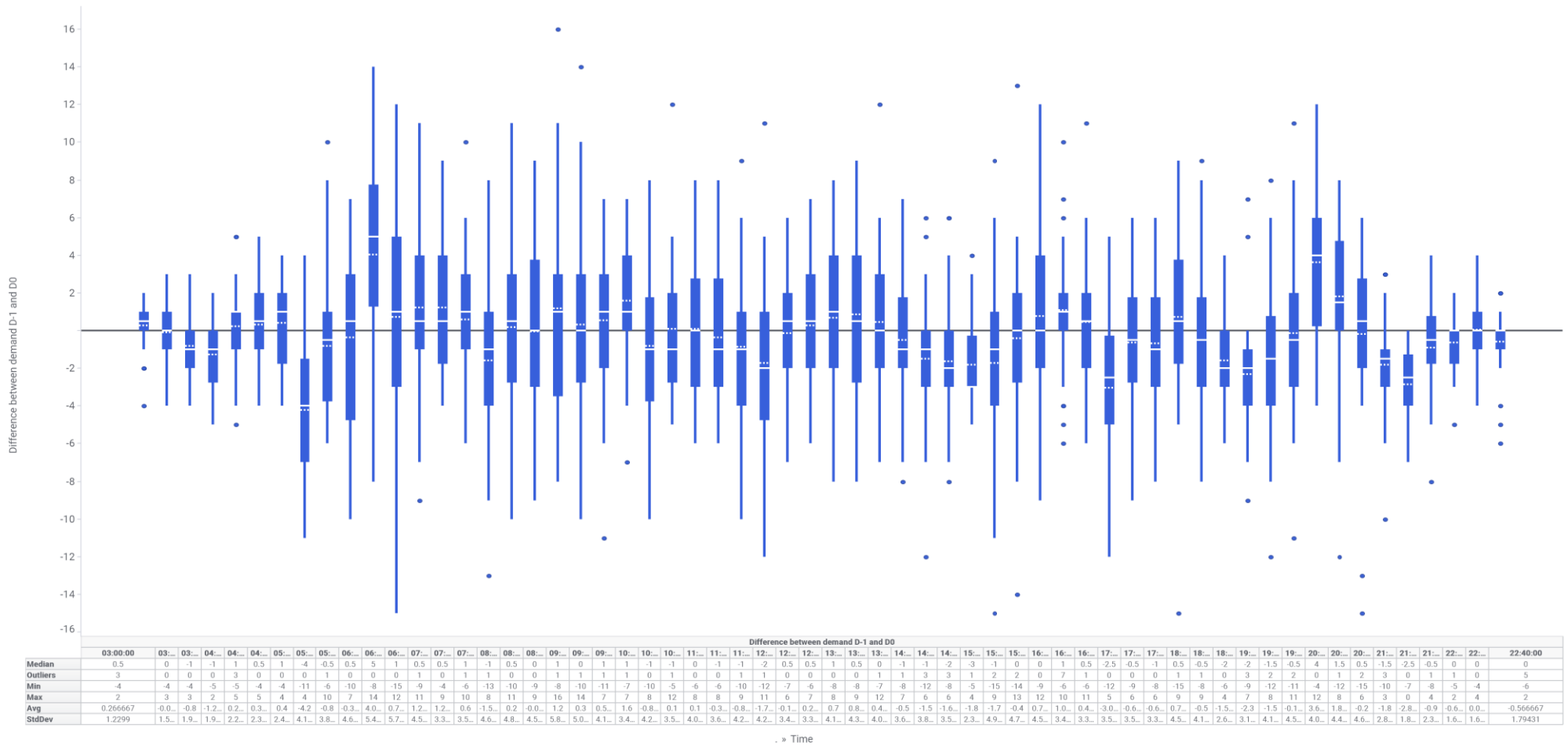
Boxplot difference per hour rolling per 20 min EHSECT2



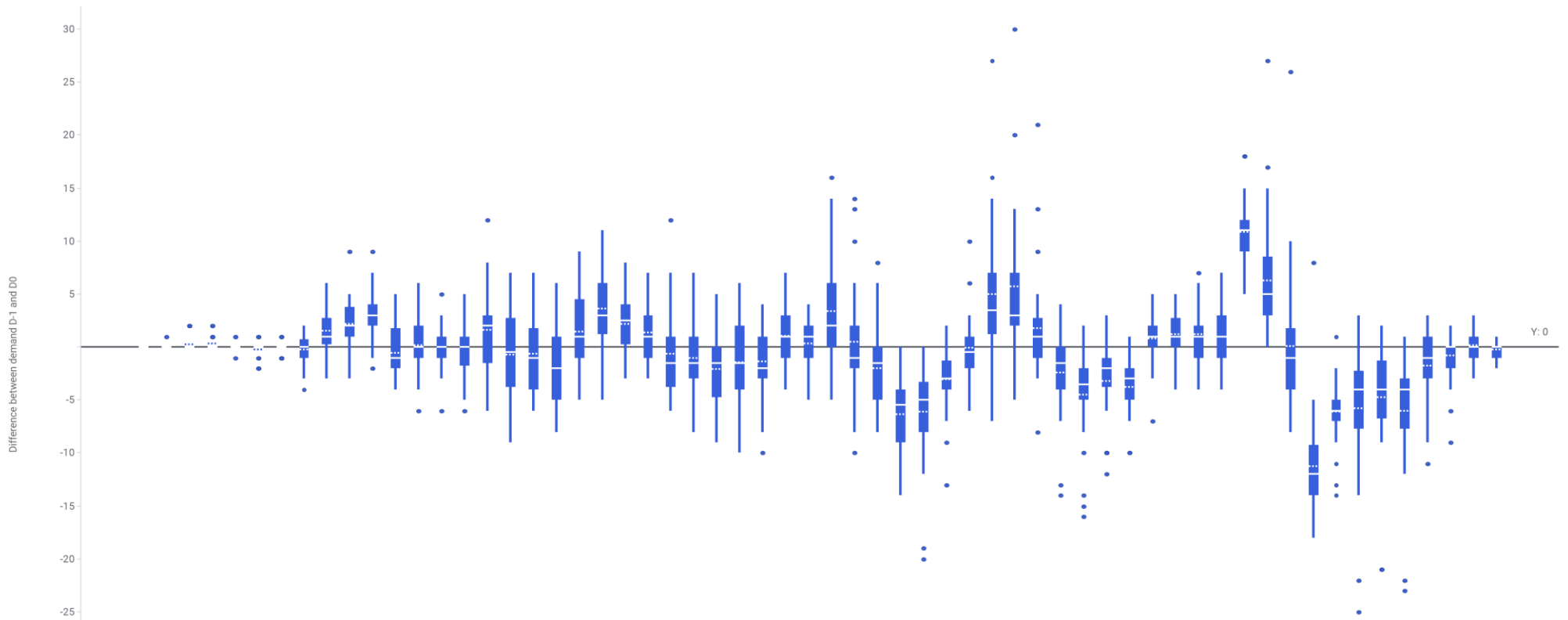
Boxplot difference per hour rolling per 20 min EHSECT3



Boxplot difference per hour rolling per 20 min EHAM Arrival South



Boxplot difference per hour rolling per 20 min EHAM Departure South



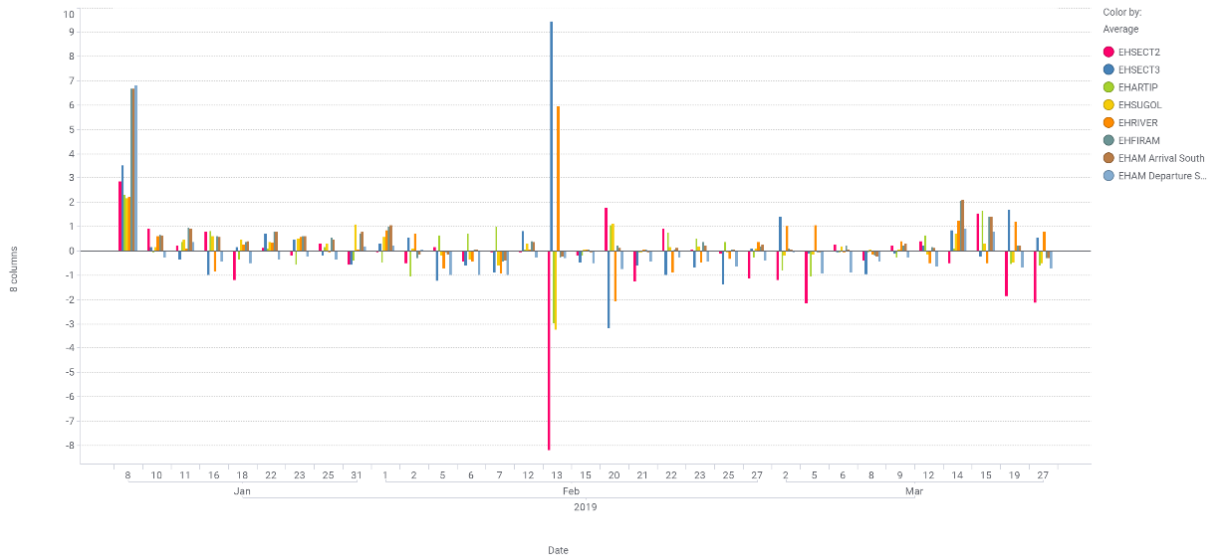
	03:00:00	03:00:00	03:00:00	04:00:00	04:00:00	04:00:00	05:00:00	05:00:00	05:00:00	06:00:00	06:00:00	06:00:00	07:00:00	07:00:00	07:00:00	08:00:00	08:00:00	08:00:00	09:00:00	09:00:00	09:00:00	10:00:00	10:00:00	10:00:00	11:00:00	11:00:00	11:00:00	12:00:00	12:00:00	12:00:00	13:00:00	13:00:00	13:00:00	14:00:00	14:00:00	14:00:00	15:00:00	15:00:00	15:00:00	16:00:00	16:00:00	17:00:00	17:00:00	17:00:00	18:00:00	18:00:00	18:00:00	19:00:00	19:00:00	19:00:00	20:00:00	20:00:00	20:00:00	21:00:00	21:00:00	21:00:00	22:00:00	22:00:00	22:00:00	22:40:00
Median	0	0	0	0	0	0	0	1	2	3	-1	0	0	0	2	-0.5	-1	-2	1	3	2.5	1	-1.5	-1.5	-1.5	-1.5	-2	1	1	2	-1	-1.5	-5.5	-5	-3	-0.5	3.5	3	1	-1.5	-3.5	-2	-3	1	1	1	1	11	5	-1	-12	-6	-4	-4	-4	-1	0	0	0	
Outliers	0	1	4	7	3	10	9	1	0	1	2	0	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	4	1	0	2	2	2	2	2	4	2	4	5	2	1	0	1	0	2	2	1	1	4	2	2	2	1	2	0	0
Min	0	0	0	0	-1	-2	-1	-4	-3	-2	-4	-6	-6	-6	-6	-9	-6	-8	-5	-5	-3	-3	-6	-8	-9	-10	-10	-4	-5	-5	-10	-8	-14	-20	-13	-6	-7	-5	-8	-14	-16	-12	-10	-7	-4	-4	-4	5	0	-8	-18	-14	-25	-21	-23	-11	-9	-3	-2	
Max	0	1	2	2	1	1	2	6	9	9	5	6	5	5	12	7	7	6	9	11	8	7	12	7	5	6	4	7	4	16	14	8	0	0	2	10	27	30	21	4	2	3	1	5	5	7	7	18	27	26	8	1	3	2	1	3	2	3	1	
Avg	0	0.0	0.2	0.3	0.0	-0.2	-0.1	0.2	1.5	2.1	3	-0.5	0.1	0	0	1.6	-0.7	-0.6	-2	1.4	3.6	2.2	1.4	0.6	-1	-2.1	-1.4	-3.3	1.0	0.3	3.4	0.5	-1.9	-6.3	-6.1	-3.0	-0.1	4.9	5.7	1.8	-2.2	-4.4	-3.2	-3.7	0.8	1.2	1.2	0.9	10	6.3	0.1	-11	-6.1	-5.7	-4.7	-6	-1.7	-0.8	0.1	-0.266667
StdDev	0	0.1	0.6	0.5	0.3	0.8	0.5	1.3	1.8	2.3	2.3	2.4	2.7	2.1	2.6	4.1	4.3	3.9	3.7	3.6	3.5	2.9	2.5	4.0	3.4	3.5	4.1	3.2	2.7	2.4	5.1	5.3	4.0	3.7	4.7	3.0	3.1	6.6	6.8	5.2	4.0	4.4	3.6	2.5	2.4	2.0	2.6	2.5	3.1	5.7	6.6	4.8	3.1	6.0	5.1	5.5	3.1	2.3	1.3	0.827682

.> Time

## Appendix XII. Average difference per date

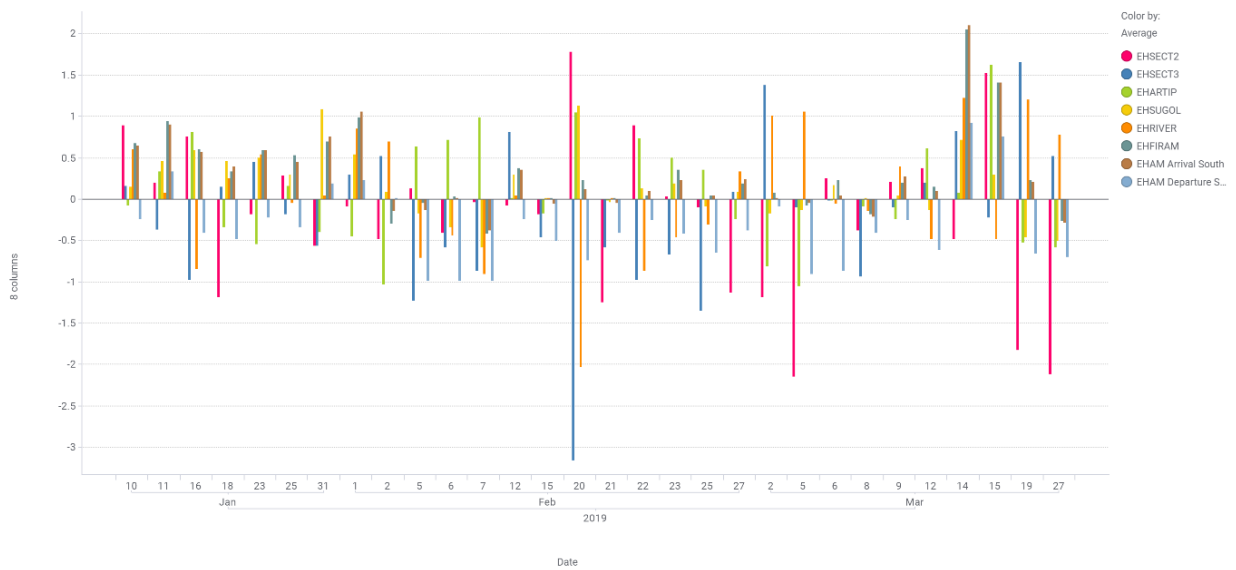
All data:

Average difference per date per airspace segment



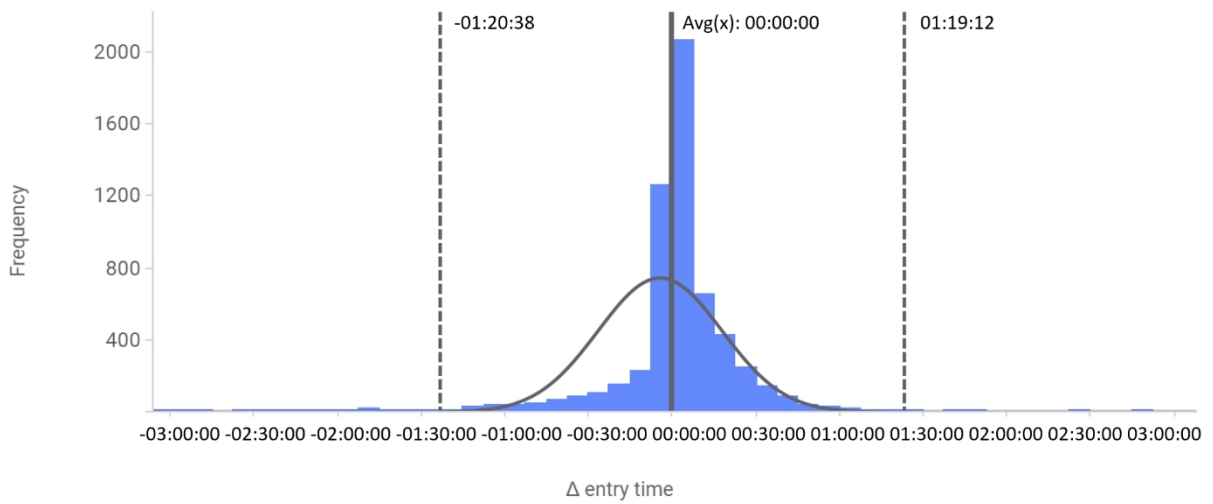
After filtering special days:

Average difference per date per airspace segment

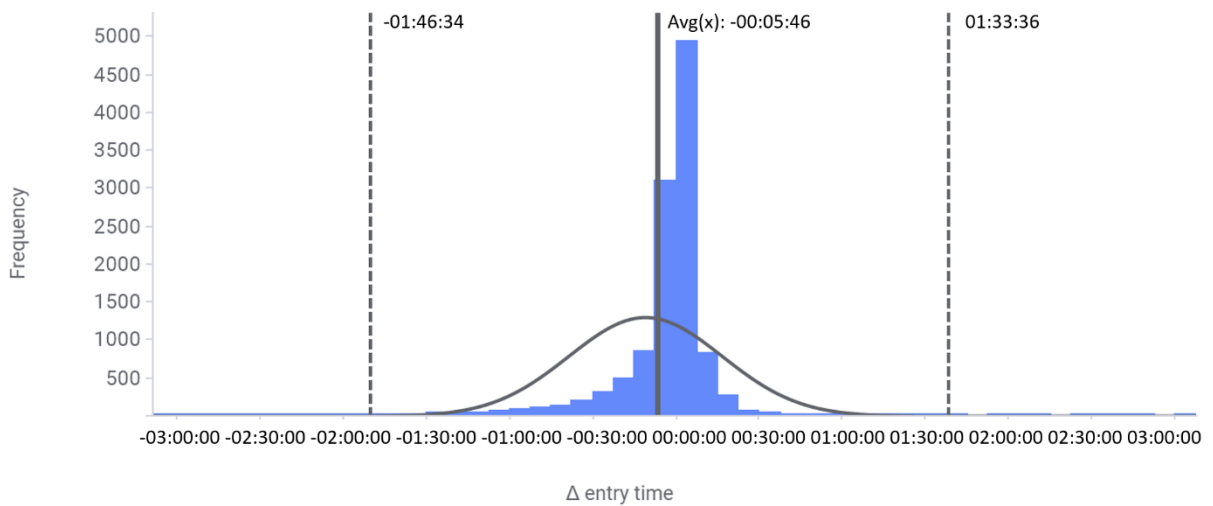


## Appendix XIII. Distribution difference in entry time

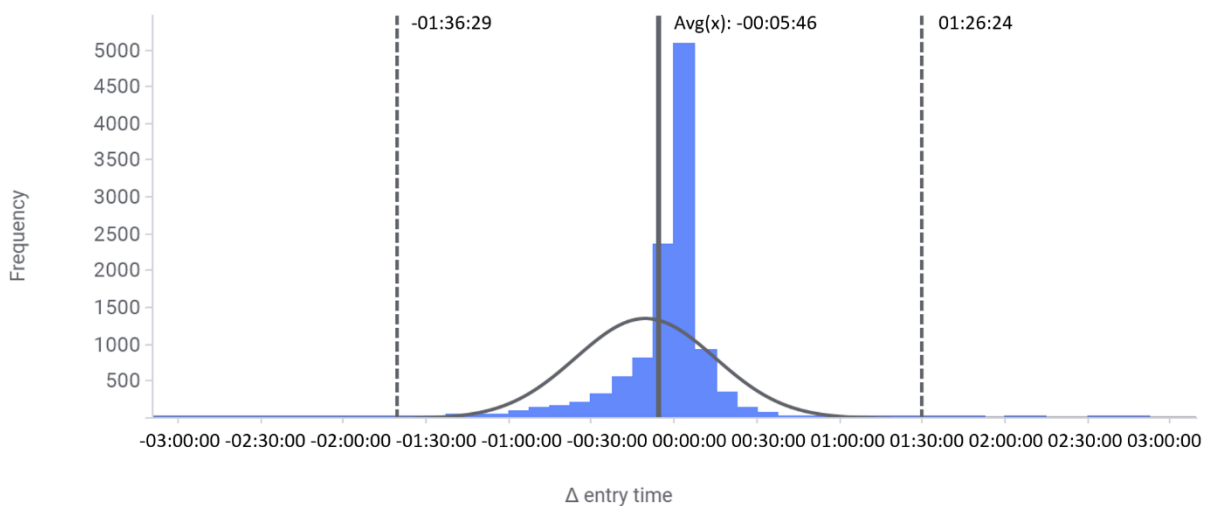
Distribution difference in entry time D0 with D-1 EHSUGOL



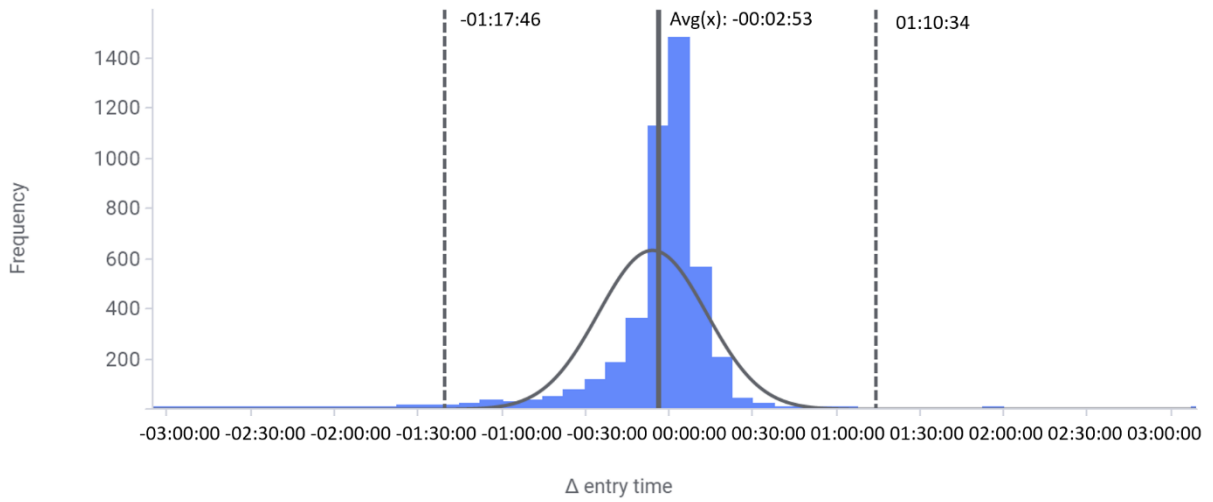
Distribution difference in entry time D0 with D-1 EHSECT3



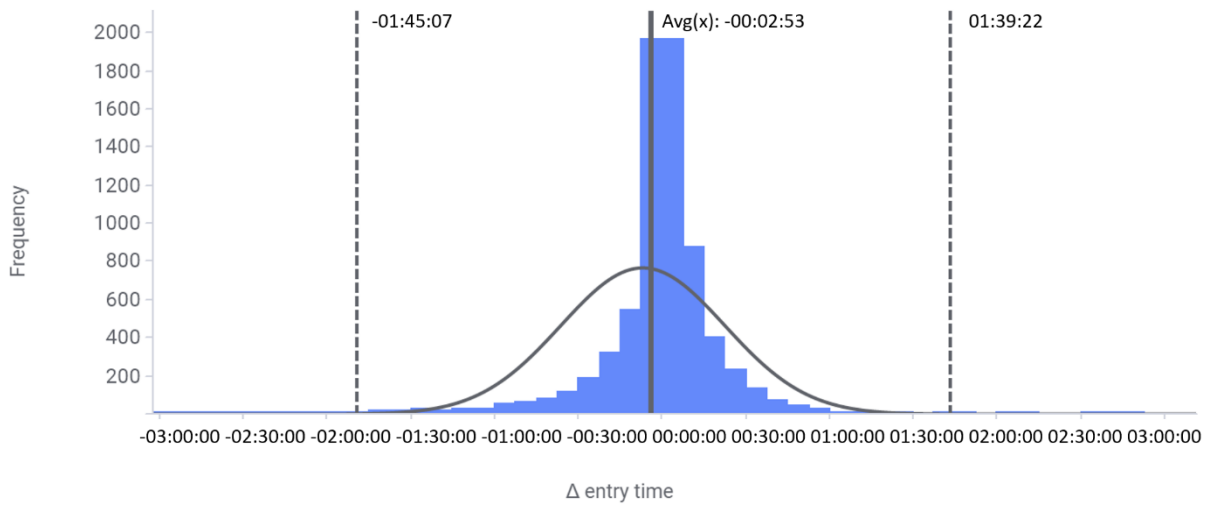
Distribution difference in entry time D0 with D-1 EHSECT2



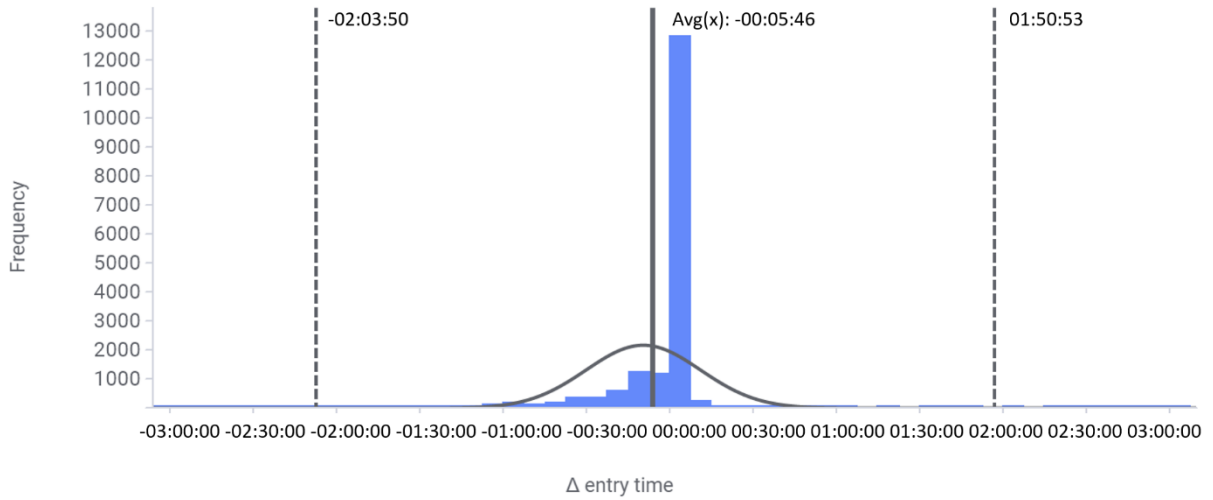
Distribution difference in entry time D0 with D-1 EHRIVER



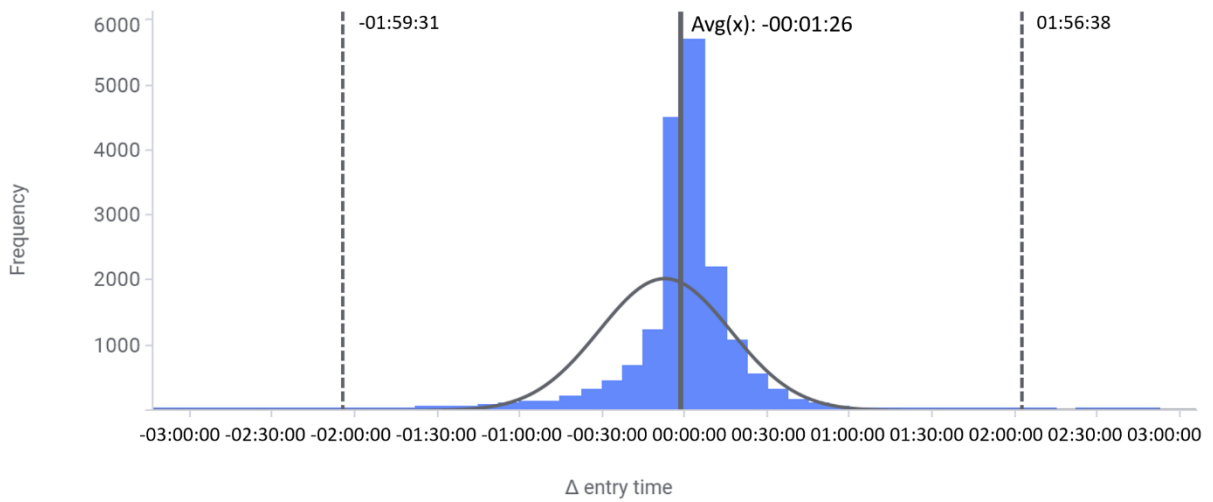
Distribution difference in entry time D0 with D-1 EHARTIP



