

Buffers as an instrument to manage airspace capacity

A study on the use of stack holding as an alternative to ATFM delay during peak hours at Schiphol airport

Thesis



KDC Mainport Schiphol – Centre of Excellence

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Abstract

At this moment, supervisors at LVNL have insufficient insight into the effects and possibilities of using buffers in the Dutch airspace during the operational phase of flight, in order to issue less Air Traffic Flow Management (ATFM) slots. Amsterdam Schiphol has the most ATFM delays of all European Airports. Especially around and during peak hours, traffic arrives in bunches at the border of the Dutch Flight Information Region (FIR) and LVNL has to delay the traffic to deal with the unpredictability of the inbound traffic flow. ATFM delays have substantial effects for the airlines and to improve this situation, this research investigates what options LVNL has to absorb traffic within the Dutch airspace to decrease the number of ATFM delays.

The options to buffer air traffic within the Dutch airspace have been researched with the use of literature. Hereafter, the applicability of the buffer possibilities is investigated with the use of observations in the LVNL Area Control Centre, interviews with air traffic controllers and data analysis of historically used buffer capacity. As a result, within the Dutch airspace, LVNL can use linear holding (use of speed reduction without extending the flight path) and path-stretching (use of vectoring) to absorb small delays of 2 to 3 minutes. However, in individual cases, tactical path-stretching with the use of vectoring can absorb longer delays of 5 to 6 minutes depending on the complexity of the airspace sectors, according to the air traffic controllers who have been interviewed. To absorb longer delays, holding stacks are used as a path-stretching procedure with a maximum delay absorption capability depending on fuel on-board. However, both linear holding and path-stretching in the Dutch airspace are rather a type of *symptom control* and are both not the optimal solution to deal with the unpredictability of air traffic. As part of the European network, airspace borders should not be constraining the efficiency of the operation and to increase predictability, stability and efficiency for the Air Traffic Control, airlines and the airport operator; partnerships within FABEC should be used to streamline the inbound traffic outside of the Dutch airspace.

Keywords: Air traffic management, buffer capacity, airspace, delay, peak hour, airport, runway, air traffic controller, holding stacks, flow management.

Preface

The final product of my bachelor Aviation is the thesis “Buffers as an instrument to manage airspace capacity”, based on interviews with air traffic controllers at LVNL, data analysis on historical vector usage in the Dutch airspace and observations in the Area Control Centre at LVNL. It has been written to fulfil the graduation requirements of Aviation at the Amsterdam University of Applied Sciences (AUAS), for the specialisation honours programme Aviation Management. I was engaged in researching and writing this thesis from February to July 2019.

The thesis research was at the request of the Knowledge and Development Centre (KDC), which facilitated an internship. Together with my supervisor, Yoram Obbens, the research question was formulated. The research was difficult and required thorough knowledge of Air Traffic Management, the aviation sector and the different stakeholders involved. These six months have been an outstanding learning experience; I believe the amount of personal growth during this thesis is equivalent to the growth during the rest of my bachelor’s programme. For this opportunity, I would like to use this preface to thank the KDC managers: Evert Westerveld (LVNL), Coen Vlasblom (KLM) and Boudewijn Lievegoed (Amsterdam Airport Schiphol).

I would also like to thank Yoram Obbens for the guidance through these complex subjects and Alina Zelenevska for the direction given to keep this research up to track. Besides, I would like to thank the air traffic controllers and LVNL’s data analysts, without whose cooperation I would not have been able to conduct this analysis. And above all, my tutors Frenchez Pietersz, Catya Zuniga and Geert Boosten deserve a special note of thanks, for always being available during times I was lost again in the research.

At last, I am very thankful to my KDC colleagues, fellow students and friends: Without you, I would never be able to finish this thesis.

Thank you.

Kyara Metz

Amsterdam, 12 July 2019

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List of Abbreviations

AAA	Amsterdam Advanced ATC (system)
AAS	Amsterdam Airport Schiphol
ABI	Advance Boundary Information
ACC	Area Control Centre
ACC-SUP	Area Control Centre Supervisor
A-CDM	Airport Collaborative Decision Making
ACID	Aircraft ID
ACOMAN	Area Conflict Detection Manager
AMAN	Arrival Management
ANSP	Air Navigation Service Provider
APLN	Approach Planner
APP	Approach Control
APP-SUP	Approach Control Supervisor
ARTAS	ATM Surveillance Tracker and Server
ASAP	Advanced Schiphol Arrival Planner
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATFCM	Air Traffic Flow and Capacity Measurements
ATS	Air Traffic Services
AUAS	Amsterdam University of Applied Sciences
CDM	Collaborative Decision Making
CMA	Capacity Management and Analytics
CTO	Calculated Time Over
CTOT	Calculated Take off Time
D0	Day of operation
EC	Executive Controller
EOBT	Estimated Off Block Time
ETO	Estimated Time Over
ETO- stack	Expected Time Over IAF without considering other traffic
ETOT	Estimated Take off Time
FABEC	Functional Airspace Block Europe Central
FIR	Flight Information Region
FMP	Flow Management Position
FMPC	Flow Management Position Controller
KDC-CoE	Knowledge and Development Centre Mainport Schiphol Centre of Excellence
LVNL	Air Traffic Control the Netherlands
MUAC	Maastricht Upper Area Control
NM	Network Manager
NMOC	Network Manager Operations Centre
PLC	Planning Controller
SES	Single European Sky
SESAR	Single European Sky ATM Research
SIPOC	Supplier Input Process Output Customer
TMA	Terminal Control Area
UCO	Under Control
VEMMIS	Veiligheid, Efficiency & Milieu Management Information System
command.	

Summary

To be able to deal with the unpredictability of air traffic, Amsterdam Schiphol has the most Air Traffic Flow Management (ATFM) delays of all European Airports (EUROCONTROL, 2019d). This delay is generated predominantly through inbound regulations. Especially around and during peak hours, traffic arrives in bunches at the border of the Dutch Flight Information Region (FIR). The reason for putting in place inbound regulations is to manage, or prevent, overload or over demand situations. However, the decision-support information on which Area Control Centre (ACC) supervisors act is currently not accurate enough to effectively manage traffic demand. The reason behind this is that regulations must be put in place at least two hours before aircraft enter the AMS FIR.

The research objective is to investigate the options to buffer air traffic in the Dutch air space in the tactical phase (day of operation) and to analyse the applicability of these delay techniques to the current operation of LVNL. In this research, the following research question is:

Which operational possibilities does LVNL have to buffer inbound traffic and to what extent can these buffers be used in managing the operational inbound peak capacity?

Buffer capacity is defined as the potential to absorb traffic in the Dutch airspace to wait for the availability of runway capacity.

To answer the research question, a combination of qualitative and quantitative research methods has been chosen. The options to buffer air traffic within the Dutch airspace have been researched with the use of literature. Hereafter, the applicability of the buffer possibilities is investigated with the use of observations, interviews and data analysis. As a result, the first possibility is a combination of linear holding and vectoring, and can be used to absorb small delays of 2 to 3 minutes in standard situations. The second possibility is vertical holding to absorb longer delays. However, in the current layout is this tool rigid and is not efficient enough to use the maximum inbound peak hour capacity.

Delay with the use of buffers is necessary, because of the unpredictability of air traffic. The capacity of the current buffers is not enough to decrease the number of ATFM delays. To increase the capacity and the effectivity, a revision of the layout and operation is required. To use vertical holding effectively, the aircraft throughput must increase with the use of additional holding stack(s). Further research with the use of simulation is required to determine how many stacks are necessary and how the operation must be revised to feed the runways optimally.

To use linear holding effectively without increasing the complexity of the airspace, the buffer capacity can be included in the standard arrival routes. Further research on the physical characteristics of the sectors is required to determine how the routes can be extended, and a simulation model is required to determine the throughput times and capacity of the routes. Notwithstanding, the Dutch air space is relatively small to absorb traffic linearly. To absorb larger delays, the recommendation is to increase the area in which the LVNL can influence the traffic through partnerships with adjacent Air Navigation Service Providers.

However, buffers are not the solution for the root cause of this problem, decreasing the unpredictability would be. For the benefit of all stakeholders, it is recommended to include arrival management in Airport Collaborative Decision Making (A-CDM) and to investigate the inefficiencies along with all the stakeholders concerning the arrival process with a root cause analysis, starting with the departure process at the departure airport.

1 Introduction

This research investigates LVNL's inbound flow at Schiphol during peak hour operations. Specifically, to what extent buffers in the inbound flow can be used as a management tool during peak demand. Inbound peak hour capacity of Schiphol Airport is one of the most crucial factors for the current and future operational performance; Therefore, it is an essential topic for KLM, Amsterdam Airport Schiphol (AAS) and LVNL according to the department of Capacity Management and Analytics (CMA). In managing this operational peak hour capacity, LVNL's CMA requested more insight into the use of buffers in LVNL's operations to sustainably increase the peak hour capacity.

The Knowledge and Development Centre Mainport Schiphol Centre of Excellence (KDC-CoE) assigned this research as a graduation thesis assignment. The KDC Mainport Schiphol is an overarching research department introduced for the development and improvement of the Mainport Schiphol, in cooperation with the four main stakeholders: AAS, KLM, the Ministry of infrastructure and Water Management and LVNL (KDC, n.d.).

In cooperation with the Amsterdam University of Applied Sciences (AUAS) and TU Delft, KDC created the Centre of Excellence (CoE). Within the CoE, the universities are providing research in the form of graduation thesis assignments to stimulate new innovative solutions or improvements for the Mainport Schiphol. The AUAS is involved in the subject Capacity Management, to research the operation within the constraints that arise on the airport and in the surrounding airspace (KDC, n.d.).

An introduction to the research assignment paragraph 1.1 explains the background of the problem, and paragraph 1.2 provides the problem statement. The research relevance is described in paragraph 1.3, and paragraph 1.4 gives an overview of the research questions. Paragraph 1.5 states the research scope and boundaries. Additionally, paragraph 1.6 clarifies the assumptions and limitations. Finally, the thesis structure is set out in paragraph 1.7 to function as a reading guide.

1.1 Background of the problem

First, one must understand what buffers mean in this research. The International Warehouse Logistics Association (2010) defines buffers as: 'The level of merchandise/goods to be stocked as needed to accommodate regular sales orders, taking into consideration low and peak periods.' According to Watson (2013), this definition is also known as an inventory buffer: A safety stock to compensate for long or variable lead-times. Additionally, he defines a time buffer as when the demand exceeds the availability of products, and the customer must wait for availability. The time buffer definition comes close to the meaning of buffers in this research.

In Air Traffic Flow Management buffers are used to delay traffic when the traffic demand exceeds the available arrival capacity and can be divided into en-route delay and ground delay. Ground delay is also known as an Air Traffic Flow Management (ATFM) slot imposed by the Network Manager at EUROCONTROL. ATFM slots cause delays for airlines at the outstation, because they must wait before departure until the route or destination airport has enough capacity available (Cook, 2016). According to EUROCONTROL (2019), Schiphol has the highest number of airport delays issued in 2018. When an aircraft has departed and has to wait for the availability of runway or airspace capacity, en-route delays become necessary. In this research, the buffer capacity is defined as the potential to absorb traffic in the Dutch airspace to wait for the availability of runway capacity.

During peak hours, the operation can increase the number of runways to a 2+1 or 1+2 configuration (arrival runways + departure runways). Between the peak hour transitions (inbound to outbound peak or vice versa), it is allowed to make use of a fourth runway (2+2 configuration),

to prevent capacity loss (Kanis, 2017). The norm for the usage of the fourth runway is an average of 40 movements per day and a maximum of 80 movements per day (Alders, 2015). The actual peak hour capacity is determined by the Air Traffic Control (ATC) supervisor on the day of operation (D0) and depends on the weather conditions, staff availability and runway combination. The supervisor of Approach Control determines the actual runway capacity and the Area Control Centre (ACC) Supervisor determines the accompanied capacity in the airspace (FIR) and decides on using Air Traffic Flow and Capacity Measurements. If the expected airspace demand exceeds the capacity, the Area Control Centre Supervisor communicates the maximum capacity with EUROCONTROL. The Network Manager (NM) at EUROCONTROL will issue Air Traffic Flow Management (ATFM) slots to prevent unsafe operations.

However, the decision-support information on which ACC supervisors act is currently not accurate enough to effectively manage traffic demand. Because the Network Manager (NM) at EUROCONTROL mechanism works based on pre-departure delays and the regulations must be put in place at least two hours before aircraft enter the AMS FIR. Once aircraft are airborne, the NM has no means to delay them. Besides, another aspect of the current way of managing airspace capacity is that it is not suitable for maintaining sufficient traffic pressure on the Terminal Control Area (TMA) and runways according to the strategy experts at LVNL. Under-utilisation of capacity is one of the drawbacks of relying on NM solutions. Stack holding could be a better alternative to increase utilisation of TMA and runway capacity.

1.2 Problem statement

Currently, the information on which decisions are made is inaccurate to a level that no regulations are put in place where they should have been, and vice versa. As an alternative to putting in place regulations, one could argue that stack holding is a good alternative. However, ATC has the holding stacks as a safety option in case of unforeseen circumstances (unpredicted low visibility at the airport, or runway/airport closure) and is hesitant to use the stacks as a daily operational solution for large demand-capacity unbalances.

1.3 Research relevance/significance

Schiphol has the most ATFM airport delays of all the European Airports (Figure 1). Weather and airport capacity were the primary causes of delay, according to EUROCONTROL (2019).