Distribution difference in entry time D0 with D-1 EHAM Departure South

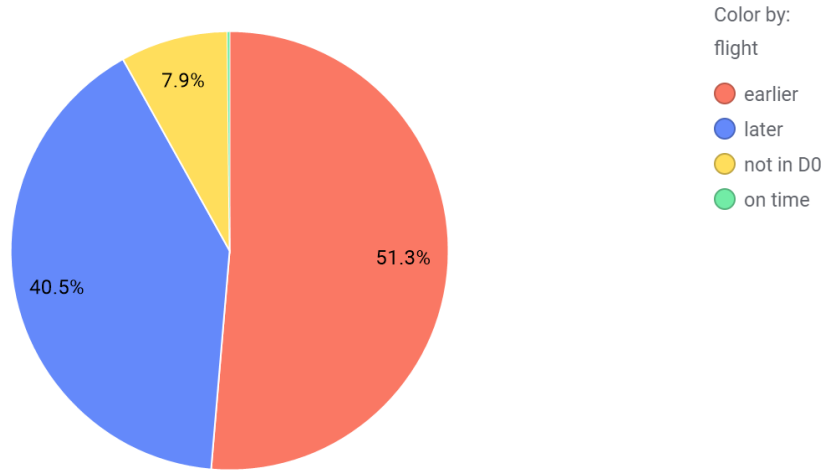


Distribution difference in entry time D0 with D-1 EHAM Arrival South

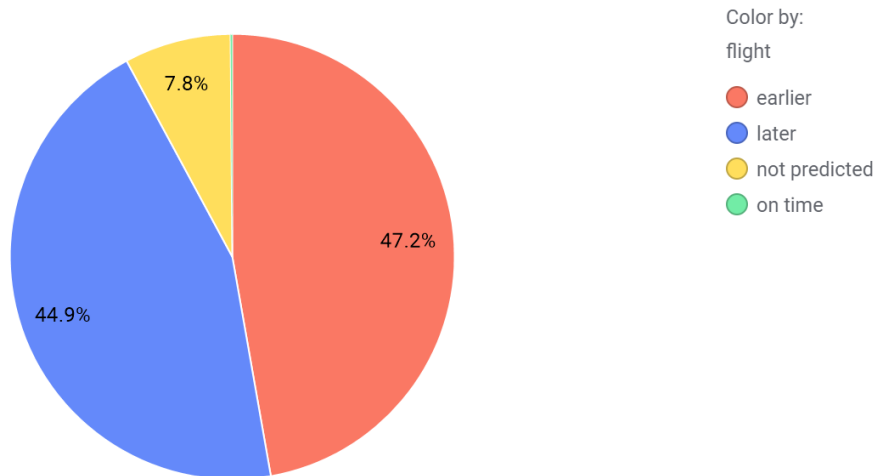


# Appendix XIV. Analysing differences in entry time general

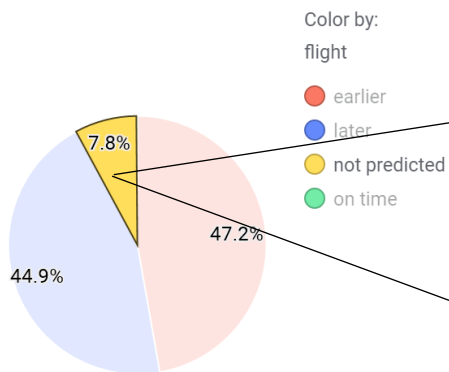
D-1 versus D0 entry time EHFIRAM



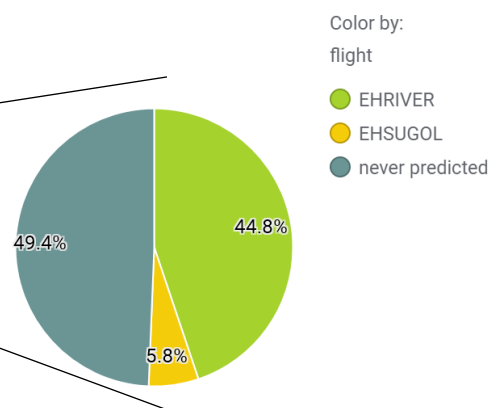
D0 versus D-1 entry time EHARTIP



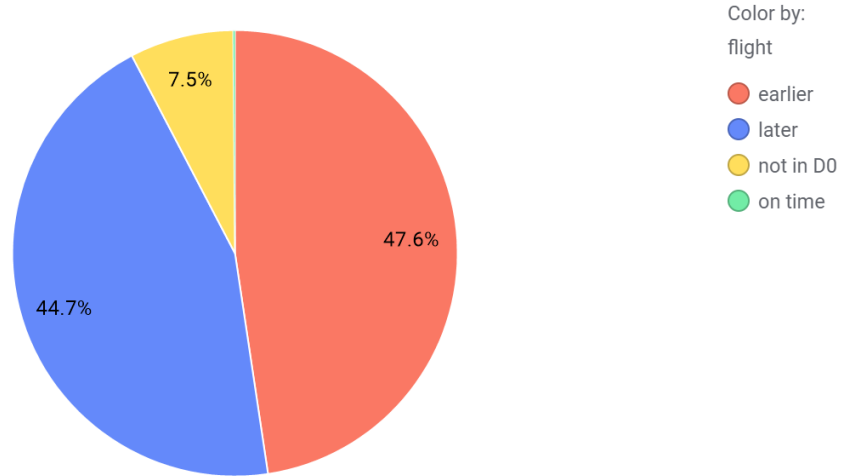
D0 versus D-1 entry time EHARTIP



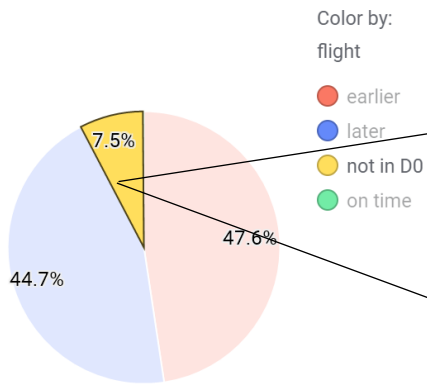
D0 versus D-1 not predicted in EHARTIP



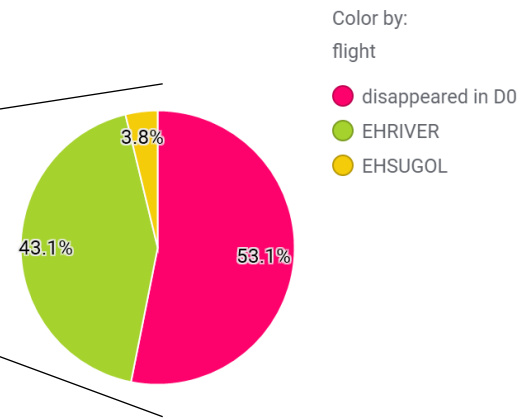
D-1 versus D0 entry time EHARTIP



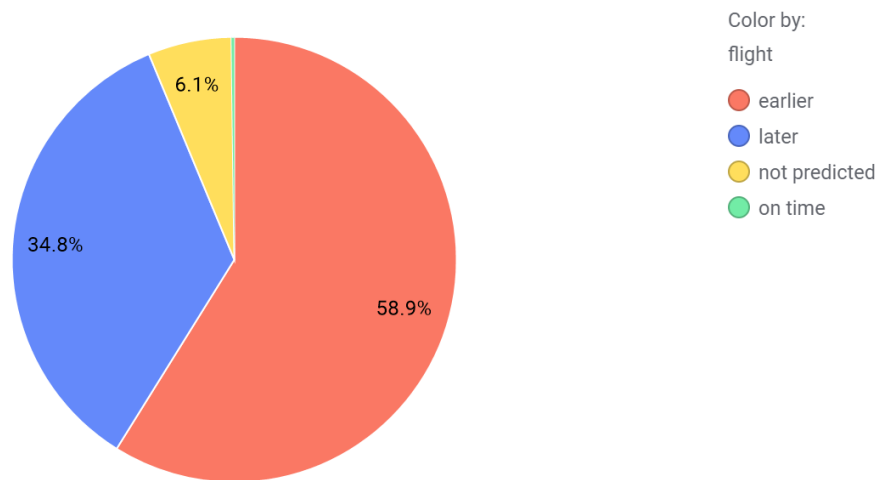
D-1 versus D0 entry time EHARTIP



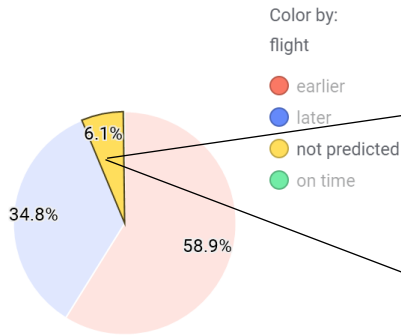
D-1 versus D0 not in D0 in EHARTIP



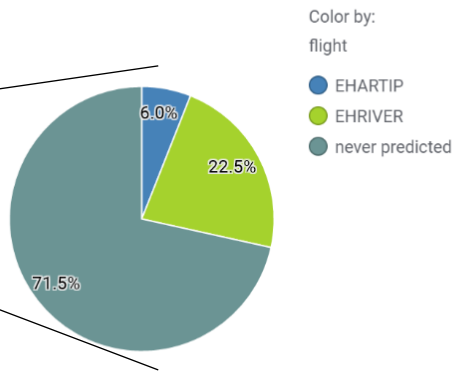
D0 versus D-1 entry time EHSUGOL



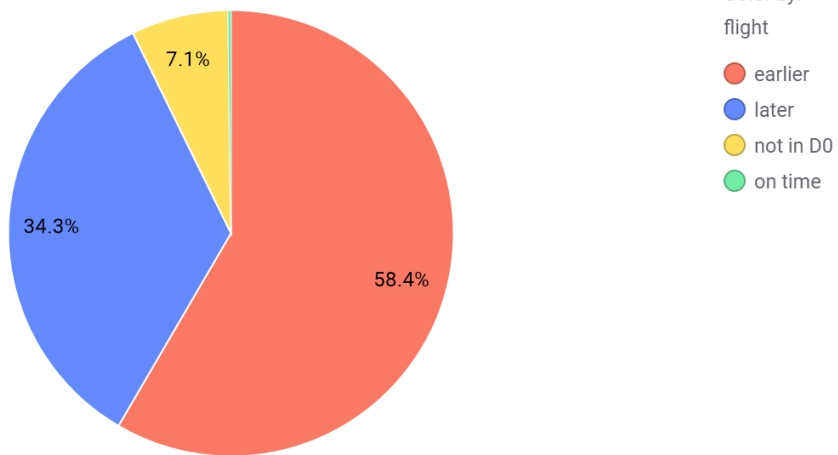
D0 versus D-1 entry time EHSUGOL



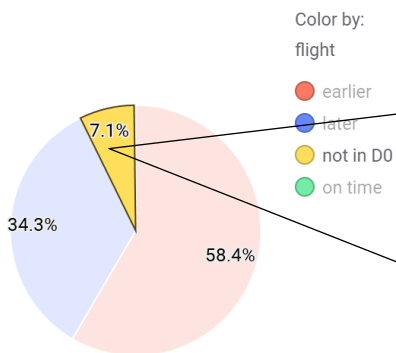
D0 versus D-1 not predicted in EHSUGOL



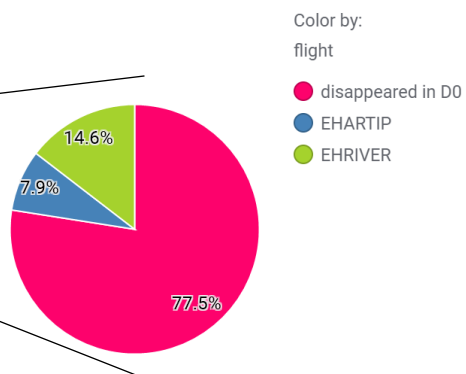
D-1 versus D0 entry time EHSUGOL



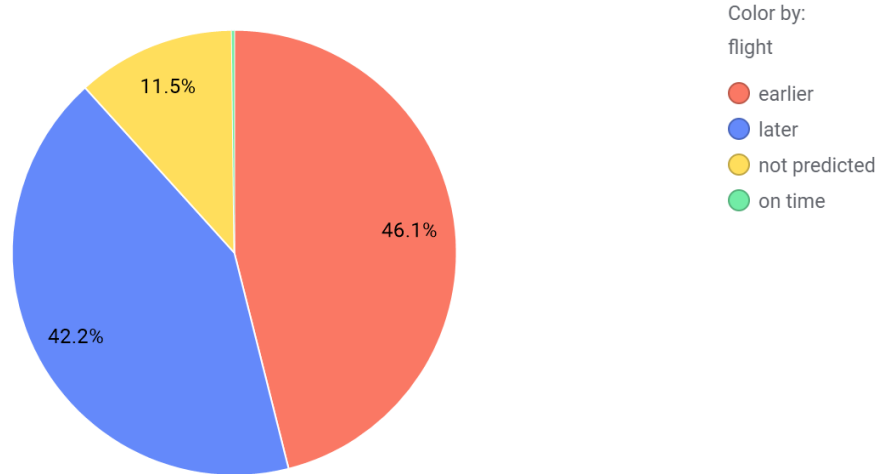
D-1 versus D0 entry time EHSUGOL



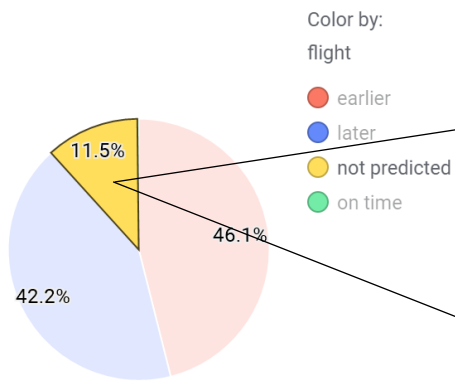
D-1 versus D0 not in D0 in EHSUGOL



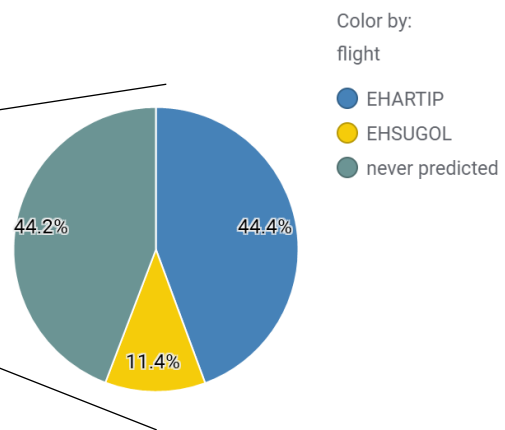
D0 versus D-1 entry time EHRIVER



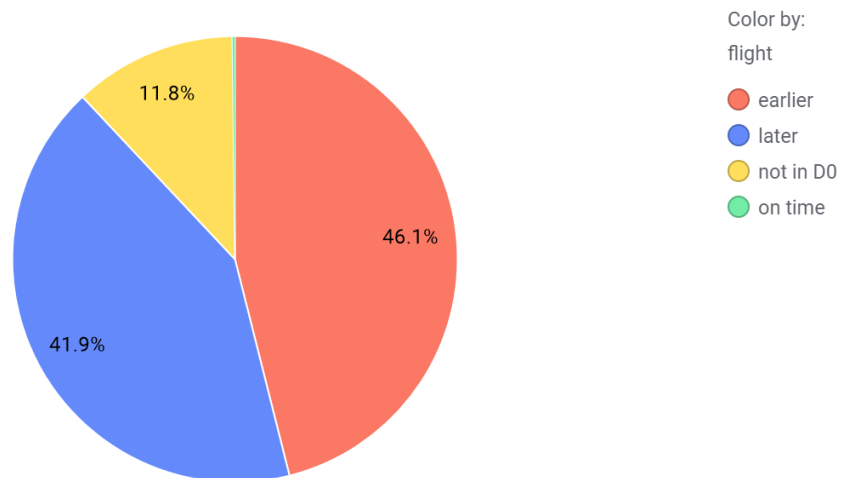
D0 versus D-1 entry time EHRIVER



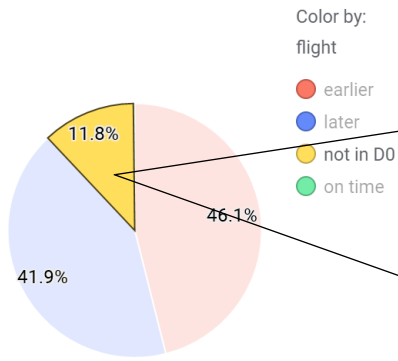
D0 versus D-1 not predicted in EHRIVER



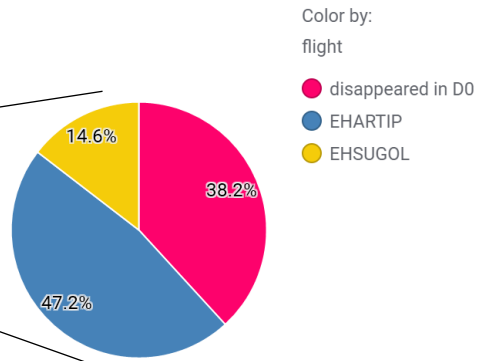
D-1 versus D0 entry time EHRIVER



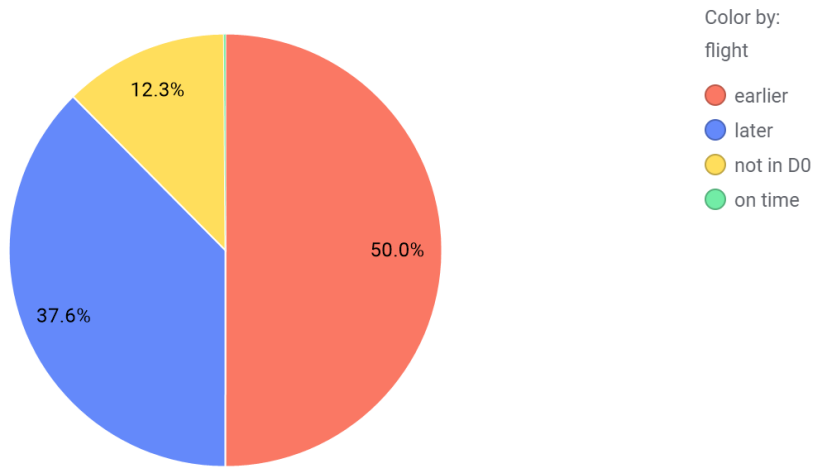
D-1 versus D0 entry time EHRIVER



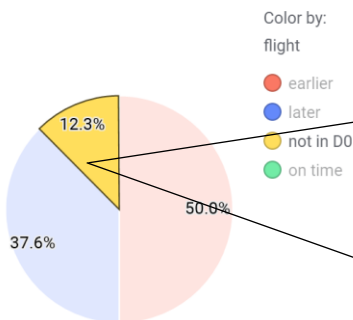
D-1 versus D0 not in D0 in EHRIVER



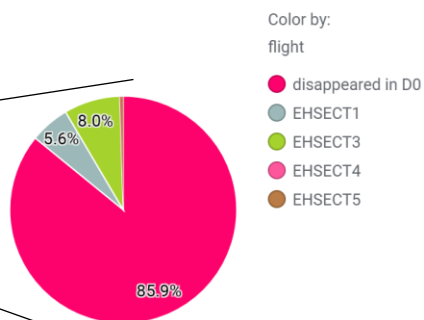
D-1 versus D0 entry time EHSECT2



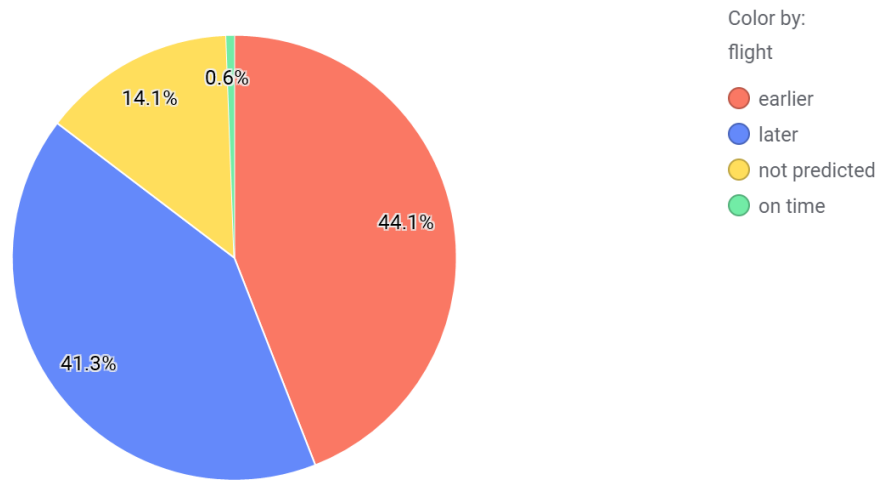
D-1 versus D0 entry time EHSECT2



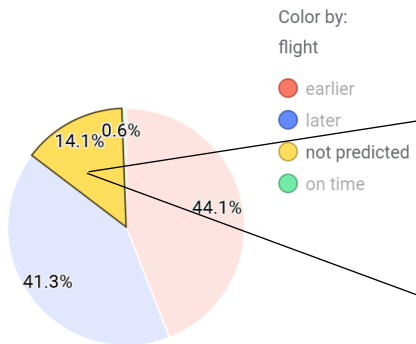
D-1 versus D0 not in D0 in EHSECT2



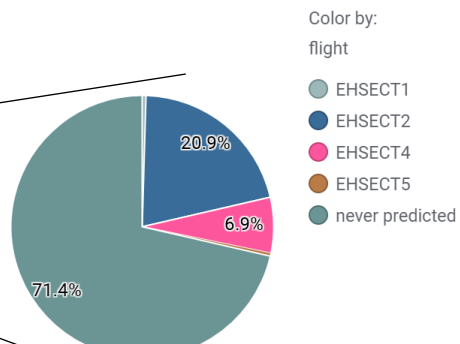
D0 versus D-1 entry time EHSECT3



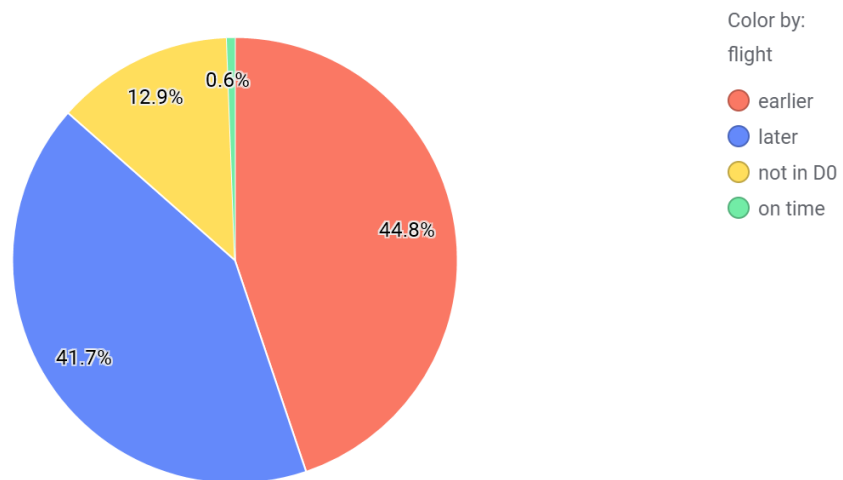
D0 versus D-1 entry time EHSECT3



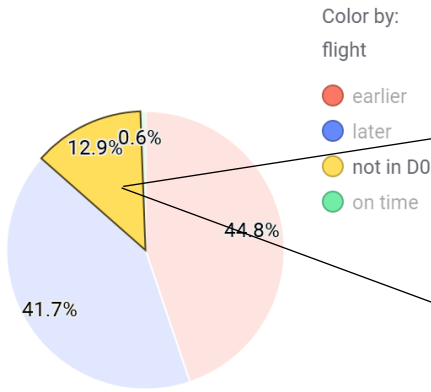
D0 versus D-1 not predicted in EHSECT3



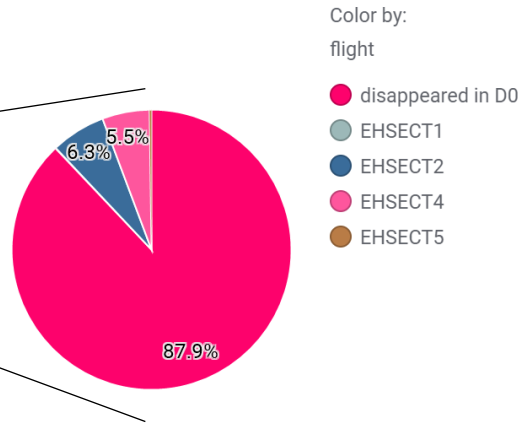
D-1 versus D0 entry time EHSECT3



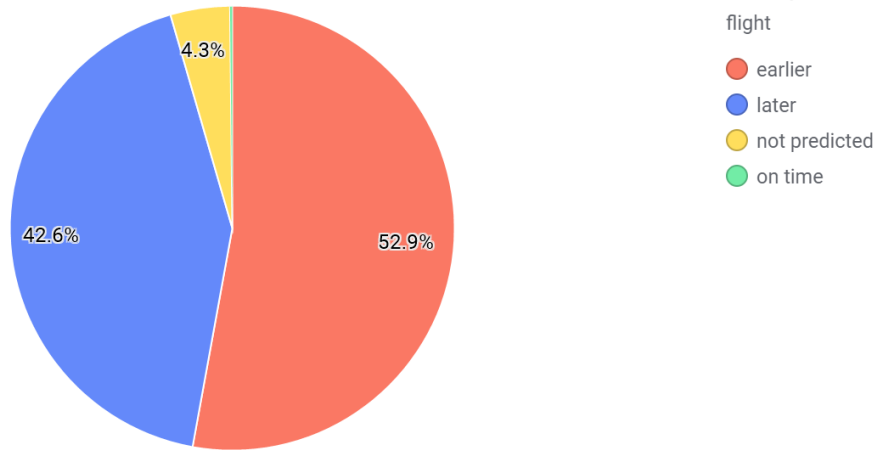
D-1 versus D0 entry time EHSECT3



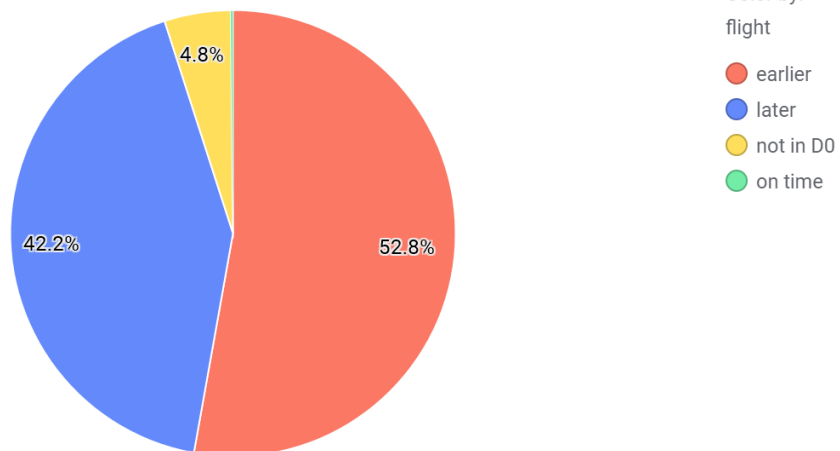
D-1 versus D0 not in D0 in EHSECT3



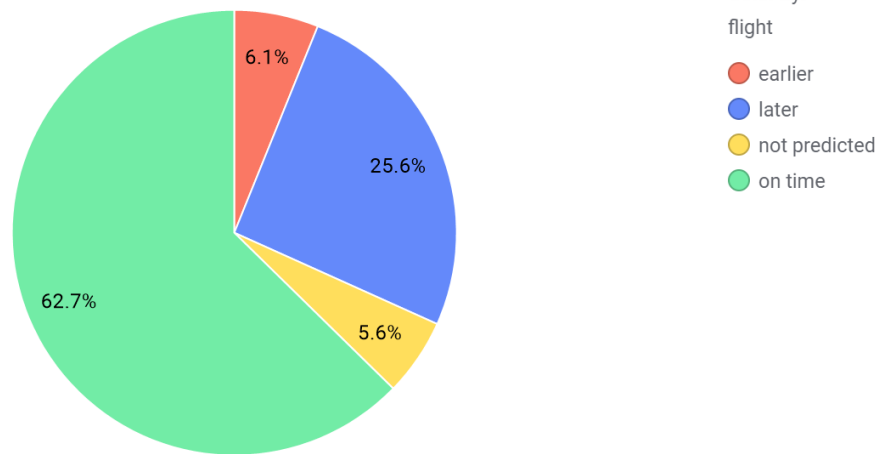
D0 versus D-1 entry time EHAM Arrival South



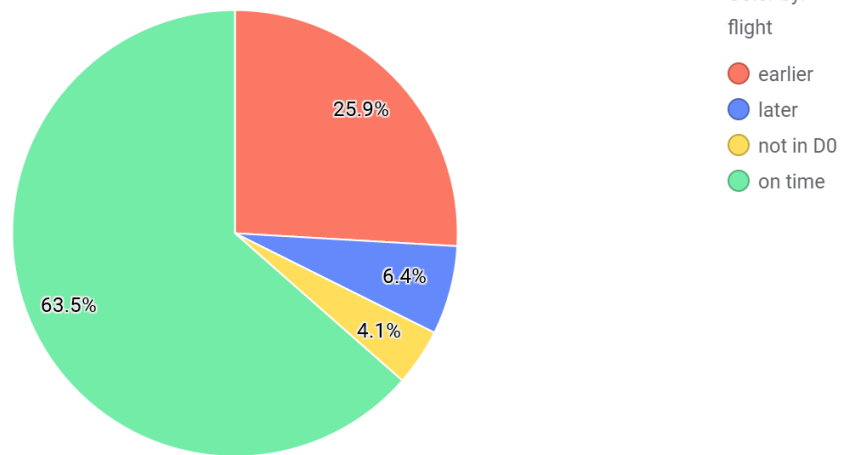
D-1 versus D0 entry time EHAM Arrival South



D0 versus D-1 entry time EHAM Departure South

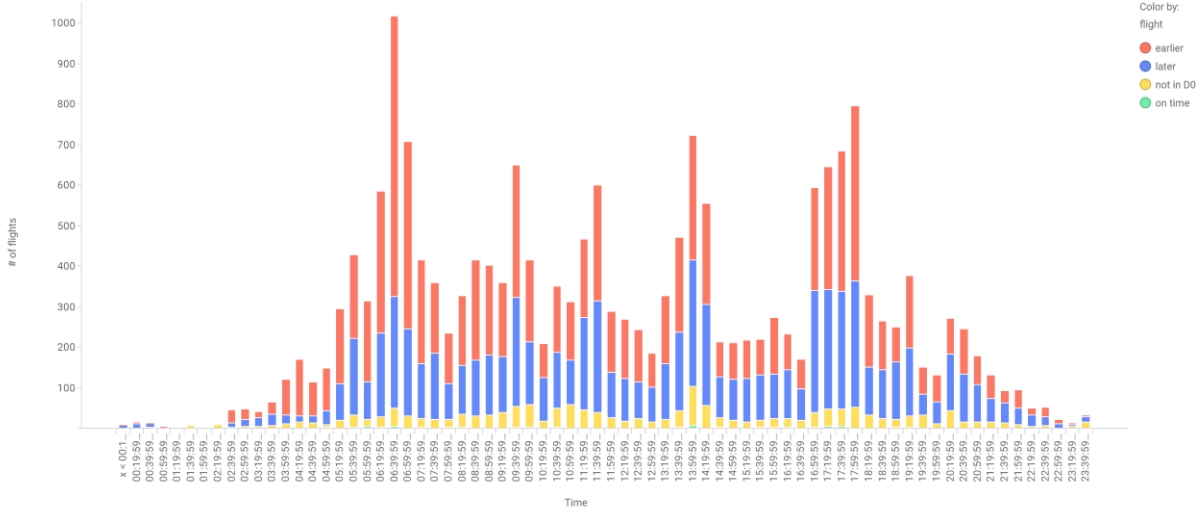


D-1 versus D0 entry time EHAM Departure South

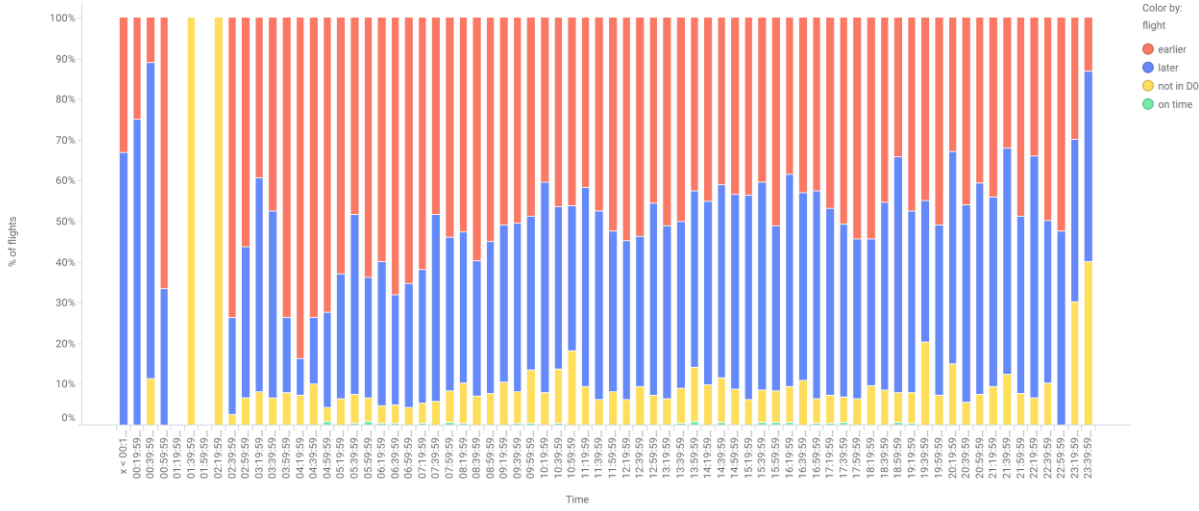


# Appendix XV. Analysing difference in entry time per 20 minutes

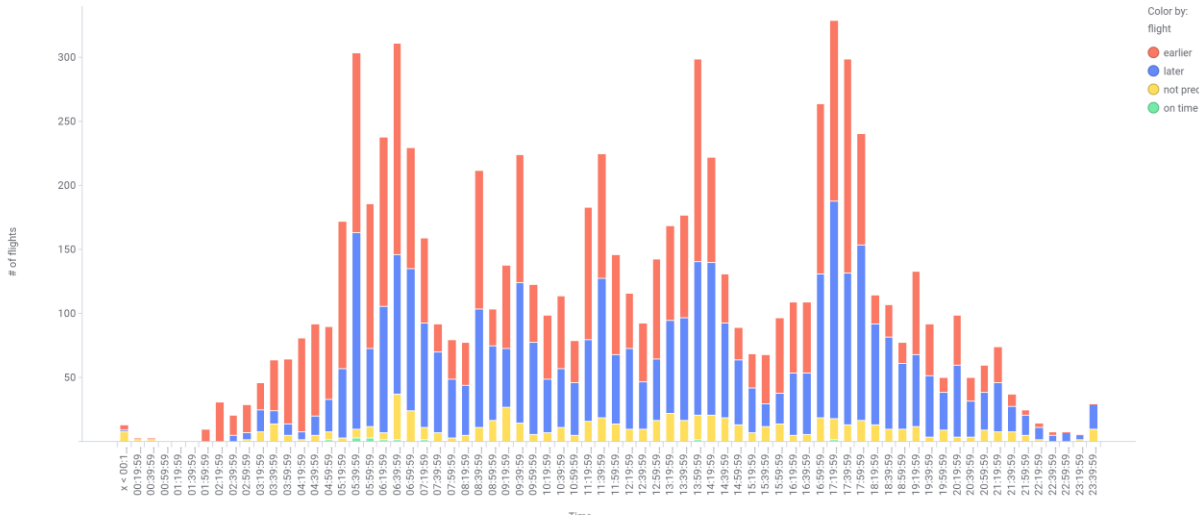
D-1 versus D0 entry time per 20 min EHFIRAM



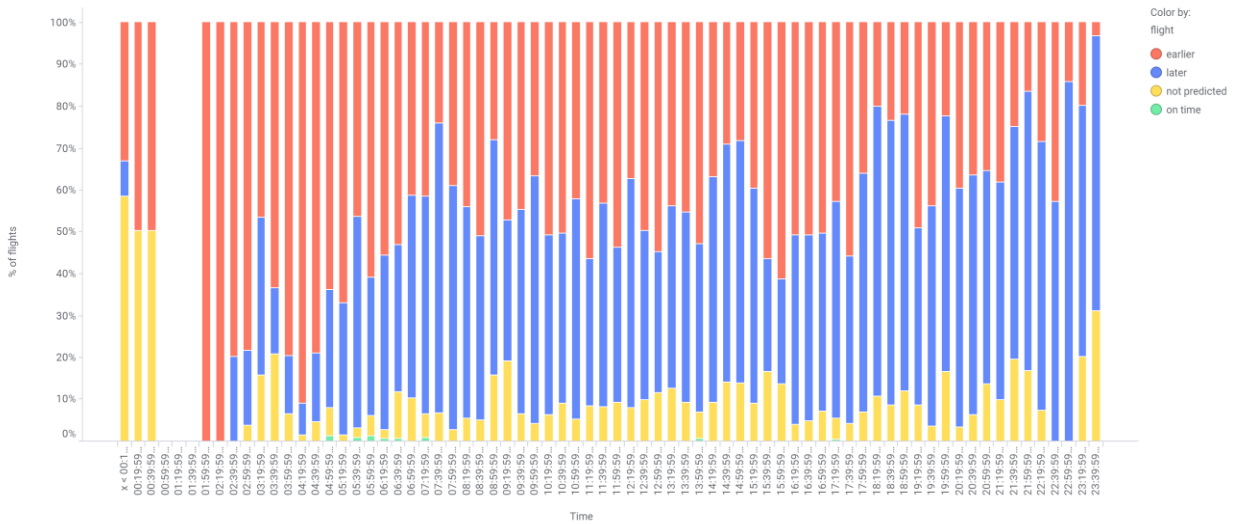
D-1 versus D0 entry time per 20 min EHFIRAM



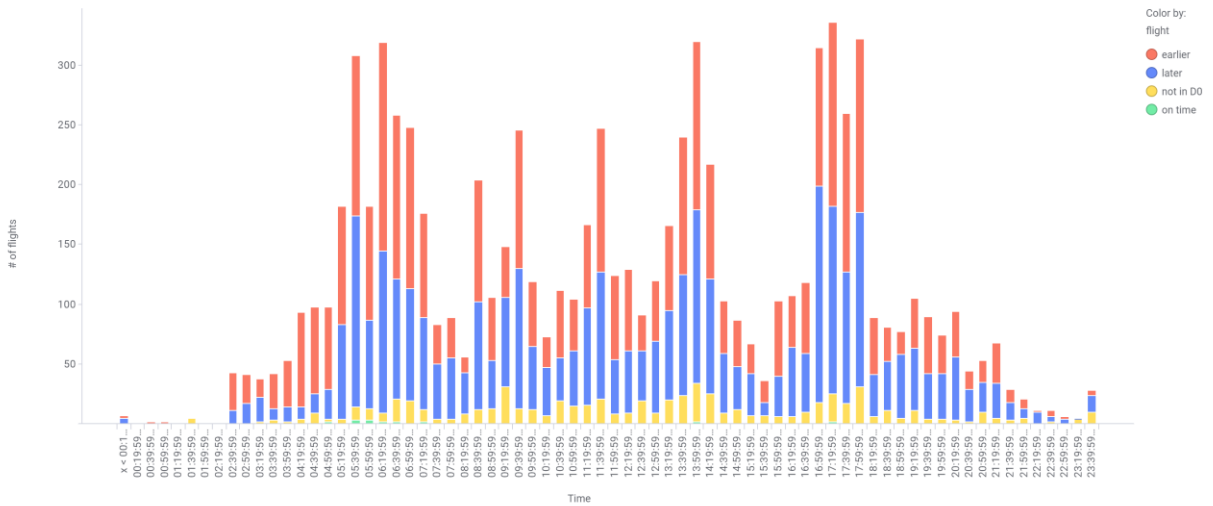
D0 versus D-1 entry time per 20 min EHARTIP



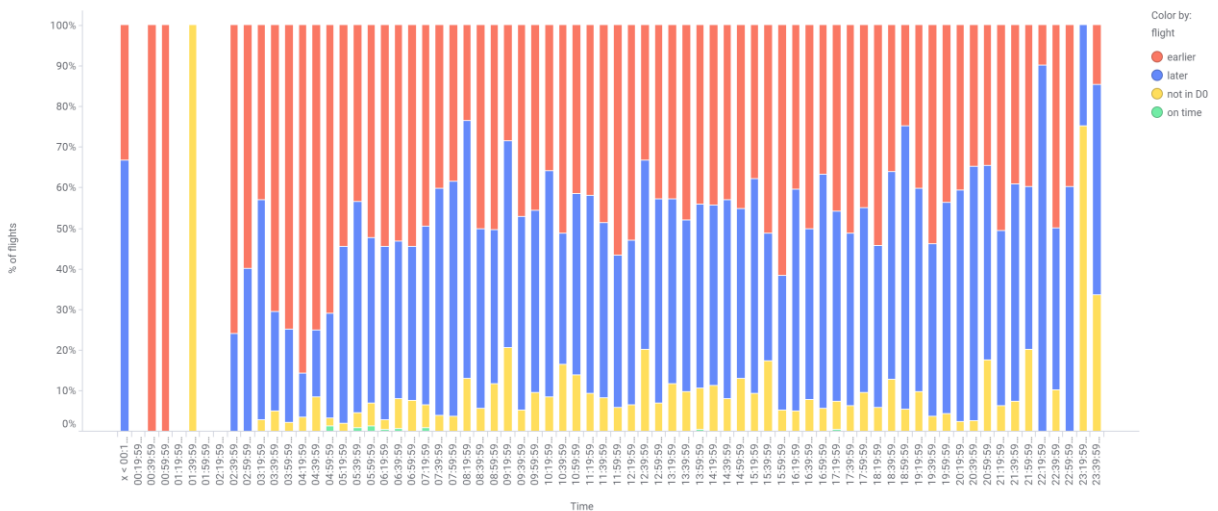
D0 versus D-1 entry time per 20 min EHARTIP