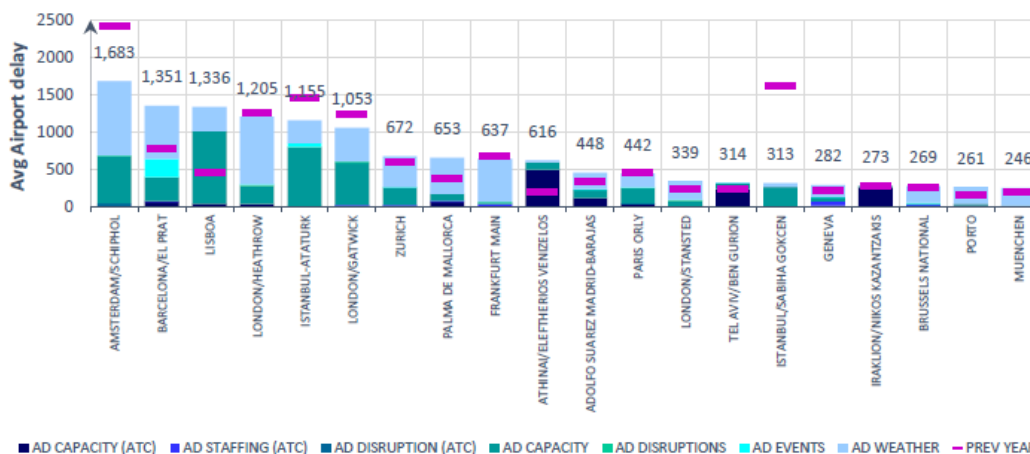


Figure 1: Top 20 airport delay locations during 2018 (EUROCONTROL, 2019)

A stable inbound flow is valuable for the operation of all KDC stakeholders. Controlled use of buffers can make the peak hour inbound capacity of LVNL' operation more reliable, and LVNL can be less strict in regulating the capacity (ATFM slots). To better substantiate the decision making, CMA plans to create a Decision-Making Tool for declaring peak hour capacity on D0.

This tool will be based on planning data, predictions of D0 and data from the past. Insight in the effects of proactive use of buffers as a peak hour management practice to absorb disruptions or over-demand, it will also be input for the Decision-Making Tool.

Additionally, according to CMA, the use of buffers will make it possible to increase the use of latent capacity and to be able to recover delays earlier. On the other hand, also with the use of buffers, safe and orderly handling of traffic needs to be guaranteed at all time.

1.4 Research Questions

The main research question is:

Which operational possibilities does LVNL have to buffer inbound traffic and to what extent can these buffers be used in managing the operational inbound peak capacity?

To answer the main question, the supporting sub- and background questions are:

1. How is the current operation of LVNL arranged regarding inbound traffic?
To analyse which operational possibilities LVNL has to buffer inbound traffic it is vital to understand how the current operation of LVNL is arranged, this will be researched in sub-question 1. The supporting background questions are:
 - How is the inbound flow of air traffic controlled?
 - What tools does the air traffic controller have to influence the actual arrival time?
 - How does LVNL currently uses buffers in controlling the inbound traffic?
 - What influences the regulation of peak hour capacity?

2. What is the current capacity of the inbound traffic buffers?
Sub-question 3 will provide insight in the capacity of the inbound traffic buffers, investigating the extra complexity and the impact to the air traffic control workload. The supporting background questions are:
 - How does proactive usage of buffers fit in the LVNL operation?
 - What are the characteristics of the different stacks?
 - What is the capacity of the buffer possibilities?
 - For how long can a buffer have effect on the operation?

3. How can the LVNL operation use buffers proactively to manage inbound traffic?
Research on how the proactive use of buffers within the LVNL operation can be used is investigated in sub-question 2. The supporting background questions are:
 - What is the definition of proactive usage of buffers?
 - How do other airports use buffers in controlling the inbound traffic?
 - What are the characteristics of the LVNL operation?

1.5 Research scope

The buffers available in the airspace starting from the Dutch FIR (Flight Information Region) boundaries to the Amsterdam TMA (Terminal Control Area) are investigated.

This research regards the inbound traffic flow towards Schiphol in the operational phase, to use as insight for the (pre-) tactical phase of ATM. The strategic phase of balancing capacity and demand with the use of airport slot coordination is out of the scope of this research. This research only includes Dutch civil airspace. Additionally, the vector capacity in the TMA is excluded, because this capacity is mainly used as resolution room to optimise runway capacity. Other Dutch

Airports than Schiphol are not investigated. Airport capacity requirements (e.g. extra runways, taxiways) and buffer possibilities within the airport ground infrastructure facilities are excluded.

Whether the use of buffer capacity is an improvement compared to the use of ATFM slots is not discussed, this research is rather about insight in the possibilities of using en-route buffer capacity.

Insights in possible use of buffers within the current operation concept are researched, a different operational concept for Schiphol as, e.g. the “holding concept” used at Heathrow Airport is not researched. No operational procedures are changed.

Because this research is performed within the KDC-CoE objectives, the effects towards LVNL and the benefits and disadvantages for the sector will be part of the research. To provide a complete picture of the complexity of the system, the human side of ATM will be investigated with the use of interviews with air traffic controllers.

1.6 Assumptions, Limitations, and Delimitations

Firstly, the assumption has been made that the air traffic controllers’ perception of available buffer capacity is a fitting representation of the actual buffer capacity. This assumption is necessary to be able to include the complexity of air traffic control in the analysis. Secondly, because July 2018 is one of the busiest months, the assumption is made that July 2018 is representative for available buffer capacity.

1.7 Thesis structure

The structure of the thesis is as follows:

1. Executive Summary
2. Introduction
 - a. Background
 - b. Problem statement
 - c. Research questions
 - d. Explanation of the thesis structure
3. Methodology
4. Literature review
 - a. Definition, benefits, and elements of different buffers
5. Analysis
 - a. Arrival process at Amsterdam Schiphol
 - b. Current buffers at Amsterdam Schiphol
 - c. Possibilities of buffers
6. Results
 - a. Listed per sub-question
7. Conclusions
 - a. The answer to the main research question
8. Discussion
9. Recommendations
10. References in APA style
11. Appendices
 - a. Including student’s reflection on the assignment steps, progress, expectations, achievements, etcetera.

2 Methodology

Firstly, the consideration between quantitative and qualitative research in combination with the research instruments used is elaborated in paragraph 2.1. Secondly, an explanation of the representativeness of the study in paragraph 2.2. Next, the strategy of data gathering is explained in paragraph 2.3.

2.1 Research Design

Air traffic management is a combination of measurable KPIs, strict prescripts, and the hard to measure sight of the human intuition and the resolving capacity of the controller. This research tries to pin down this combination in providing insight into the buffer capacity in the Dutch airspace. For this reason, a combination of qualitative and quantitative research techniques is chosen. The research process is visualised in Figure 2. The possibilities of buffer capacity and the effects to the stakeholders are explored by desk research. Moreover, with quantitative research insight in the current buffer capacity is provided by analysing historical data on route deviation. Further possibilities of buffering are examined through observations in the Area Control Centre and interviews with air traffic controllers. The following paragraphs contain an overall description of the research approach per sub-question.



Figure 2: Process design

2.1.1 How is the current operation of LVNL arranged regarding inbound traffic?

To answer this sub-question, firstly, an overview of the tactical demand balancing techniques currently used, the operational processes and the tool currently used to delay traffic is created by qualitative desk research based on operating manuals and training manuals (Luchtverkeersleiding Nederland, n.d.-a) (Luchtverkeersleiding Nederland, n.d.-b); these are made available by LVNL. Additionally, observations at the ACC controller, ACC supervisor and Flow Management Position is used to create an in-depth in the overview. Because air traffic controllers are constantly required to use a high degree of mental flexibility to resolve situations, ATC is for a large part based on the intuition and training of air traffic controllers (Cook, 2016). For this reason, semi-structured interviews are held with two ACC controllers and one APP/TWR controller to substantiate the insight into the decision making itself. The ACC point of view is the most important to determine buffer capacity to manage the air traffic flow. Air traffic controllers are a scarce resource. Therefore, two ACC controllers who have experience with capacity management research have been chosen for the interviews.

2.1.2 What is the current capacity of the inbound traffic buffers?

The type of buffers considered in this part of the analysis is the buffers already used in the current system. The most used tool to absorb delay by ACC is the use of vectoring in the sectors. Therefore, much data is available regarding the use of vectors. The capacity of vectoring is determined quantitatively with the use of historical data. The distribution of time and distance the aircraft uses from the Flight Information Region (FIR) entry to the Initial Approach Fix (IAF) for all the different arrival routes is investigated. This way, insight is created in the differences between the different arrival routes and where the most capacity to vector traffic is available. To again include the intuition of the air traffic controllers in the research, the results of the quantitative analysis are presented to three ACC controllers, to determine whether they recognise the patterns shown in the data.

2.1.3 How can the LVNL operation use buffers proactively to manage inbound traffic?

To research the different possibilities to proactively use buffers, first a literature research regarding en-route delay absorption is conducted. Followed by in depth desk research on how airports make use of buffer capacity in the inbound traffic flow. The research continues with investigating the possibility for increased use of holdings at designated stack areas. A simplified theoretical model of the holding capacity is created based on qualitative research. The purpose is to give the first insights into how holding capacity works when the usage would be extended. There is only a minimal amount of data available on the current use of holding capacity (maximum of two layers in the used data set); therefore, the data did not provide enough insight in what would happen if the usage is significantly increased. Interviews with two ACC controllers are used to figure out what the most significant bottleneck is in the holding capacity process, and with this, a simplified model is build up. The model is presented to three ACC controllers to see whether they recognise how the model is build up.

2.2 Data collection

The method of data collection is explained in the following sub-sections. Firstly, the strategy of quantitative data collection is explained in 2.2.1. Secondly, the method to collect qualitative data is explained in 2.2.2.

2.2.1 Quantitative data

The dataset used to give insight into the current vector buffer capacity consist of one month of all inbound flights to Amsterdam Schiphol. The data used is actual data of aircraft positions according to the ATC radar tracks. Because of the assumption that there is more traffic during a summer season, the busiest month of summer 2018 (July 2018) is chosen as dataset containing 20,945 flights. The outbound and overflying aircraft are filtered out of the dataset. Because most of the buffering takes place in the sectors (area between FIR and IAF), the dataset consists of information on the time and distance of aircraft between the FIR boundary and the IAF as visualised in Figure 3. Holding patterns are also used as buffer tool, however on a small scale compared to the vectoring. To give a representative overview of the vector capacity, the flights that had to be put on hold are filtered out of the set. Because, when holding is chosen as a buffer tool, the controller will not use much vectoring to constrain the workload, and this could affect the deviations in the vector capacity. Two types of data collection are used during the quantitative research regarding the vector capacity.

Firstly, AAA (Amsterdam advanced ATC system) recordings and ARTAS (ATM surveillance tracker and server) radar tracks are used with post-processing by the ATM expert at KDC-CoE, Ferdinand Dijkstra. Dijkstra created a tool to verify which STAR (Standard Arrival Route) was used, even though the actual path deviated from the beams of the STAR. The tool locates the nearest beam and links the beam to the radar location and time over. The Distance To Go (DTG) and Time To Go (TTG) are determined afterwards out of AAA with the actual distance and time flown from a specific point. Therefore, this data can be used to determine the distribution of the actually flown routes and because of the linking to the beams, it is possible to analyse the variance between different routes. All flights without a recorded IAF or FIR entry point have been excluded from the dataset, this was a total of around 80 flights which were excluded. These waypoints are combined with a row per ACID with the use of references. To verify whether all flights are combined correctly an *If* statement has been used in a new column.

Secondly, VEMMIS, an information system that stores the operational data of LVNL, is used to be add information on holding and runway usage. The data available varies from performance indicators to detailed flight information. VEMMIS makes use of Flight IDs, whereas, the data in

the AAA and ARTAS dataset makes use of Aircraft ID and corresponding date and time. To combine the two datasets, a unique ID was created of the ACID and date as well in the AAA and ARTAS dataset as in the dataset generated by VEMMIS. With the VLOOKUP function in Excel the amount of holding has been added to the Excel sheet. In this way, it was possible to filter out all flights delayed by holding. With the merge of flight, a minimal amount of flights was lost, because the AAA and ARTAS dataset missed one day of data (30 July).

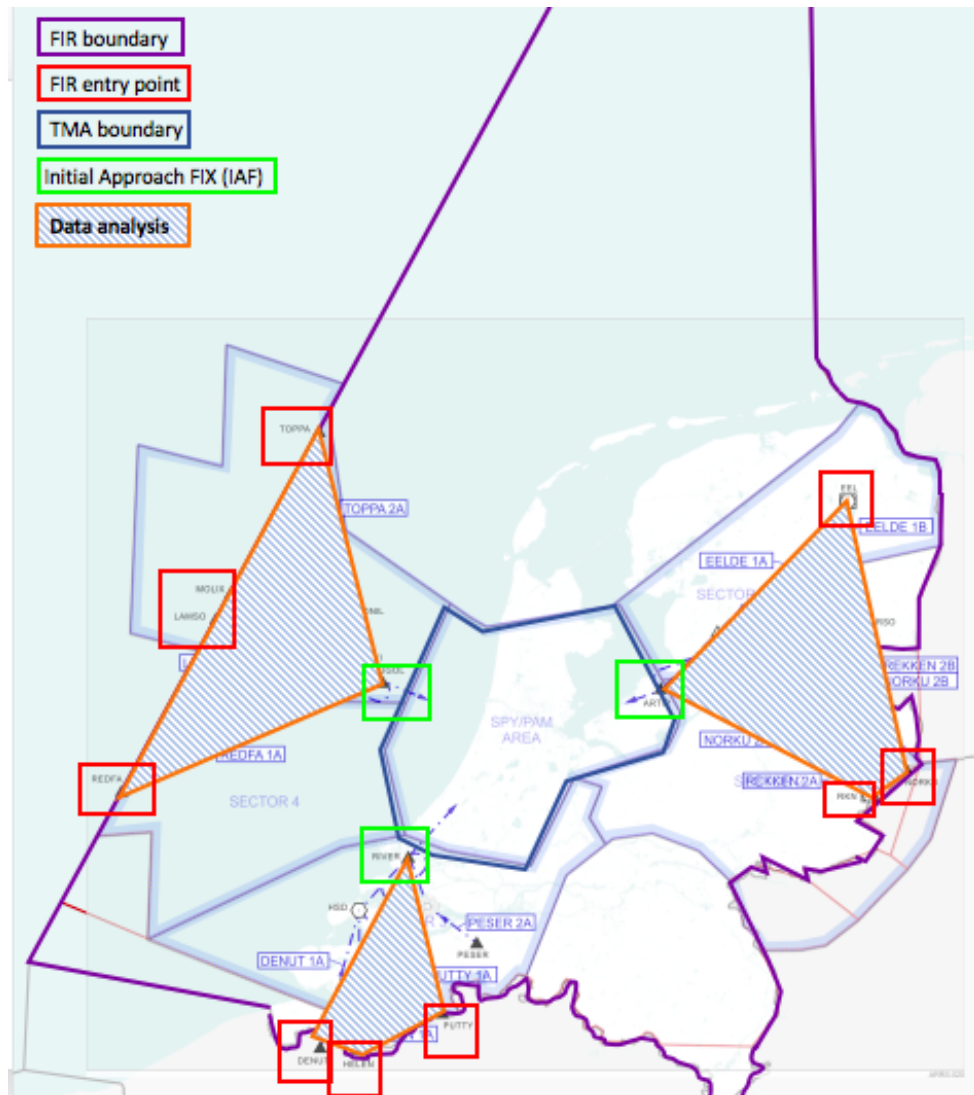


Figure 3: Data analysis area on map (Compiled by author based on Luchtverkeersleiding (n.d.-b) and Wassenberg (2019))

2.2.2 Qualitative data

For qualitative research, semi-structured interviews are chosen as the data gathering technique. The interviews are recorded and scripted. Patterns are drawn up out of the concepts and insights gathered during the interviews. Because of the limited availability of air traffic controllers, three ACC controllers and one TWR/APP controller were interviewed. The chosen controllers are familiar with capacity management and analytics techniques and were able to provide specialised insights. The ACC controller's viewpoint is the most important to incorporate in the research towards buffer capacity because they manage the capacity. Therefore, the sample size of ACC controllers is more substantial than the sample size of the TWR/APP controllers.