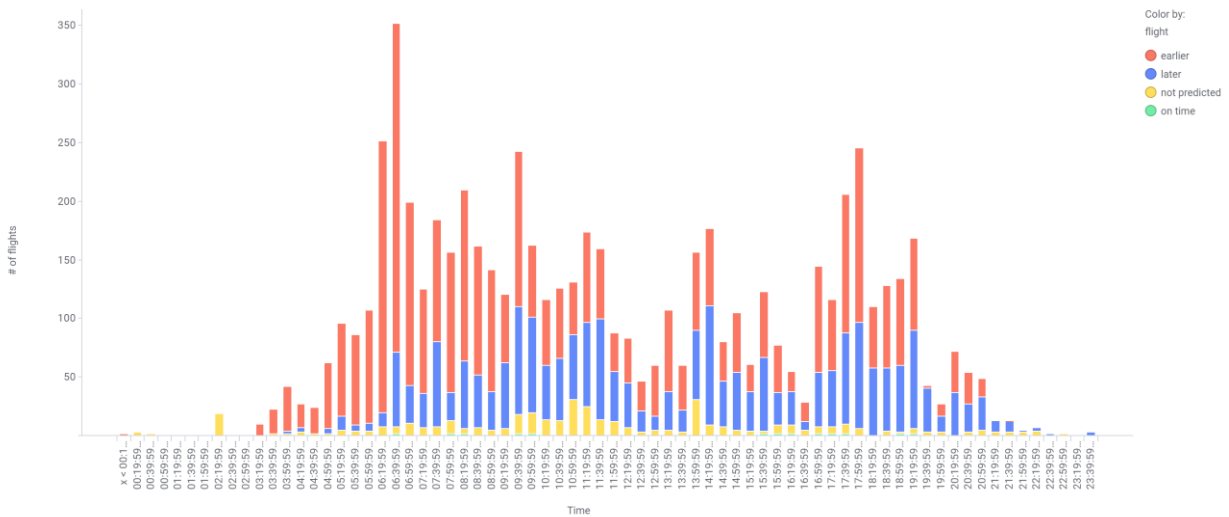
D-1 versus D0 entry time per 20 min EHARTIP



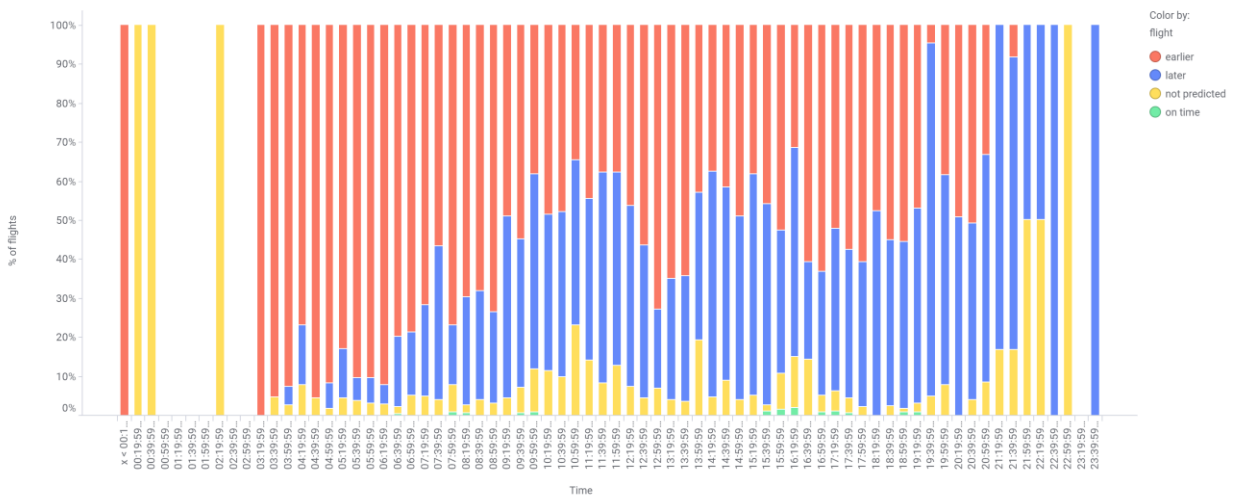
D-1 versus D0 entry time per 20 min EHARTIP



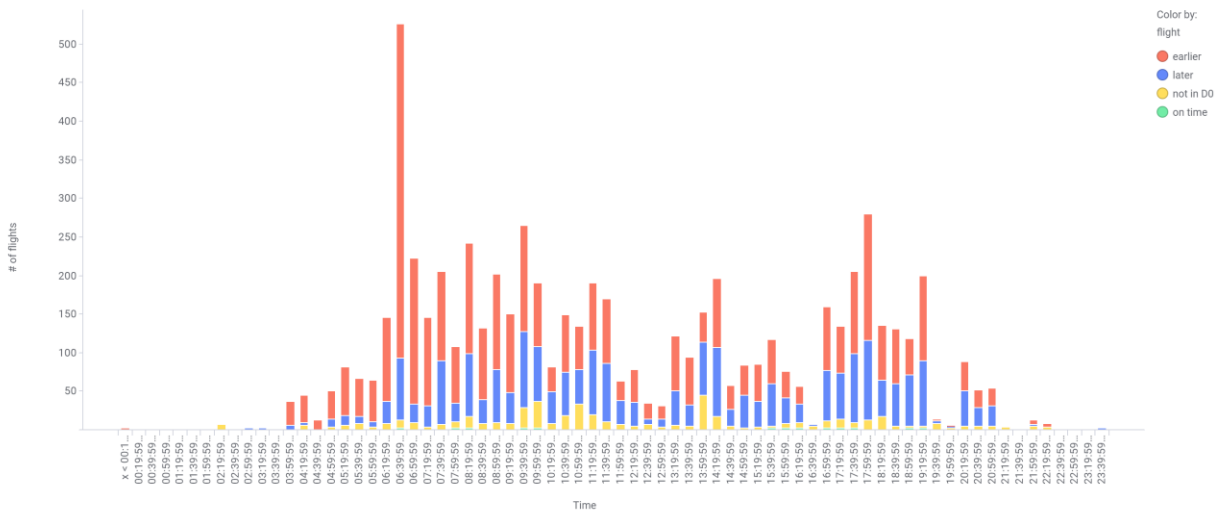
D0 versus D-1 entry time per 20 min EHSUGOL



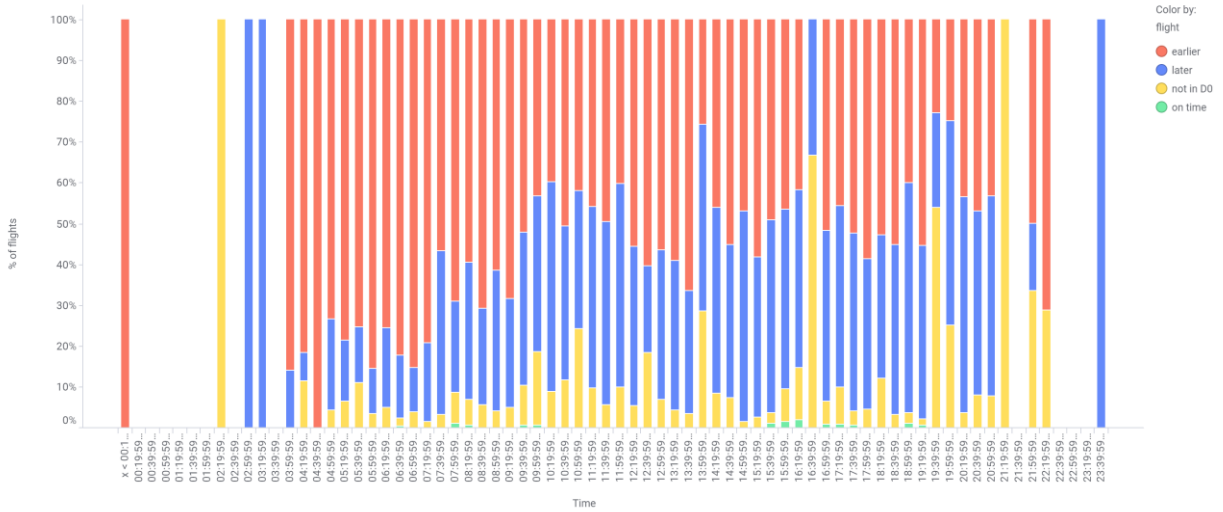
D0 versus D-1 entry time per 20 min EHSUGOL



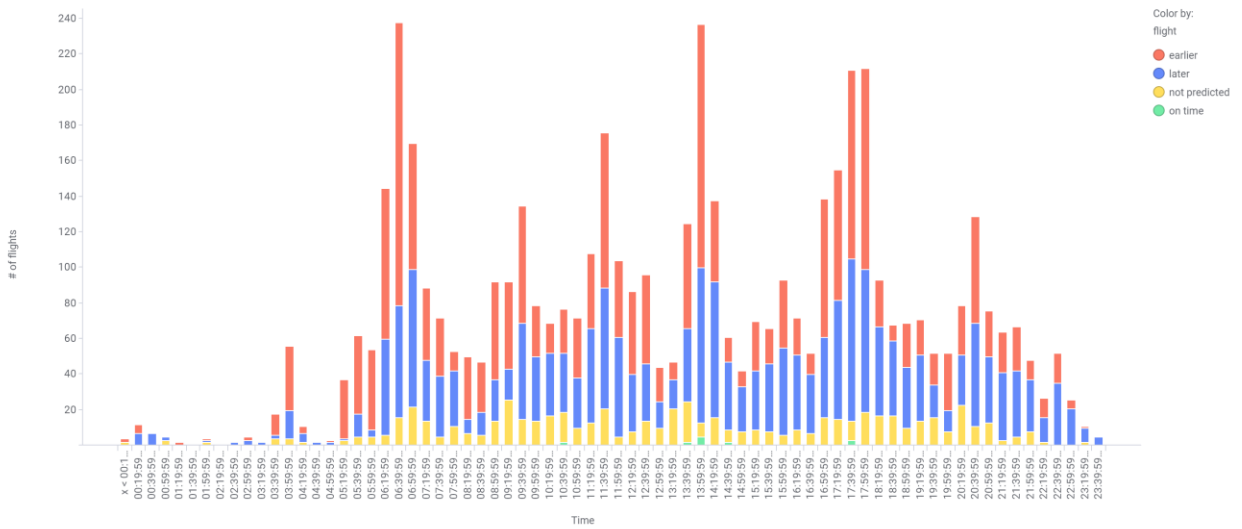
D-1 versus D0 entry time per 20 min EHSUGOL



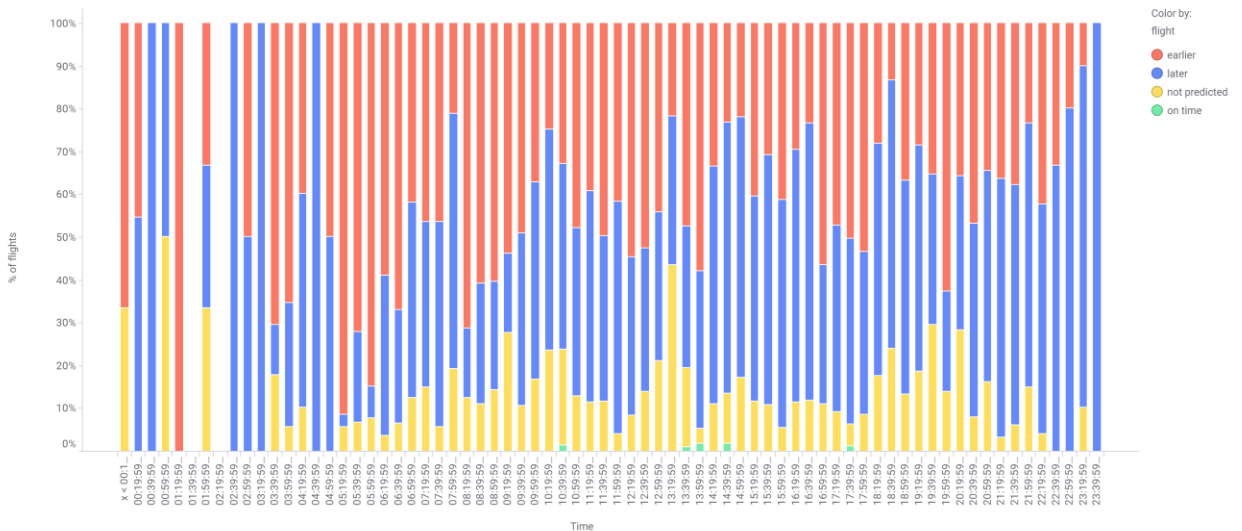
D-1 versus D0 entry time per 20 min EHSUGOL



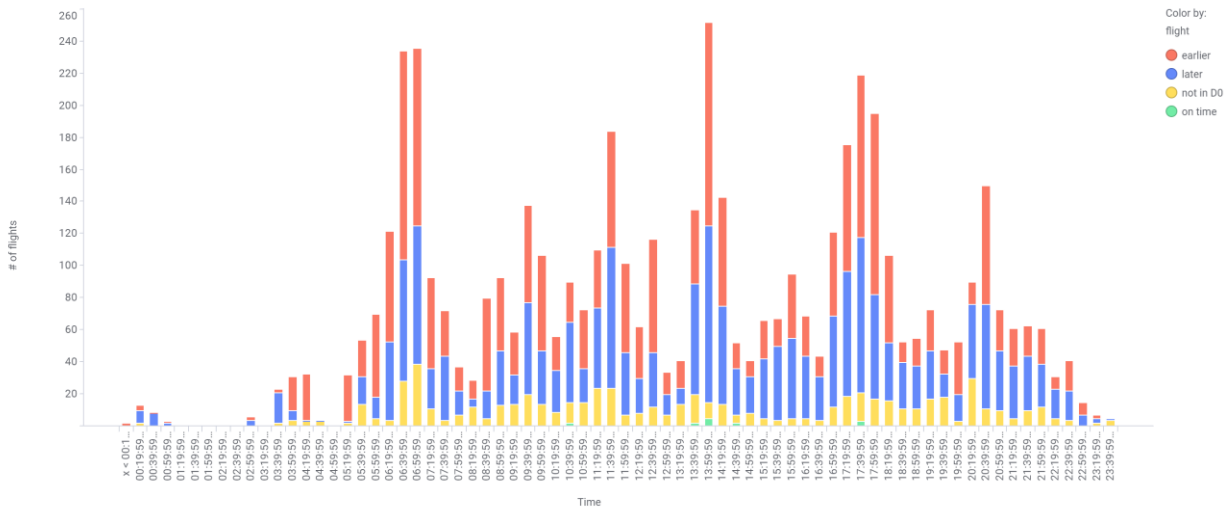
D0 versus D-1 entry time per 20 min EHRIVER



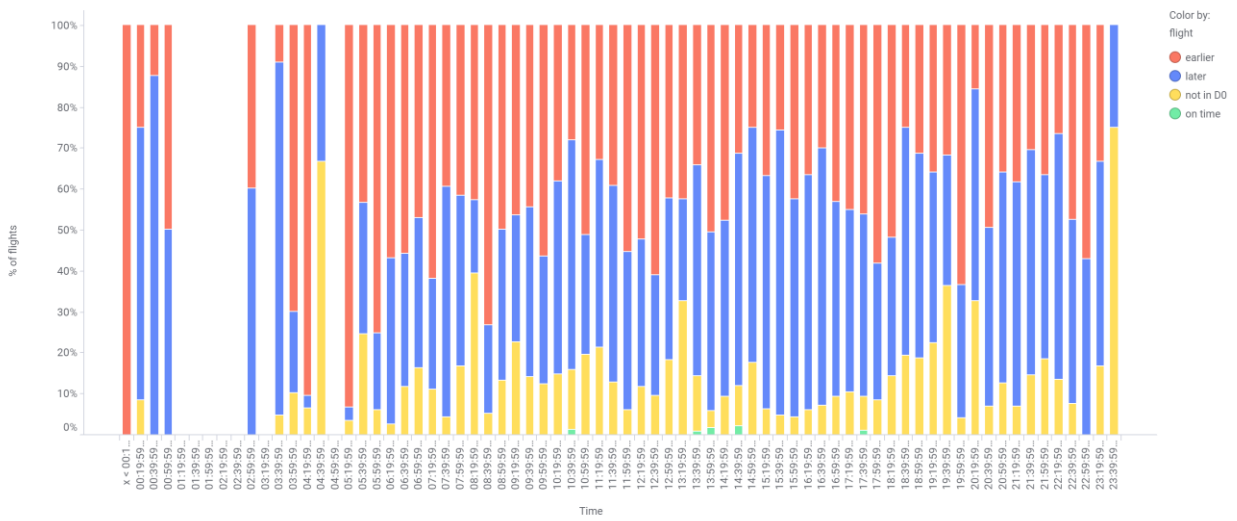
D0 versus D-1 entry time per 20 min EHRIVER



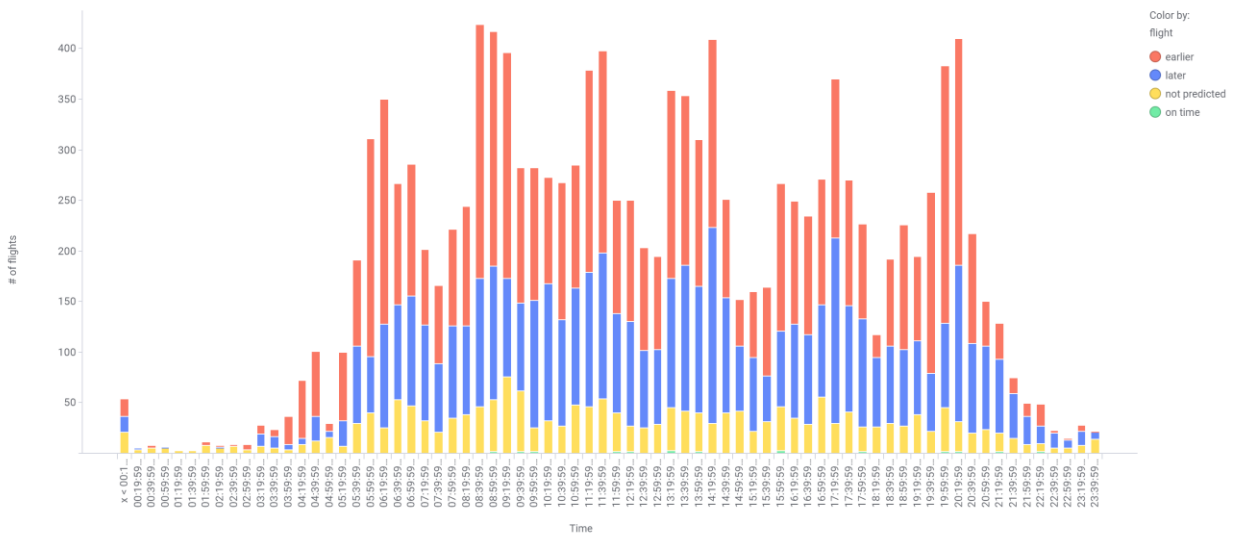
D-1 versus D0 entry time per 20 min EHRIVER



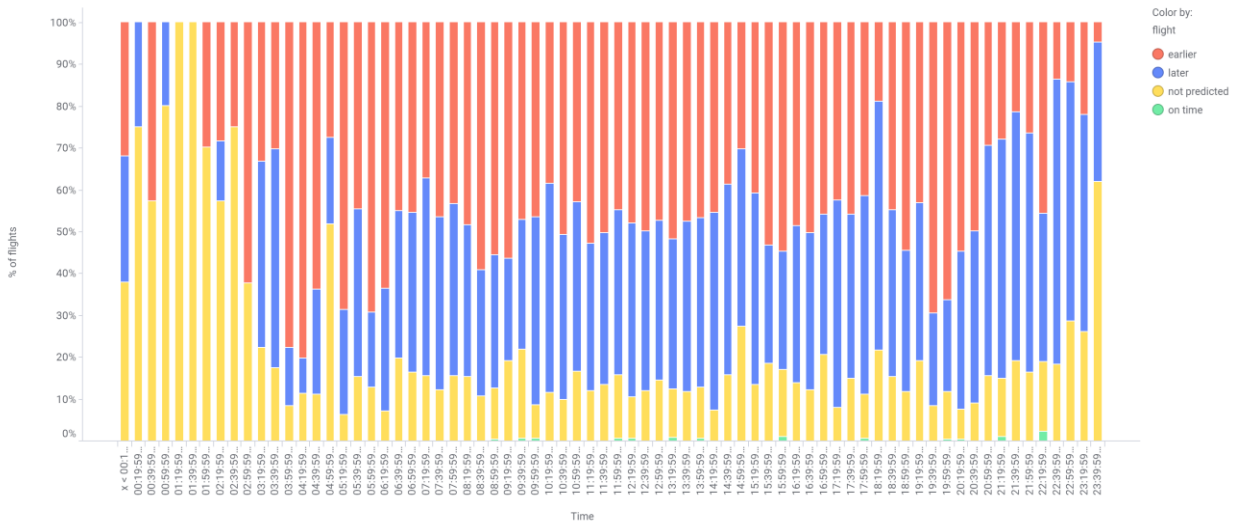
D-1 versus D0 entry time per 20 min EHRIVER



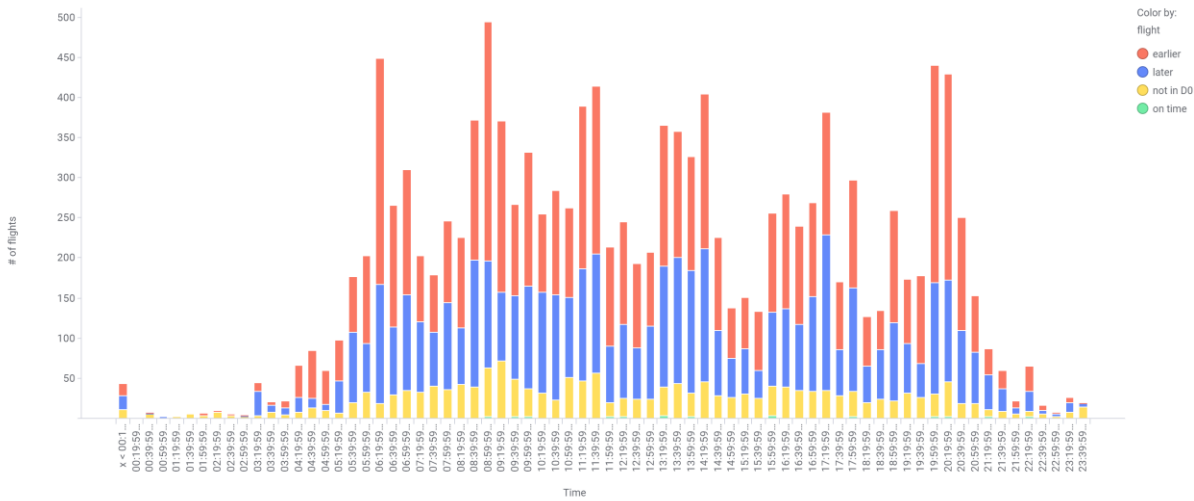
D0 versus D-1 entry time per 20 min EHSECT2



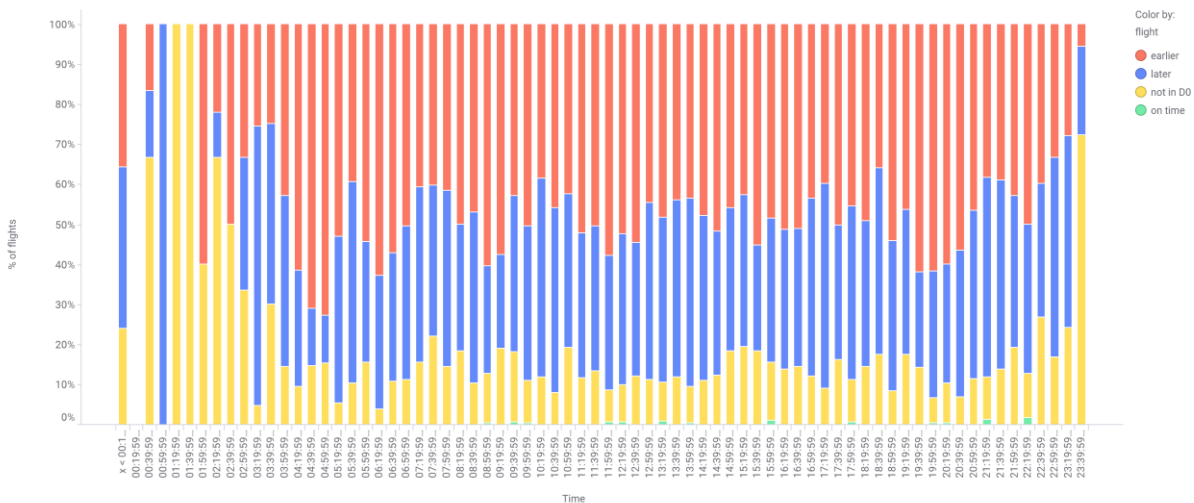
D0 versus D-1 entry time per 20 min EHSECT2



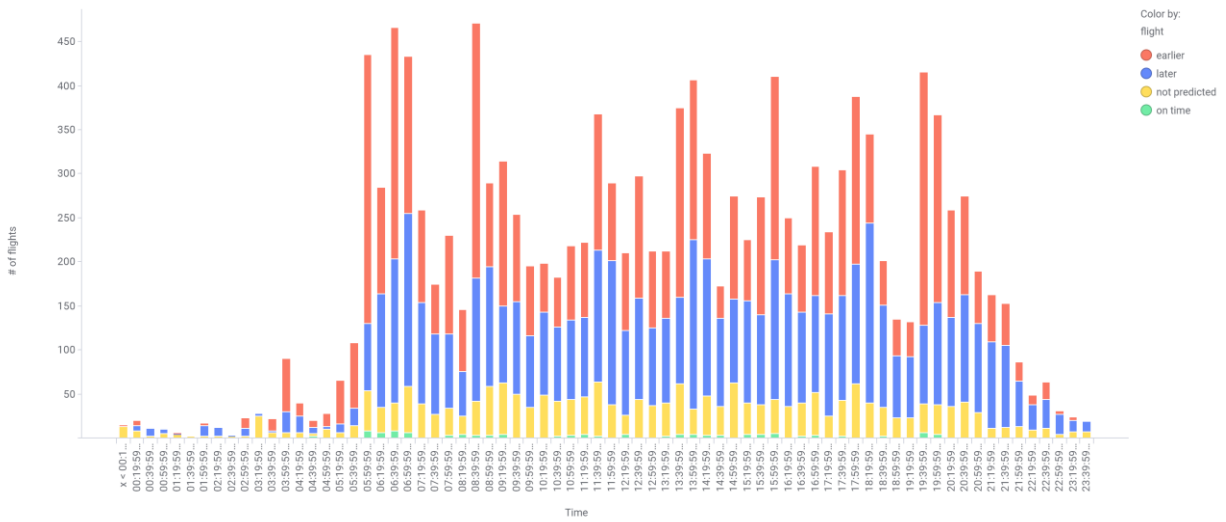
D-1 versus D0 entry time per 20 min EHSECT2



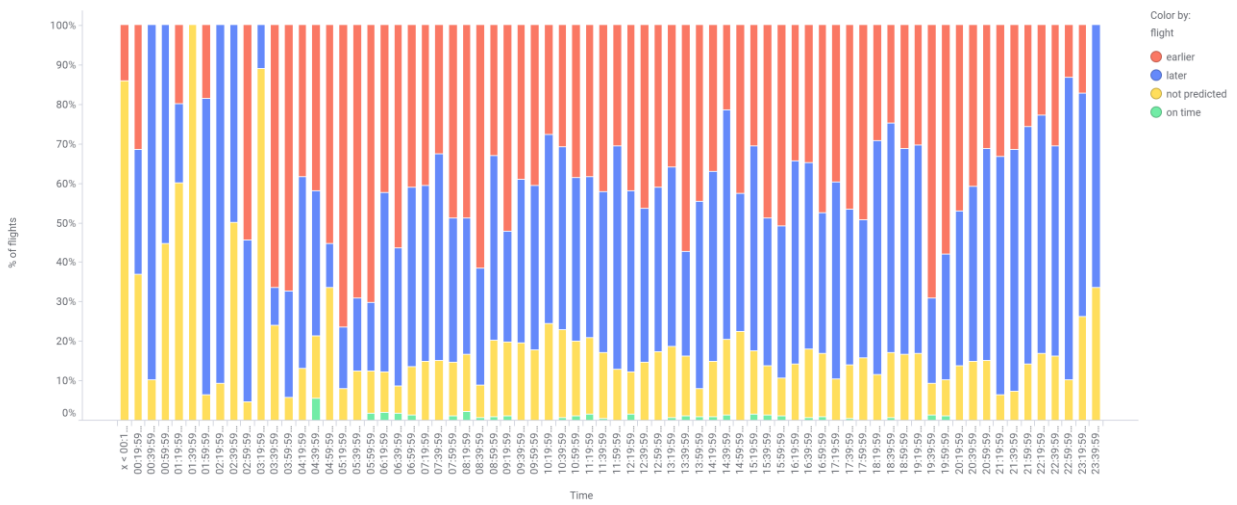
D-1 versus D0 entry time per 20 min EHSECT2



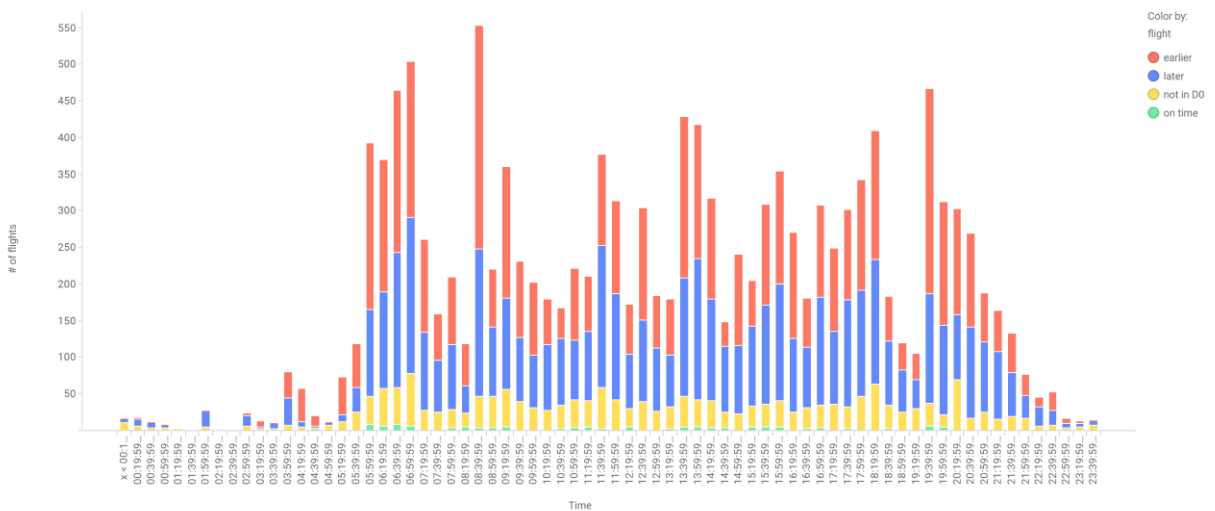
D0 versus D-1 entry time per 20 min EHSECT3



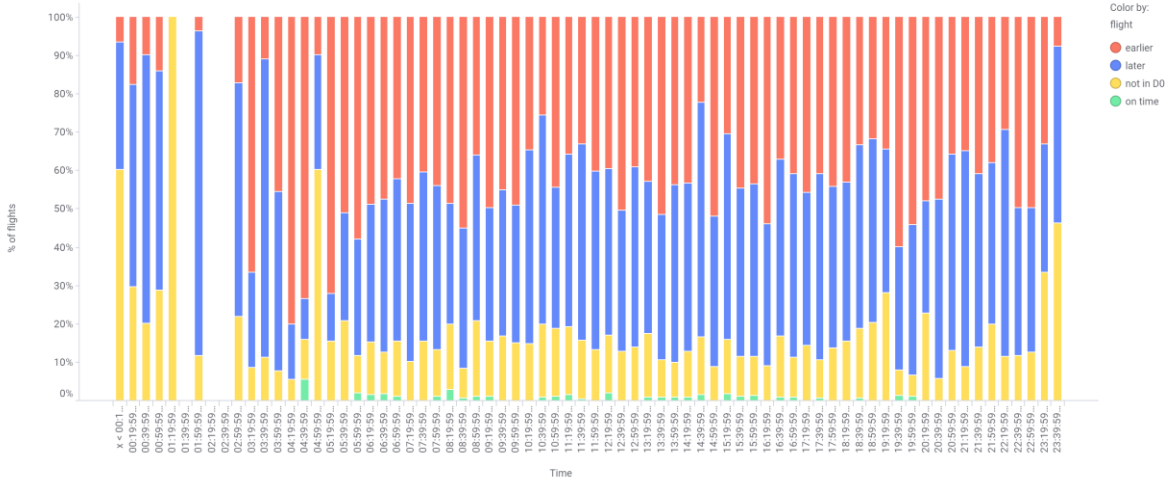
D0 versus D-1 entry time per 20 min EHSECT3



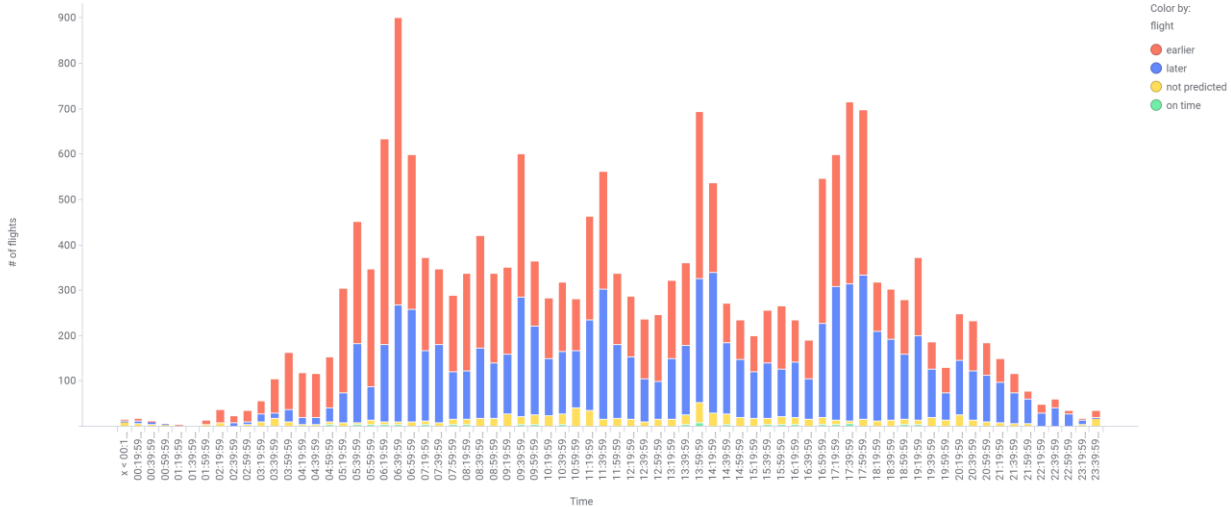
D-1 versus D0 entry time per 20 min EHSECT3



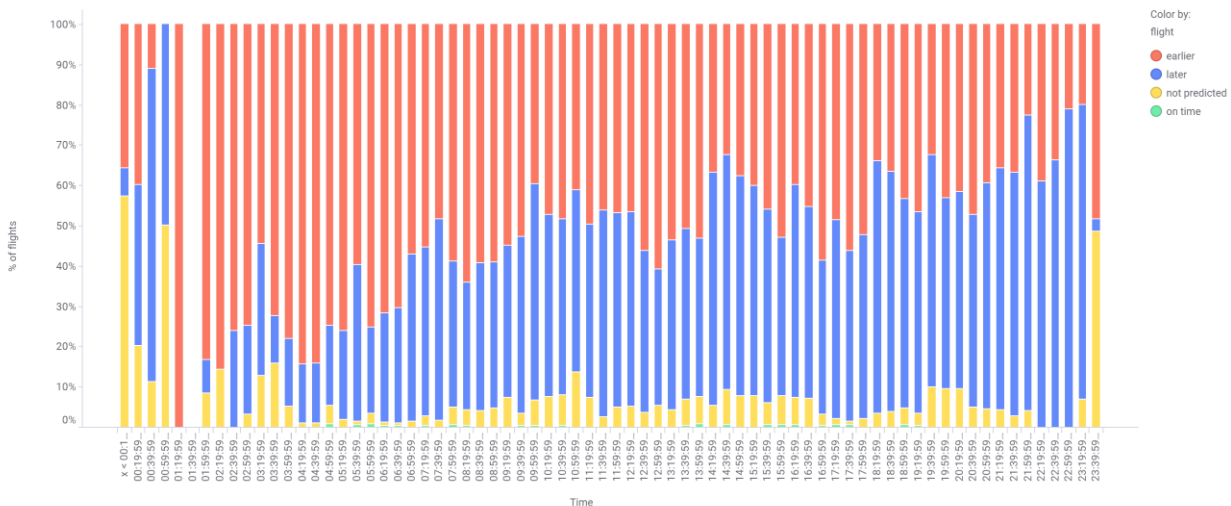
D-1 versus D0 entry time per 20 min EHSECT3



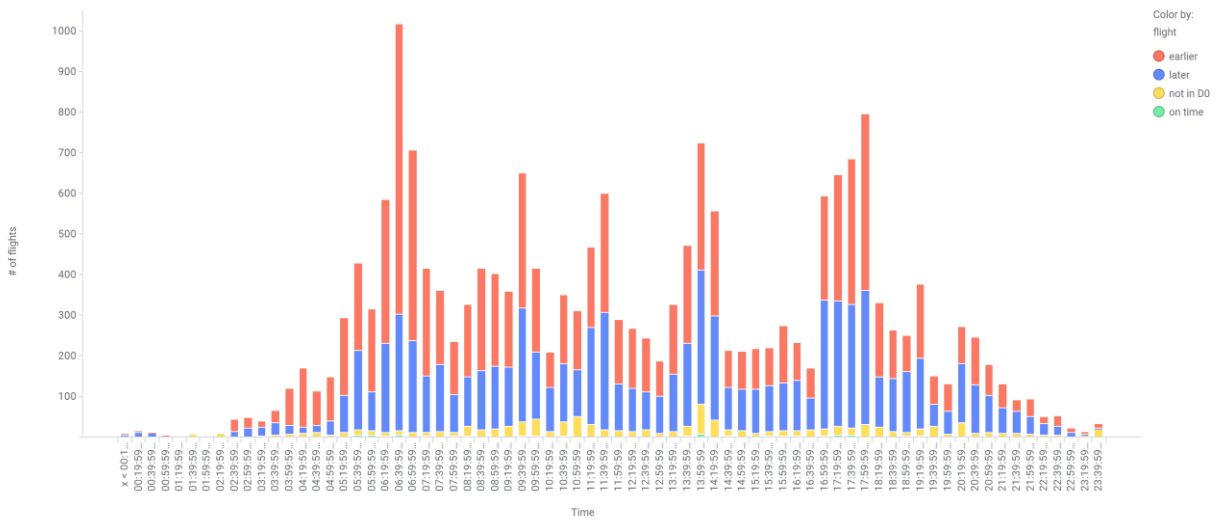
D0 versus D-1 entry time per 20 min EHAM Arrival South



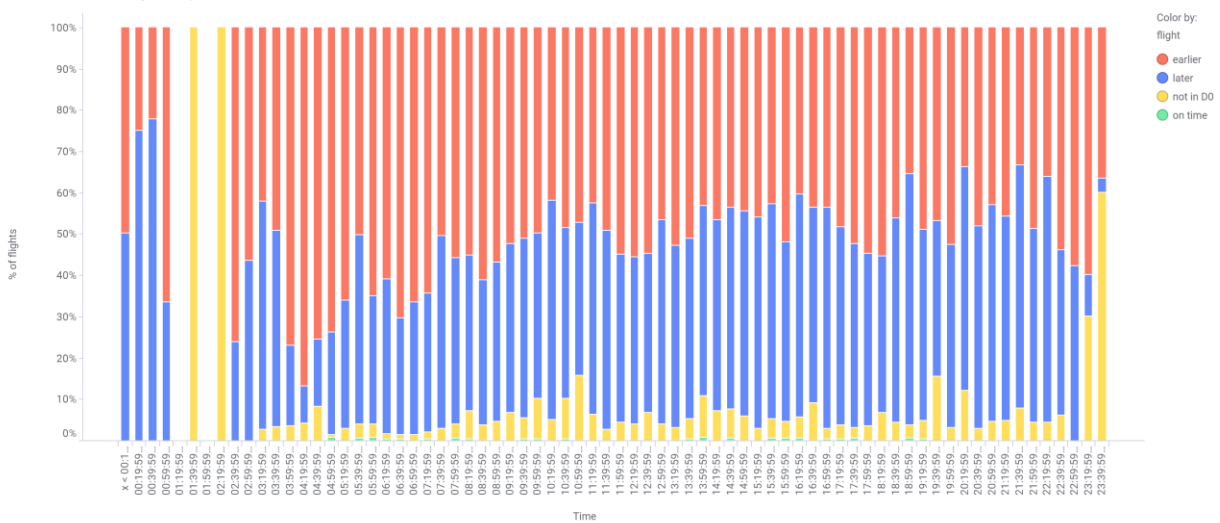
D0 versus D-1 entry time per 20 min EHAM Arrival South



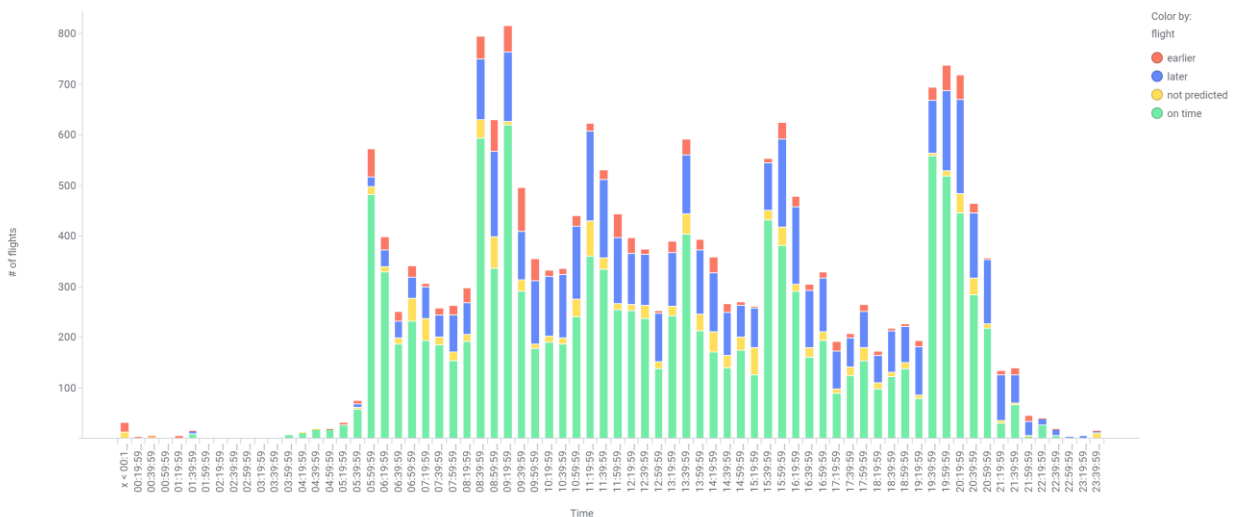
D-1 versus D0 entry time per 20 min EHAM Arrival South



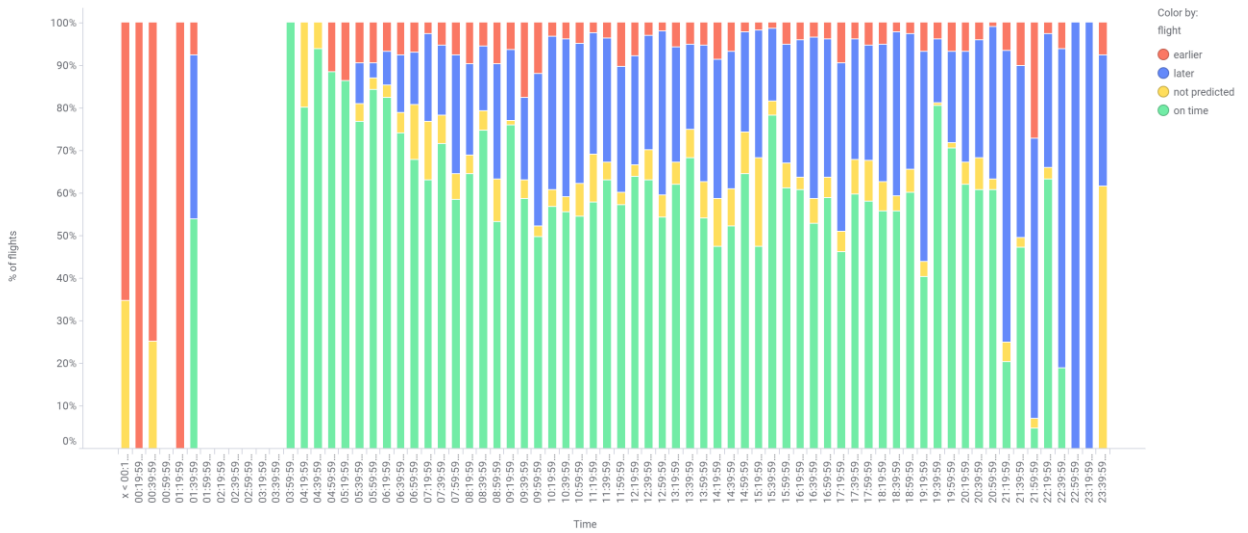
D-1 versus D0 entry time per 20 min EHAM Arrival South



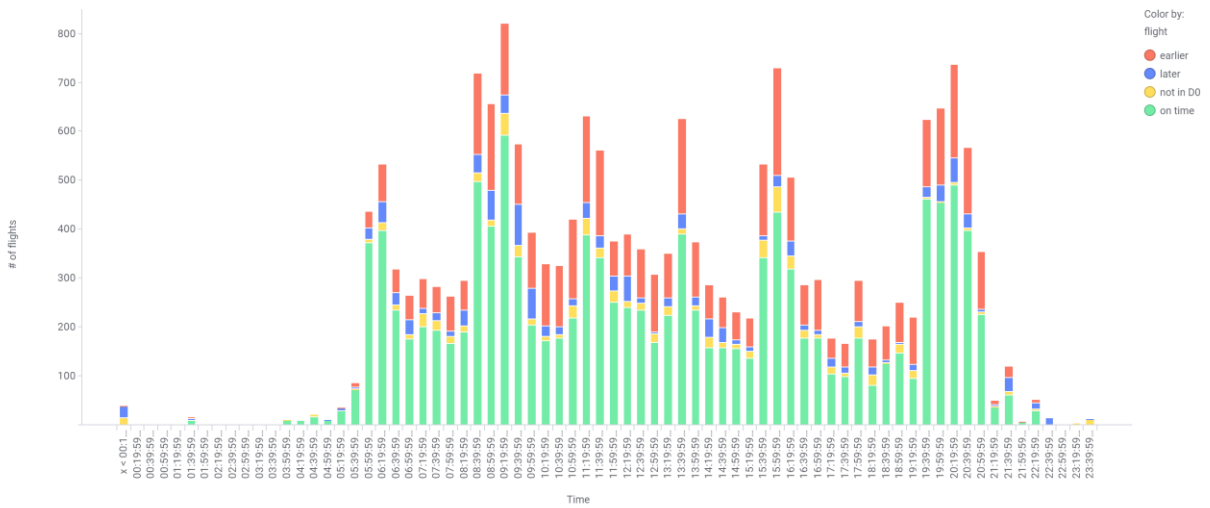
D0 versus D-1 entry time per 20 min EHAM Departure South



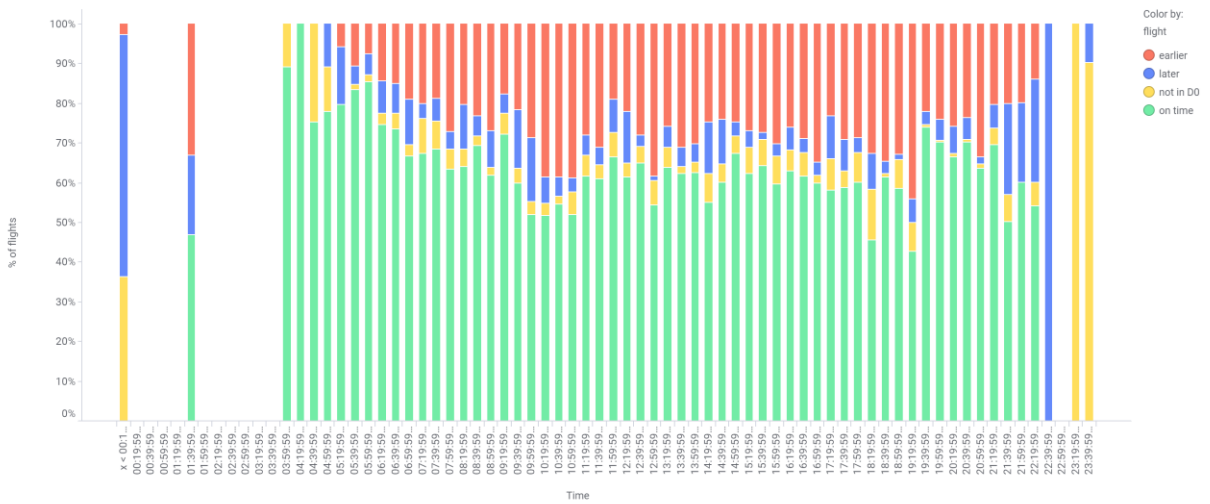
D0 versus D-1 entry time per 20 min EHAM Departure South



D-1 versus D0 entry time per 20 min EHAM Departure South

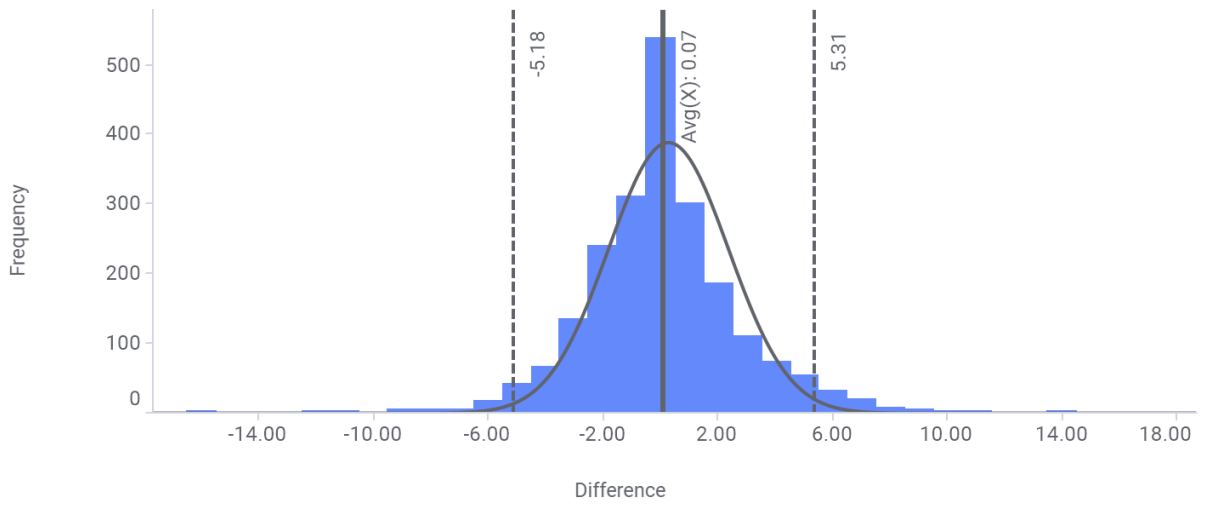


D-1 versus D0 entry time per 20 min EHAM Departure South

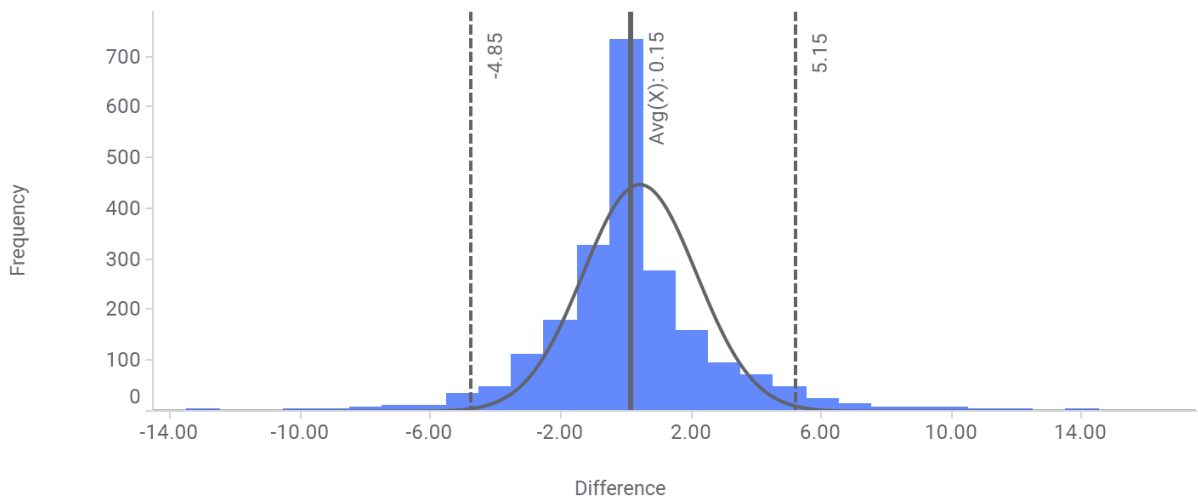


## Appendix XVI. Distribution of difference in demand

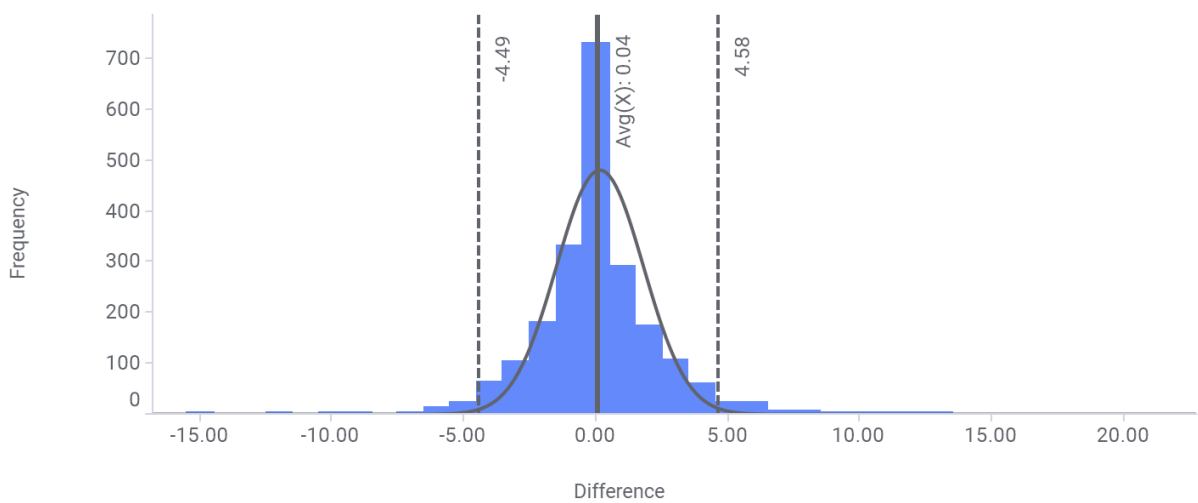
Distribution difference EHARTIP



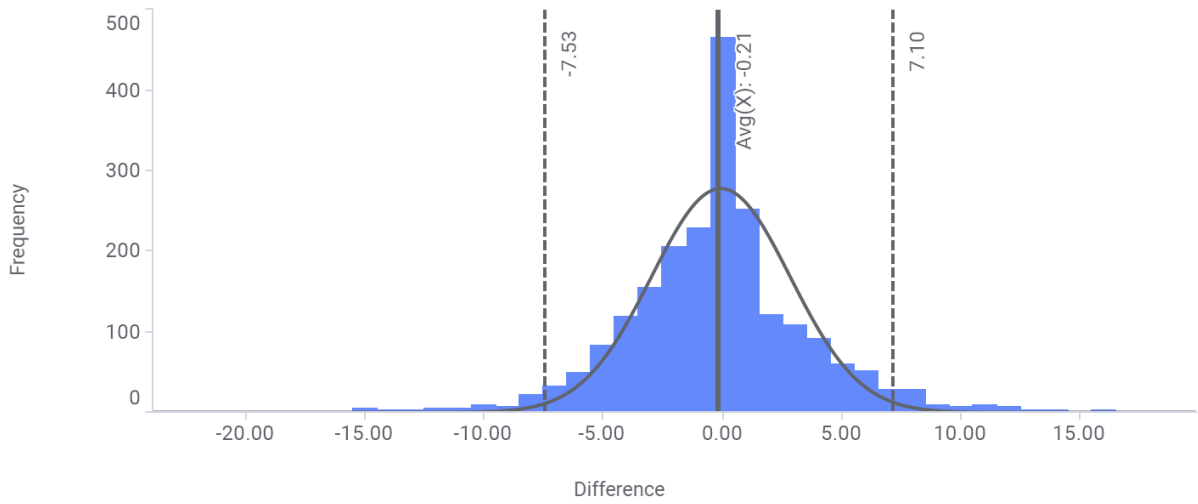
Distribution difference EHSUGOL



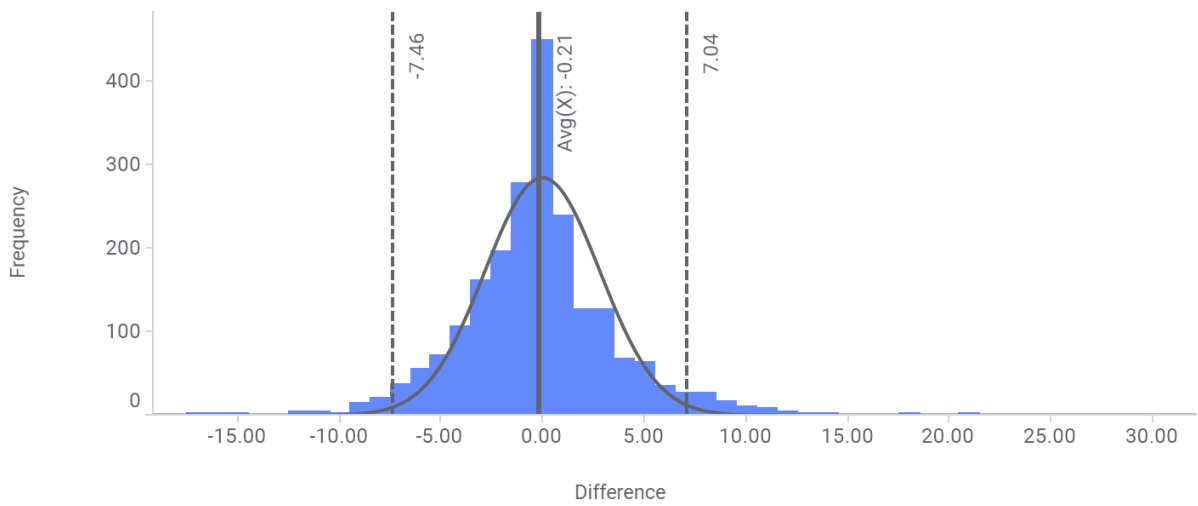
Distribution difference EHRIVER



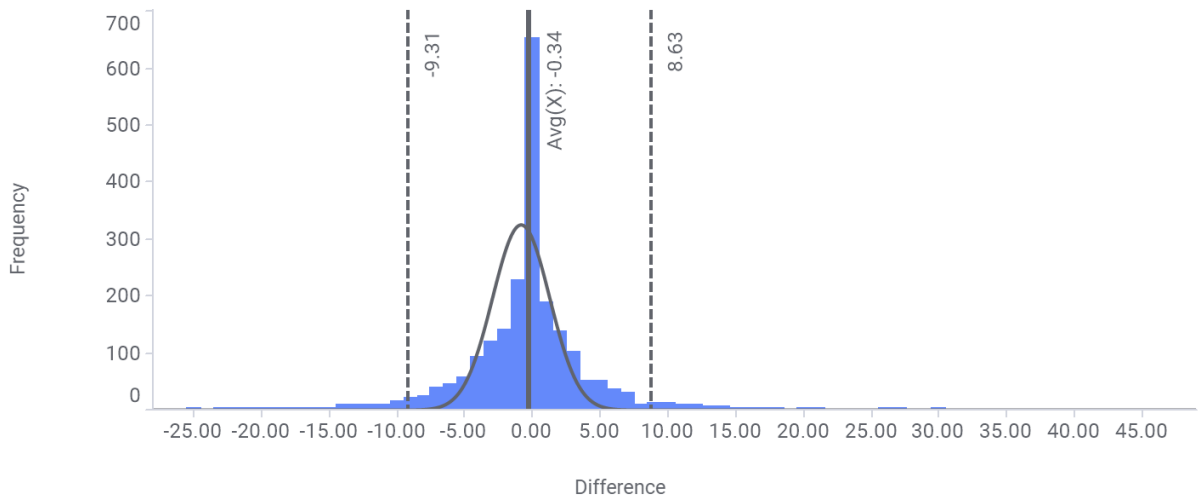
Distribution difference EHSECT2



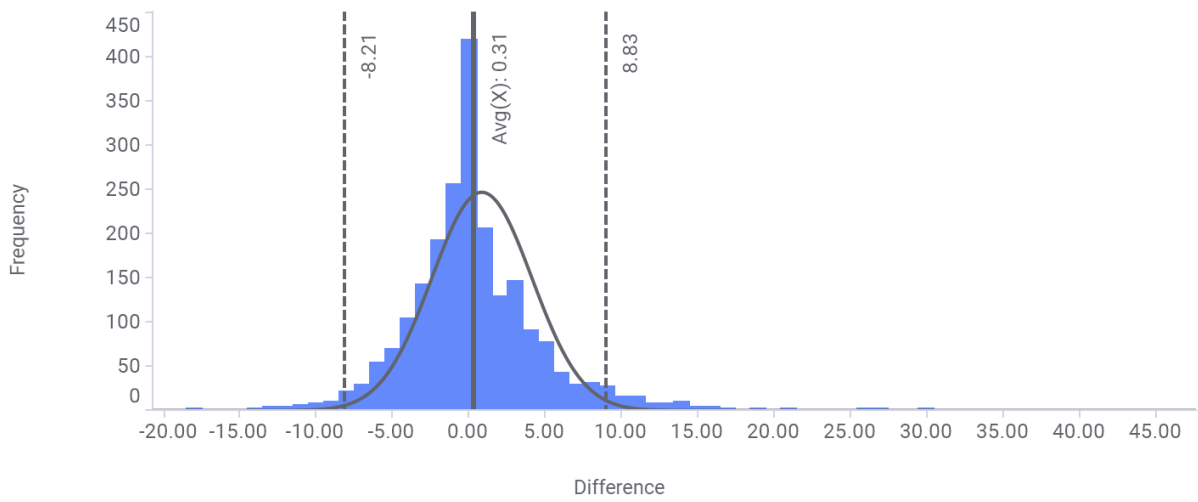
Distribution difference EHSECT3



Distribution difference EHAM Departure South



Distribution difference EHAM Arrival South

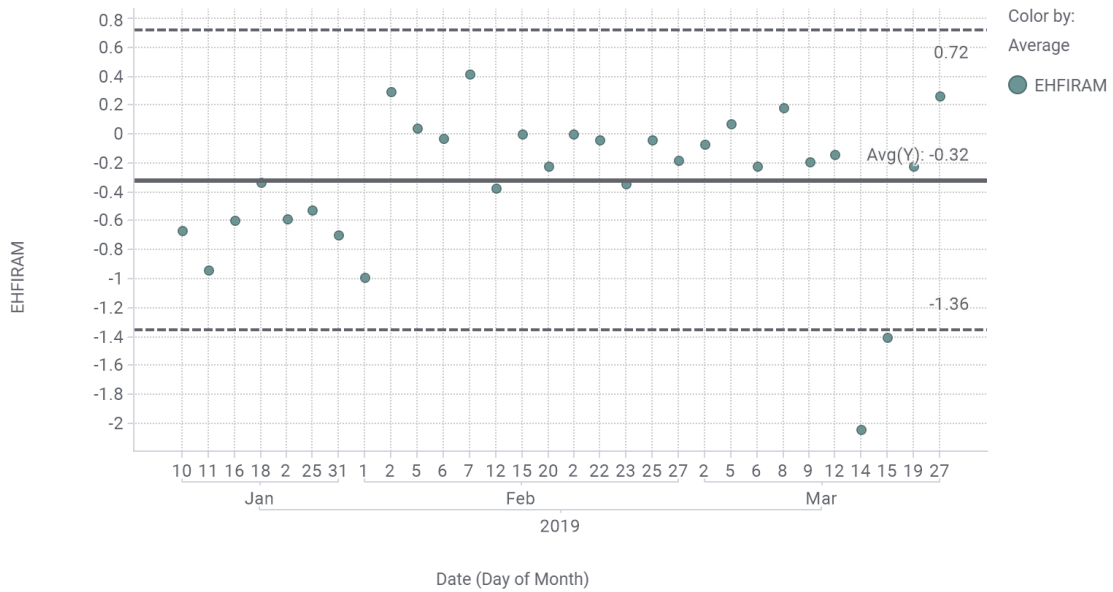


## Appendix XVII. MFE

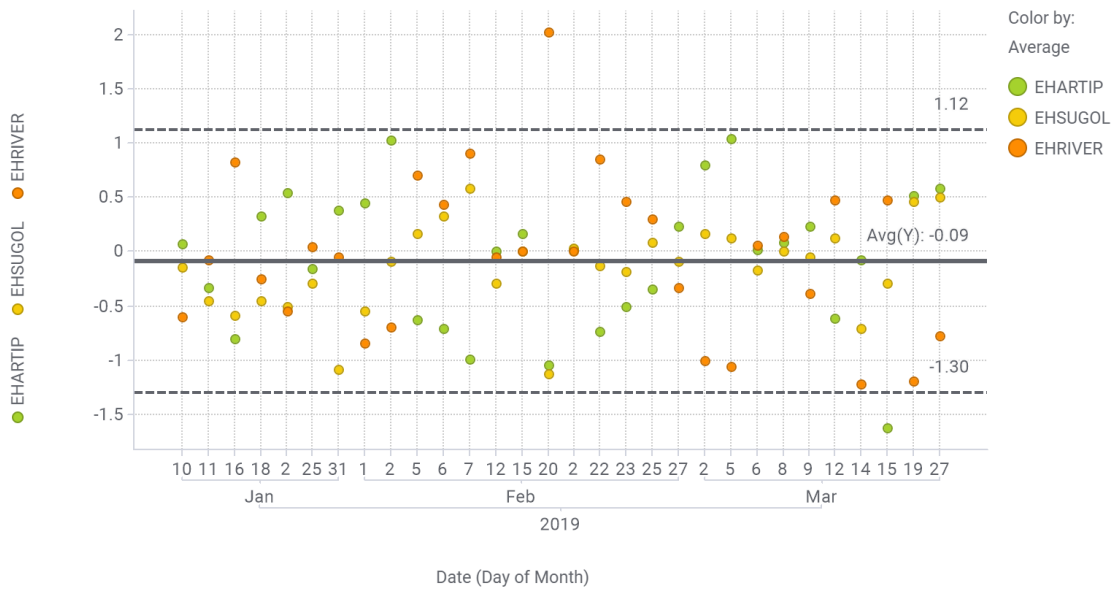
Date	MFES EC2	MFES EC3	MFEA RTIP	MFESU GOL	MFERI VER	MFEFI RAM	MFEA RR S	MFEA RR N	MFED EP S	MFED EP N
10/01/2019	-0.889	-0.153	0.069	-0.139	-0.597	-0.667	-0.639	-0.639	0.236	0.236
11/01/2019	-0.194	0.361	-0.333	-0.458	-0.069	-0.944	-0.903	-0.903	-0.333	-0.333
16/01/2019	-0.750	0.972	-0.806	-0.583	0.833	-0.597	-0.569	-0.569	0.403	0.403
18/01/2019	1.181	-0.139	0.333	-0.458	-0.250	-0.333	-0.389	-0.389	0.472	0.472
23/01/2019	0.181	-0.444	0.542	-0.500	-0.542	-0.583	-0.583	-0.583	0.222	0.222
25/01/2019	-0.278	0.181	-0.153	-0.292	0.042	-0.528	-0.444	-0.444	0.333	0.333
31/01/2019	0.556	0.556	0.389	-1.083	-0.042	-0.694	-0.750	-0.750	-0.181	-0.181
01/02/2019	0.083	-0.292	0.444	-0.542	-0.847	-0.986	-1.056	-1.056	-0.222	-0.222
02/02/2019	0.472	-0.514	1.028	-0.083	-0.694	0.292	0.139	0.139	-0.014	-0.014
05/02/2019	-0.125	1.222	-0.625	0.167	0.708	0.042	0.125	0.125	0.986	0.986
06/02/2019	0.403	0.583	-0.708	0.333	0.431	-0.028	-0.014	-0.014	0.986	0.986
07/02/2019	0.028	0.861	-0.986	0.583	0.903	0.417	0.375	0.375	0.986	0.986
12/02/2019	0.069	-0.806	0.000	-0.292	-0.042	-0.375	-0.347	-0.347	0.236	0.236
15/02/2019	0.181	0.458	0.167	0.000	0.000	0.000	0.056	0.056	0.500	0.500
20/02/2019	-1.778	3.153	-1.042	-1.125	2.028	-0.222	-0.111	-0.111	0.736	0.736
21/02/2019	1.236	0.583	0.014	0.028	0.000	0.000	0.042	0.042	0.403	0.403
22/02/2019	-0.889	0.972	-0.736	-0.125	0.861	-0.042	-0.097	-0.097	0.250	0.250
23/02/2019	-0.028	0.667	-0.500	-0.181	0.458	-0.347	-0.222	-0.222	0.417	0.417
25/02/2019	0.097	1.347	-0.347	0.083	0.306	-0.042	-0.042	-0.042	0.639	0.639
27/02/2019	1.125	-0.083	0.236	-0.083	-0.333	-0.181	-0.236	-0.236	0.375	0.375
02/03/2019	1.181	-1.375	0.806	0.167	-1.000	-0.069	-0.014	-0.014	0.083	0.083
05/03/2019	2.139	0.097	1.042	0.125	-1.056	0.069	0.042	0.042	0.903	0.903
06/03/2019	-0.250	0.014	0.014	-0.167	0.056	-0.222	-0.042	-0.042	0.861	0.861
08/03/2019	0.375	0.931	0.083	0.000	0.139	0.181	0.208	0.208	0.403	0.403
09/03/2019	-0.208	0.097	0.236	-0.042	-0.389	-0.194	-0.264	-0.264	0.250	0.250
12/03/2019	-0.375	-0.194	-0.611	0.125	0.472	-0.139	-0.097	-0.097	0.611	0.611
14/03/2019	0.472	-0.819	-0.069	-0.708	-1.222	-2.042	-2.097	-2.097	-0.917	-0.917
15/03/2019	-1.514	0.222	-1.625	-0.292	0.472	-1.403	-1.403	-1.403	-0.750	-0.750
19/03/2019	1.819	-1.653	0.514	0.458	-1.194	-0.222	-0.208	-0.208	0.653	0.653

<b>27/03/2019</b>	2.111	-0.514	0.583	0.500	-0.778	0.264	0.278	0.278	0.694	0.694
<b>Total</b>	0.214	0.210	-0.068	-0.153	-0.045	-0.320	-0.309	-0.309	0.341	0.341