3 Literature review and stakeholders' analysis

As explained in the introduction, in Air Traffic Flow Management buffers are used to delay traffic when the traffic demand exceeds the available arrival capacity. Delay is defined as unplanned deferment of a scheduled activity (BusinessDictionary.com, n.d.) and can have large effects on the plan stability.

The stakeholder analysis presented in paragraph 3.2 shows that the effect of delays is different for every stakeholder. The focus of the literature study is on tools to delay aircraft en-route; the study is presented in 3.2. Finally, in 3.3 conclusions regarding the literature review are presented.

First one must understand why traffic demand can exceed the available arrival capacity at a level 3 coordinated airport. According to Riebeek (2019), Amsterdam Schiphol is a level 3 coordinated airport, which means that a slot coordinator determines when and which airline can operate at the airport (per 20 minutes brackets at Schiphol). This coordination is necessary because if this is not the case, the demand for airport infrastructure will significantly exceed the capacity of the airport (IATA, 2018). Moll (2019) explains in his recent research the effect of bunching: a term used for flights arriving in accumulated chunks instead of an even distribution, which leads to arriving traffic demand exceeding the available capacity. Moll (2019) concluded that the structural over demand is already existing within the declared slot brackets, and this becomes visible when the slot declaration is reviewed per 20 minutes – rolling 10 minutes. Therefore, the skewness of airport slot declaration contributes to the bunches experienced at the FIR boundary. This uneven distribution of flights causes workload issues for ATC, which requires intervention to assure a safe operation; by using ATFM slots, holding and vectoring.

Additionally, as Riebeek (2019) found in recent research, flight schedules and flight plans do not always adhere to the airport slots. This deviation can be partly attributed to the planning buffers of airlines. These planning buffers make the actual arrival unpredictable, which affects the planning of ATM workload and could cause the issue of more ATFM slots.

Bunching is also referred to in the research of Caccavale, Iovanella, Lancia, Lulli, & Scoppola (2014), who give insight in the queuing theory applied in the arrivals at London Heathrow. They created a simplified model to forecast the air traffic, which can represent the real data of London Heathrow and can be used to predict the input into the buffers at Amsterdam Schiphol. A critical finding in the research of Caccavale et al., 2014, is that the actual arrivals planned in consecutive slots are inversely correlated. In other words, when the first slot of arrivals contains less aircraft than initially planned, the next slot of arrivals will contain more aircraft than initially planned. Additionally, this model (2014) shows that congestion is remarkably reduced when the standard deviation is reduced. In other words, the uncertainty is reduced, and the reduction of uncertainty leads to a reduction of congestion during the arrival process. However, this model did not include the use of multiple runways and differences in capacity. To decrease the uncertainty in arrivals, Moll (2019) suggests in his research to issue slots in smaller time brackets.

3.1 Stakeholders analysis

KLM's Airport and Route Development department, the department of Innovation Development at AAS and the department Strategy and Capacity Management at LVNL are the most significant stakeholders in this research regarding the inbound flow towards Amsterdam Schiphol because of their alignment with the KDC. Additionally, other airlines that have Schiphol as their destination make up part of the stakeholders for this research. When the buffers result in delay, ground handlers also become stakeholders. EUROCONTROL, as the Network Manager, is a stakeholder because of Airport Collaborative Decision Making (A-CDM) and issuing ATFM slots. Lastly, the surroundings of Schiphol are a stakeholder because of the nuisance and emissions. Yet, these stakeholders all have different objectives aligned with varying models of business. The influence of the stakeholder and their interests are set against each other in a stakeholder's analysis matrix in Figure 4.

3.1.1 Airport Collaborative Decision Making (A-CDM) and The Network Manager Operations Centre (NMOC)

Amsterdam Schiphol has implemented Airport Collaborative Decision Making (A-CDM). The A-CDM objective is to have a more efficient use of resources and an improved punctuality and predictability (Skybrary, n.d.-c). The aim is for A-CDM partners to be able to optimise their decision-making in collaboration with other A-CDM partners, knowing their shared or conflicting objectives and constraints, besides the actual and predicted situation. A-CDM facilitates decision making by sharing accurate information and by adapting procedures, mechanisms and tools (EUROCONTROL, 2012). Part of A-CDM is the Collaborative Management of Flight Updates for the purpose of Air Traffic Flow and Capacity Measurements (ATFCM) throughout the ECAC area (member states of the European Civil Aviation Conference). ATFCM manages the gate-to-gate balance of demand and capacity (EUROCONTROL, 2012).

The overarching party in European aviation is the European Committee. In the legislation regarding the Single European Sky, the European Commission created the Network Manager function at EUROCONTROL to optimise the European aviation network's performance to avoid inflight holding and overloading the sectors (Cook, 2016) (Skybrary, n.d.-c) (EUROCONTROL, 2019c). According to EUROCONTROL (2019c), the Network Manager has the following functions:

- to develop and create Route Network Design;
- to provide a central function for Frequency Allocation;
- to coordinate improvements to SSR Code Allocation;
- to carry out the Air Traffic Flow management function.

The Network Manager provides CDM airports with time estimates based on Flight Update Messages (FUM) for arriving flights (EUROCONTROL, 2012) (Cook, 2016). Additionally, the Network Manager is responsible for ATFM slot management to balance demand and capacity by delaying the departing flights (EUROCONTROL, 2012), ATFM slots are explained in more depth in 3.2.1. As this research concerns ATFCM in and to the Dutch airspace it is of interests for the Network Manager as guard of the European network.

3.1.2 Amsterdam Airport Schiphol and the surroundings

The surroundings of Schiphol have a significant influence on the airport's capacity management. Schiphol's runway usage is restricted by the Alders Agreement (Alders, 2013). The purpose of these restrictions is to protect the surrounding residents. The sector is facing the challenge to find a balance between the need of increased airport capacity and the negative effects on the surrounding residents. If the proposed buffer tools have an effect on the surrounding residents in noise or pollution nuisance (or when the residents think it will), the residents have a voice to the politics and policy makers of the region.

As a result of the Alders Agreement (Alders, 2013), Schiphol is always allowed to use a 1+1 runway configuration, one departure runway and one arrival runway. During peak hours, Schiphol is allowed to increase the number of runways to a 2+1 or 1+2 configuration. Between the peak hour transitions (inbound to outbound peak or vice versa), it is allowed to make use of a fourth runway (2+2 configuration), to prevent capacity loss (Kanis, 2017). The norm for the usage of the fourth runway is an average of 40 movements per day and a maximum of 80 movements per day (Alders, 2015). This results in a declared peak capacity of 68 movements at Schiphol (EUROCONTROL, 2018b).

Schiphol is a hub airport with a four to five-peak system that connects the intercontinental and European network of KLM and partner airlines according to M2P consulting (2015) (Figure 4). According to the analysis performed by M2P consulting (2015), hub performance is determined by its bank structure and the impact of the structure on connectivity, fleet productivity, and operational stability. In a hub, a balance has to be found between connectivity versus productivity

and short connection times versus operational stability. Because KLM requires a large feeder network to operate all the different city pairs, peak hour capacity is of great concern (Keul & Veldhuis, 2014). According to Keul and Veldhuis (2014), the minimum connection times between the inbound and outbound flights are kept as small as possible to make as much use of the capacity and to attract transfer passengers. Nevertheless, as explained by M2P consulting (2015) short connection times results in a less stable operation and operating in such a hub structure creates challenges.

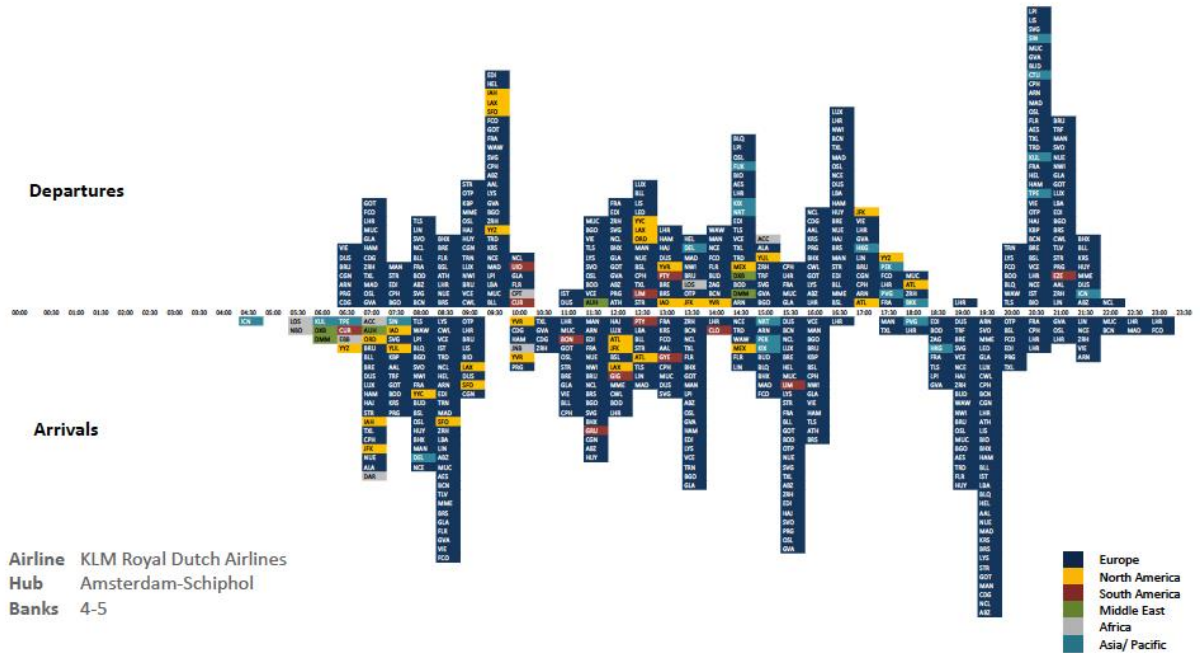


Figure 4: Peal system KLM at Schiphol Airport (M2P Consulting, 2015)

Cost of delay airport

AAS is responsible for the ground infrastructure and the accompanied logistics at the airport. To be cost efficient, an airport needs operational stability. The ground infrastructure must cope with the effects when aircraft are delayed or arrive earlier than planned. Delays result in a less optimal use of aircraft parking stands, gate facilities and personnel which leads to increased operation costs (EUROCONTROL, 2000). Moreover, delay affects the perception of the airport among passengers (EUROCONTROL, 2008). Nevertheless, AAS will experience minimal direct effects of the use of en-route buffers of this research.

3.1.3 Airlines

KLM is a full-service carrier operating with a hub-and-spoke network. KLM connects the world through its hub at Amsterdam. Amsterdam has a relatively small local market, only 30% of the passengers are O&D passengers and 70% of the passengers are transfer passengers (Schiphol Group, n.d.). The connectivity is therefore an important KPI. The connectivity is highly dependent on transferring passengers. Connecting passengers can choose between different competing hubs and the quality of connecting flights in these peaks can influence the attractiveness of Schiphol to these passengers. At Schiphol, the connectivity is created by the in- and outbound peaks. Maintaining a sustainable peak hour operation is therefore important for KLM. Because of KLM's attendance in the sector briefings and their participation in KDC, they have more influence on the peak hour strategy and research towards improvements than other airlines at Schiphol. Therefore, KLM has an individual spot in the stakeholders' matrix in Figure 5 apart from the total group of airlines.

Cost of delay airlines

Delays cause missed connections and loss of trust by passengers, severely influencing the airline profitability (both direct and indirect) (Cook, 2009). Ground delays costs extra time with the

Ground Handler and delays in air space for example, holding and vectoring cost fuel. Because of these effects, the interests of the airlines are very high in the stakeholders' analysis matrix, see Figure 5. According to Cook (2007), the industry has a strong focus on departure delays. This is not particularly logical when considering the airlines business model of connecting city pairs through multiple legs with short minimum connecting times; as KLM offers with its hub at Amsterdam. Additionally, the service expected by the passenger in terms of arrival punctuality should also be considered. Therefore, it is possible to conclude that looking at arrival delays is relevant to the industry.

What is considered as punctuality is not always helpful with regards to the costs of delay. Usually, when a flight arrives no later than 15 minutes after the scheduled time the flight is still *on time*. Cook (2007) argues that on the one hand this is reasonable, the considered punctuality is due to the unpredictability of air traffic operation. It is not unusual to expect multiple aircraft at the same time according to the schedule, while this would be physically impossible due to runway constraints and the available airport infrastructure. Moreover, departure windows are also not accurate (e.g. an ATFM regulated departure slot is considered – 5 minutes to + 10 minutes (Cook, 2007)). However, arriving 15 minutes after being scheduled could already cause missed connections. Furthermore, Boekhout (2018) explains the indirect costs of unpunctuality; when passengers perceive an airline as unpunctual, they may choose another airline instead the next time they book a flight.

Airlines try to prevent costly missed connections by locking the unpredictability into the schedule in advance. Airlines buffer extra time in the schedules, reserve extra crew and/or plan spare aircraft. The costs of these, called by Cook (2007) *strategic level delays*, can be expressed in the underutilisation of aircraft. The more the airline knows in advance, the less strategic delay costs are necessary to be incorporated to deal with the unpredictability. An example of this is the arrival operation at London Heathrow: The airlines know that an extra 15 minutes holding time is necessary to include in the schedule. In this case, the cost of underutilisation falls due. Whereas, if this was included for every airport and it was not used in 9/10 cases, this scheduled holding time leads to inefficient aircraft utilisation.

Next to strategic level delays, Cook (2007) also distinguishes tactical level delays. The definition of this is the occurrence of actual delays on the day of operation. The corresponding costs are the re-booking and compensation of passengers.

3.1.4 Ground handlers

To continue with ground handlers, as with the airport operator, delays cause deviations from the planning and with that less efficient use of the resources. Less efficient use of resources has effect on the necessary amount of ground equipment and personnel. Nevertheless, these costs will be passed on to the airline (EUROCONTROL, 2000). Therefore, the interests of the ground handlers in this research are assumed to be minimal.

3.1.5 Aeronautical Service Providers (ANSP)

LVNL is as Aeronautical Service Provider (ANSP) responsible for safe air traffic flows in the Dutch airspace and airports. LVNL aims to be the best ANSP in the world considering safety, people and reliability (LVNL, n.d.). The consideration between issuing ATFM slots and en-route buffers has effect on the ANSPs, because en-route buffers demand extra Air Traffic Controller resources to handle the traffic (Delgado, Cook, Cristóbal, & Plets, 2015). However, Delgado et al. (2015) conclude that the controller cost is below the delay costs of issuing ATFM slots in 73% of the cases they investigated. The stakeholders benefitting of less ATFM slots are the airlines and passengers. When considering en-route buffering beyond the scope of the Dutch FIR, other ANSPs become interested, because this would demand use of capacity within their airspace. As

the scope of the research is en-route buffering within the Dutch FIR, adjacent ANSPs influence and interest is medium to high in the stakeholders' matrix (Figure 5).

As the airlines are the users of the service provided by LVNL, en-route buffer capacity as a management tool has the potential to improve the reliability of LVNL as a service provider for the airlines. As the main implementing party, LVNL is the stakeholder with the most influence within this research. KLM as the largest user of the Dutch ATM system has very high interests in the arrival operation and should therefore be managed closely. The other airlines should be kept informed on the arrival operation due to influence in their strategic level delay costs. Additionally, the Network Manager at EUROCONTROL and neighbour ANSPs should be kept informed due to the effects on the ATFCM. The surroundings should be kept satisfied because of the influence they have on politics regarding the airport. The effects on AAS and the ground handlers are expected to be minimal and should be monitored. The stakeholders' analysis visualises the interests and influence of the different stakeholders against each other and is presented in figure 5:

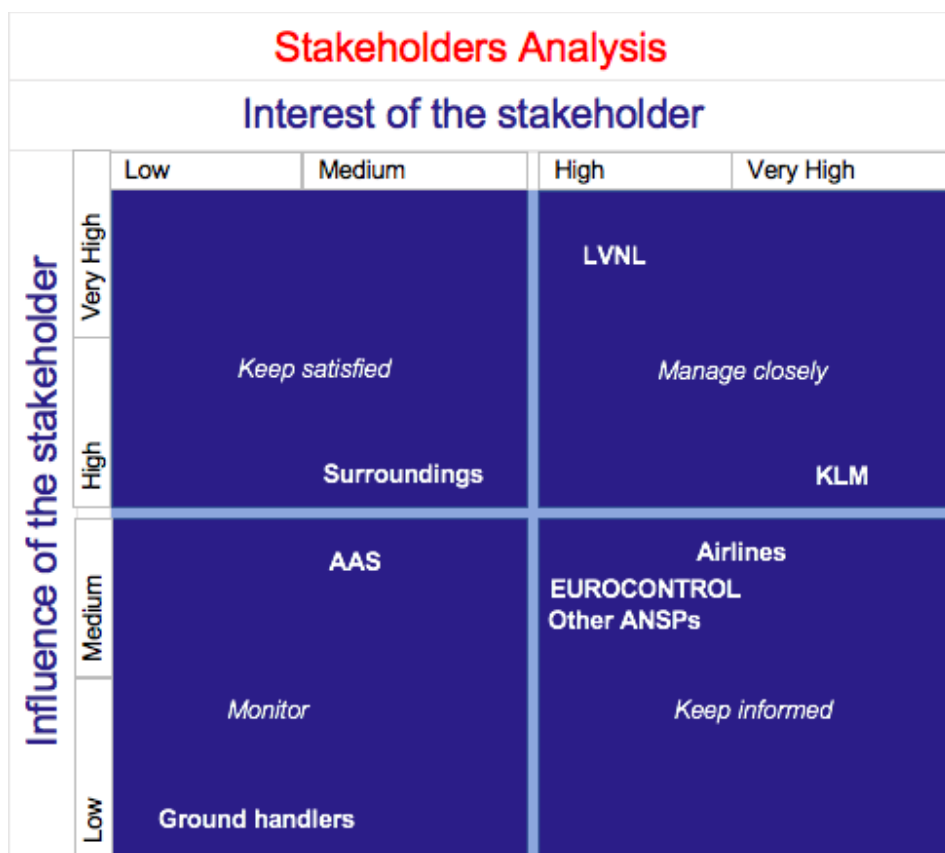


Figure 5: Stakeholder analysis buffers as capacity management tool LVNL

3.2 Procedures to delay air traffic during the flight operation

According to Nieuborg (2014), air traffic delay can be divided over the several phases of a flight (Figure 6). The focus of this research is on the possibilities of delaying a flight in its final phase while already having entered the Dutch airspace. Within the en-route phase, Nieuborg (2014) defines the buffer area in the last phase as the additional Arrival Sequencing and Metering Area (ASMA) (Figure 6). ASMA time is the time in an area of 40 NM from the airport in which the ANSP of the destination airport handles the traffic, whereas the Additional ASMA time is the difference between the transit time in non-congested conditions (unimpeded ASMA time) and the actual conditions. Additional ASMA time is caused by vectoring and holding to sequence the flow towards the runway and to absorb overdemand. Additional ASMA time represents the time generated by the inefficiencies in the arrival management and has a direct effect on fuel burn and emissions (Christien, Hoffman, Trzmiel, & Zeghal, 2018). Reasonably, the amount of ATFM delays influence the amount of additional ASMA time (EUROCONTROL, 2018b). ATFM slots as

part of pre-departure delay is discussed in 3.3.1, followed by the explanation of the en-route phase possibilities. Extended arrival management and linear holding are respectively discussed 3.3.2 and 3.3.3. Finally, the (speed) vectoring and vertical holding in the ASMA phase of flight are discussed in 3.3.4 and 3.3.5.

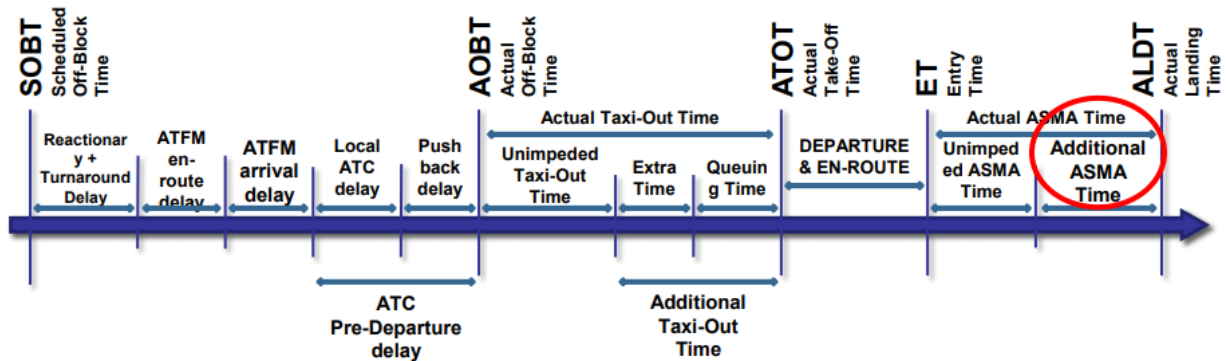


Figure 6: Additional ASMA time (Nieuborg, 2014)

3.2.1 Pre-departure delay with the use of Air Traffic Flow Management (ATFM)

According to Payne, Pena, Tisdall, Ratcliffe, Byus, & Fucharoen (n.d.) ATC needs ATFM to deal with the lack of ability to accurately predict demand, the lack of common situation awareness with the other stakeholders, unmanageable peaks in traffic demand and military exercises. The use of ATFM prevents excessive airborne holdings, excessive speed control and extended downwind legs. The objective of ATFM is to be able to handle the most capacity in every circumstance and to cope with high workload, stress and fatigue as experienced by the controllers.

At the ANSP, the Flow Management Position (FMP) monitors the expected traffic counts per twenty minutes and can issue a maximum. The process of ATFM slots is calculated with the use of an automated Computer Assisted Slot Allocation (CASA) system at the Network Manager EUROCONTROL as part of the broader philosophy of information sharing in A-CDM (Cook, 2016). When the expected traffic counts exceed the set maximum, the CASA system will calculate the necessary delay. The delay will be added to the Estimated Take off Time (EOBT) which will then result in a Calculated Take off Time (CTOT) (Boekhout, 2018). The effects of ATFM delays are illustrated in Figure 7, wherein the following A-CDM terminology are included in the illustration:

- EOBT = Estimated Off Block Time
- ETOT = Estimated Take off Time
- CTOT = Calculated Take off Time
- ETO = Estimated Time Over
- CTO = Calculated Time Over

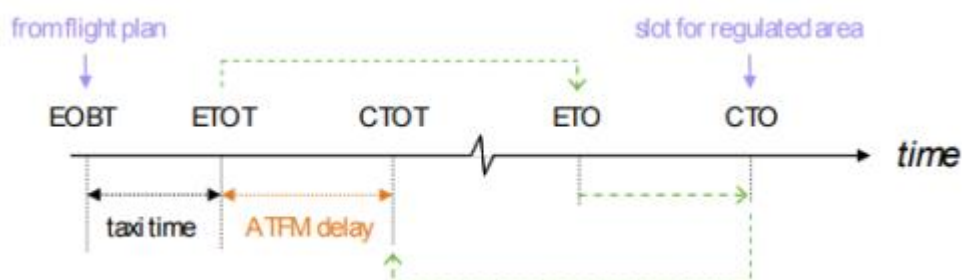


Figure 7: ATFM regulation layout (EUROCONTROL, 2016a)

According to Boekhout (2018), the effectiveness of ATFM measures is negatively influenced by the decision making of pilots and airlines. After a Calculated Take-Off Time (CTOT) is issued and the aircraft takes off later than planned to prevent over-demand at Schiphol, the pilot can e.g. ask for directs at adjacent centres. As a result, the aircraft will arrive earlier than the planned CTO slot and will cause again over-demand at Schiphol. The other way around, when the capacity is higher than was expected it takes time to increase the arrival flow with the use of ATFM delay because the aircraft are still at the outstations.

3.2.2 Linear holding: Arrival Management (AMAN) and Extended Arrival Management (XMAN)

Arrival Management means arranging arrivals into an efficient flow. When speaking of AMAN, people usually refer to the software designed to assist in sequencing the arrival streams with the use of an electronic display which shows the time management regarding the arriving flights (EUROCONTROL, 2010). The AMAN system provides a sequence planning for the runway, and the corresponding expected times over fixes.

As visualised in figure 7, the AMAN process at Amsterdam starts when MUAC (Maastricht Upper Area Control) receives the ABI (Advance Boundary Information) 15-30 minutes' prior passing the FIR boundary. Based on this information and the radar information the AMAN system (ASAP: Advanced Schiphol Arrival Planner) determines what the EAT, ETA (Expected Time of Arrival) and slot time of that aircraft will be (Luchtverkeersleiding Nederland, n.d.-a). The APLN optimises the ASAP generated planning to eliminate delays as much as possible (LVNL, n.d.-b). When the aircraft's position is ETO-stack – 14 minutes (Expected Time Over IAF without considering other traffic), the ETA, EAT and slot time will be frozen and will be sent to the APLN screen. From this moment, only the APLN (Approach Planner) can make changes to this planning and the APLN will have to communicate changes to the ACC controller (Hollebeek, 2019). In the TMA, the APP controller has the aircraft Under Control (UCO).

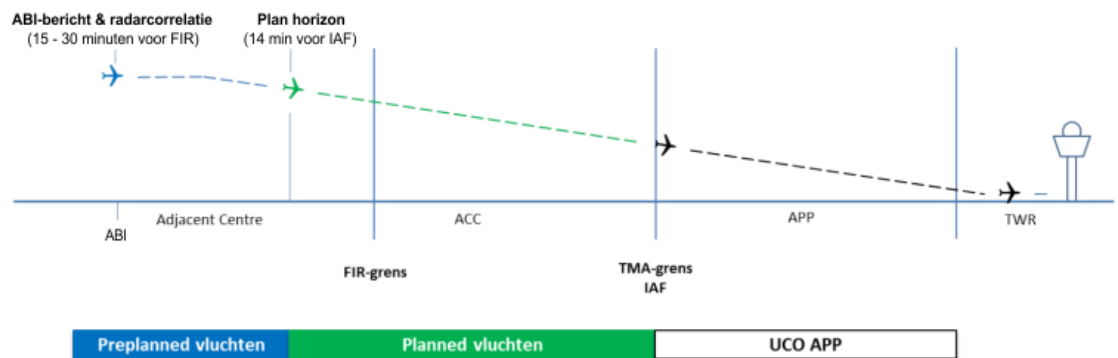


Figure 8: Advanced Schiphol Arrival Planner (LVNL, n.d.-b)

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The objective of AMAN is to support the controller to optimise the runway capacity and to regulate the flow of aircraft entering the FIR. The last function is useful to spread bunches of aircraft entering the FIR around the same time with the use of linear delay absorption (speed vectoring) (EUROCONTROL, 2010). AMAN is slightly less effective in combination with vertical holdings, because vertical holdings are rigid and not precise to plan expected time over fixes (EUROCONTROL, 2010).