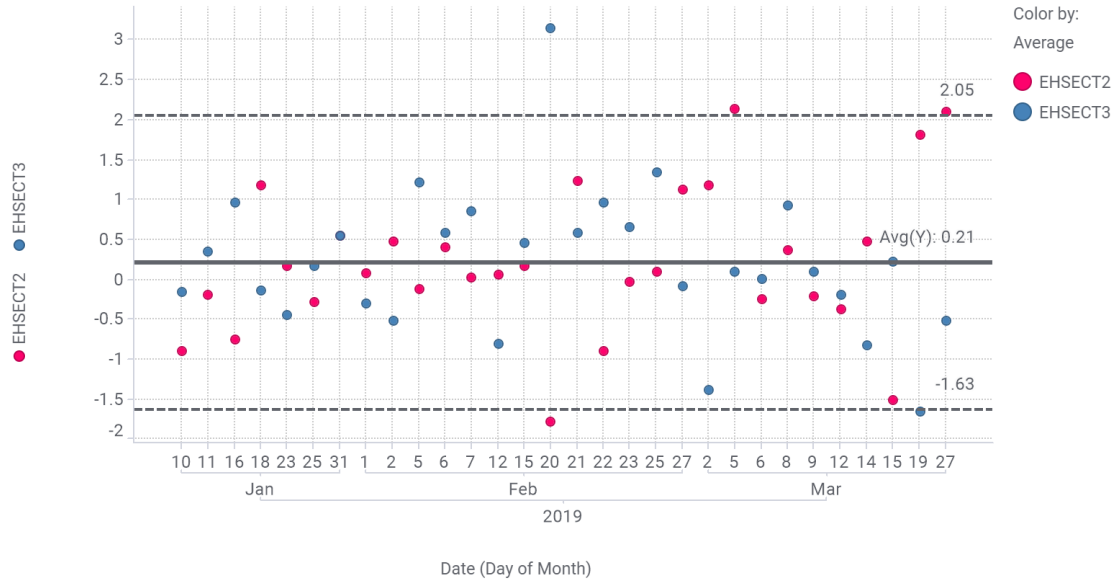
Average MFE EHFIRAM



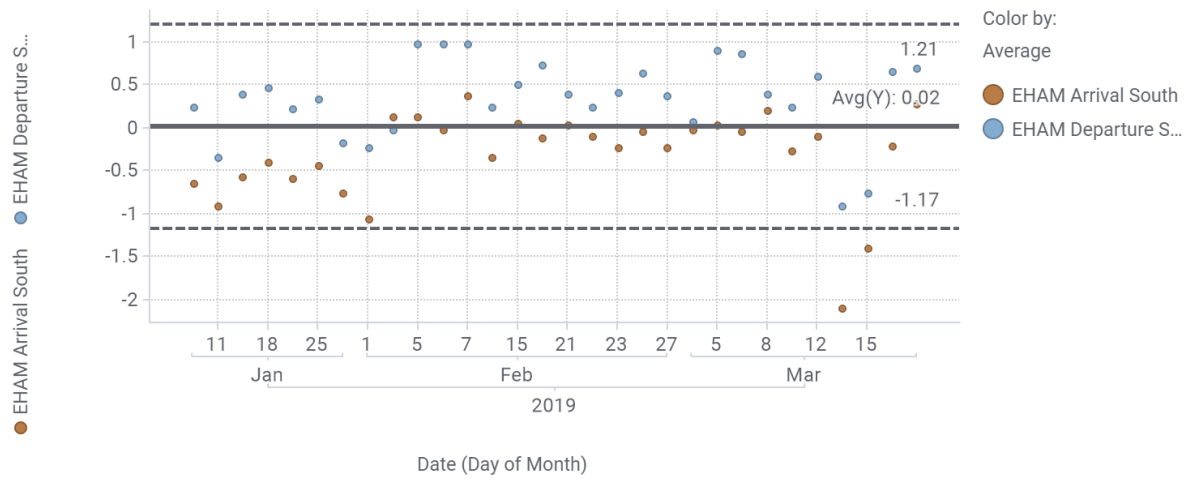
Average MFE stacks



### Average MFE Sector 2 & 3

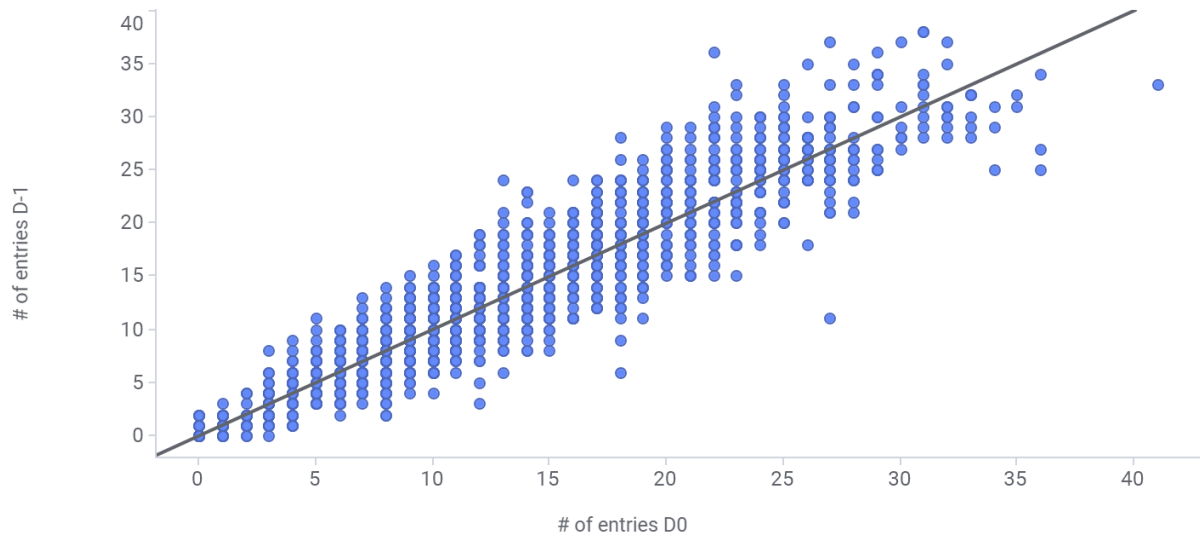


### Average MFE EHAM Arrival & Departure South

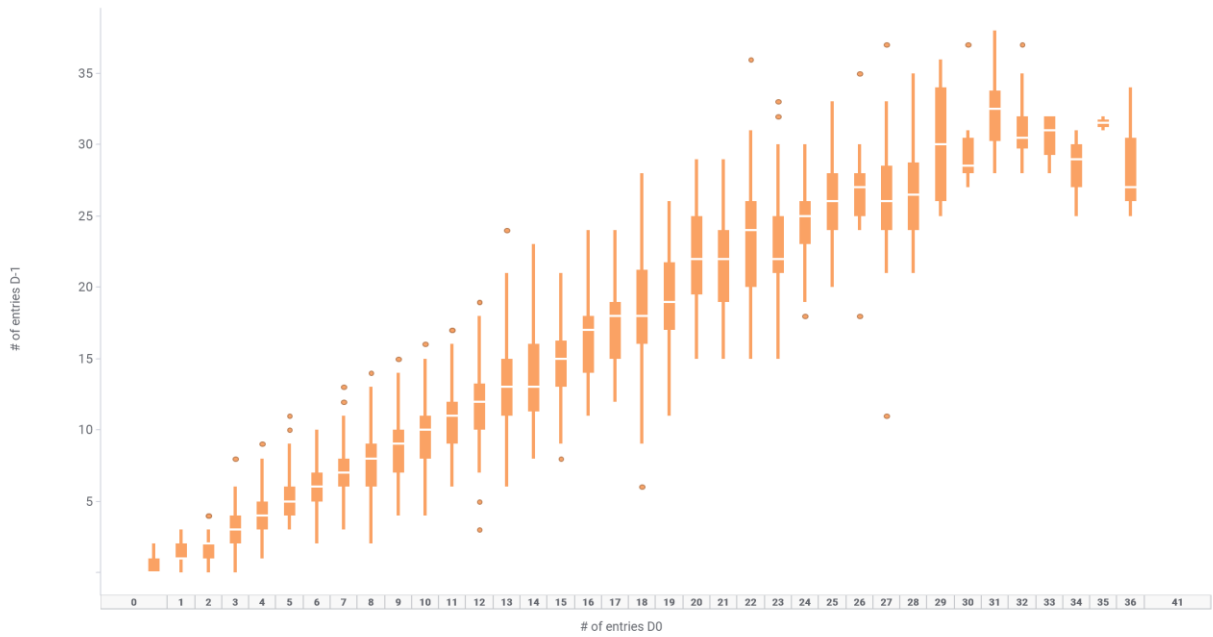


## Appendix XVIII. Scatterplots

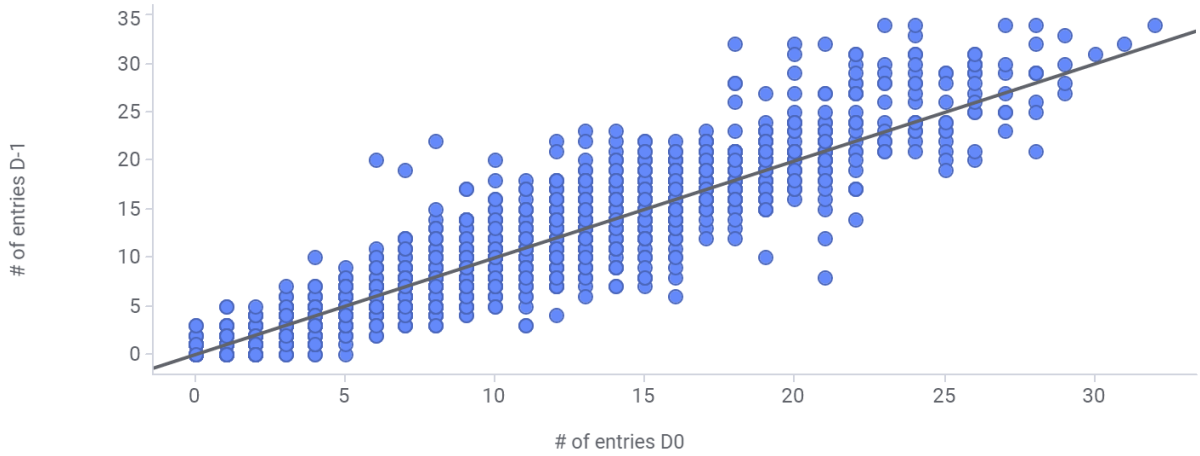
Scatterplot EHARTIP



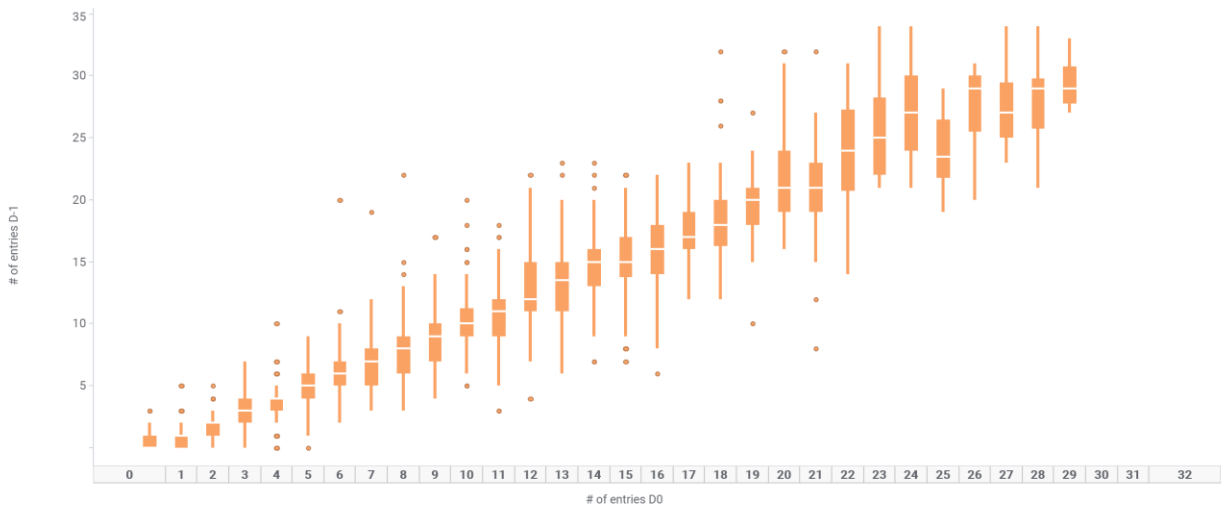
Boxplot of scatterplot EHARTIP



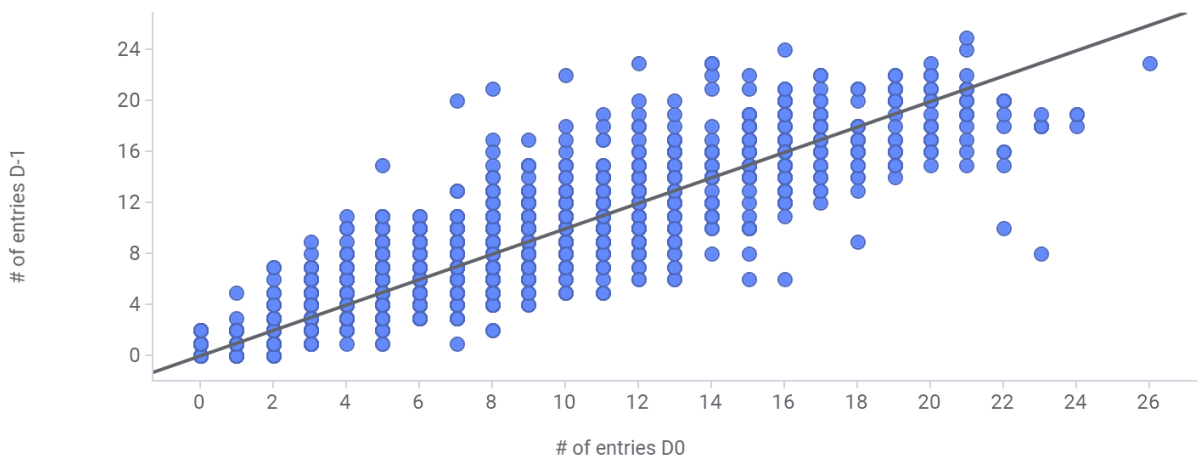
Scatterplot EHSUGOL



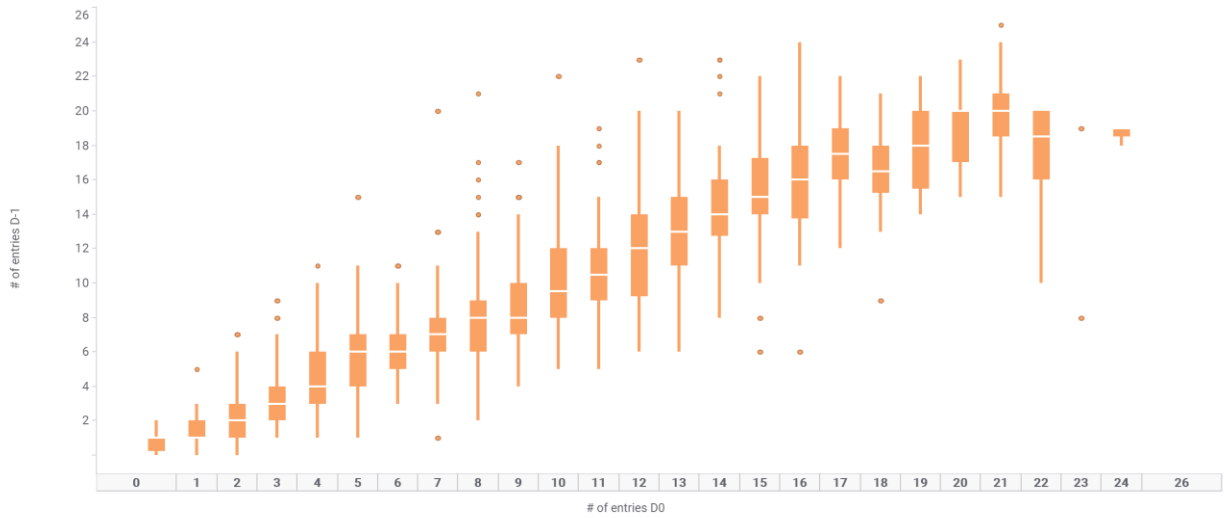
Boxplot of scatterplot EHSUGOL



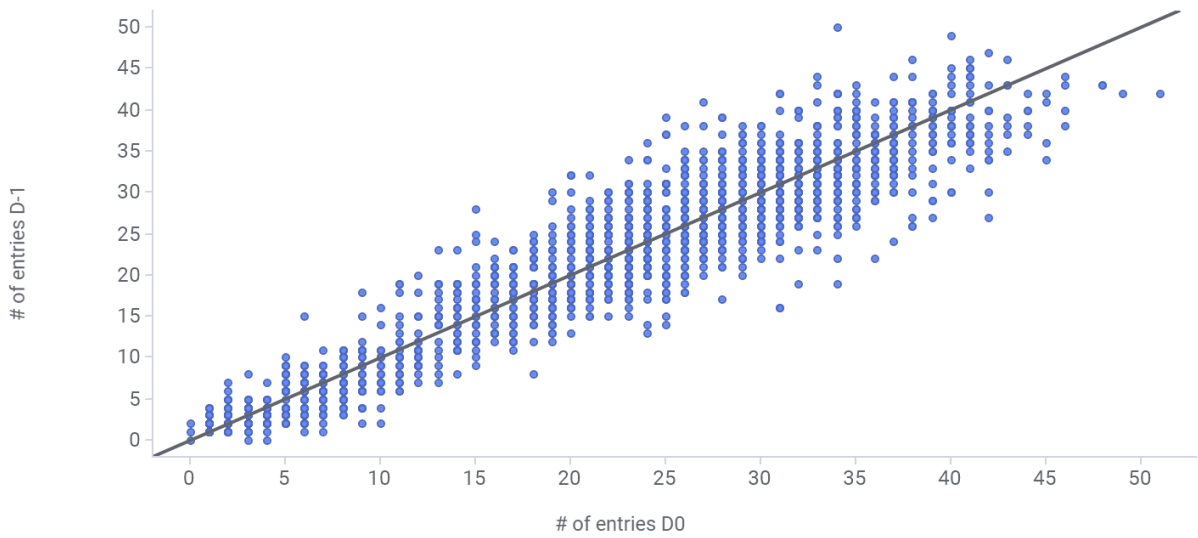
Scatterplot EHRIVER



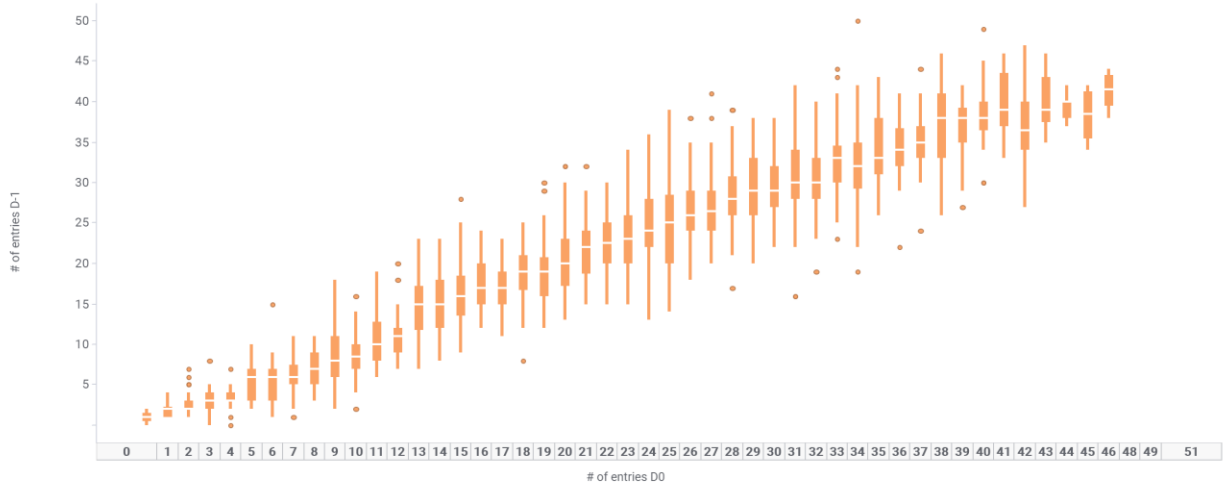
Boxplot of scatterplot EHRIVER



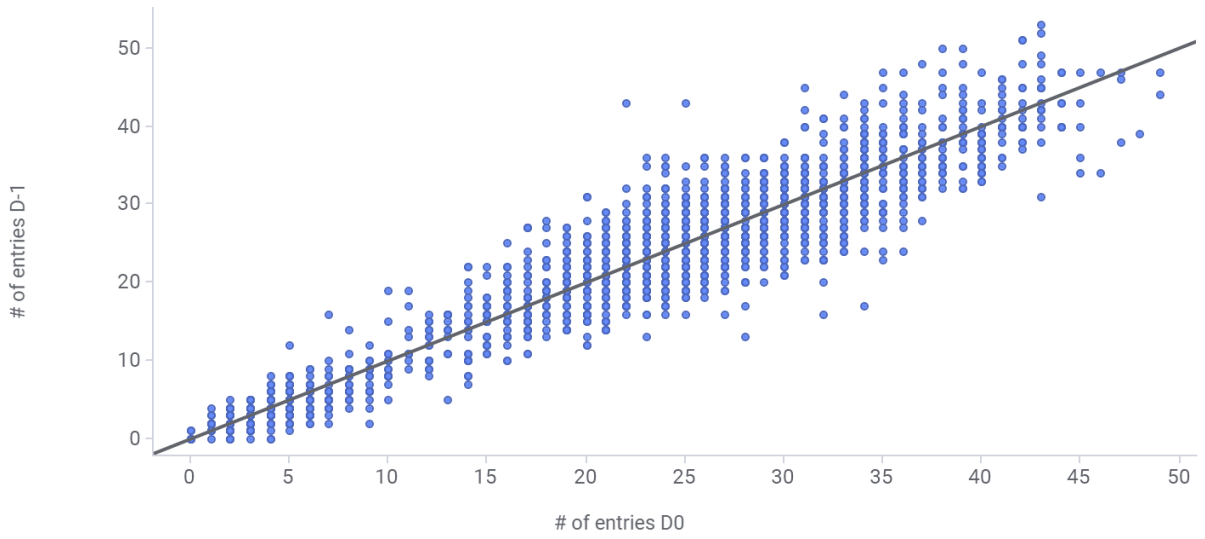
Scatterplot EHSECT2



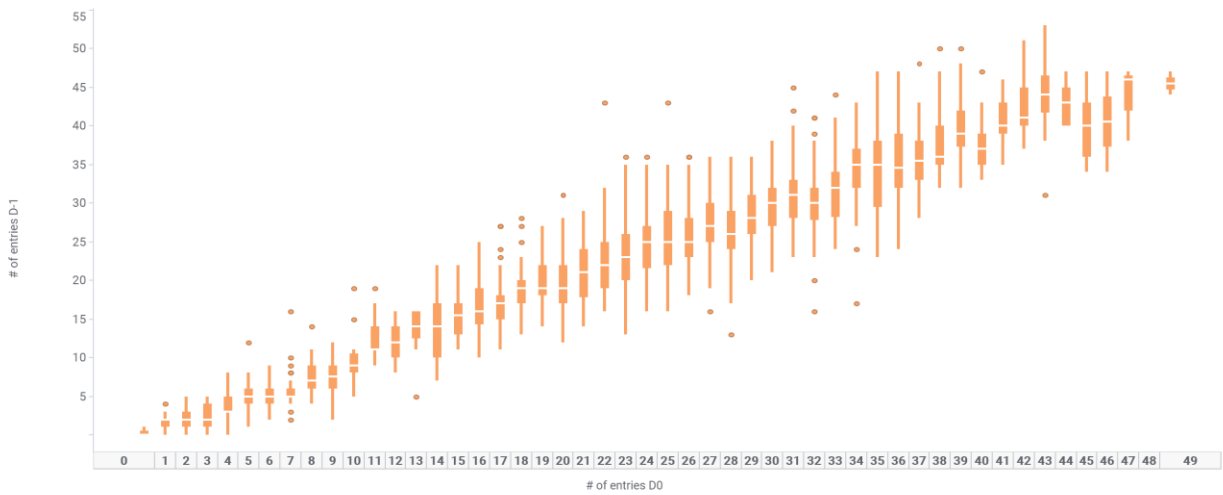
Boxplot of scatterplot EHSECT2



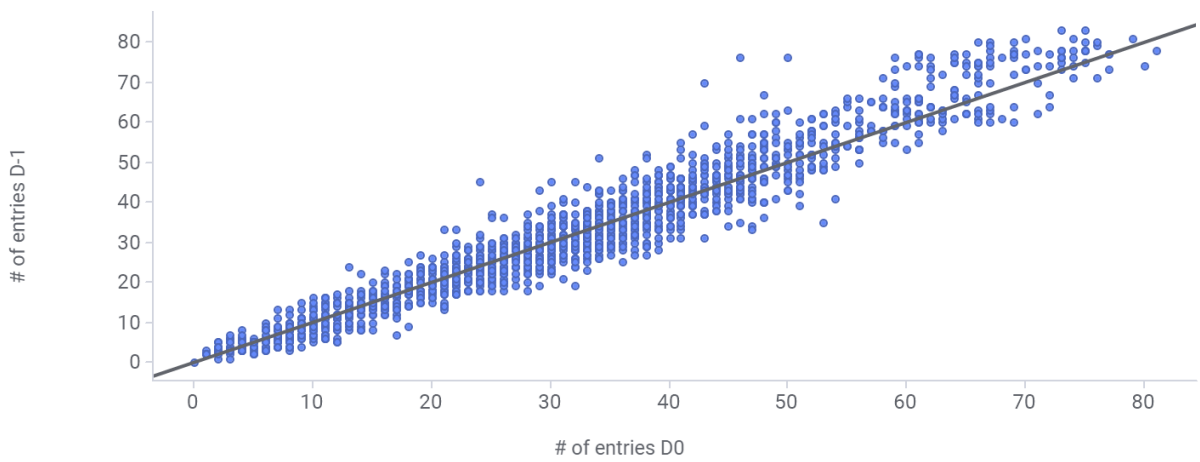
Scatterplot EHSECT3



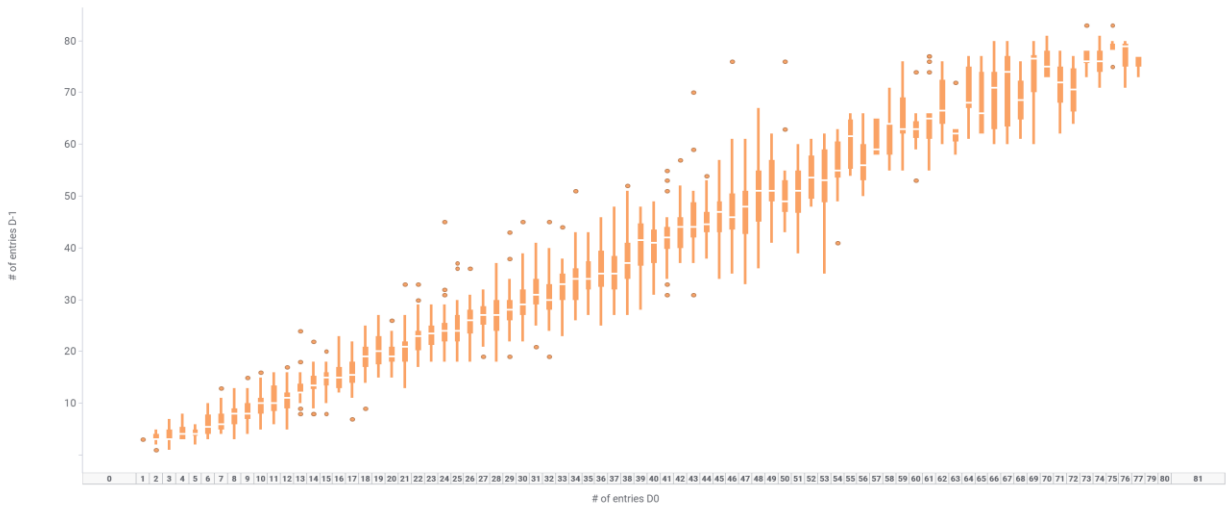
Boxplot of scatterplot EHSECT3



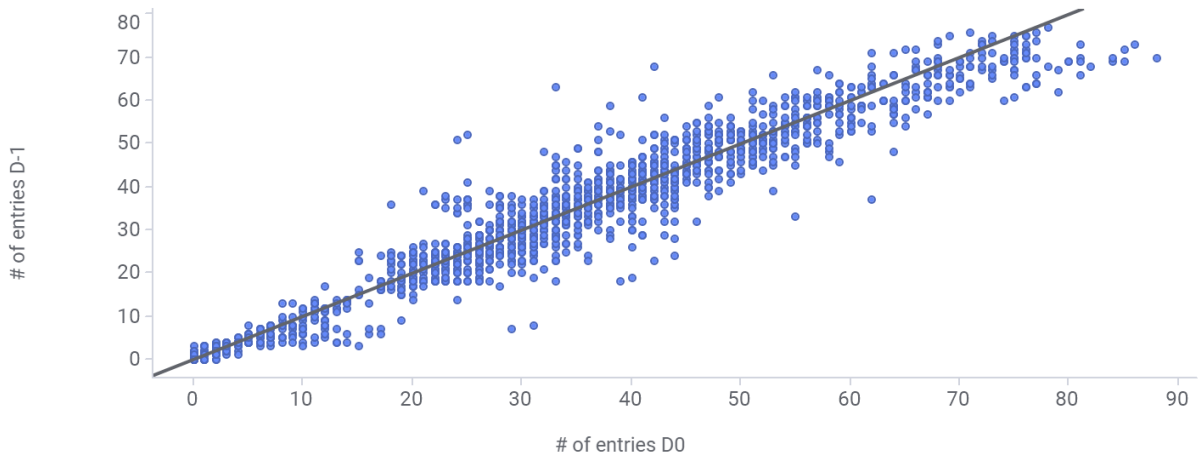
Scatterplot EHAM Arrival South



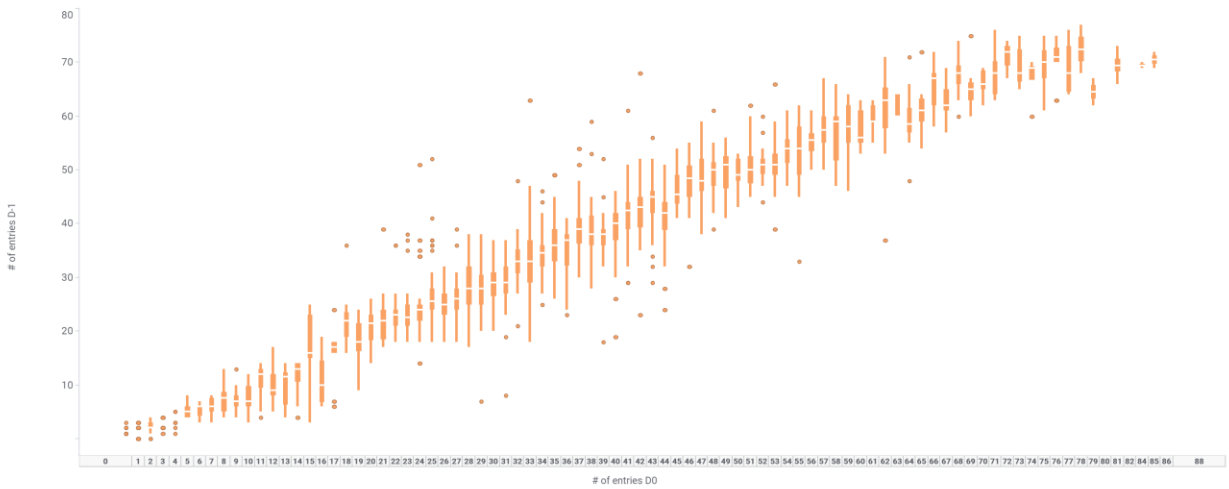
Boxplot of scatterplot EHAM Arrival South



Scatterplot EHAM Departure South



Boxplot of scatterplot EHAM Departure South

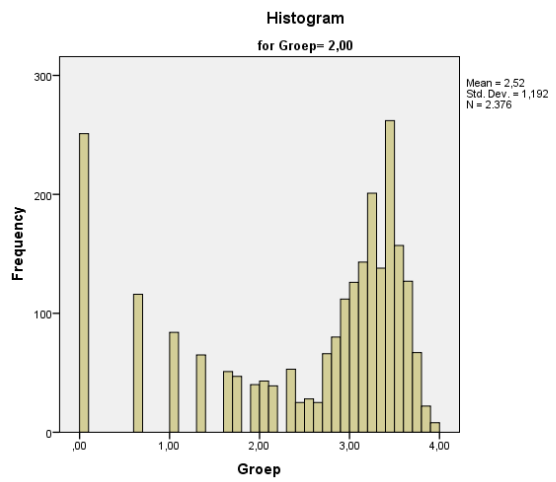
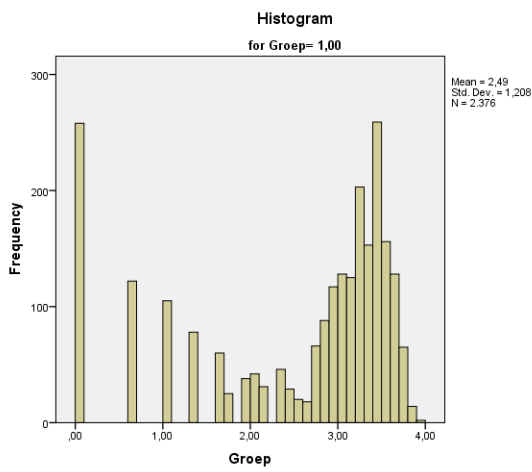
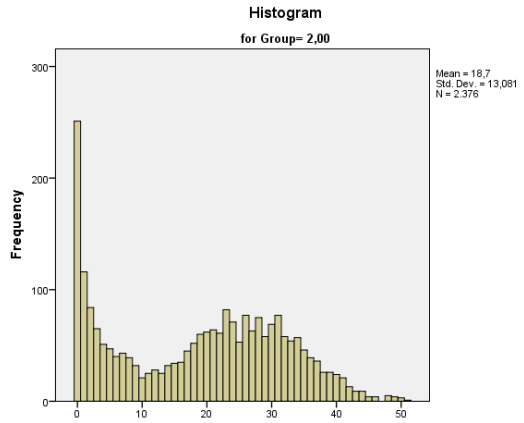
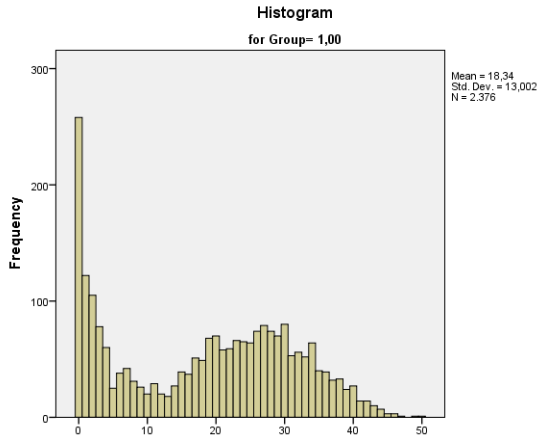


# Appendix XIX. Histograms of demand and log-transformation

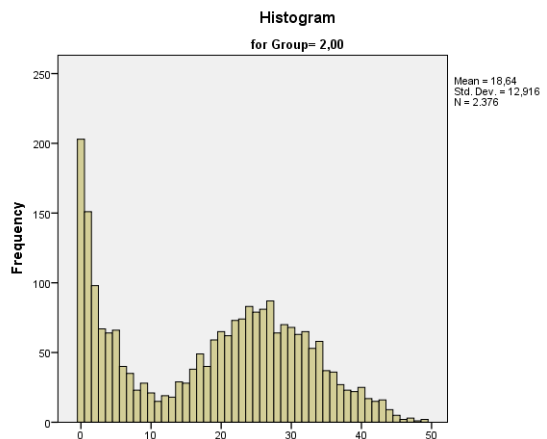
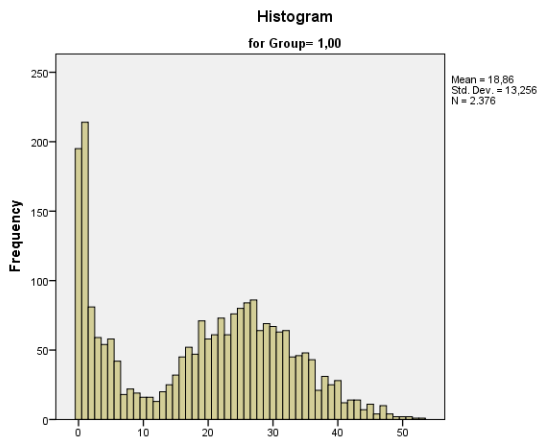
Group 1 is D-1