Current procedures allow aircraft to pass the IAF within a margin of two minutes (LVNL, n.d.) With the further implementation of ASAP and the Speed And Route Advisor (SARA), the margin to pass the IAF can be reduced to thirty seconds (van Horssen, 2017). SARA allows precise speed monitoring, to allow the ACC to better adhere to the EAT. However, when AMAN is

expecting a more precise adherence at the EAT, the use of vertical holding becomes even more impractical because of the inexact timing over the fix.

Cross-Border Arrival Management (XMAN)

Cross-Border Arrival Management (XMAN) is an extension on the AMAN system already in operation on many European Airports. XMAN is an initiative part of the Single European Sky (SES) and at London Heathrow airport part of a broader objective to eliminate stack holding for the longer term. The objective of SES is to reduce costs for airspace users, maintain a safe and an efficient operation and reduce the impact on the environment (Mobility and Transport European Commission, 2017).

According to Kok, Tielrooij, and Dijkstra (2019), the effectiveness of the AMAN system is dependent on the size of the airspace. The AMAN system calculates an Expected Approach Time (EAT) of the aircraft at the IAF (Initial Approach Fix) to enter the TMA. The objective is to create an optimal flow towards the runway and is based on the distance to go, the aircraft types and preferred speed profiles of the traffic within the AMAN range. For the case of Schiphol, the EAT is available for the Amsterdam ACC controllers when flights cross the range of 14 minutes from the IAF. The ACC controllers use can reduce speed or add track miles to deliver the aircraft at the IAF in the right timeslot. However, in a small airspace the space to reduce speed or add track miles is limited.

XMAN causes speed reduction in the cruising phase of flight and contributes to the SES objective by reducing the time aircraft spend in the more fuel-intensive holding phase of flight. Arrival information (AMAN) is shared with partner ANSP centres and the controllers at these centres' slow aircraft down up to 350 NM before the destination airport to anticipate on expected delays. According to the department Mobility and Transport of the European Commission (2017), the NATS reduced on average one minute of holding time per aircraft during the XMAN trial at London, which resulted in the saving of 15,000 tonnes of CO₂ and 4,700 tonnes of fuel in 2014. Fuel is one of the largest costs for an airline. Additionally, the reduction of holding time caused a reduction in noise for the communities living beneath the holding stacks. The Heathrow situation is visualised in Figure 9. When Heathrow XMAN is in full in full operational service it has the potential to make annual savings of €17M in fuel costs and up to 65,000 tonnes of CO₂ according to the department Mobility and Transport of the European Commission (2017).

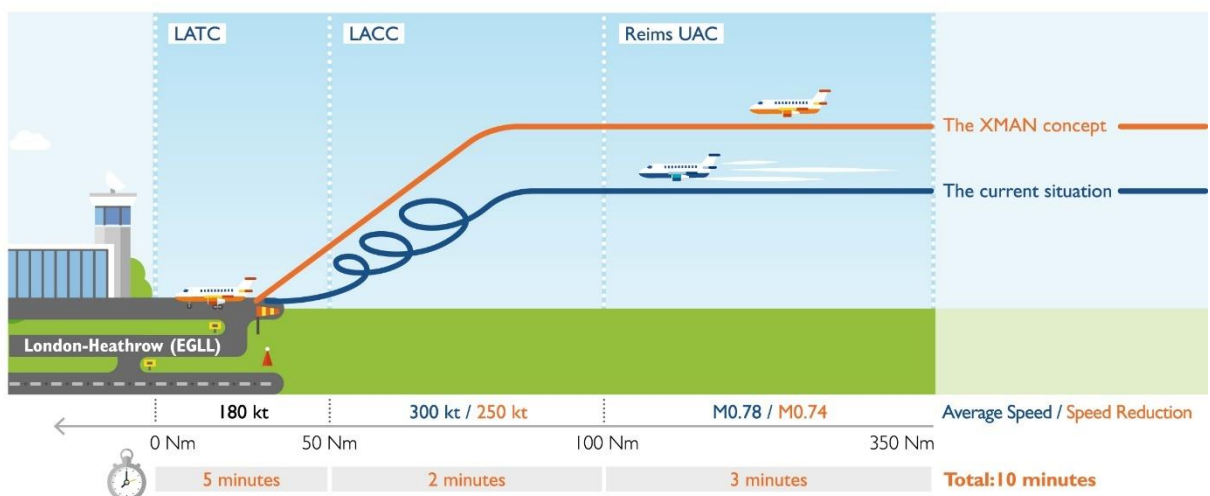


Figure 9: Extended Cross Border Arrivals London Heathrow Airport (European Commission, n.d.)

Moreover, Vanwelsenaere, Ellerbroek, Hoekstra, and Westerveld (2017) found in a recent study on Extended Arrival Management (XMAN) at Schiphol, that the AMAN process is negatively affected by pop-up flights. Pop-up flights depart within the horizon of the AMAN system. This report (Vanwelsensere et al., 2017) states extending the AMAN horizon causes substantially

grow in pop-up flights. These pop-up flights must fit in the already fixed Arrival planning, which often results in the necessity to revise the schedule. These updates cause unpredictability, increases workload, and it results in a less accurate AMAN process.

Furthermore, the recovering of delay is more flexible with the use of linear holding when implemented on a large scale in SESAR with the use of Collaborative Decision Making (CDM). According to Xu and Prats (2017b), aircraft flying in linear holding can accelerate to the speed as initially planned if the delays are cancelled ahead of schedule. Nevertheless, to be truly effective airlines must be willing to provide specific flight information to the Network Manager and CDM has to be effective throughout Europe (Xu et al., 2017b).

3.2.3 Predefined linear path-stretching procedures

Predefined path-stretching is used to delay airborne aircraft and sequence arriving aircraft into predefined legs towards a specific point without incurring extra full consumption (Xu & Prats, 2017a). It can be used instead of providing vectoring (tactical path-stretching) or vertical holding (Gill, 2014). *Point Merge* (Figure 10) is a type of path-stretching in which ATC clearance is given to fly the longest hold route. As soon as the correct separation between the aircraft is achieved, the aircraft receives clearance to direct to the *merge point*. After the merge point, a single arrival path to the runway will be resumed (Gill, 2014). When implemented in the last phase of flight to sequence traffic into the TMA, Nicolaon (2002) states in his research presentation that linear holding can only absorb *reasonable* delays of 6 to 7 minutes. However, results of recent research by Xu and Prats (2017a) suggests predefined linear path-stretching patterns can absorb delays of 25 minutes without extra fuel cost when implemented on a large scale.

Favennec, Rognin, Trzmiel, Vergne, & Zegha (2010) performed several simulation-runs towards the use of Point Merge linear holding in different ACC sectors. The main benefits Favennec et al. (2010) reported are: 'The easiness and robustness of the procedure, a better and clearer division of tasks and roles, reduction of workload and of communication, enhanced safety and capacity, better delivery to approach and a better view of the arrival sequence.' Their research conclusion states that the air traffic controllers experienced Point Merge as easy to use and that the technique was of great use in combination with arrival manager slots. According to their simulation the reduced workload improved the safety and potentially increased capacity. Additionally, the distance and time flown, and fuel consumption were similar to the baseline model. However, the controllers note the risk of losing vector skills due to the decrease in practise.

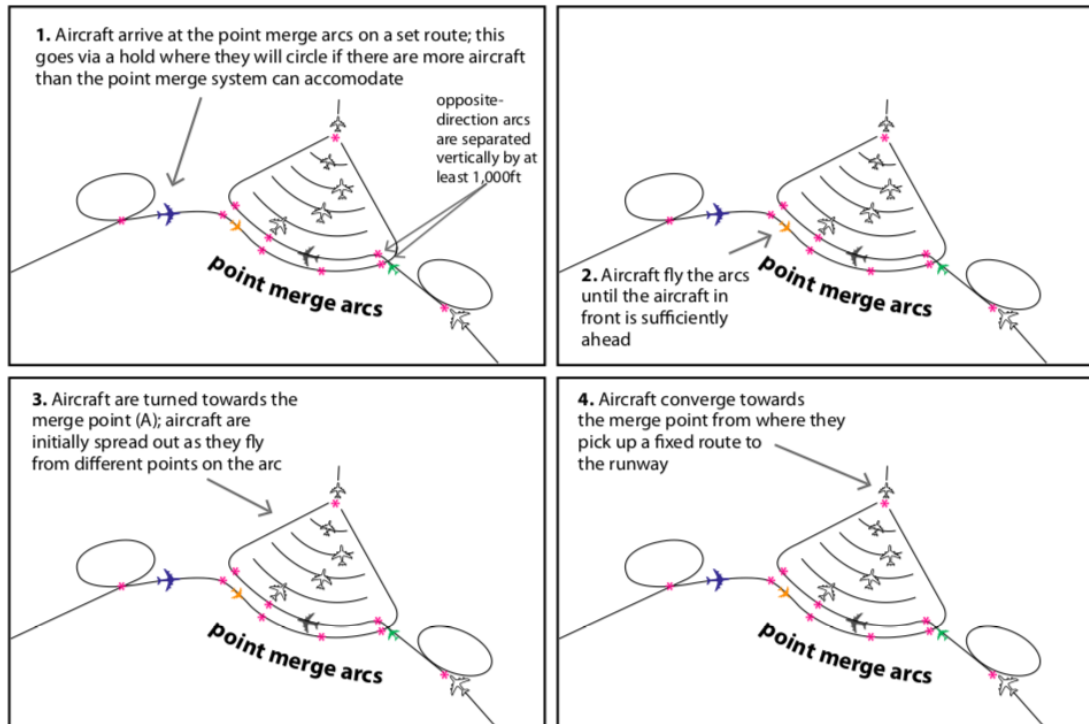


Figure 10: Point Merge (Gill, 2014)

3.2.4 (Speed) Vectoring

According to Skybrary (n.d.), the definition of vectoring is the provision of navigational guidance to the aircraft in the form of specific headings. Vectoring is comparable to linear holding (3.2.3), because the legs are extended. However, with linear holding the legs are predefined, vectoring is a tactical intervention and often involves a deviation from the planned route safety or capacity reasons (EUROCONTROL, 2010a). The purpose of using vectors is to achieve and/or maintain the desired track of an aircraft. Often in combination with speed control, vectoring is an accurate measure used to control the desired distance before reaching the IAF and this is used to sequence the traffic flow.

3.2.5 Vertical Holding

According to Merriam-Webster's online dictionary (2019), holding patterns are defined as 'the usually oval course flown (as over an airport) by aircraft awaiting clearance especially to land'. Using holding patterns in stacks as a tool to manage inbound flow can result in a sustainable use of runway capacity, because it prevents the occurrence of gaps in landing sequences due to uncertainties. Additionally, in contrast to the use of vectors, the use of holding stacks has the capability to absorb long delays (Nicolaon, 2002). Figure 11 indicates the ground track of a standard holding pattern in still-air conditions (Skybrary, n.d.-b). When the aircraft has entered the hold, to fly a standard pattern, all turns are to the right with an expected average bank angle of at least 25° or a rate of turn of 3° per second according to Skybrary (n.d.-b).

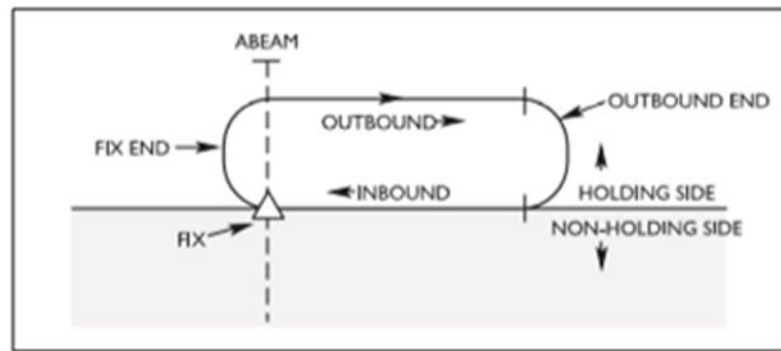


Figure 11: Ground track holding pattern (Skybrary, n.d.-b)

The use of vertical holding stacks at London Heathrow

In London, the proactive use of holding stacks makes sure London Heathrow can perform 98% of its runway capacity because the stacks create a constant stream of arrivals to optimally sequence the flow (Curtis, 2016). It is proactive use of holding stacks because the ANSP acts in anticipation instead of in reaction; they know their operation is constraint and to get the most out of it they use the holding stacks to make the maximum use of their capacity. Although, proactive usage of buffers in the ASMA create delay for the sector, the delay is predictable. As explained in paragraph 3.1.3, strategic level delays are a cost for the airline when the delay was anticipated but not necessary (Cook, 2007). Additionally, pre-hand knowledge of the delay and the realistic arrival times at the airport result in an adapted resource planning for the CDM partners. Nevertheless, the proactive use of holding stacks results in fuel and emission costs.

Heathrow is the primary hub of British Airways and its primary constraint is runway capacity with two parallel runways in the east-west or west-east configuration (Heathrow, 2018). According to the standard arrival charts (NATS, 2019b), the arrival routes of Heathrow have multiple vertical holding stacks, of which four are used to feed the two runways. Namely: Bovingdon, Lambourge, Ockham and Biggin (Heathrow, 2018). The lowest four levels of the stacks are controlled by the approach controller. This way the controller pulls out aircraft when there is room in the runway sequence. Four stacks are used to feed one runway, this allows the APP controller to prevent gaps in the runway sequence and to consider wake turbulence categories to get the maximum out of the two runways (Haskins, 2013).

3.3 Literature review conclusion

Along the lines of Nieuborg (2014), Figure 12 has been created to visualise the possibilities discussed in the literature review to delay air traffic during the different phases of flight. Delay is necessary to deal with the unpredictability of air transport and spread bunches in the arrival flow to optimally and safely utilise runway capacity.

The first delay possibility discussed is the use of ATFM slots in the pre-departure phase. The objective of ATFM is to handle the most capacity as possible and protects the controller in coping with a high workload as a result of excessive airborne holdings, excessive speed control and extended downwind legs. Nevertheless, the arrival flow is unpredictable and when there is more capacity than was expected ATFM slots are not flexible. Besides, the effectiveness of ATFM slots is negatively influenced by the decision making en-route by pilots and airlines to preserve the connectivity.

During the en-route phase it is possible to delay traffic with Extended Arrival Management (XMAN) and Linear holding. Both are effective for de-bunching and sequencing traffic without excessive extra fuel use. Besides, the recovery of delay is more flexible than with ATFM slots. The effectiveness is however dependent on the size of the airspace and requires cooperation with adjacent ANSPs.

In the last phase of flight, it is also possible to use linear holding with Point Merge. Point Merge is an effective tool in combination with the Arrival Management slots as used in the current ASAP system. Implementation of Point Merge requires a new design of arrivals with the buffers included in the routes. Nevertheless, the amount of delay possible to absorb with Point Merge is dependent on the size of the air space. The same goes for the use of (speed) vectoring, which has an accurate outcome but a limited room to absorb delays. Vertical holding stacks do have the capability to absorb long delays, nonetheless they are rigid and inaccurate in combination with the ASAP system.

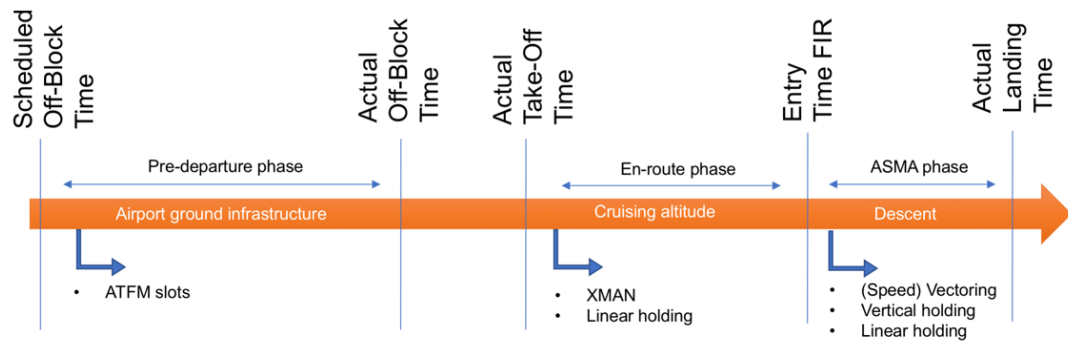


Figure 12: Tools to delay air traffic (Compiled by author based on Nieuborg (2014))

4 How is the current operation of LVNL arranged regarding inbound traffic?

This chapter consists of an overview of the current process of aircraft entering the Dutch air space with the destination Schiphol from the viewpoint of LVNL. To bring the current operation of LVNL in perspective, Figure 13 provides an overview of the Dutch FIR. However, the tactical planning of inbound traffic starts already three hours' prior to the aircraft entering the FIR and is discussed in paragraph 4.1. Paragraph 4.2 provides an overview of the arrival management at Amsterdam Schiphol, which starts 15-30 minutes' before passing the FIR boundary. Paragraph 4.3 consists of an analysis of the different operational departments responsible for the traffic from the point the aircraft enters the FIR. Additionally, paragraph 4.4 explains the buffer possibilities the air traffic controllers currently use and reflects the decision-making process concerning the use of buffers based on interviews with two Area Control Centre air traffic controllers.

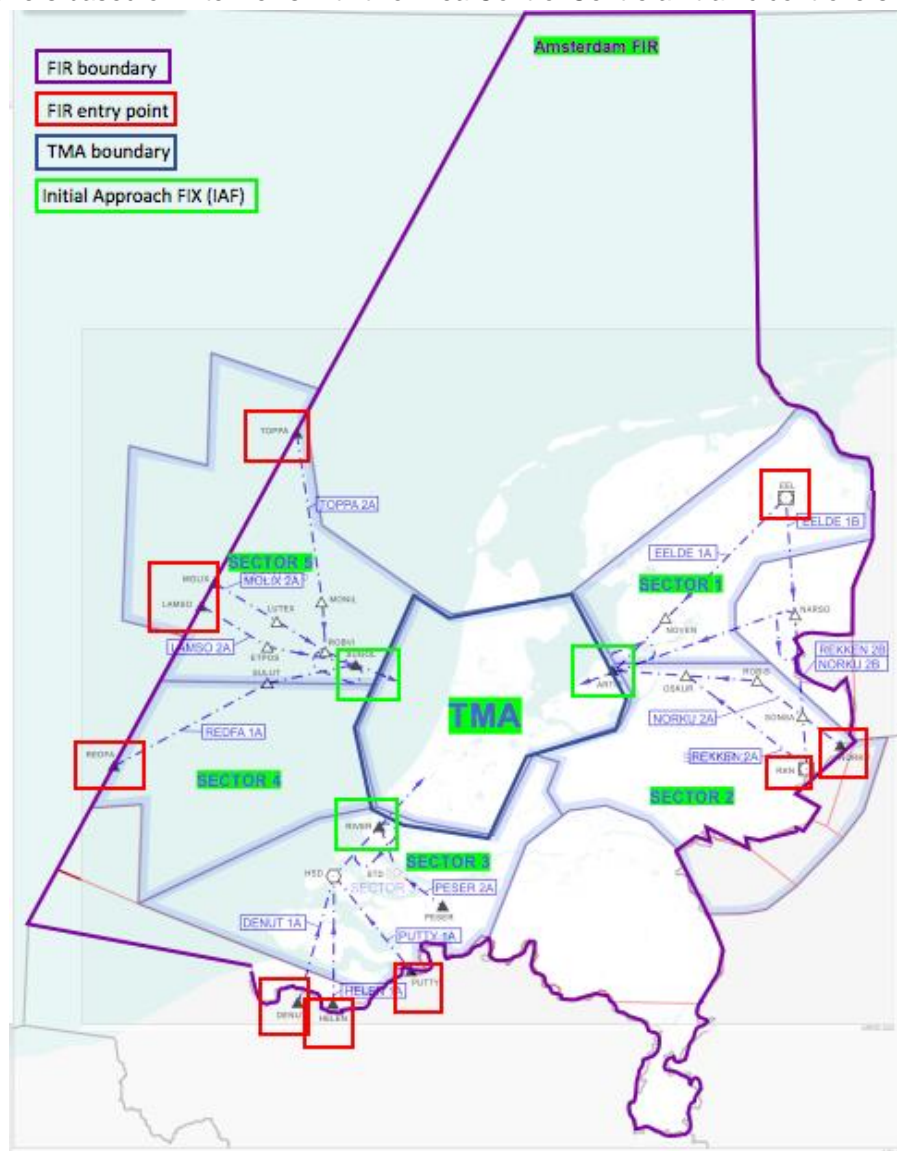


Figure 13: Dutch airspace compiled by author based on Luchtverkeersleiding Nederland (n.d.-b) and Wassenberg (2019)

4.1 Demand Capacity Balancing and Air Traffic Flow Management



Figure 14: Process LVNL regarding inbound traffic Amsterdam Schiphol

The tactical planning of the Area Control Centre (ACC) supervisor starts with demand capacity balancing around three hours before the aircraft passes the FIR boundary. During this planning, the Flow Management Controller (FMC) and the supervisor estimate the amount of aircraft and the workload for the air traffic controllers in the sectors (Figure 13) while observing at the expected demand, the air traffic controllers on duty, the expected weather and the expected runway combination. As observed in the Area Control Centre, the workload is especially essential for the capacity balancing in sector 3, because this is a relatively small sector with a high amount of different traffic (with traffic to or from Brussels Airport, Rotterdam The Hague Airport, Eindhoven Airport and Amsterdam Airport Schiphol). The supervisor can decide to use Air Traffic Flow Management measures (ATFM) as explained in paragraph 3.2.1 to prevent excessive air traffic demand in the sectors and at the airports. The supervisor actively limits the air traffic, and as a result, aircraft will receive ATFM departure slots by EUROCONTROL to regulate the traffic flow. As explained in paragraph 3.2.1, an ATFM slot is the difference between the Expected Take-Off Time (ETOT) and the Calculated Take of Time (CTOT) issued by the Network Manager at EUROCONTROL and causes additional ground time at the departure airport for the airline. The decision made by the supervisor to use ATFM regulations or absorb the traffic with the use of vectors or holding is for a large part based on the expectations for how long the capacity demand will exceed the available capacity according to the observations in the ACC.

4.2 Approach planning and the Arrival Management system

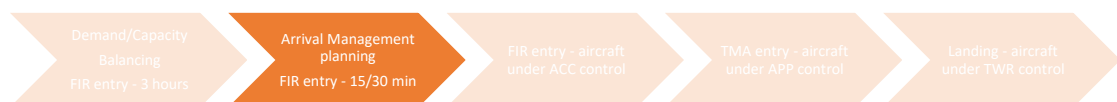


Figure 15: Process LVNL regarding inbound traffic Amsterdam Schiphol 2

The inbound process continues with the aircraft heading towards the Dutch FIR and the start of AMAN (Arrival Management) as explained in 3.2.2. The AMAN system (ASAP) determines the time the aircraft must pass the IAF (Initial Approach Fix) (+- 2 minutes' deviation). The objective of ASAP is to obtain a stable traffic flow towards the Schiphol TMA (Terminal Control Area), to use the runway capacity optimally and to generate realistic and stable EATs (Expected Approach Time) at the IAF. The APLN (Approach Planner) uses ASAP to plan the inbound traffic from the IAF to the preferred runway. This information is shared with ACC; who is responsible for sequencing the inbound traffic efficiently and delivering the aircraft at the IAF at the right EAT (LVNL, n.d.-b) (Hollebeek, 2019).

4.3 The operational inbound process



Figure 16: Process LVNL regarding inbound traffic Amsterdam Schiphol 3

The conversation with the air traffic controllers during the interview explained that the most limiting factor in the LVNL arrival process is at the end of the process, the runway capacity (Appendix II). The responsibility of a flight starts when the adjacent centre transfers the flight to LVNL at the FIR boundary as visualised in Figure 17. From this point, the Area Control Centre (ACC) at LVNL has control. Detailed visualisations of the FIR-boundary and the five ACC-sectors are presented in respectively Appendix III: Dutch airspace and Appendix IV: ACC sectors. Next to the inbound process, the ACC controller is also responsible for the departing and overflying aircraft in his sector. The ACC controller organises the traffic in a sequence and manages the traffic confirm the right flight level (FL) and speed as agreed with the approach (APP) controller. At the Initial Approach Fix (IAF), the ACC controller transfers the responsibility to the APP controller (Luchtverkeersleiding Nederland, n.d.-b).

After that, the APP controller continues the sequencing to line the aircraft up for the runway. The APP controller is responsible for the air traffic control from the IAF to the ILS (Instrument Landing System) during the approach phase, but also the other way around during the departure phase until the aircraft is airborne (Cook, 2016). As soon as the pilot confirms the aircraft is turned to the correct ILS, the pilot is requested to contact the TWR control and the responsibility of the air traffic control transfers from APP to TWR. After the landing clearance from TWR, the aircraft can land on the runway. After landing, GND (ground control) guides the aircraft while it taxies to the gate. The TWR control is responsible for runway management and controls the aircraft movement on taxiways and airport facilities (Cook, 2016).

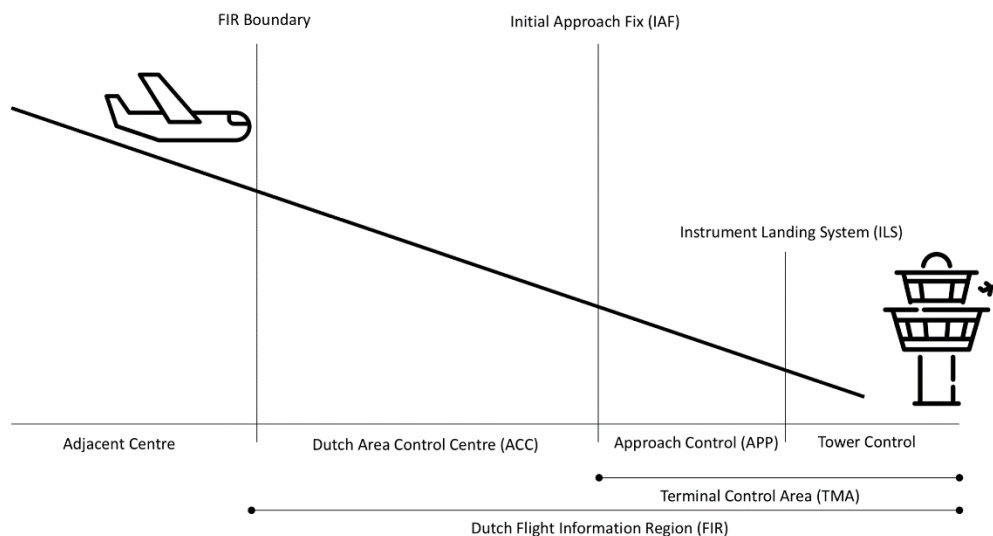


Figure 17: Inbound process Flight Information Region to Runway Threshold

4.4 The operational inbound process and the current use of buffers

The buffer capacity is the room to absorb the traffic that cannot directly be handled in the next sector. This capacity becomes necessary when dealing with over-demand, unexpected circumstances or if one of the chains in the inbound process is not functioning optimally (e.g. bunching of aircraft, arrival times of aircraft, approach planning flaws or air traffic controller flaws). In the current process, mainly ACC makes use of buffers with vectors, speed vectors and holding stacks to absorb traffic, which is not yet allowed to pass the IAF. The use of buffers in the Dutch air space is the difference between the Expected Time Over (ETO) IAF and the Actual Time Over (ATO) the IAF. Additionally, adding buffer time between the ETO and the ATO affects the Actual Landing Time (ALDT).

4.4.1 The Initial Approach Fix

The IAF is the entry point for the Schiphol TMA as visualised in Figure 12. The Amsterdam TMA has three IAFs: SUGOL, ARTIP and RIVER. The ACC controller guides the aircraft towards the IAF to pass the IAF within its timeslot (EAT), with the use of arrival routes as presented in detail in Appendix V: Arrival routes. At the IAFs, the ACC controller can make use of holding stacks to buffer inbound traffic before aircraft enter the TMA. When the aircraft enters the TMA, the air navigation responsibility of the aircraft transfers to the APP (Approach controller).