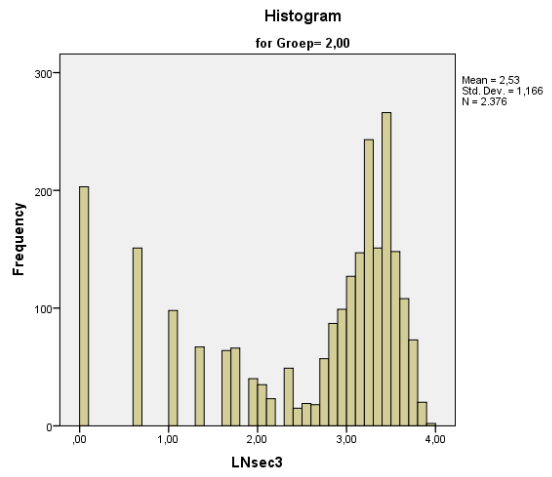
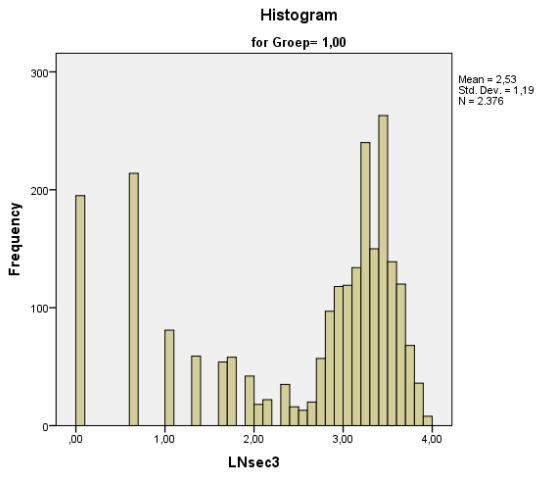
Group 2 is D0

EHSECT2

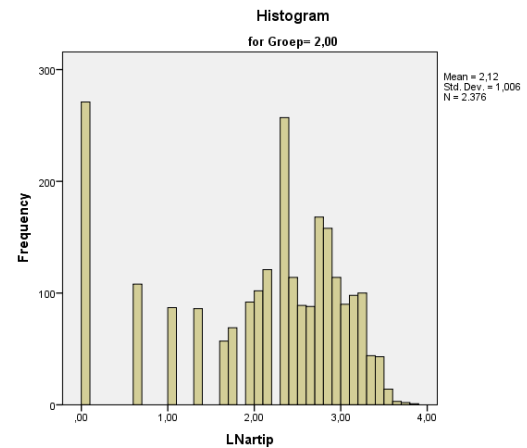
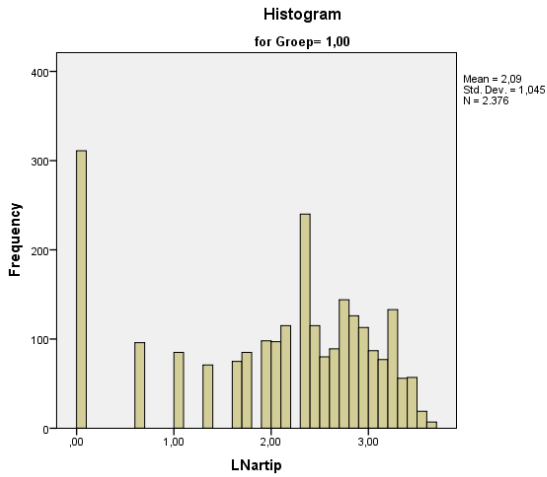
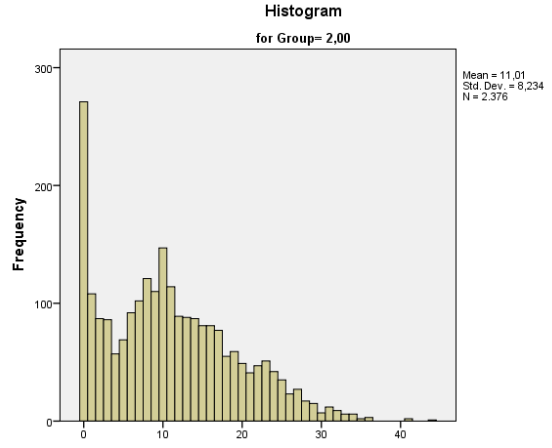
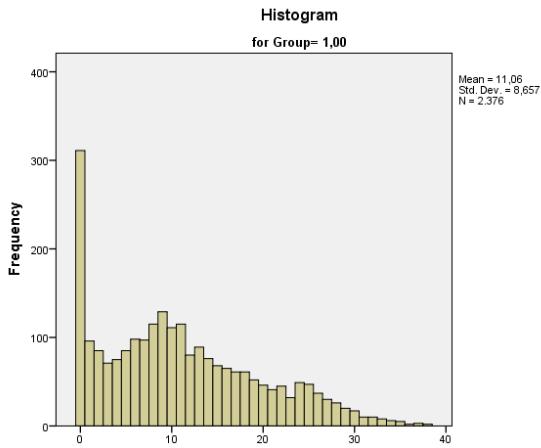


EHSECT3

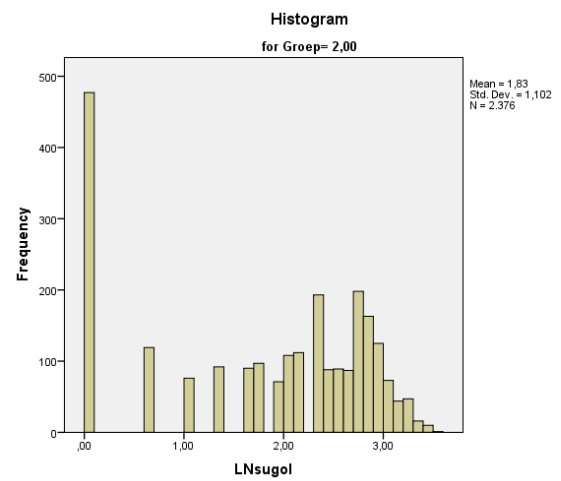
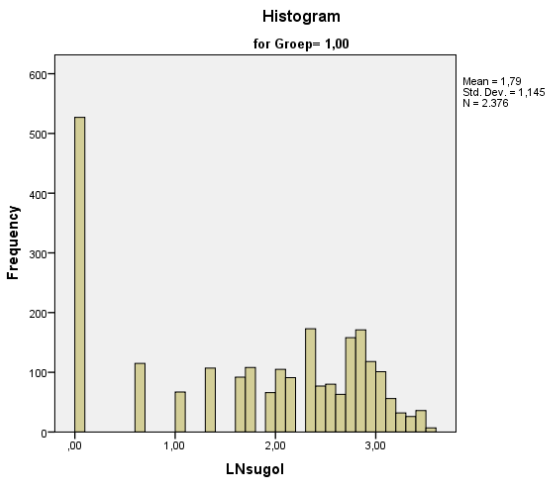
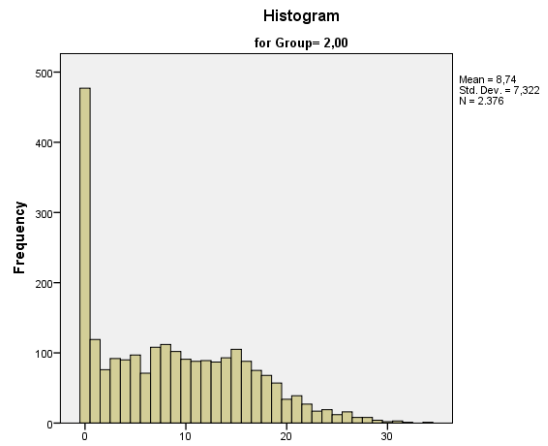
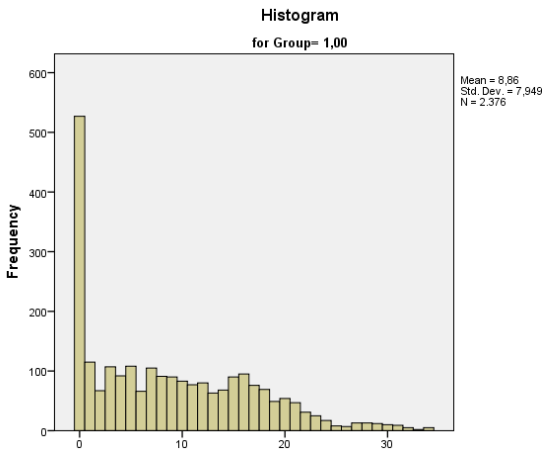




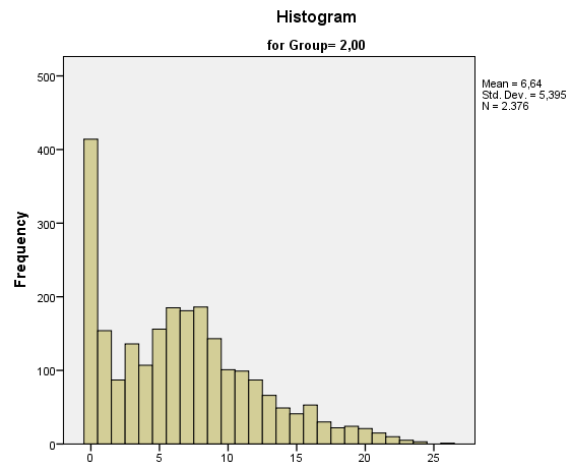
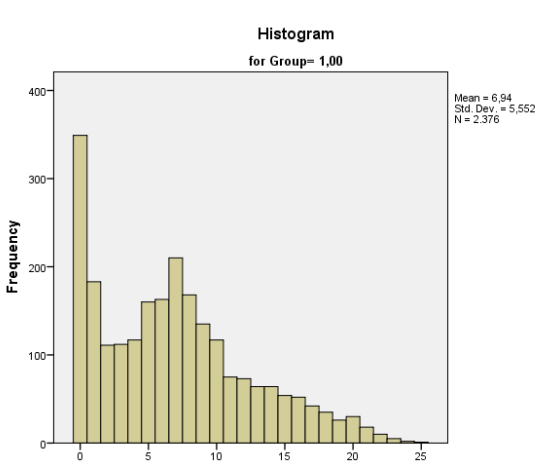
**EHARTIP**

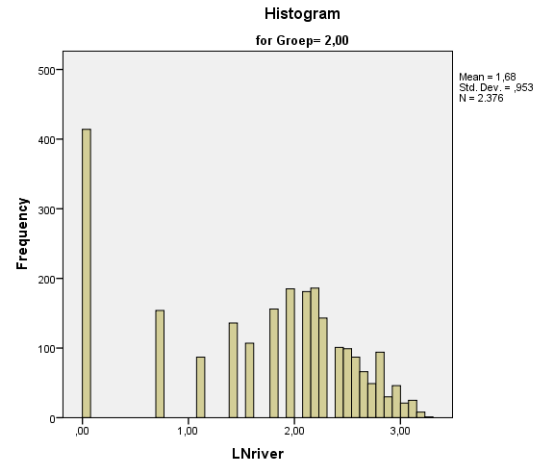
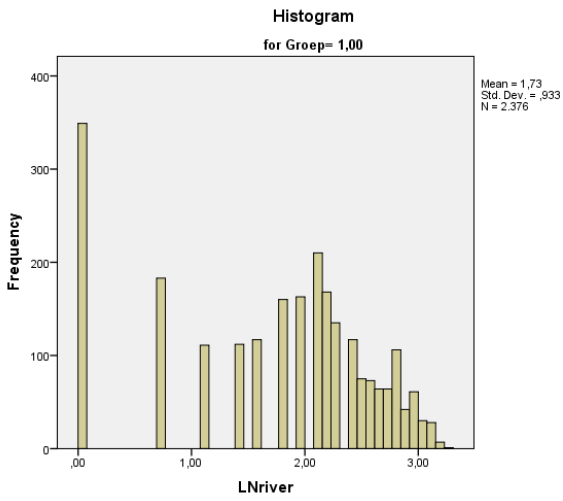


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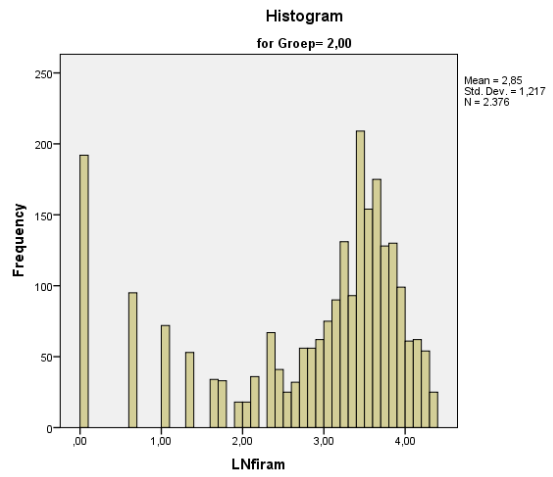
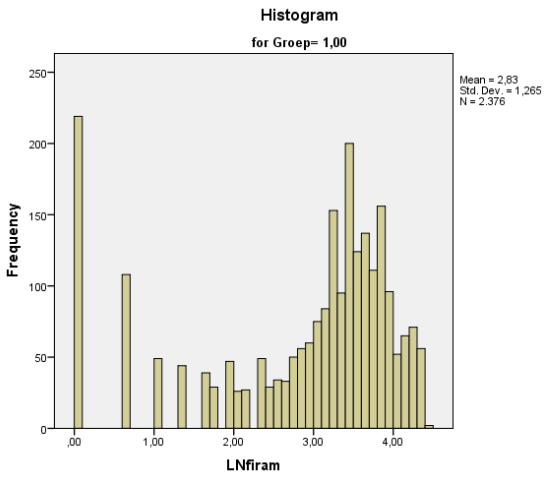
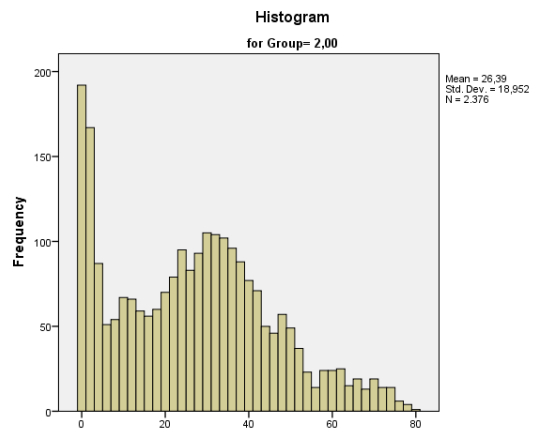
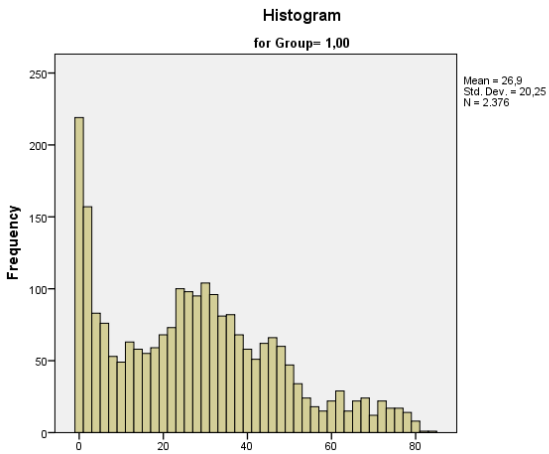


**EHRIVER**

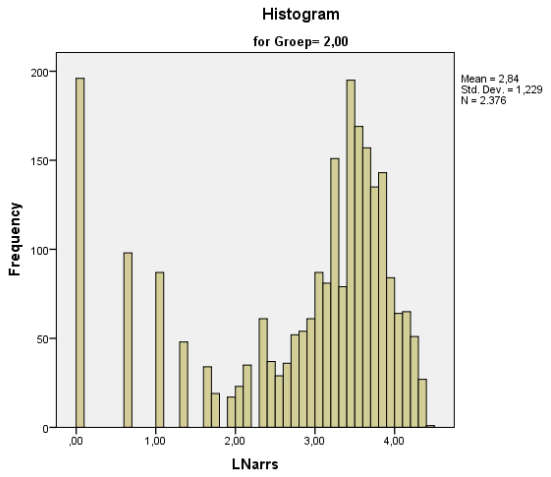
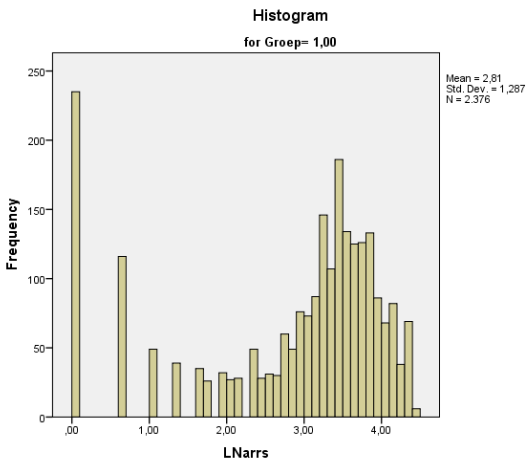
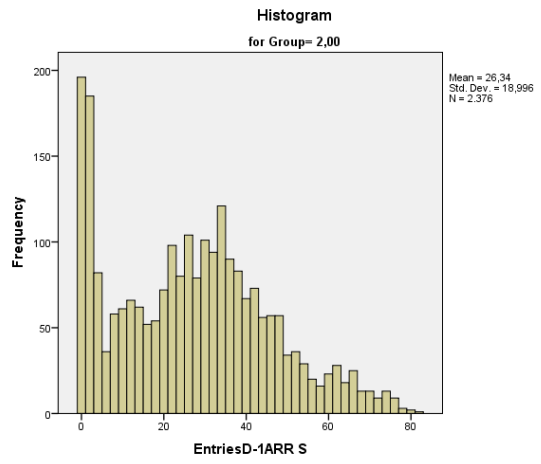
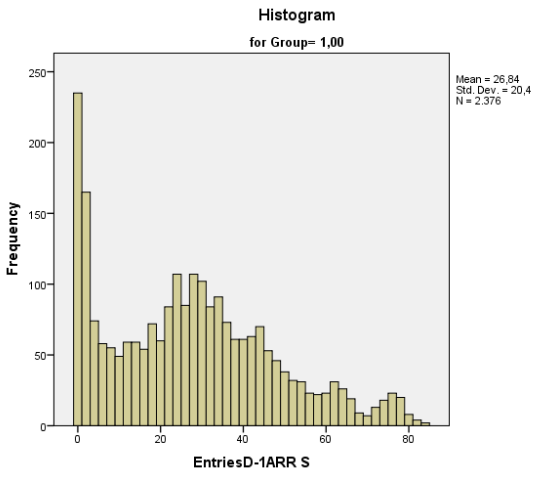




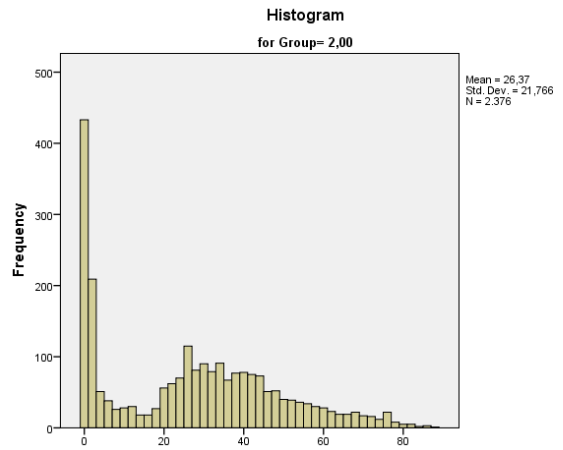
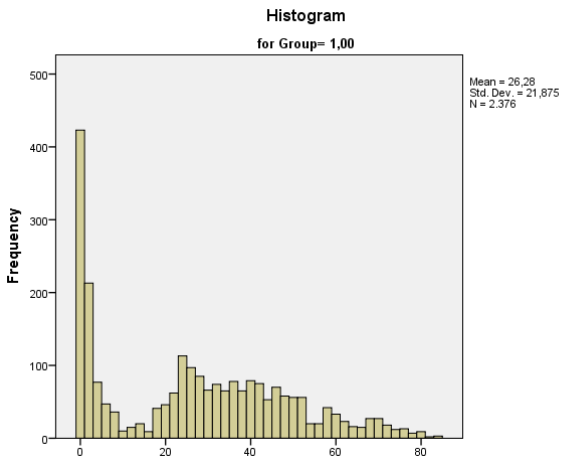
**EHFIRAM**

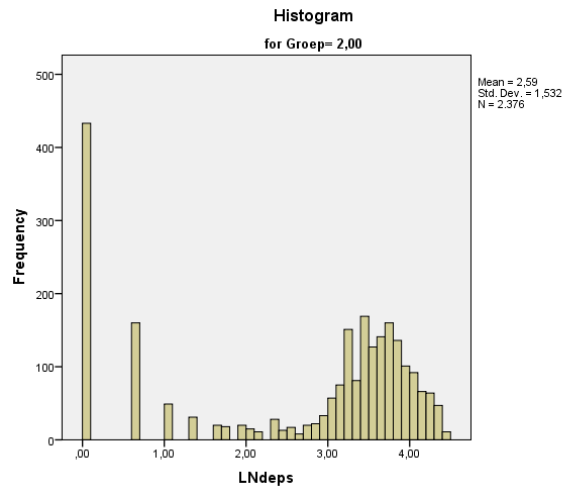
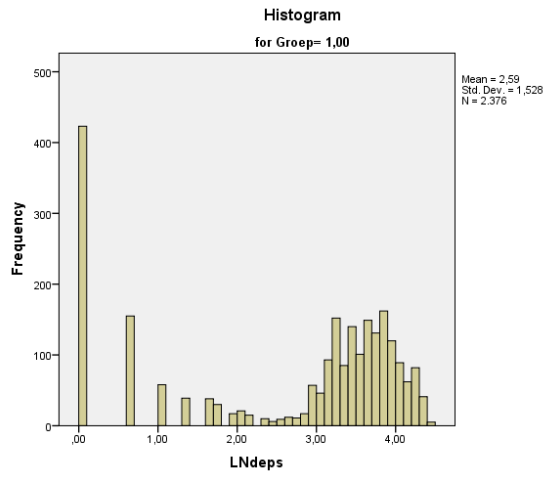


**EHAM Arrival South**



### EHAM Departure South

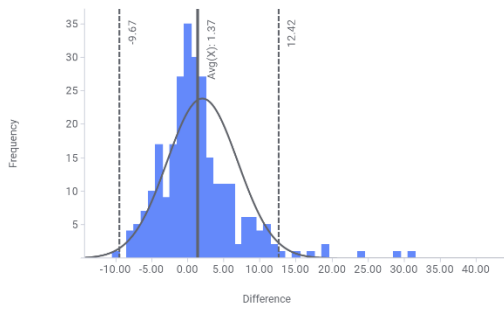




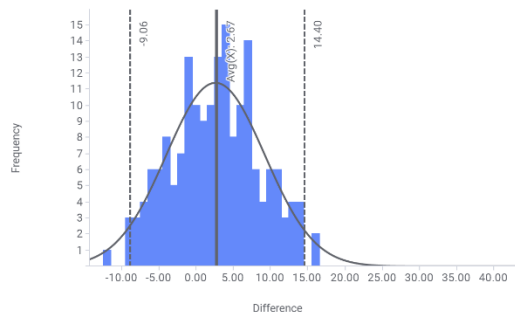
# Appendix XX. Statistics EHFIRAM peak hours

## Distribution difference EHFIRAM peak hours

Distribution difference 5th peak hour EHFIRAM

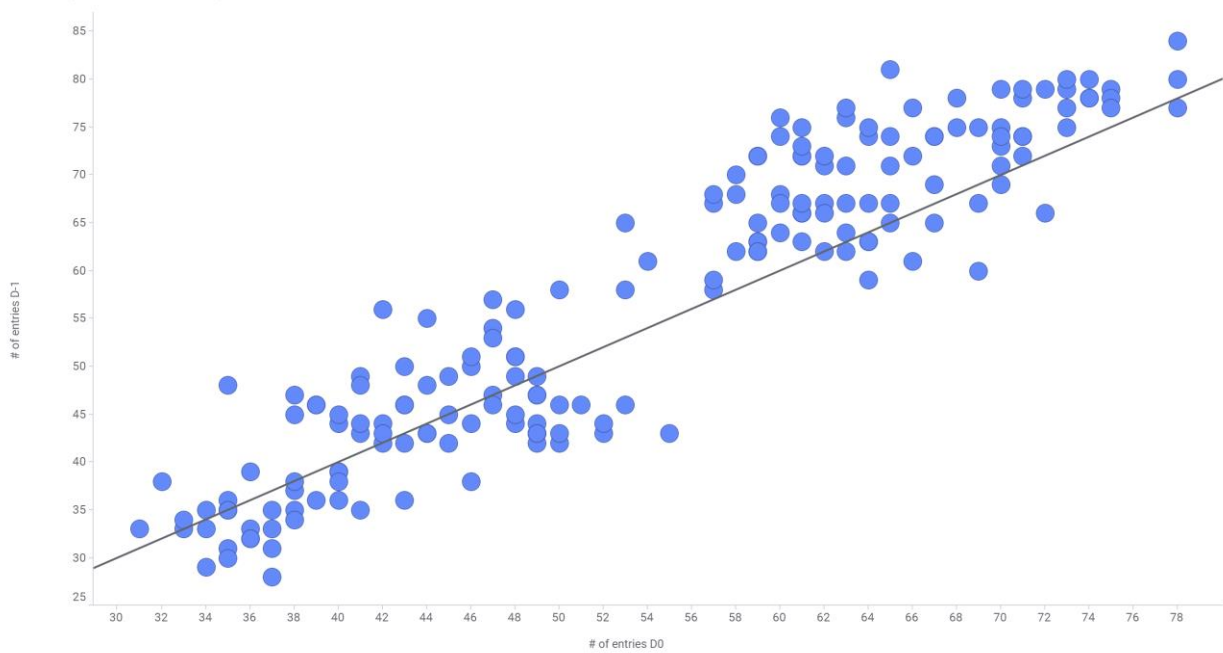


Distribution difference 1th peak hour EHFIRAM

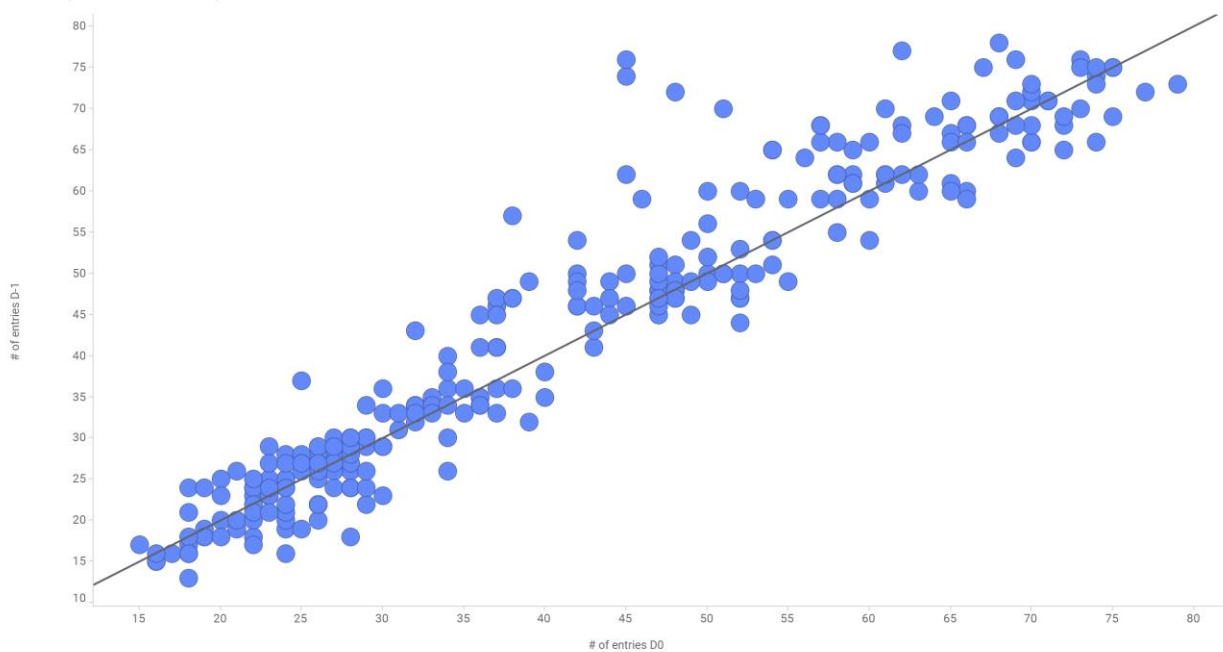


## Scatterplots EHFIRAM peak hours

Scatterplot EHFIRAM 1th peak hour



Scatterplot EHFIRAM 5th peak hour



MFE and percentage of demand D0 in D-1

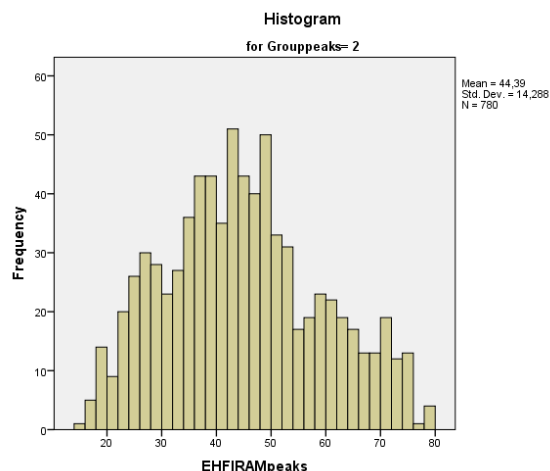
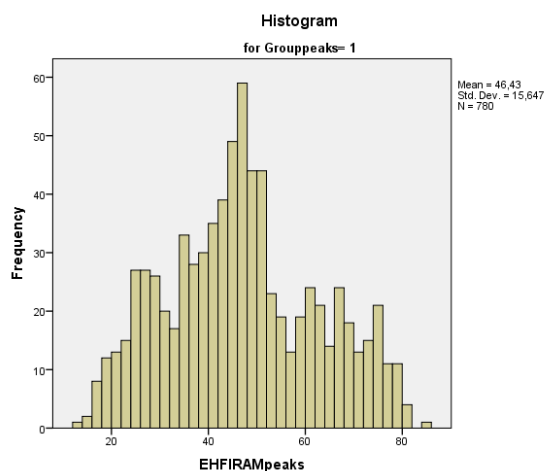
Date	MFE	% 1th peak	% 5th peak	% total peaks
10/01/2019	-1.96153846	-3.48	-3.75	-4.22885572
11/01/2019	-3.61538462	-4.78	-8.31	-7.6986077
16/01/2019	-2.23076923	-3.86	-3.90	-4.98710232
18/01/2019	-2.07692308	-2.33	0.00	-4.45177246
23/01/2019	-2.30769231	-11.21	1.02	-5.13259196
25/01/2019	-3.03846154	-2.64	-3.22	-6.55058043
31/01/2019	-6.19230769	-10.67	-16.71	-13.02589
01/02/2019	-4.23076923	-9.12	-5.46	-9.06842539
02/02/2019	-1.5	-5.64	4.10	-3.86138614
05/02/2019	-1.38461538	-6.76	-1.29	-3.16901408
06/02/2019	-0.88461538	-3.93	-1.50	-1.93602694
07/02/2019	-1.30769231	0.61	-4.46	-2.75526742
12/02/2019	-0.76923077	-3.65	0.77	-1.71969046
15/02/2019	-0.5	-3.68	1.95	-1.05092967
20/02/2019	-0.88461538	-2.74	2.26	-1.89925681
21/02/2019	-1.80769231	-2.99	-0.49	-3.71835443
22/02/2019	-0.30769231	-8.64	3.13	-0.63041765
23/02/2019	-1	-9.20	1.26	-2.27471566
25/02/2019	-1.42307692	-3.38	-3.29	-2.84615385
27/02/2019	-0.15384615	-3.52	2.49	-0.32467532
02/03/2019	-0.84615385	-3.43	3.65	-1.96956132
05/03/2019	-1.15384615	-3.66	-0.50	-2.43309002
06/03/2019	-1.76923077	-6.18	0.24	-3.64212193
08/03/2019	-1	-4.58	3.15	-2.06841687
09/03/2019	-2.96153846	-5.01	-9.24	-6.91823899
12/03/2019	-0.26923077	-0.57	-7.41	-0.57283142
14/03/2019	-7.15384615	-4.37	-25.93	-14.53125
15/03/2019	-5.07692308	-3.76	-13.83	-10.4347826
19/03/2019	-2.5	-6.96	-2.91	-5.31914894
27/03/2019	-0.96153846	-1.51	-0.97	-2.03583062

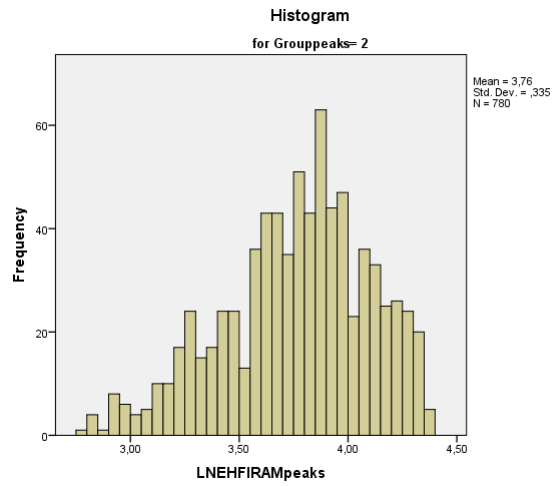
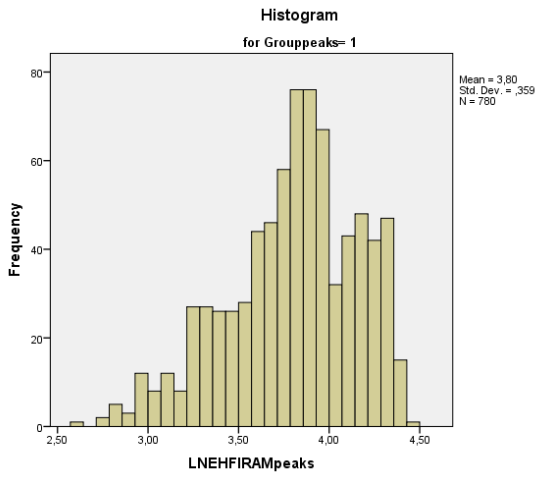
Histograms of demand and log-transformation EHFIRAM

Group 1 = D-1

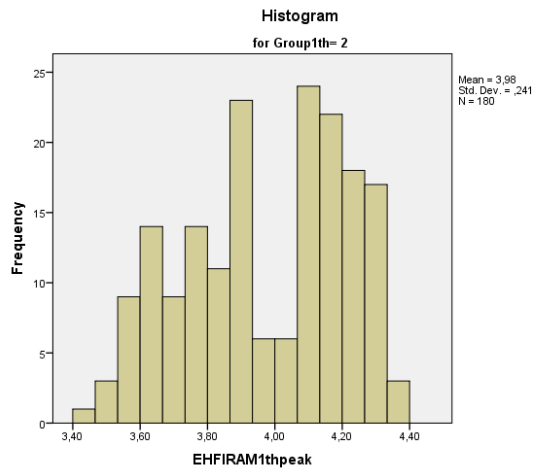
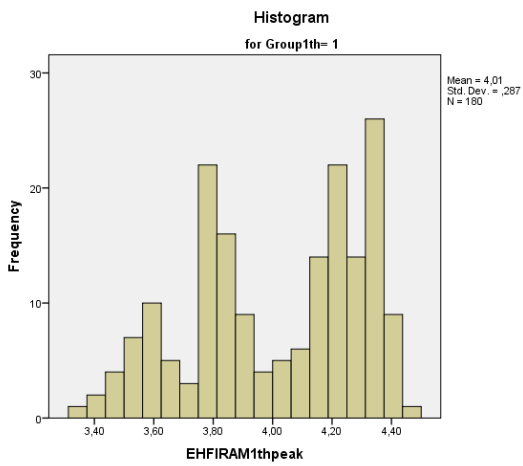
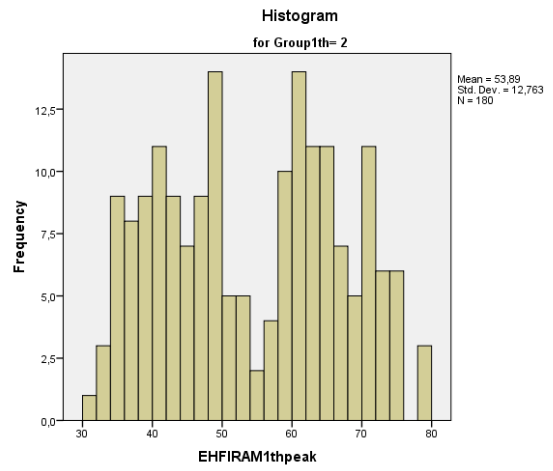
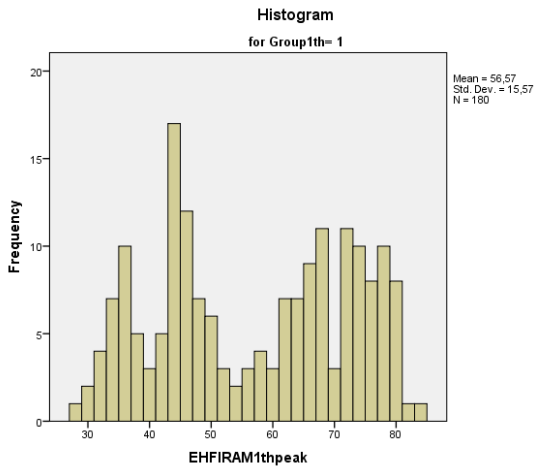
Group 2 = D0

EHFIRAM all peak hours

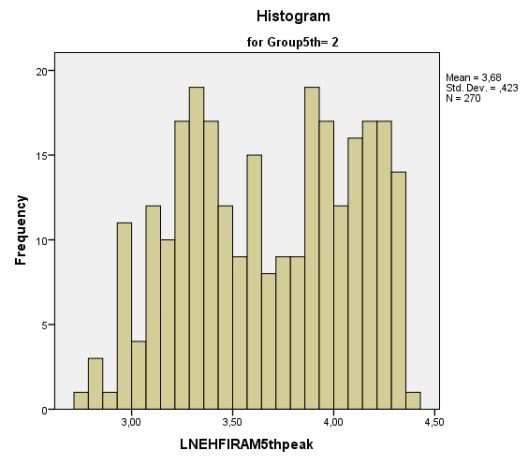
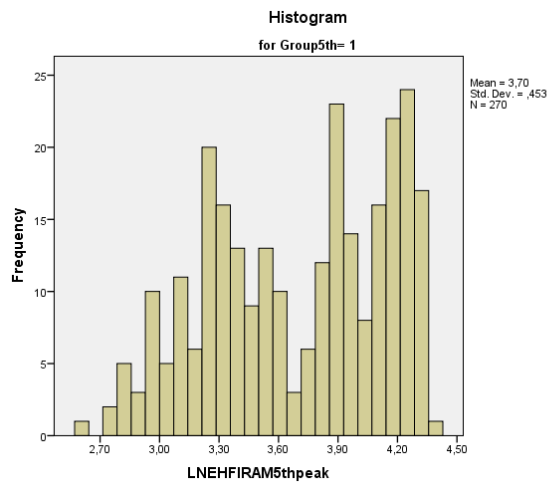
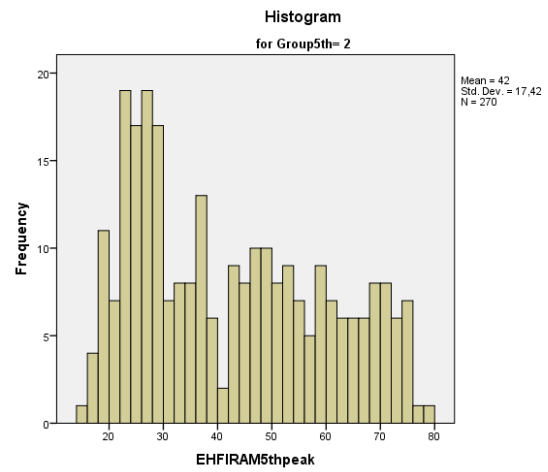
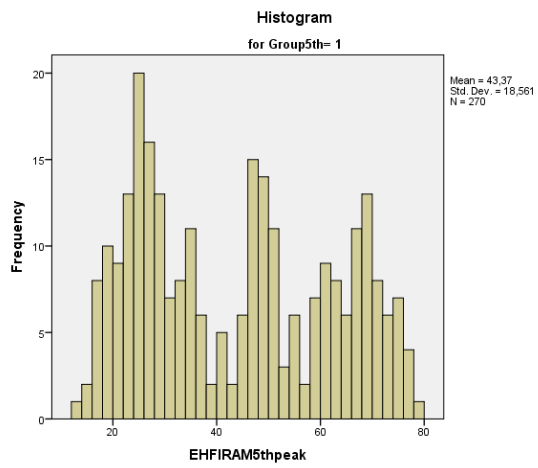




**EHFIRAM first peak hour**



**EHFIRAM fifth peak hour**



## Appendix XXI. Vision of experts

### Interview vision of expert: supervisor

Interviewee: Marc Nieuwenhuijs, Supervisor ACC.