4.4.2 Area Control Centre

The ACC control area is divided into five sectors and the SPY/PAM area. The sectors are presented in Appendix IV: ACC sectors. The amount of expected traffic determines how many air traffic controllers are necessary to handle the sectors. In peak demand situations, sector 2 can be split up to decrease the workload. The decision of which buffer will be used to handle the traffic is for a large part based on how much delay must be absorbed. With the use of holding stacks, it is easier to absorb more substantial amounts of delay.

Additionally, necessary for this decision is the complexity of the sector, this is affected by (expected) weather, the number of adjustments of the APLN in the previous period, the number of non-inbound traffic, the amount of expected inbounds, the transfer conditions from the adjacent centre and incidents/emergencies. Weather affects the complexity in case of (thunder)storms because aircraft must deviate from the routes. Moreover, wind affects the descent performance and increases or decreases (ground) speed.

4.4.3 (Speed) Vectoring in the ACC sectors

(Speed) Vectoring is the most often used buffer method in the Dutch air space. In the sectors, ACC controllers can use vectoring to deviate from the arrival routes to be able to transfer the aircraft into the TMA within the EAT window. According to the interviewed controllers, flexibility is the main advantage of using vector and speed instructions; there are many possibilities, and the effects of these instructions are easy to predict. Nevertheless, the room to use vectoring is limited, and it can create more complexity in the sectors. There will not be a conflict between traffic when every aircraft follows the standard routes. Once the air traffic controller decides to deviate from these standard routes with the use of vectors, it is possible to create conflict with other traffic, and the situation leads to additional complexity for the controller to keep track. Besides the vector capacity is constraint by the physical characteristics of the sector and the available space, the vector capacity is also constrained by the complexity of the (expected) traffic in the sector and the ability of the air traffic controller to handle the complexity.

4.4.4 Holding stacks in the current inbound operation at LVNL

Holding stacks can be used to absorb long delays according to Nicolaon (2002), and this is agreed with by the air traffic controllers because holdings stacks are not limited by the size of the airspace and aircraft in holding do not interfere with other traffic. Additionally, an advantage of using holding stacks on individual flights is that the delay takes place closer to the airport; when the delay time decreases, it is easier to resolve the delay.

However, according to the interviewed air traffic controllers, the use of holding stacks as a buffer is less flexible than the use of vectoring. The inflexibility is because the traffic must be transferred to the APP controller in the TMA at the right FL and according to the ASAP timeslots (EAT). The ACC controller pushes the aircraft into the TMA within the EAT window ((+ - 2 minutes' deviation). Push is chosen as a vocabulary to explain the situation while referring to the supply chain push-pull strategy. The definition of push is in this situation comparable of the definition in supply chain management: 'A system where orders are issued for completion by specified due dates, based on estimated lead-times, or where the flow of material in a product structure is controlled and determined by the lower levels.' according to the glossary of O'Byrne (n.d.) at The Logistics Bureau.

This push strategy is paced by the ASAP planning; however as explained in 3.2.2, the use of holding stacks is a rigid method in combination with AMAN because holding stacks are imprecise (EUROCONTROL, 2010).

Moreover, losing the height to be at the right FL costs time in a holding stack. In the stack, aircraft are laterally separated in layers of 1000 ft. When an aircraft A descends to the right FL to pass the IAF into the TMA, the following aircraft B can start to descend when there is enough longitudinal separation. Only when aircraft B is on the next layer, the aircraft C above can start to descend. Officially, the controller can give aircraft C command to descend to the next layer when aircraft B is 300 ft. below the previous layer, but the controller determines whether the 300 ft. rule is used depending on the complexity of the situation.

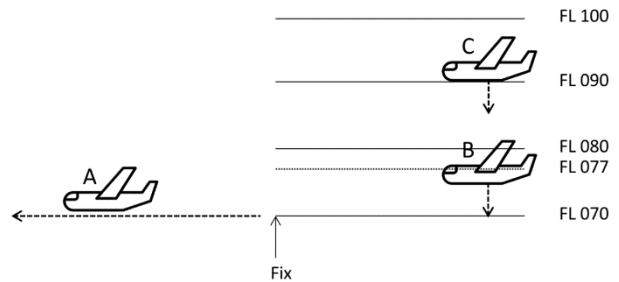


Figure 18: Holding stacks operation

It is important to keep in mind that every aircraft type and pilot reacts differently. When an aircraft is cleared to descent 1000 ft to the next layer in the holding stack, the aircraft will start to descent from approximately 250 ft/min building up to 1000 ft/min. However, shortly after an aircraft's clearing to decent 1000ft, it is forced to level off after roughly 500 ft. As a result, the air traffic controllers indicate that an aircraft needs on average 1.5 minutes to descent 1000ft. The minimum vertical separation between aircraft is 1000 ft. Because of the uncertainty of the exact descent rate according to aircraft type and the pilot flying, aircraft in consecutive layers in a stack cannot descent at the same time. When the top aircraft has a faster descent rate than the aircraft below, the minimum separation will be in jeopardy.

Additionally, the inbound timing to the fix is regulated by the air traffic controller. Inbound timing for a standard hold is one and a half minutes (Skybrary, n.d.-b). However, the exact timing of the whole patterns is difficult to predict in a stack because every aircraft and pilot is different and will not descend or turn at the same rate. Besides, according to the interviews, because holdings stacks are not used often, the proficiency of ACC controllers causes a less efficient use of holding stacks.

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4.5 Conclusions regarding the current inbound operation at LVNL

Approximately three hours before the aircraft enters the FIR, the inbound process at LVNL starts with demand capacity balancing at the ACC. The ACC-SUP and the FMP estimate the demand, and the capacity in the sectors based on air traffic controllers on duty, expected weather, and expected runway combination. When the expected demand exceeds the available capacity, the ACC-SUP has two options: Regulate inbound traffic with ATFM on departure airports or delay absorption in de Dutch airspace. The ACC-SUP considers the requirement of ATFM mainly based on how long the demand will exceed the capacity.

The following step in the inbound process at LVNL starts about 15-30 minutes before the aircraft enters the FIR, with the aircraft popping up in the ASAP system. The APLN can adapt the EATs to sequence a stable traffic flow towards the runways optimally. When the aircraft enters the FIR, the aircraft is in the area of responsibility of the ACC. The ACC controller is responsible for transferring the aircraft over the IAF in the right EAT slot, and this is comparable to a push strategy. To de-bunch the traffic and delay the aircraft to pass the IAF at the right EAT, the controller uses (speed) vectoring or holding stacks. These possibilities to buffer traffic are used

reactively, the aircraft is already in the sector but cannot enter the TMA yet. The choice between vectoring and holding stacks are based on how much delay must be absorbed and the complexity of the sector.

Moreover, the advantage of (speed) vectoring is flexibility and accuracy. The disadvantage of (speed) vectoring is, however, the limited space in the Dutch airspace and the buffer capacity depends on the room to extend the flight paths. Besides, vectors create more complexity in the sectors. The advantage of holding stacks is the possibility to absorb long delays without increasing the complexity in the sectors. However, the exact timing in the holding stack is hard to predict, and this makes the tool rigid and often inaccurate in combination with the ASAP slots. The bottleneck in the usage of holding stacks is mainly the altitude of the aircraft and the time to descent to the next stack layer, besides the reaction time of the pilot also affects the stack performance.

When the ACC controller transfers the aircraft over the IAF, the APP controller sequences the aircraft in line for the ILS intercept. After which the responsibility transfers to the TWR control. After the landing clearance from TWR, the aircraft can land on the runway.

5 What is the current capacity of the inbound traffic buffers?

ACC currently uses mostly (speed) vectoring as a buffer to absorb delay in the sectors. The area available for vectoring is determined quantitatively with the use of historical data (July 2018) in paragraph 5.1. The distribution of time and distance the aircraft uses from the Flight Information Region (FIR) entry to the Initial Approach Fix (IAF) has been investigated for the different arrival routes. The entry FIR waypoint determines which route has been used. To include the expert judgement of the air traffic controllers in the research, the results of the quantitative research is presented to three ACC controllers to verify whether the findings match the operational reality.

5.1 Historical data to determine vector capacity

To analyse the available vector capacity in the current inbound operation, historical data is used. 5.1.1 presents the data processing steps used to analyse the buffer capacity. Because the historical data regards a combination of speed commands and vectoring with the use of headings, the analysis results in the available space in distance and time to use buffer capacity. The analysis of the available vector space is presented in 5.1.2. For every Standard Arrival Route, the minimum/maximum/average and standard deviation has been calculated for the Δ time and Δ miles. This creates insight into the differences and where in the Dutch airspace, the most capacity is to vector traffic. To verify whether the difference in distribution between the routes is significant, a Levene's test has been performed in SPSS. The differences between the routes are presented in 5.1.3.

5.1.1 Data processing steps

The first step in the data processing is to prepare the sets in such a way it is possible to combine the AAA/ARTAS (Table 1) and the VEMMIS (Table 2) datasets.

An example flight of the pre-processed data collected out of AAA and ARTAS:

ACID	FL [ft]	DTG [Nm]	TTG [s]	Waypoint	Abeam-dist [Nm]	Date [YYYYMMDD]	Time [hh:mm:ss]	Hour of the day [h]
AAL204	280.75	151.9	1828	DOLAS	8.05	20180701	05:36:51	5
AAL204	200.00	97.2	1348	ENITO	2.10	20180701	05:44:51	5
AAL204	200.00	96.2	1338	DIBAL	1.96	20180701	05:45:01	5
AAL204	186.00	85.2	1237	BUKUT	0.74	20180701	05:46:42	5
AAL204	180.00	77.6	1165	LAMSO	0.21	20180701	05:47:54	5
AAL204	69.25	39.9	734	SUGOL	0.47	20180701	05:55:05	5

Table 1: AAA and ARTAS dataset ACID: AAL204

Where:

- ACID: Aircraft ID;
- FL: Flight Level in feet;
- DTG: Distance To Go in Nm;
- TTG: Time To Go in seconds;
- Waypoint: The waypoints in flight plan;
- Abeam-dist: The closest distance between aircraft and waypoint;
- Date and time: The moment aircraft passes the waypoint.

An example of the pre-processed provided VEMMIS data:

ACID	ATO	FLIGHT_ID	CALLSIGN	ATA	RUNWAY	HOLDING_NR	HOLDING_TIJD	PIEK_TYPE	PIEK_NR
BT16RV	1-7-2018 06:21:10	11280158	BT16RV	1-7-2018 06:37:39	18C	1	3,033333333	INBOUND	1
GIA088	1-7-2018 06:21:25	11280164	GIA088	1-7-2018 06:39:39	18C	1	6,25	INBOUND	1

Table 2: VEMMIS dataset ACID: BT16RV and GIA088

Where:

- ACID: Aircraft ID;
- ATO: Actual Time Over (stack);
- FLIGHT_ID: VEMMIS registration;
- ATA: Actual Time Arrival (Runway Threshold);
- RUNWAY: Runway used;
- Holding_NR: Amount of holding orbits flown;

- HOLDING_TIJD: Time in holding;
- PIEK_TYPE: Current peak (inbound, outbound, off-peak or night configuration);
- PIEK_NR In which peak the flight landed.

To calculate the delta of time (Formula 1) and track miles (Formula 2) between the FIR boundary and the IAF two new columns have been added to the Excel file:

$$\Delta \text{ time} = \text{time I} - \text{time II} \quad (1)$$

$$\Delta \text{ miles} = \text{DTG I} - \text{DTG II} \quad (2)$$

The following table (3) shows the result of the combined data:

Acid	FL I [ft]	DTG I [Nm]	TTG I [s]	waypoint I	abeam-dist I [Nm]	Date	time I
AAL204	180.00	77,6	1165	LAMSO	0.21	1-7-2018	05:47:54

Acid check	FL II [ft]	DTG II [Nm]	TTG II [s]	waypoint II	abeam-dist II [Nm]	date	time II	ΔTime	ΔMiles	UnID	Holding
AAL204	69.25	39,9	734	SUGOL	0.47	20180701	05:55:05	00:07:11	37,7	AAL20443282	0

Table 3: Combined dataset ACID: AAL2014

5.1.2 Analysis of the available vector space

The calculations on the Δ time and Δ miles per arrival route are presented in respectively Table 4 and Table 5. The assumption is that the distribution, as seen in the historical data, is representative for the vector capacity available; in other words, the capacity used is equal to the capacity available. The assumption has been made because ATC is a very particular job; the actual buffer capacity is dependent on the complexity of the sector in combination with the specific air traffic controller on duty. Cook (2016) even describes ATC as paradoxical: ‘On the one hand, they are bound by restrictive procedures and a great number of very strict prescripts. On the other, they are constantly faced with unusual situations that require a very high degree of intellectual flexibility’. Because of this paradox, the buffer capacity is based on the controllers’ intuition and resolving capacity within the historical data.

To exclude the outliers in the analysis, all values above or below two times the standard deviation (95%) will be excluded in the final range. This assumption has been made because the outliers are not representative for tactical vector capacity, but rather show manoeuvres that were necessary in exceptional cases. The sample size is the number of flights entering the FIR in July 2018. Only the routes with more than 1% of the total number of flights (20,000) are considered to have a significant sample size to continue researching.