Interviewer: Flore Wassenberg

Interview date: 25-04-2019

Transcribed on: 30-04-2019

Verified by Marc Nieuwenhuijs on: 10-05-2019

Flore 00:00:16

Zou je voor mij je dag kunnen omschrijven als je dus wel die D-1 predictie die gemaakt wordt als je die mee zou nemen.

Marc 00:00:16

Ja. Ervan uitgaand dat er zeg maar nog niet bij pre-tactisch gereguleerd wordt.

Flore 00:00:25

Een beetje van beide, het wordt nu nog niet echt gebruikt in operatie, maar als het wel zou worden gebruikt, wat zou er dan anders zijn?

Marc 00:00:33

Het zou wel handig voor mij zijn en wat anders zou zijn is dat je alles gewoon in 1 document hebt. Dus wat het aanbod is, het weer, onderhoudswerkzaamheden, eigenlijk alles wat erin staat, donor vluchten, allemaal die dingen die d'r omheen zijn, activiteiten van de militairen. Dus dat je niet uit verschillende bronnen iets moet gaan halen.

Flore 00:00:56

Dat het makkelijker wordt met alles uit 1 document.

Marc 00:00:58

Ja, want soms ben je gewoon niet op de hoogte van iets en dat hoor je dan weer laten of dat staat weer ergens in de supervisors mailbox. Nou dat zijn allemaal dingen weet je wel, daardoor is de kans vele malen groter dat je gewoon dingen niet meeneemt die beslissing of er gewoon geen weet van hebt.

Flore 00:01:16

En als je dat dan zou hebben, dus zo'n heel document, hoe zou je dat dan gebruiken? Want kijk je daar dan een dag van tevoren voor tijdens je werkzaamheden naar en gebruik je dat dan om de dag daarop te reguleren?

Marc 00:01:28

Ja ik denk als je dat (D-1 plan) krijgt dan. Ik denk dat het ultiem zou zijn dat je inderdaad een dag van tevoren al de restricties voor de volgende dag ieder geval tot een uur of 12 lokaal zeg maar voor de volgende dag al d'r in kan gaan zetten. En dan nog altijd aanpasbaar door de nacht supervisors of zo omdat het weer anders is of er gebeurt iets of, etc. Je maakt het hele proces veel voorspelbaarder, in plaats van elke nacht om half 5: wordt er een rem op gegooid of niet?

Flore 00:02:03

Want ze heeft dat ook voor invloed op de dag van operatie, dat het daardoor nog makkelijker wordt?

Marc 00:02:08

Ja ik denk het wel want nu is het eigenlijk om een reactie op wat er gebeurt en met een D-1 proces denk ik dat je gewoon aan de voorkant kan gaan zitten in plaats van achteraf proberen de boel te gaan redden. Dat je het al helemaal ingericht hebt.

Flore 00:02:31

Wat zou je dan echt anders gaan doen dan normaal? Je hebt dan als je het zou gebruiken dan kan je al gaan reguleren en hoe gaat dat dan nu precies?

Marc 00:02:40

Ja nu ga je eigenlijk, kijk je tot hoe de pieken eruit gaan zien. Ik neem maar even de nacht, dan kom je om half 5 als supervisors naar beneden en dan kijk je wat het aanbod is en wat het weer doet. En is het weer goed dan reguleer je standaard op 65, maar je hebt ook wel eens dat het slecht zicht is of weet ik veel wat, dan moet je terug naar 44 en dat zijn natuurlijk gelijk en als het aanbod dan, dat hebben we zeker in de zomer wel eens, dan is het aanbod 80. Ja dan is dat echt een klap in zo'n heel netwerk, dus als je dat al eigenlijk van tevoren ziet aankomen in de dag daarvoor, dan zou je dus 's avonds al dat gewoon erin kunnen gaan zetten en dan nou wetend dan dat je dan alleen nog maar hoeft fine te tunen. Dus dan zet je d'r bijvoorbeeld 50 in en dan denk je van nou ja misschien wordt 't wel 40 maar het zou ook wel 60 kunnen worden maar dan weet je een bepaalde bandbreedte, maar dan ga je niet meer van 80 naar 40 of zo. Niet meer die enorme klappen. En want dan heb je die klap gemaakt naar 40 en dan krijg je natuurlijk al dat verkeer wat erachteraan komt, die boeggolf noemen we dat. Dan gaan we dan ook weer zitten door reguleren. Dus dat kun je al veel beter veel eerder doen.

Flore 00:03:56

En wat zou voor jou belangrijk zijn dat dan in die predictie echt zit? Je zei al 1 document, alles bij elkaar. Zijn er nog meer dingen die belangrijk kunnen zijn?

Marc 00:04:06

Nou ik denk dat het op het moment, de gegevens die d'r nu in staan die zijn al heel belangrijk en met name is natuurlijk 9 van de 10 keer het weer een soort van lijdend hier, zicht, wind. Maar die staan er al in, het zou wel mooi zijn om die verwachtingen steeds nauwkeuriger te krijgen. Want volgens mij zijn ze daar met het KNMI ook al mee bezig om dat gewoon nog beter voor elkaar te krijgen omdat er nu toch een te grote mate van onvoorspelbaarheid in zit. En belangrijke andere dingen zoals grote oefeningen van de militairen, waarvan je denkt dat heeft impact.

Flore 00:04:58

Want die krijg je nu ook al te horen toch?

Marc 00:05:00

Ja die krijg je nu ook te horen. Ja ik denk dat het nu al ook in de D-1 staat, in ieder geval dat frisian flag was er natuurlijk. Ik heb daar zelf niet meer mee te maken gehad als supervisors echt, met het Friese vlag dat ik daar iets mee moest. Maar dan is het wel belangrijk dat ze misschien kunnen aangeven van nou ja waar verwacht je dan meer werk voor ons? Is dat alleen in een sector omdat er zeg maar een window voor de militair heel veel wordt opengesteld dus dat we dat we een stuk vrij moeten blijven. Of is het eigenlijk alleen maar van nou ja de militairen zijn heel druk je kan niet direct vliegen. Wat we nu veel vaker hebben dat we hun gebied krijgen en een beetje dat soort details.

Flore 00:05:51

En wat is jouw invloed nu al geweest binnen het D-1 project? Je hebt inderdaad af en toe al die plannen te zien gekregen.

Marc 00:05:58

Dat klopt, nou ja mijn invloed kan ik niet direct zeggen, ik weet wel dat ik wel mijn feedback heb gegeven aan Jeroen over bevindingen of het wel of niet klopte.

Flore 00:06:12

Dus een beetje achteraf gezien van wat er in dat plan stond hoe goed dit was?

Marc 00:06:14

Ja, klopte het een beetje. En het was vaak klopte het aardig en soms ook helemaal niet en dat had dan weer met het weer te maken.

Flore 00:06:22

Vooraf met echte grote verstoringen dat er dan minder voorspeld wordt?

Marc 00:06:26

Klopt.

Flore 00:06:31

Wat je hier ziet dat zijn mijn bevindingen. Waar ik voornamelijk op uitkomen, je hebt die verschillende sectoren, deze sectoren worden ook genoemd in het D-1 plan, er zijn er wel meer. Waar ik voornamelijk op uitkom is dat er vaak net iets meer wordt voorspeld dan gekomen. Dus als naar de tekst kijkt, want dat geeft aan hoeveel aantal vliegtuigen per hoeveel uren is dat nou precies. Nou ja en de standaard deviatie dat houdt dus in, als er gemiddeld genomen nu even 18 vliegtuigen komen dat er dan plus 4 of min 4 zou kunnen zijn.

Marc 00:07:07

Oke ja.

Flore 00:07:10

Nou als je dit is zo een beetje zou zien. Ik heb ook nog een plaatje met iets meer de pieken. Vaak kijken jullie ook wel naar de pieken. Ook van de verschillende sectoren en het blauwe is dan de predictie en het roeie is wat het is geweest.

Marc 00:07:26

Oké.

Flore 00:07:27

Dus dat je ziet ja predictie die komt bij de pieken er vaak wel net iets boven uit, dus dat er toch iets meer voorspeld wordt dan er uiteindelijk komen.

Marc 00:07:36

Ja.

Flore 00:07:37

Maar als je dat zo zou zien, als je dit zou gebruiken, wat zou dan het gevolg zijn voor de operatie? Dat er dus net iets meer wordt dan voorspeld.

Marc 00:07:46

Ja. Kijk ik vind het heel verrassend om te zien. Dat had ik niet verwacht.

Flore 00:07:54

Niet allemaal hoor, want departure dat ligt weer net iets beter op elkaar en hier dan ook weer juist in de avondpiek minder.

Marc 00:08:18

Is het nou wel zo dat zeg maar al het blauwe wat er overheen komt wel weer past onder de rode lijn? Want je hebt hier natuurlijk zegt me iets te veel maar hier zie je wel wat gaten.

Flore 00:08:28

Ja dat er wel weer wat ruimte is. Dit is er nu ook rollend genomen, per uur en dan rollend per 20 minuten. Dus uiteindelijk komt waarschijnlijk inderdaad wel op neer dat het past. Want er zit eigenlijk een vliegtuig drie keer in.

Marc 00:08:41

Ja want eigenlijk elk vliegplan wat gefiled wordt, die kist die komt er ook. En ik denk dat dit met name komt door die min 5 plus 10 wat ze hebben bij een slot tijd. Dat kan behoorlijk dan afwijken vandaag. Daardoor hebben we ook vaak nog steeds toch wel van die bunches, terwijl we het helemaal gereguleerd hebben, dan denk je nou dan zou het keurig moeten komen. Maar ja als er natuurlijk 4 min 5 gaan en die d'r voor zitten gaan er 4 plus 10 weg. Dan heb je er 6 op dezelfde tijd al bijvoorbeeld wat je eigenlijk niet zou willen. Dus ja. Ik kan hier niet zoveel verder dat ik zeg van nou ja als je ziet dat er altijd iets meer verwacht wordt maar wat er niet komt dan zou je dus zeg maar de capaciteit iets omhoog kunnen zetten of zo want dan zou je onder de streep nog steeds goed zijn.

Flore 00:09:38

Maar, dat moet jullie zeggen hoor, maar ik denk dat het fijner is dat er eerder te veel wordt voorspeld dan te weinig.

Marc 00:09:47

Ja klopt. Ja ik heb liever dat onder de streep net iets minder komt dan dat er een net iets meer komt.

Flore 00:09:52

Want anders dan heb je ook een probleem qua bezetting denk ik?

Marc 00:09:55

Klopt ja.

Flore 00:09:56

Want als je dit zou weten, dat je weet van nou ja het is eigenlijk altijd standaard net iets te veel, je weet dat je dus dan die predictie krijgt. Wat zou dat dan voor gevolg zijn voor jou werkzaamheden? Denk je dat dit dan nog steeds bruikbaar is?

Marc 00:10:14

Ja dat denk ik zeker, je ziet het ook in wel in de praktijk dat het vaak heel hoog staat of dam staat er toch nog wat te hoog en dan uiteindelijk zie je hem toch weer inzakken. Dus dat is ook wel de ervaring die je d'r mee hebt. En dit wetende dat geeft je wel zoiets van nou ja als je dan een keer een uitschieter ziet dat je niet gelijk denkt van: 'oh ik ga nog effe extra een regulatie er inzetten want anders, ik moet m'n mensen beschermen'. Wat natuurlijk op zich een heel goed streven is en wat we ook zeker moeten doen.

Flore 00:10:45

Want jullie kijken dan ook echt een dag van tevoren naar de bezetting van hoeveel luchtverkeersleiders je nodig hebt?

Marc 00:10:52

Ja. Nouja het is eigenlijk al helemaal uit gedokterd dus wij zitten eigenlijk zondag tot en met vrijdag hebben we een standaardbezetting alleen zaterdag zijn er iets minder mensen. Da 's gewoon gebaseerd op het aanbod van het verkeer. Alleen als je een, want dat wordt er nu ook al aangeven in de D-1 overzicht, van hoeveel mensen hoeveel posities verwacht je en daar zou je natuurlijk wel veel meer kunnen doen om je mensen efficiënter in te zetten.

Flore 00:11:25

Gebeurt dat nu vaak dat toch blijkt dat je te weinig hebt? Gisteren zei ook dat je langer door moest.

Marc 00:11:33

Maar gisteren was er toevallig dan een zieke en die kon niet meer opgevuld worden. Dus toen hadden we gewoon een dienst te weinig. Dat is op te vangen alleen dat betekent dat alles gewoon wat langer blijft zitten en dat het wat langer duurt. Gisteren was ook een rare dag weer met heel veel vertraging en zo. Dus vandaar dat het dat het gisteren niet lukte om te komen maar. Ik denk dat we in 98 procent van de gevallen dat we gewoon uitstekend met de mensen zitten. Het is het is zelfs zo dat er eigenlijk in 98 procent van de tijd zitten we eigenlijk met te veel mensen. Maar daar is het systeem een beetje op ingericht dat we ook moeten kunnen holden en als dat niet het geval is dan kunnen die mensen iets anders gaan doen is.

Flore 00:12:22

Ja als je dus nou nog maar de sectoren kijkt, welke vind jij het belangrijkste dat ze echt goed voorspeld worden? Waar kijken jullie voornamelijk naar?

Marc 00:12:33

Met name naar de stacks. Dus naar ARTIP, SUGOL en RIVER. Dat daar niet hele rare dingen in komen want het totaalplaatje de hele FIRAM die kan best een beetje hoog staan, maar als dat keurig verdeeld is dan is de werklast verdeeld. Maar stel nou, je ziet wel met name in de ochtend dat SUGOL een hele hoge last heeft en die moet je dan soms ook gewoon extra reguleren. En dat heb je 's middags weer bij ARTIP zo wisselt dat een beetje.

Flore 00:13:21

Ja en die staan er nu redelijk goed voor qua aantal met wat te veel wordt voorspeld dus dat op zich best wel goed. Alleen de standaard deviatie ja dat kan af en toe nog in verhouding met het aantal vliegtuigen, je ziet ongeveer 10 vliegtuigen dat dan misschien wel met 3 kan afwijken.

Marc 00:13:37

Ja.

Flore 00:13:38

Zou dat vervelend zijn als je toch van we hebben voorspeld 10 maar het blijkt toch 13 te zijn?

Marc 00:13:48

Ja dat kan lastig zijn. Zeker hoe het binnenkomt natuurlijk, of die 13 die kunnen zeg maar in 10 minuten komen. Maar ze kunnen ook 13 in 20 minuten komen en dan heb je zoiets van nou als dat een beetje verdeeld is dan is er helemaal niks aan de hand.

Flore 00:14:04

Ja dat is beetje afhankelijk van hoe 't op het uur verdeeld is.

Marc 00:14:07

Ja klopt.

Flore 00:14:15

En als jij zou moeten kijken van hoeveel afwijking ten opzichte van de predictie met een uiteindelijk (actual). Wat zou jij acceptabel vinden? Want het is voor mij een beetje te kijken van wat we nu hebben is dat goed genoeg of zouden we in bepaalde sectoren of op bepaalde manieren toch nog accurater moeten zijn.

Marc 00:14:41

Ik vind een afwijking acceptabel, ik denk ook niet dat je zonder afwijkingen kan werken. En normaalgesproken zie je dat we eerder zeggen van nou we gaan liever aan de kant van ietsje te veel zitten dan te weinig omdat we weten dat we dat eigenlijk altijd gewoon wegwerken.

Flore 00:15:01

En wat een beetje uit mijn data bleek is dat als je dagen hebt waar uiteindelijk best wel harde wind is of nou ja ik heb ook de staking van de Belgen die is ook heel duidelijk te zien in mijn predictie. Als je dat van tevoren zou weten van nou ja 't is voorspeld dat 't best wel slecht wordt. Kun je daar dan rekening mee houden dat de predictie dan ook slechter zou kunnen zijn?

Marc 00:15:22

Dus dat de predictie slechter is dan de?

Flore 00:15:26

Dat ie gewoon minder goed aansluit op de dag van operatie. Dus dat de afwijking groter is omdat er slecht weer is voorspeld, en dat ze niet goed weten hoe.

Marc 00:15:34

Ik denk dat een supervisors altijd en de FMP'er altijd 4 tot 6 uur vooruit moeten blijven kijken van: klopt het wat we hebben gedaan, klopt het nog steeds, wat doet de wind, zicht, noem maar op. Je zou best wel vaak, of regelmatig, vaak is denk ik niet het goede woord, maar best wel regelmatig, dat er met name als er verstoringjes zijn, dat hoeven geeneens hele grote zijn, dat je als supervisors nog steeds moet blijven finetunen. Kijk als alles gewoon prachtig mooi weer is en het aanbod is gewoon te veel dan kun je dat gewoon van tevoren reguleren en dan zou je denk ik als supervisors geeneens heel veel meer aan hoeven doen want dan loopt het gewoon.

Flore 00:16:29

Nou dit waren eigenlijk alle vragen die ik wilde stellen. Voor de rest is iets minder gerelateerd op mijn onderzoek maar misschien nog wel relevant, mocht je er iets over willen zeggen. Vooral qua inschatting van het aanbod hoe dat nu gaat. Met die D-1 predictie kijk je dus naar dat plan en dat is dan een inschatting maar hoe wordt dat nu gedaan? Eigenlijk zijn dat dan die standaard dagen waar jij het over had.

Marc 00:16:57

Ja. Nu hebben we natuurlijk helemaal geen plan. Het plan wordt gemaakt door de supervisors die 9 van de 10 keer een restrictie d'r in zet bijna voor z'n collega. Want de nacht chef doet het voor de ochtend chef. 's Ochtends kijk je natuurlijk zelf, maar die reguleert ook al vaak voor de middag piek omdat je het wel een aantal uur van tevoren moet doen. Dus wat nu eigenlijk gebeurt, je hebt het er ook niet over met je met je opvolger want die ga je niet lopen bellen met: 'ik ga dit doen'. Een hele enkele keer gebeurt het wel omdat je ergens over twijfelt en denk je van: 'ja 't zal ik nou heel voorzichtig gaan zitten of neem ik toch een beetje een gok'. Dan kijk je vaak van wie is mijn opvolgende supervisors want ook in de supervisors groep heb je natuurlijk ook nog wat verschillen met de een is voorzichtig en de ander denkt van de ah kom maar. Dus en enkele keer overleg je. Maar je doet het gewoon, je kijkt gewoon die 4 tot 6 uur vooruit minimaal. En het enige wat we doen is we zet 'm er in en 9 van de 10 keer bellen we de KLM van: nou dit is ons plan, dit gaan we doen. Dus dan weten jullie dat alvast. Maar dat is dan eigenlijk meer hebt inlichten van joh over 5 minuten zet ik die regulatie er in. Dus zij kunnen daar zeg maar ook niet echt rekening mee houden. Het is niet zo dat ik 's ochtends om 11 uur bel van nou: 'ik verwacht dat ik vanavond.., nou let op hoor'.

Flore 00:18:26

Zo ver vooruit kijk je eigenlijk niet?

Marc 00:18:27

Nee. Of moet heel slecht zijn maar ja dan heeft de KLM, die kijkt ook naar het weer en dergelijke, die zien ook wel van oh dat zal vanavond wel eens een probleem kunnen zijn.

Flore 00:18:37

En dat zou je dan wel doen als je al zo'n D-1 plan hebt?

Marc 00:18:40

Nou ik denk, of je het hele plan naar je stakeholders moet sturen weet ik niet, maar misschien het capaciteit gedeelte wat wij verwachten, ik denk dat je dat zo ook naar de KLM zou kunnen cc-en bijvoorbeeld. En naar de luchthaven zelf dat ze weten van: 'oh die gaan dat doen'. Zodat de mensen veel meer voorbereid zijn.

Flore 00:19:02

En hoeveel uur vooruit zou je dat dan doen?

Marc 00:19:06

Die zou ik misschien ook al op de D-1 zoals we 'm nu krijgen, eind van de middag krijg je de verwachting voor de volgende dag.

Flore 00:19:21

Wordt er nu echt een capaciteit naar buiten gebracht richting de stakeholders, vooral richting KLM waarschijnlijk?

Marc 00:19:27

We hebben natuurlijk het, hoe heet dat formulier wat approach afgeeft, capacity forecast geloof ik. Nee het... Nou ja waar ze aangeven welke banen en hoeveel capaciteit.

Flore 00:19:40

Het is eigenlijk een beetje een standaard formuliertje met als die banen in gebruik zijn heb je die capaciteit.

Marc 00:19:44

Ja precies. Dus dat krijgen ze en het zou ook zo moeten zijn dat als wij dus in een fase hebben dat zij ook die fase bij die baan moeten geven alleen dat gebeurt niet altijd weet je wel dus daar is nog wel eens wat verwarring over. Dus ze krijgen het nu wel maar dat is eigenlijk nog wel heel grof.

Flore 00:20:08

Voor de rest is het nog een beetje qua implementatie, mocht het helemaal in gebruik worden genomen, hoe denk jij dat andere mensen die dus nu nog niet betrokken zijn binnen het D-1 project en ook de luchtverkeersleiders zelf hoe die er in staan? Staan ze d'r open voor?

Marc 00:20:21

Ja ik denk zeker dat voor een verkeersleider dat het ook prettig zou zijn. Ik denk als ik zelf gewoon als verkeersleider dienst heb en ik kom op zaal, dat bij wijze van op dat de grote scherm een klein grafiekje van de verwachte operatie van die dag staat. Van nou we verwachten ongeveer deze capaciteit te gaan doen en eventueel nog een reden erbij omdat als normaal is dan hoeft het niet dan zien ze: doen gewoon 65 en 68 in de avond business as usual, maar als ze zien het is lager allemaal, due to wind, due to visibility, of weet ik veel wat. Maar dan hebben ze al een idee van oh er is gereguleerd of het is geen normale dag. Dat is voor een verkeersleider wel handig want als je alleen verkeersleider ben sta je d'r toch wat verder vanaf, dan snap je die hele materie met reguleren en hoe dat allemaal werkt en zo dat is toch een beetje een ding van ja dat doen ze daar bij de supervisor desk en ik kijk wel. Je ziet de verkeersleider ook niet heel snel kijken op CCIS op de regulatie pagina, is er gereguleerd of niet? En dat doe ik zelf wel altijd maar dat is omdat ik supervisor ben van: 'oh is er nog wat gedaan of niet?' Dus dat zeker toegevoegde waarde voor de verkeersleider.

Flore 00:21:44

Dat waren de vragen van mij. Heb jij nog vragen voor mij?

Marc 00:21:45

Nee eigenlijk niet. Ik ben benieuwd naar de resultaten.

## Interview vision of expert: FMPC 1

Interviewee: Ger Lautenbach, FMP ACC.

Interviewer: Flore Wassenberg

Interview date: 25-04-2019

Transcribed on: 02-05-2019

Verified by Ger Lautenbach on: 09-05-2019

Flore 00:00:15

Als je die Predictie hebt, die D-1 Predictie die je krijgt, hoe ziet jouw dag er dan uit? Wat is de invloed daarvan op jouw werkzaamheden?

Ger 00:00:15

Op dit moment nog niet echt veel.

Flore 00:00:16

Maar mocht je de D-1 Predictie wel gebruiken uiteindelijk? Nu is het inderdaad nog een trial.

Ger 00:00:23

Ja precies, nou het geef je een beetje een indicatie voor wat je kan verwachten maar het zijn geen klinkklare cijfers. Dus het is een afspiegeling van wat er gerealiseerd is een week, zoals als ik naar morgen kijk, dan kijk ik eigenlijk naar een week geleden. En wat er toen gerealiseerd is, als het allemaal nominaal was. Als er stakingen waren of er was heel veel onweer of allerlei andere effecten. Dit zit daar dan niet in, en als het er wel in heeft gezeten, dan gaat de network manager dat eruit filteren. Of ze pakken de dag daarvoor, dat kan ook. Dan zeggen ze meestal, dan nemen we die dag als representatief. Dat laden we dan in en dat geeft gewoon meer een indicatie, niet meer, niet minder.

Flore 00:01:05

Als jij dus dat D-1 plan wat er tot nu toe is, als jij dat dan krijgt, wat gebruik je daar dan uit?

Ger 00:01:13

Het D-1 plan of de PREDICT data?

Flore 00:01:15

Nu het plan, dus in je werkzaamheden krijg je nu het plan te zien met al die figuurtjes.

Ger 00:01:21

Van Jeroen Devilee bedoel je?

Flore 00:01:21

Ja.

Ger 00:01:24

Nu nog niet echt veel. Het is eigenlijk meer een startpunt van wat je dan met D-1 gaat doen. We krijgen nu een dag van tevoren via de email, omdat het een trial is natuurlijk, het D-1 plan voor de dag dat je in dienst hebt. Het zou eigenlijk zo moeten zijn dat je het D-1 plan krijgt op het moment dat je 's morgens op dienst komt voor de dag daarna. Ze komen morgenochtend bijvoorbeeld op dienst, heel vroeg, kwart over 6. En dan moet daar een D-1 plan liggen voor de zaterdag, de dag daarna, en dan hebben ze alles wat op kantoor is uitgevogeld en wat er dan aan data, dat zit in het D-1 plan, maar dan is het nog niet klaar. Dan gaat het werk pas eigenlijk beginnen.

Flore 00:02:05

En inderdaad als je dat scenario zo voorstelt en jij komt daar dan en dat plan ligt staat dan klaar, wat zou dan voor jou daar de voordelen van zijn en hoe zou je dat dan gaan gebruiken?

Ger 00:02:18

Ja dat ligt er een beetje aan van wat erin staat natuurlijk. Wat van invloed kan zijn op de eerstvolgende pieken in de volgende ochtend.

Flore 00:02:25

Want wat vind jij belangrijk dat erin staat?

Ger 00:02:27

Ik vind belangrijke of er systeem degradaties zijn of dat er speciale vluchten zijn die van invloed kunnen zijn op de nominale capaciteit die we hebben op Schiphol. Of dat er op Schiphol onderhoudswerkzaamheden zijn dusdanig dat de veldafhandeling zodanig is dat het weer invloed heeft op de capaciteit. Alles zeg maar wat niet nominaal is, waarvan inschatting is van: he, dat gaat waarschijnlijk in de cijfers, dat hoort daarin te staan, maar het hoort ook bijvoorbeeld een doorkijk met het weer. Als verwacht is dat er morgenochtend heel slecht weer is, wind of zicht, dan is het ook wel handig dat het daar al een beetje instaat. Dat in ieder geval over nagedacht is en dat er een inschatting is van nou ja misschien 20 procent reductie of misschien wel 40 procent. Maar dat is een initiële waarde. En op het moment dat je op dienst komt dan ga je kijken met de gegevens die je dan hebt, later op de dag of in de avond, moet en we het plan bijstellen. En dan 's avonds dan zeg je van oké, ik ga nu ingrijpen. De volgende ochtend ga ik mijn piek reguleren. Zo zie ik dat heel D-1 zeg maar. En daarin is ook je PREDICT data.

Flore 00:03:37

En wat zou je anders doen als je een D-1 plan hebt, ten opzichte met wat je nu doet?

Ger 00:03:41

Nou ja het is een start. Het scheelt mij zoeken zeg maar. Nu moet ik uit verschillende bronnen de informatie halen of ik vraag het aan de SUP, maar nu heb ik al een start moment met inbreng informatie.

Flore 00:03:57

Zou je als je dit al, omdat je het dan een dag eerder krijgt dan dat je nu de gegevens hebt, zou je dan ook al eerder gaan reguleren? Zou je dan al eerder veranderingen doen?

Ger 00:04:11

Ja nou ja kijk, zo ver zijn we natuurlijk nog niet, we zijn helemaal nog niet zo pre-tactisch aan het reguleren, dat begint nu een beetje te ontstaan. Maar ja dat neemt niet weg dat we in lijn met het pre-tactisch management, wat de network manager doet, dat proces weet je wel, dat we daarop moeten aanhaken. Dus die mooie momenten dat je dan bekijkt de volgende dag, dat je kijkt hoe die PREDICT data, als iedereen daar ze pre-tactische regulaties in heeft staan, of je daar wat mee gaat doen. Die van Maastricht daar heb ik last van of weet je wel, dat soort dingen allemaal dat is natuurlijk wat we allemaal nog moeten gaan leren. Maar daar ga je wel naartoe. En dan is PREDICT maakt dan wel deel uit van het proces. Dan gaat de network manager met die data, krijg je het ADP plan, het ATFCM Daily Plan, dus op D-1, en daar kun je in zien wat er allemaal gaat gebeuren. Ook of jouw pre-tactische regulatie wel goed is ingesteld. Met begin en eindtijd en alles erop en eraan. Ja en dat is een rol in het proces, ja en dan zal een keer een moment moeten komen van, oké ik ga pre-tactisch reguleren en wat is dan het moment? Is ook iets wat we moeten gaan leren en besluiten.

Flore 00:05:20

Jij zit daar wel toekomst in dat dat gaat gebeuren?

Ger 00:05:22

Dat kan niet anders, kan niet anders. Zoals we het nu doen is eigenlijk veel te laat. 4 uur/half 5 's nachts is gewoon echt te laat. Dat is iets wat we moeten veranderen.

Flore 00:05:53

Wat is jouw invloed al geweest binnen het D-1 project want je hebt natuurlijk altijd die plannen gekregen.

Ger 00:06:00

Ik heb wel wat feedback geven op een bepaalde D-1 voorstellen. Maar ik heb ergens nog een gesprek met Jeroen over de vervolgstappen en ook over fase 2 van de trial. Want ik denk dat we veel meer in lijn moeten met de network manager en waar ik net ook zei, ik nu via de email als ik morgen een dienst heb. Dan kom ik dus op zaal met een D-1 plan die gisteren gemaakt is voor vandaag.

Flore 00:06:30

Vandaag weten ze het eigenlijk al beter.

Ger 00:06:32

Ik kan er niks meer mee doen weet je, ik kan alleen maar beoordelen.

Flore 00:06:34

Je zou eigenlijk de dag van tevoren als je dan werkt dan inderdaad dat plan moeten krijgen.

Ger 00:06:40

Ja, en als je dan de volgende dag dienst hebt, zou nog mooier zijn. Dat je eigenlijk werkt aan je eigen D-1 plan. Dat zou ik nog beter vinden.

Flore 00:06:48

Hoe vind je die plannen die tot nu toe hebt gekregen? Hoe vond je daar de kwaliteit van? Zou je dat kunnen gebruiken want je tot nu toe hebt gekregen?

Ger 00:06:59

Ja ik vind die grafiekjes, ik kan het heel slecht lezen, voorname kleine lettertjes, maar dat kan ook de leeftijd zijn. Ja ik zou d'r wat specifiekere van maken, wat vergroten. Maar ja dat is cosmetisch en inhoud begrijp ik wel dat ze zeggen van: en dan en dan denken wij dat daar dan een hoge piek is. Oké prima. En dat geeft je dan wel de trekken om te gaan kijken van is het inderdaad zo op de dag van de uitvoering, kijkend naar de volgende dag. Want het verandert ook.

Flore 00:07:39

Dat tabelletje dat zijn eigenlijk mijn bevindingen. En wat ik daarin heb onderzocht is vooral, of in het algemeen gezegd, komt er vaak op neer dat er meer vliegtuigen worden voorspeld dan er komen. En dat is een beetje vertaald in hoeveel vliegtuigen per uur dat dan zouden zijn? Of 1 vliegtuig per hoeveel uur dan meer of minder is voorspeld.

Ger 00:08:03

Ja is dat dan zo? Dus in de PREDICT geeft die meer aan dan dat in werkelijkheid komt? Bedoel je dat te zeggen?

Flore 00:08:08

Ja en dat is meestal het geval, bij sector 2 en departure is dat allebei niet. Maar bij de andere sectoren is dat wel het geval. En de standaard deviatie die geeft dan nog aan als gemiddeld genomen ongeveer 18 of 19 vliegtuigen per uur komen, dan kan dat dus nog plus 4 of min 4 zijn.

Ger 00:08:27

Dat is best veel.

Flore 00:08:29

En de vraag is dus nu als je deze data als je die zou gaan gebruiken, wat is het gevolg hiervan voor de operatie mocht je dit gaan gebruiken? En is 't ook bruikbaar genoeg?

Ger 00:08:45

Kijk als je zegt dit zo rond de 20 in uur en dat is een plus of min 4, dat vind ik wel een grote deviatie. Dat is meer dan 10 procent wat we gewend zijn. Dat vind ik veel.

Flore 00:09:01

Dit is hoe het nu is en mijn onderzoek is natuurlijk ook een beetje om een aanbeveling te geven van ja dit zou beter moeten kunnen. Maar zoals het nu is zou het dan ook al wel bruikbaar zijn? Om in ieder geval een indicatie te hebben hoe het de volgende dag gaat zijn.

Ger 00:09:17

Maar dit is PREDICT data die jij van de network manager vergelijkt toch?

Flore 00:09:21

Ja.

Ger 00:09:21

Ben je wel eens bij de bron geweest?

Flore 00:09:23

Nee dat ga ik ook nog doen in. Want ik wil ook nog weten hoe precies zij die data opbouwen inderdaad.

Ger 00:09:31

En waarom ze dan tot zo'n data komen, ze zijn ook wel eens in staat om gewoon vluchten te klonen in een PREDICT sample. Het is gewoon eigenlijk een sample die ze creëren, fictieve omgeving. En dan gaan ze daar al die regulatie in stoppen op een gegeven moment en dat is dan het plan. D'r zit wel een bepaalde filosofie achter en waarom dat dan voor ons zo afwijkt. Ik vind dit wel veel. Ten opzichte van 18,7 per uur. Is meer dan 20 procent.

Flore 00:10:01

Dus jij zou zeggen, eigenlijk hoe het nu is, is het nog niet bruikbaar genoeg voor om daar echt op te kunnen reguleren.

Ger 00:10:09

Ja misschien zou je vanuit je eigen kracht op moeten gaan hè. Wat is het aanbod geweest en wat hebben we gerealiseerd? Dus niet naar PREDICT kijken maar tactical. Wat is het aanbod geweest, 2 uur van tevoren, dat kun je gewoon uit de systemen halen. En wat hebben we op dat moment gerealiseerd. En daar kun je ook een vergelijking maken en daar zou je ook misschien zelfs je eigen PREDICT op kunnen ontwikkelen zeg maar. In plaats van alleen maar van de network manager uitgaan. Ja ik zou denk ik toch eerst bij de bron gaan kijken want er zit natuurlijk een bepaalde filosofie achter, ik heb het wel eens gezien. Zij bouwen dat op een bepaalde manier ook getweekt voor hun eigen werkwijze, zijn manieren om te managen. Maar zoals dit vind ik dat te veel.

Flore 00:11:00

Jij geeft eigenlijk aan van hoe het nu door de network manager gedaan wordt is eigenlijk niet de manier zoals jij het zou willen, maar misschien eerder vanuit LVNL.

Ger 00:11:07

Nou ja kijk ik vind die deviatie die je hier aangeeft vind ik te ruim.

Flore 00:11:10

Ja.

Ger 00:11:11

Want wij zitten bijvoorbeeld met bunch definities voor bepaalde zoals ARTIP, dan kijken we naar 15 per 20 meer dan 15 of meer dan 8 per 10. Dus als ik 9 heb, heb ik in theorie al een bunch. Dan zit ik op 1 afwijking te kijken in 10 minuten en hier zit je met 4 op een uur. Dat vind ik nogal wat.

Flore 00:11:38

Ik heb de verschillende sectoren die ook in het D-1 plan staan onderzocht. Welke zijn het belangrijkste als het een goed voorspeld worden voor jou?

Ger 00:11:49

Stacks.

Flore 00:11:50

Ja dat zijn echt de belangrijkste sectoren?

Ger 00:11:53

Ja dat zijn de belangrijkste, die maken samen FIRAM. We kijken natuurlijk primair naar FIRAM. Als dat een overload geeft, kijk natuurlijk naar waar ligt dan de pijn, welke stack heeft dat? Welk wachtgebied kunnen we het af met alleen bijvoorbeeld een stack te reguleren, zodat we niet alles hoeven te doen, doen we ook, of we proberen zelfs de vluchten om te zetten naar een andere stack, zodat de verdeling beter is, en dat er dan wel misschien een hogere capaciteit accepteren of een hoger aanbod. Maar dat we zien dat het goed verdeeld is over 2 banen. Er zijn allerlei manieren, maar die 3 je hebt ARTIP, SUGOL en RIVER en FIRAM is voor ons ook cruciaal. Dus eigenlijk monitor je alleen de inbounds vaak, natuurlijk kijken we ook naar de combinatie van sector oost en zuid, met name zuid, want dat is een hele lastige sector. We hebben nu ook sinds kort de mogelijkheid om daar te splitsen met een inbound controller en een ....., wat we met sector 2 ook al kunnen doen. Dan kunnen we met 5 man kun je d'r zitten. En dat is natuurlijk wel ideaal,

dan kun je veel meer verkeer af. Dus we kijken ook tuurlijk naar die 2 (sectoren) maar ja de focus ligt toch wel op de inbounds vaak.

Flore 00:13:00

Je gaf aan van dit vind je teveel, de standaard deviatie, welke afwijking of hoeveel zou jij wel acceptabel vinden?

Ger 00:13:12

10 procent, van een traffic volume.

Flore 00:13:15

En dat dan totaal, dus eigenlijk 5 procent omhoog of 5% omlaag.

Ger 00:13:18

Nou ja kijk, 't is nu via EUROCONTROL, zoals je zo'n FIRAM monitort, die hebben wij op 65 staan, onze monitoring value. Maar je moet niet gek opkijken als dat je daar plus 10 procent erbij krijgt, ondanks het feit dat je reguleert, dus je krijgt altijd 6 meer waarschijnlijk. En het heeft met de collectiviteit van het netwerk te maken, dus de variabele die een vlucht die in plaats van z'n route vliegt, een direct krijgt, die hoog gaat vliegen en dus sneller, dan is ie eerder hier. 't CTOT window van min 5 plus 10 rondom je vertrektijd, dat dus een kwartier. Als die heel laat in zijn CTOT window vertrekt dan komt die ook veel later, misschien wel net in een ander staafje terecht, qua aanbod. Dus er zijn heel veel variabelen waarbij een verwachte uur capaciteit, die je afgeeft zeg maar, gewoon een plus of min 5/6 meer kan worden. Omdat ie net aan het einde van de regulatie of begin van de regulatie d'r net bij komt in het uur snap je? Daar kun je niet zoveel aan doen, dus je moet wel altijd een marge rekening mee. En wat wij ook gedaan hebben is 65, daarop reguleer je in de ochtend, maar we hebben eigenlijk een landingscapaciteit van 68. Maar we doen bewust 65 omdat je natuurlijk ook met wide bodies zit, grote kisten, moet je meer separeren. Om dan toch naar die 68 te komen, dan doen we nu 65. En 's avonds doen we 68 omdat je daar veel meer mediums tussen hebt zitten. Die kan je makkelijker af, dan kun je korter separeren.

Flore 00:14:44

Als je dan die Predictie en dat D-1 plan zou krijgen, wil je dan ook dat er liever te veel dan te weinig is voorspeld? Ik heb hier ook de grafiekjes is van hoe het op dit moment is. De rode lijn is de actual, en de blauwe is de voorspelling. Dus want vaak erop neerkomt is dat in de pieken d'r wel meer wordt voorspeld dat er uiteindelijk is gekomen. Denk je ook van nou ja beter te veel dan te weinig voorspeld?

Ger 00:15:15

En dit is nadat het is afgehandeld? De rode, is dat na realisatie?

Flore 00:15:21

Die rode is uiteindelijk de laatste ingediende vliegplannen, dus daar heeft officieel nog geen luchtverkeersleiding aan gezeten.

Ger 00:15:26

Oke, want als je de luchtverkeersleiding sausje hebt, dan vlak je zo'n piek zomaar af.

Flore 00:15:32

Dus dit is nog zonder regulaties is eigenlijk.

Ger 00:15:35

Oké.

Flore 00:15:37

Maar er is ook gekeken naar het aanbod en dit is dan per uur en rollend per 20 minuten ook zoals jullie de figuren normaal krijgen. Heb je ook zoiets van het is beter dat in zo'n piek misschien iets meer wordt voorspeld dat er uiteindelijk komt?

Ger 00:15:54

Ja je kan beter maar wat defensiever zitten dan dat je teveel laat komen, dat je het eigenlijk niet kan hebben toch.

Flore 00:16:01

Dat lijkt mij inderdaad ook.

Ger 00:16:03

Dat is wel logisch.

Flore 00:16:08

Dan heb ik verder nog een beetje de vraag van hoe gebeurt het nu precies? En dan vooral qua inschatting van het aanbod, jij gaf al aan dat je inderdaad 65 of 68 afgeeft. Maar waar wordt dat dan op gebaseerd?

Ger 00:16:24

Die 65?

Flore 00:16:26

Ja, of mocht het weer slecht zijn, waar baseer je op dat je dat afgeeft?

Ger 00:16:34

Beton capaciteiten, dus hoeveel vluchten je per uur werkelijk in een nominale situatie zou kunnen laten landen op een baan tijdens een uur maximaal. Rekeninghouden met voldoende separatie, geluid, dat soort dingen allemaal. En dan komen ze volgens mij op 34 per uur na 2 banen is 68. En 's morgens hebben ze 65 gedaan in verband met die verkeersmix.

Flore 00:16:59

En dan wordt dus van tevoren gekeken van wat is het aanbod en moet je reguleren?

Ger 00:17:04

Ja kijk, die 65 komt dus uit een soort van, ja daar is over nagedacht, dat is een monitoring value, dus je kijkt eigenlijk wat je hier ook doet, je legt daar eigenlijk zo'n lijntje overheen, daarmee identificeer je ook meteen waar de pieken zijn, toch. Waar je te veel eigenlijk zou hebben. Dan ga je kijken naar wat is dan de samenstelling en dan bepaal je of je zegt van ik ga reguleren of je kijkt naar die samenstelling in de verdeling over de stack en de verdeling over de banen, nou ja maar het is misschien wel meer dan 65 maar in deze weersomstandigheden, deze baancombinatie, gaan we het gewoon redden. Gaan we niet reguleren, dat zijn elke keer de afwegingen die je doet. Dat doe je samen met SUPs, zowel toren als ACC.

Flore 00:17:48

Want waar zit jij vooral, jij zit bij ACC?

Ger 00:17:50

Ja, FMP zit naast de ACC SUP op zaal. We zitten achter dezelfde desk op zaal. Als je de Supervisor ACC hebt, daarnaast zit een FMPer.

Flore 00:18:07

Mocht dit hele plan in een verdere fase zitten denk jij dat de luchtverkeersleiders gewoon de normale luchtverkeersleiders en de andere supervisors en FMPCs, of die d'r open voor staan om uiteindelijk die Predictie te gaan gebruiken, dat D-1 plan?

Ger 00:18:27

Ja. Dat denk ik wel. Er gaat wel tijd overheen. Het is natuurlijk een andere manier van managen, dat wordt steeds belangrijker. Dus ja dat denk ik wel.

Flore 00:18:39

Dus je denkt dat ze ook nog wel even tijd voor gewenning nodig hebben?

Ger 00:18:42

Dat denk ik wel, en ook training. Mensen moeten natuurlijk bewustzijn van waarom we dit op deze manier doen, waar dit vandaan komt. Het gaat natuurlijk met name om stabiliteit van het totale netwerk en niet alleen van Schiphol. Dat is nogal anders denken. Het is nu heel erg intern gericht maar we moeten natuurlijk ook extern gaan kijken. Daar is dit ook met name voor bedoeld.

Flore 00:19:09

Ja, dat uiteindelijk jij met deze Predictie meer transparanter kan zijn qua capaciteit uitgeven richting de airlines.

Ger 00:19:15

Ja precies, het is stabiel voor je klant, ze zijn natuurlijk niet altijd blij mee als je gereguleerd, want dat zijn hun delay minuten maar goed, dat is nou eenmaal het spel. Maar goed, als jij als hele grote luchthaven, als bijdrage aan het netwerk, op het laatste moment in ene gaat snijden, wat denk je wal wat dat voor een effect heeft verder in Europa, dat is enorm. Iedereen zit natuurlijk naar diezelfde staafjes te kijken en hij heeft daar z'n eigen ATM systeem op ingericht en als jij dan naar Schiphol zegt van nou doen we effe anders, ja dan heeft dat heel veel effecten, ze hebben daar mensen op ingeroosterd, ze hebben sectoren gesplitst en noem maar op. En dat moet dan in een helemaal anders. Ja dat kan niet, dat moet ook echt veranderen.

Flore 00:19:55

Je staat inderdaad dan ook wel open voor die veranderingen die moeten komen?

Ger 00:20:00

Ja, ik zeker. Ja die veranderingen moeten zeker komen, maar die gaan er ook wel komen, heeft alleen tijd nodig. Je moet het gefaseerd gaan brengen, zodat je de hele goegemeente meekrijgt want met zo'n big bang dat gaat niet werken.

Flore 00:20:12

Nee. Zeker niet.

Ger 00:20:14

En daar heeft PREDICT natuurlijk ook bijdrage aan, kan je ervoor kiezen om te zeggen van nou, doen we een PREDICT van de netwerk manager of gaan we onze eigen PREDICT ontwerpen, dat doet MUAC ook volgens mij. Volgens mij de Zwitsers ook, maar dat weet ik niet zeker. Bij Maastricht Upper Area Control Centre die, volgens mij hebben zij hun eigen Predictie systeem. Zou je ook na kunnen vragen. Dus die zijn niet afhankelijk van de data van de netwerk manager, die gebruiken ze wel, maar op een andere manier. Maar ook zijn eigen sausje overheen. Is ook een idee. Ga je van je eigen krachten uit, in plaats van afhankelijk.

Flore 00:20:53

Ja dat was nu ook een beetje het doel van mij, van hetgeen wat er dus nu gebruikt wordt, data van de netwerk manager, hoe goed is dat nou en is dat bruikbaar? D'r zijn denk ik zeker wel dingen dat ik de conclusie geef van wel of niet bruikbaar. Maar ik zal het niet zo zwartwit geven, maar natuurlijk aanbevelingen geven. Dan kan er inderdaad ook zeker in een vervolgonderzoek gekeken worden van zijn er niet andere opties die misschien beter zijn.

Ger 00:21:16

Ja precies, je hebt een eigen operatie en je gaat ook niet alleen D-1 maar post-ops is natuurlijk ook heel belangrijk, maar daar gaat ook op gezet worden. En vanuit die post-ops op krijg je natuurlijk een leercurve. Dat kun je natuurlijk gebruiken om te zeggen van nou ja dan ga ik wel onze eigen PREDICT ontwikkelen, ik denk dat dat veel beter is. Je moet niet afhankelijk zijn, denk ik.

Flore 00:21:40

Ja dat waren eigenlijk alle vragen die ik had, heb jij nog vragen voor mij?

Ger 00:21:45

Nee. Je gaat dit presenteren aan CMA? Daar doe je dat toch voor of niet?

Flore 00:21:50

Ja, ik heb met Leo en Jeroen contact, die sturen mij ook een beetje in mijn onderzoek van hoe en wat, of ik nog steeds op de goede weg. Inderdaad mijn resultaten heb ik ook laten zien.

## Interview vision of expert: FMPC 2

Interviewee: Steven Geurten, FMP.

Interviewer: Flore Wassenberg

Interview date: 25-04-2019

Transcribed on: 30-04-2019

Verified by Steven Geurten on: 09-05-2019

Flore 00:00:10

Wat precies jouw functie want je bent een Flow Management Position Controller, maar wat doe je dan vooral?

Steven 00:00:10

Ja ik monitor het aanbod en capaciteit voor het Nederlandse civiele luchtruim, en voor de Nederlandse luchthavens met civiel gebruik waar verkeersleiding plaatsvindt dus dat betekent Schiphol, Rotterdam, Eelde, Beek en ook Eindhoven.

Flore 00:00:23

Vergeleken met een supervisor, wat is dan meer jouw taak?

Steven 00:00:27

De supervisor is eindverantwoordelijk, maar van de twee ben ik degene die eigenlijk de meeste kennis heeft van het systeem en het is aan mij eigenlijk om overloads te constateren en eventueel advies af te geven bij de supervisor.

Flore 00:00:46

Je hebt al meegekregen van het D-1 project, zou jij je dag kunnen beschrijven als jij dan zo'n D-1 predictie krijgt? Wat voor invloed dat heeft op je werkzaamheden of op een operatie.

Steven 00:01:01

Ja het is natuurlijk zo dat we nog echt in een trial phase zitten dus er op dit moment nog niks mee doen. Maar theoretisch kunnen we op basis daarvan al meteen een plan trekken voor wat gaan we de volgende ochtend doen. Kunnen we op een standaard capaciteit gaan zitten qua regulaties. Blijkt uit de cijfers dat er misschien helemaal geen regulatie nodig is. Of is de kans groot dat we verder moeten gaan knijpen vanwege het weer of werkzaamheden bijvoorbeeld.

Flore 00:01:26

Wat heeft dit voor invloed op de dag van de operatie. Mocht je dus al zo'n predictie een dag van tevoren krijgen.

Steven 00:01:34

Voor ons wat het verschil maakt, ik denk dat het voor meer rust gaat zorgen. Op het moment dat we pas heel laat een beste restrictieve restrictie instellen. Dan heeft dat voornamelijk veel effect op het verkeer, maar het heeft ook veel effect op ons omdat wij op een gegeven moment zitten we van ja we moeten nu echt de knoop gaan doorhakken, we moeten nu echt wat doen. En als je dat van tevoren al hebt ingesteld en dan alleen nog maar hoeft fine te tunen dan zorgt dat voor veel meer rust.

Flore 00:01:58

Dus is eigenlijk als je dan op de dag van de operatie zelf werkt en dat is al gedaan en dag van tevoren voor jou dan heb je het wel wat rustiger?

Steven 00:02:06

Ja.

Flore 00:02:06

Wat is er dan anders dan normaal? Hoe gaat het dan precies normaal qua drukte en werkzaamheden? Mocht je dus die predictie niet gebruiken.

Steven 00:02:18

Het probleem wat we ook deels hebben is dat, wij hebben een gecombineerde taak, wij zijn FMP'er en we zijn ook FISO: Flight Information Service Officer, voor het VFR het verkeer. En 's nachts zijn wij officieel alleen fiso en is er geen FMP. De nacht supervisor die begint om 11 uur en die gaat rond een uurtje of 12/1 naar bed wordt uiteindelijk om half 5 pas wakker. Als er 's nachts geen verkeer is doen wij wel FMP-werkzaamheden erbij. Maar stel nou dat we heel druk moeten zijn op FMP omdat daar dingen aan de hand zijn of dat daar beslissingen worden gemaakt, maar we hebben op dat moment verkeer op de frequentie we kunnen we niet van onze positie af. Dus op het moment dat het en eigenlijk druk is op FMP en het verkeer en dan zit je in de knoop want je kan dus niks.

Flore 00:03:08

Dat zou dan beter worden als je eigenlijk van tevoren al iets beter weet.

Steven 00:03:13

Ja, want dan staat het er al. Dan hoeft alleen de supervisor nog te kijken. Ik stel dat er wordt verwacht 20 procent capaciteit beperking door weer en dat blijkt uiteindelijk 30 of 10 te worden is dat een kleine aanpassing.

Flore 00:03:25

Maar het feit dat je al weet dat je moet aanpassen is dan al mooi meegenomen?

Steven 00:03:28

Ja. Is ook iets om rekening mee te houden en ruim van tevoren.

Flore 00:03:30

Wat is voor jou belangrijk dat in zo'n D-1 predictie zit?

Steven 00:03:37

De verwachting/de kans voor grote verstoringen, dus dat zit dan samen met weer. Verwachte baan combinaties die daarin te vliegen zijn, want die baan combinaties bepalen ook de capaciteit. Werkzaamheden met capaciteiten beperkingen.

Flore 00:03:57

En als je dan zal kijken naar een aanbod, als je dus een voorspelling doet met hoeveel het aanbod zou worden dat dat al gereduceerd naar de verwachte weersomstandigheden, dus als je weet, het weer is slecht dus we zeggen dat het aanbod is gewoon nu al zoveel wordt naar verwachting, dat zou dan een voordeel zijn?

Steven 00:04:16

Ja.

Flore 00:04:16

Wat is jouw input al geweest binnen het D-1 project?

Steven 00:04:23

Ik krijg de conceptjes die worden opgemaakt te zien, hetzij op D-1, D0 of D+1. Ik kan die reviews welke informatie van nut was. En aan de hand daarvan kan ik feedback geven over welke informatie miste ik nou uiteindelijk.

Flore 00:04:42

Bleek dit al goed te zijn of wat vind jij de tot nu toe van?

Steven 00:04:47

Ik vind hem goed en hij verbetert ook steeds meer, waarbij het begon met de kans op slecht zicht en een beetje vaag nog allemaal en het nu al is naar de joh er is 20 procent kans op deze beperking en er is zoveel procent kans op deze beperking. Dat is alweer een hele verbetering. Ik weet ook dat werkzaamheden een andere impact, speciale vluchten, die er ook apart in worden vermeld. En wordt het nog mooier zou maken is, stel dat we speciale vluchten hebben zoals met afgelopen Pasen een parajumper, dat je die je meeneemt in de D-1 en die in het workloadmodel al weet te implementeren.

Flore 00:05:28

Er zitten ook grafieken bij in dat D-1 plan, dat die grafieken daarop al ingespeeld zijn.

Steven 00:05:36

Ja.

Flore 00:05:42

Wat er tot nu toe is, wat ik heb gezien in de data-analyse is dat er vaak op neer komt dat er net iets meer vliegtuigen voorspelt zijn dan dat er ook echt komen. Dat heb ik hier een beetje verteld in hoeveel 1 vliegtuig per hoeveel uur er extra of minder zouden komen. En dan heb ik hier de standaard deviatie. Dat houdt gemiddeld genomen in als er dus nou ja ongeveer 19 vliegtuigen zijn. Dat is het dan min 4 of plus 4 zou kunnen zijn. Als je dit zo zou zien en ik heb hier ook nog iets duidelijker die pieken weergegeven. Wat je ziet in een ochtend piek is dat er meer voorspelt is dan er ist gekomen. Rood is actual en blauw is dan de voorspelling. Dat heb ik van alle sectoren een beetje gedaan. Als je dit zo zou zien, wat zou dan gevolg voor jou zijn als je dit zou gebruiken? En dan qua met deze accuratie, hoe goed het nu is, is dit bruikbaar genoeg voor jou?

Steven 00:06:51

Ik denk dat het sowieso beter is dat ie hoger aangeeft dan wat je verwacht want andersom bestaat misschien de kans dat je niet reguleert en op de dag zelf in een keer ziet, oh er moet toch wel gereguleerd worden. Andersom is het denk ik wenselijker. We hebben een hele mooie simulatietool, dus daarin zou je die regulatie eraf kunnen halen om kijken wat het effect is, ik denk dat regulatie afhalen prettiger is dan regulatie opzetten.

Flore 00:07:19

Als je dit zou gebruiken voor jouw werkzaamheden geeft dat dan jou inderdaad meer rust en met deze accuratie?

Steven 00:07:33

Ik denk het gevaar wat je hierin krijgt is dat je denkt oh het wordt toch altijd minder dan wat er wordt voorspeld en dan blijkt er toch een keertje meer te zijn. Dus dat je gevaarlijke aannames maakt. Maar het is wel mooi te zien dat de trend in ieder geval, dat het wel redelijk overeenkomt.

Flore 00:07:55

Qua bezetting zou je dit dan ook kunnen gebruiken?

Steven 00:07:58

Voor de verkeersleiders bezetting?

Flore 00:07:59

Ja.

Steven 00:08:00

Ja dat is iets waar vooral de supervisors zich mee bezig houden. Daar houden wij ons niet zo heel veel mee bezig. Ik zeg alleen: ik zie dat het hier drukker wordt, heb je daar nog iemand extra voor en dan zoekt hij of zij wel uit wie dat dan zou moeten zijn.

Flore 00:08:16

Kan jij ook iets zeggen over welke sectoren het belangrijkste zijn dat ze goed voorspeld worden of waar jullie voornamelijk naar kijken?

Steven 00:08:22

Ja, ik denk dat dat op dit moment is dat vooral sector 3, omdat dat een hele complexe sector is. En daar eerder de complexiteit is die de drukte veroorzaakt dan gewoon de hoeveelheid verkeer. Voor sector 2 tot op zekere hoogte ook, die kunnen wij uitsplitsen, ook dat is een behoorlijk drukker sector en vooral in de toekomst wanneer Lelystad echt van de grond komt, krijg je daar nog meer stromen in dus dan wordt sector 2 nog belangrijker, sector 3 idem, want dat is weer een extra stroom. Ik denk dat sector 2 en 3 echte onze belangrijkste sectoren zijn.

Flore 00:08:57

Hoeveel afwijking vind jij acceptabel? Je gaf aan je hebt liever te veel, maar hoeveel teveel zou nog bruikbaar zijn? Je gaf een voorbeeld als ze 10 procent meer of minder is dan is dat fijn meegenomen dat je het al weet maar wat zou jij ja zeggen dat je acceptabel zouden vinden?

Steven 00:09:16

10 procent is misschien al best veel. Als je als je afgaat van een FIRAM, waar we 's ochtends een capaciteit hebben we 65. Dan zou dus een 10 procent marge erop. 10 procent beide kanten op of wordt dat dan 5 procent beide kant op?

Flore 00:09:33

Ja dat is aan jou, wat zou jij het fijnste vinden?

Steven 00:09:36

10 procent meer of minder is dan een te groot verschil, want dan spreek je over 6 à 7 kisten is de meer of minder, dus een variabele van 12 per uur. Dat is best wel significant verschil. En als we daar de helft van nemen, 3 kisten meer of minder, dus een variabele van 6 per uur, dat is al een stuk acceptabeler.

Flore 00:09:49

Ja want wat nu het geval is bij de FIRAM is op 25 vliegtuigen in een uur is dus ongeveer 5 meer of minder.

Steven 00:10:04

Ja dat zit er dan weer net tussenin. Dat is lastig.

Flore 00:10:08

Ik snap dat je nu ook niet precies één waarde kan zeggen.

Steven 00:10:11

Hoe hoger je accuracy hoe beter.

Flore 00:10:18

Het is ook een beetje voor mij, ik moet straks een aanbeveling geven van wat kan er nog verbeterd worden en op welke punten moeten ze vooral verbeterd worden. Ik laat nu zien kijk dit is het nu en mijn idee is door met jullie te praten ik een beetje een aanbeveling kan geven van hoe, welke kant moet nog beter en wat zou zo'n aanbeveling kunnen zijn om het te verbeteren. Bij sector 2 en de departures is nu het geval dat gemiddeld genomen juist minder verkeer is dan voorspeld. Ik zou dan natuurlijk kunnen aangeven van: liever meer dus zet daar meer marge in.

Steven 00:11:01

Ik zie bijvoorbeeld al sector 3, daar is dus de standard deviation iets meer dan 4 kisten per uur. Ja ik zou het wel mooi vinden als die naar maximaal 2 gaat. Het verschilt dan ook om welke kist het gaat. Het regio verkeer heeft dan echt en significantere hogere workload dan het mainport verkeer.

Flore 00:11:26

Het maakt denk ik ook nog uit op welk moment de predictie goed is? In de ochtend piek kun je misschien minder goed hebben verkeerd dat er verkeerd voorspeld is dan juist daarbuiten?

Steven 00:11:36

Ja afhankelijk van personeel is inderdaad handig om te weten hoe je in hoeverre kan ik die sector opsplitsen? We kunnen hem in 3 executive controllers opsplitsen. Inbound, executive en de stack controller. Maar dan moet je wel die mensen hebben.

Flore 00:11:54

Maar mocht je dus in die ochtend piek te veel hebben en dan hier in de niet piek wordt er juist eigenlijk te weinig voorspelt. Vind jij dat dan erg dat hier dan minder wordt voorspeld in zo'n niet piek omdat je dan toch niet aan je max zit?

Steven 00:12:14

Nou ja waar het toe kan leiden is dat we, we zitten gewoon op een heel strak schema als het gaat om 2 landingsbanen 1 landingsbaan en dat wisselt zich natuurlijk continu af. Op het moment dat je dit gaat reguleren, deze inbound piek hier, schuift dat allemaal door. Als je hier weer te weinig in zit en dit schuift door en je ziet: oh het past, dan laat ik hier maar regulatie eindigen. Terwijl het eigenlijk misschien juist de bedoeling is dat je hem helemaal door gaat reguleren omdat er wel te veel komt. Dus daar zit wel een gevaar met marges.

Flore 00:12:43

Dit heb ik nu ook weergegeven per uur en dan ook rollend per 20 minutes zoals jullie d'r ook naar kijken dus het is inderdaad wel als je hier zo'n enorme piek ziet, kan dat wel zijn dat, het lijkt nu een hoge piek, maar dat het eigenlijk maar om 1 vliegtuig gaat die dan 3 keer weergegeven wordt. Verder heb ik nog een beetje wat vragen iets minder gerelateerd op mijn onderzoek maar wat misschien wel van belang kan zijn als aanbeveling voor de luchtverkeersleiding. Hoe doen jullie 't nu qua inschatting van het aanbod? Hoe gaat nu als je dus niet de predictie hebt, hoe schatten jullie nu in hoeveel aanbod je gaat krijgen?

Steven 00:13:29

Dat doen we aan de hand van de EFD, de flight data. Daarin kijken we zowel naar rollende uren, aanbod per 20 minuten en verwachte workload in WLM. Dat is dus op basis van vliegplan en de up-to-date positie zoals ze vliegen. En dan kijken we eigenlijk zo'n 2 en een half tot 3 uur van tevoren, gaan we dan bepalen, moeten we reguleren of niet. Dan zijn dan zijn alle vliegplannen gefiled en zijn al een paar kisten actief en dan kun je redelijk accuraat zeggen dit is hoe het gaat worden.

Flore 00:13:55

Hoe ver kijk je uiteindelijk echt vooruit van moet je reguleren en als jij je dienst hebt, tot hoe ver ga je vooruitkijken om te bepalen of je moet reguleren of niet?

Steven 00:14:05

Ik kijk vaak zo'n 3 tot 4 uur vooruit en dan in die periode tweeënehalf tot 3 uur vooruit dan moet je gaan bepalen ga ik daar reguleren of niet, en echt uiterlijk 2 uur van tevoren, want dan dan vliegt er vaak al heel veel. Dat is toch echt wel een beetje het uiterste punt waarop je nog iets kan doen. Soms heb je een overaanbod en kun je zeggen daarna hebben we weer een onder aanbod, dus dat vangt elkaar op, dat kunnen we dan op de sector wel opvangen. Soms moet je inderdaad de beslissing maken ik ga daar toch reguleren. Maar goed als weer een rol speelt en je weet van tevoren wat voor capaciteits beperkingen het gaat opleveren dan is het heel simpel, dan weet je er komt sowieso te veel, dus dan moet er wel een regulatie komen.

Flore 00:14:50

Wat voor capaciteit of aanbod wordt er naar buiten gebracht? Dus wat vertellen jullie de KLM in dit geval, van wat de capaciteit gaat zijn, zit daar ook een buffer in vergeleken met wat jullie aan kunnen?

Steven 00:15:03

D'r zit inderdaad een buffer in. Reden daarvoor is dat ongereguleerde vluchten hebben eigenlijk een departure window van min 15 plus 15. Op het moment dat je dat je een slot krijgt dan vernauwt het wat naar min 5 plus 10 op die slottijd, maar goed je zit er wel met min 5 en plus 10. Dus op het moment dat er een paar vluchten zijn die 5 minuten eerder aankomen maar er zijn er een paar die 10 minuten later aankomen, dan heb je er in een keer te veel. En dat zie je structureel terug. D'r wordt ongeveer geschat dat zo'n 10 procent van wat je afgeeft dat krijg je er nog eens bij. Op het moment dat we 65 afgeven, kun je eigenlijk verwachten dat de 71 komen en dat komt ook redelijk uit.

Flore 00:15:43

Dus jullie doen eigenlijk altijd gewoon net iets minder afgeven omdat je toch eigenlijk ervan uitgaat dat er meer komt.

Steven 00:15:50

Ja, d'r komt ook nog bij dat hoe meer heavies ertussen zitten, dus echt hele zware vliegtuigen, hoe meer separatie je nodig hebt op final. En dat knijpt ook in je capaciteit. Zo zien we bijvoorbeeld 's ochtends zit er veel meer heavy verkeer in, dus dan zit onze inbound capaciteit standaard op 65, en 's avonds zien we veel minder heavies en zitten we op 68.

Flore 00:16:11

Je hebt nu al die D-1 predictie meegenomen. Hoe denk jij dat andere luchtverkeersleiders of andere mensen die nog niet betrokken zijn met het project, dus ook andere FMPC, zullen zij er open voor staan? Om uiteindelijk die D-1 predictie te gaan gebruiken?

Steven 00:16:36

Ja. Ja dat denk ik wel. We hebben vooral de afgelopen periode gehad dat 18/36 Centre, dat daar onderhoudt op was. En dat beperkt ons samen met de wind heel erg in de mogelijkheden die we hadden en het beperkte ons dusdanig dat we zelfs in de inbound piek maar 1 landingsbaan hadden en dat heeft een gigantische impact op het verkeer. En dat er eigenlijk de wens vanuit de operatie zelf al kwam: ja eigenlijk we weten al dat dit het weer wordt, we weten al dat we niet twee volwaardige banen kunnen gebruiken dus laten we maar vast reguleren. Het staat heel lullig als je als vlucht in een keer vanuit het niets om half 5 's ochtends in 1 keer 200 minuten delay krijgt, omdat er pas op het laatste moment wordt gereguleerd. Dus dat draagvlak is er wel zeker en ook het D-1 proces, de verhalen doen zich wel gewoon de ronde op de operationele zaal, dus men weet dat men er mee bezig is. Dus er komt ook steeds meer terrein.

Flore 00:17:31

Dan staan ze er ook voor open om het uiteindelijk echt gaan gebruiken?

Steven 00:17:36

Ja. Dat denk ik wel.

Flore 00:17:38

Er wat voor voordelen zou dat dan geven voor de luchtverkeersleiders zelf, want jullie doen eigenlijk dat reguleren, maar voor de luchtverkeersleiders, zullen zij daar ook wat van merken?

Steven 00:17:46

Dat weet ik niet. Dat durf ik niet te zeggen. In een normale operatie niet.

Flore 00:18:01

Dat waren alle vragen die ik had. Heb jij nog vragen voor mij?

Steven 00:18:08

Nee. Ik ben benieuwd waar je uiteindelijk mee terugkomt.

## Appendix XXII. Ranking airspace segments

Airspace segment	Average difference	Standard deviation	% standard deviation of total	MFE	Percentage (R-square)	Decision to hypothesis of Wilcoxon test	Total
EHSECT2	2	2	3	2	1	3	13
EHSECT3	2	2	3	2	1	3	13
EHARTIP	1	1	3	1	2	1	9
EHSUGOL	1	1	3	1	2	1	9
EHRIVER	1	1	3	1	3	1	10
EHFIRAM	3	3	2	3	1	1	13
EHAM Arrival South	2	3	2	2	1	1	11
EHAM Arrival North	2	3	2	2	1	1	11
EHAM Departure South	3	3	3	3	1	3	16
EHAM Departure North	3	3	2	3	1	3	15
EHFIRAM all peak hours	3	3	1	3	2	3	15
EHFIRAM 1th peak hour	3	3	1	3	3	3	16
EHFIRAM 5th peak hour	3	3	1	3	2	3	15

Score based on:

Top	Score (points)
Top 3	1
Top 4-6	2
Top 7-12	3