FIR entry	IAF	Sample Size	Min Δ time [hh:mm:ss]	Max Δ time [hh:mm:ss]	Average Δ time [hh:mm:ss]	St. Dev. Δ time [hh:mm:ss]
EEL	ARTIP	3820	00:04:53	00:24:00	00:09:20	00:01:16
RKN	ARTIP	164	00:05:17	00:24:00	00:09:00	00:02:30
NORKU	ARTIP	5302	00:04:10	00:22:48	00:09:23	00:01:22
DENUT	RIVER	3762	00:05:32	00:22:53	00:07:46	00:01:09
HELEN	RIVER	2505	00:04:01	00:15:08	00:07:23	00:01:20
PUTTY	RIVER	10	00:06:11	00:13:51	00:08:31	00:02:05
LAMSO	SUGOL	2872	00:04:53	00:12:10	00:06:47	00:00:54
MOLIX	SUGOL	182	00:05:36	00:10:00	00:06:44	00:00:47
REDFA	SUGOL	2897	00:06:05	00:18:20	00:10:10	00:01:18
TOPPA	SUGOL	827	00:06:43	00:20:29	00:09:43	00:01:34

Table 4: Δ time calculations FIR entry to IAF

FIR entry	IAF	Sample Size	Min Δ miles [Nm]	Max Δ miles [Nm]	Average Δ miles [Nm]	St. Dev. Δ miles [Nm]
EEL	ARTIP	3820	25,10	117,40	54,74	4,71
RKN	ARTIP	164	29,00	78,20	47,20	7,92
NORKU	ARTIP	5302	26,20	114,10	55,40	4,78
DENUT	RIVER	3762	34,90	87,10	45,72	3,20
HELEN	RIVER	2505	25,30	78,80	41,67	4,75
PUTTY	RIVER	10	29,50	51,50	34,90	6,29
LAMSO	SUGOL	2872	31,00	63,00	39,04	2,69
MOLIX	SUGOL	182	36,40	47,50	38,26	1,85
REDFA	SUGOL	2897	31,90	77,40	60,03	2,96
TOPPA	SUGOL	827	44,00	86,60	56,44	4,76

Table 5: Δ miles calculations FIR entry to IAF

5.1.3 The differences between routes

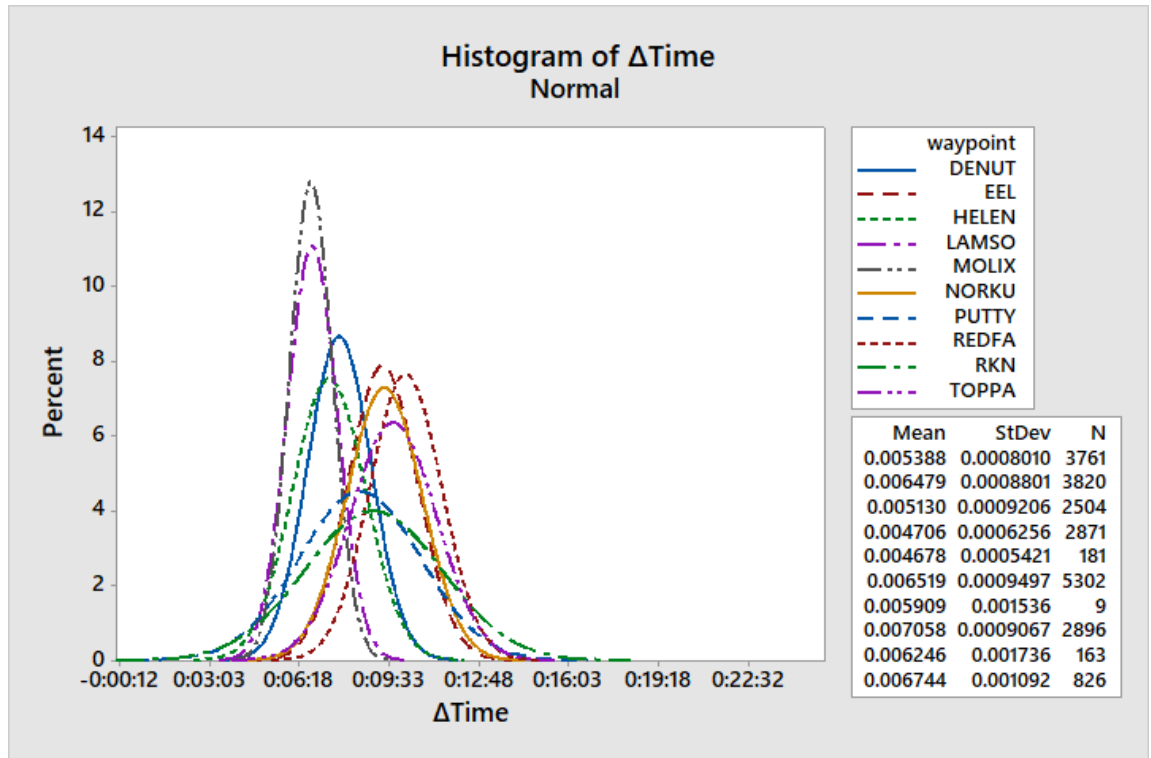
The following step is to determine whether the routes have a significantly different available capacity. Although the individual results are not normally distributed, based on Central Limit Theorem the assumption is made that because of the large sample size, the total sample is normally distributed. With this assumption, it is possible to perform a Levene's test in SPSS to see whether the standard deviations of the different routes are significantly different. The H0 (null hypothesis) is that the standard deviation of the dependent variables Δ time and Δ miles is equal across the groups of waypoints (with a standard certainty of 95%). When the Levene's test is significant (Sig. => 0.05), the H0 is accepted (spsshandboek.nl, n.d.). The results of the Levene's test is shown in table 6:

Dependent Variable	Δ time	Δ miles
Test outcome Sig.:	0,000	0,000

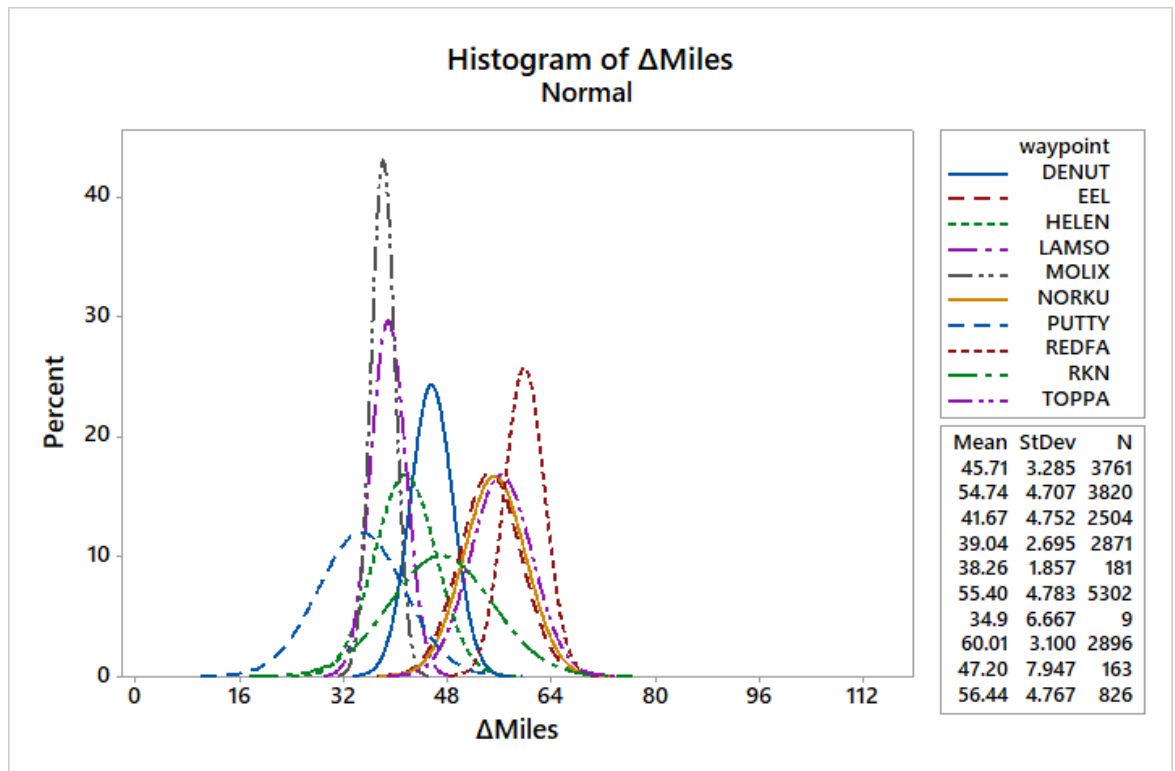
Table 6: Levene's Test of Equality of Error Variances Δ time and Δ miles according to SPSS

Both for the dependent variables Δ time and Δ miles the Sig. is <0,05; therefore, H0 is rejected. The standard deviations of the routes are significantly different. In other words, the vector capacity is different per route. Why these differences in capacity occur is reasoned with the experience of the air traffic controllers:

- Sector 3 (DENUT, HELEN, PUTTY) is more complex in terms of traffic compared to the other sectors;
- Because of the wind direction (often westerly wind) aircraft entering the FIR in the west have a higher ground speed on average, which makes vectoring more difficult and controllers will earlier decide to use holding stacks;
- Almost half of all traffic (46%) enters the IAF at ARTIP; because of the amount of traffic more vectoring is required to sequence the aircraft towards ARTIP. Besides, aircraft enter the FIR on a higher altitude at EEL and NORKU while the transfer agreements are the same at the IAF. Adequate distance is required for the descent towards the IAF;
- When there are multiple segments in the standard arrival route, it is an easier decision to extend the first leg of the route compared to routes with only one straight segment to the IAF. The differences are visualised with the normal distribution per route in percentages, Δ time is visualised in Graph 1 and Δ miles are visualised in Graph 2. To create a normal deviation, SPSS has been used.



Graph 1: Normal distribution Δ time per route in percentages



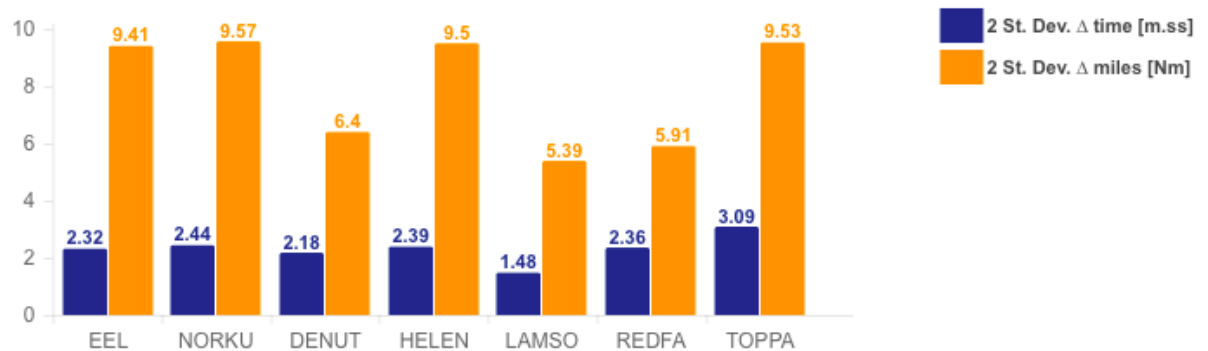
Graph 2: Normal distribution Δ miles per route in percentages

Because of the small sample size RKN, PUTTY and MOLIX are excluded from further conclusions. After the outliers have been excluded, the range between the plus/minus two standard deviation and the average represent the available vector capacity on the different routes.

5.2 Conclusions on the current capacity of the inbound traffic buffers

In the current operation, LVNL uses (speed) vectors and holding stacks to buffer traffic in the Dutch air space. Vectoring is an accurate measure used to sequence the traffic flow. With the use of vectoring as a buffer, there is a difference between the routes in the preference of absorbing delay with the use of speed vectoring or headings. Besides, there is a difference in how much delay can be absorbed. These differences are the result of the amount of traffic, the complexity of the sector, the wind as it affects the descent performance, and the physical characteristics of the routes and sectors.

The available room to vector in distance and time per route is shown in Graph 3. The capacity is based on two standard deviations in distance and time to represent 95% vector capacity used by the air traffic controllers. The 5% outliers excluded are assumed exceptional situations and not representative for the actual available capacity. The room to vector is based on historical data to include the resolving capacity of the air traffic controller; however, the vector capacity historically used is the perception of the available vector capacity by the controllers.



Graph 3: Two times standard deviation (95%) Δ time and Δ miles per route

6 How can the LVNL operation use buffers proactively to manage inbound traffic?

This section gives insight in what possibilities the LVNL has to proactively buffer traffic in the Dutch airspace, by analysing the applicability of the proactive usage of buffer capacity in London Heathrow (6.2). First, however, the definition of proactive buffers is explained in the first paragraph (6.1). As desk research shows, it is hard to predict the inbound flow, which makes buffers necessary to manage the inbound traffic. The possibilities to buffer traffic are: ATFM delays before departure, linear holding and XMAN in the cruising phase of flight and vectoring and holding stacks in the ASMA.

Amsterdam Schiphol is the airport with the most ATFM delays in Europe (EUROCONTROL, 2018) and makes use of ATFM delays to be able to deal with the unpredictability of inbound traffic. As an opposite, to deal with the unpredictability of air traffic London Heathrow mainly uses buffers in the ASMA area and is the airport with the most ASMA delays in Europe (EUROCONTROL, 2018b). The scope is to investigate possibilities to manage inbound traffic within the Dutch airspace. Because London Heathrow has the most delay in the last phase of flight, their concepts to buffer inbound traffic are interesting to research, with the purpose to investigate whether the LVNL operation has more possibilities to use buffers in managing the inbound traffic in the Dutch airspace.

The purpose of 6.3 is to give the first insights in how holding capacity works when the usage would be extended in normal operations. Interviews with two ACC controllers in chapter 4 were used to analyse what the largest bottleneck is in the holding capacity process and with this a simplified model is created. Paragraph 6.4 briefly explains linear holding as buffer option.

6.1 Definition of proactive use of buffers

As stated before, the definition of buffers in this research is the potential to absorb traffic in the Dutch airspace to wait for the availability of runway capacity. This can be done reactively, which means 'as a reaction to events or situation rather than acting first to change or prevent something' according to the Cambridge Academic Content Dictionary (2019). In other words, reactive buffers are used to respond to the capriciousness of inbound traffic. Proactive, on the other hand, means 'acting in anticipation of future problems, needs, or changes' according to Merriam-Webster dictionary (2019) or 'taking action by causing change and not only reacting to change when it happens' according to Cambridge Academic Content Dictionary (2019). Proactive usage of buffers means therefore, the anticipation to absorb traffic in order to prevent gaps in the arrival sequence to use the runway capacity optimally. Proactive use of buffers is a result of the consideration of the supervisor to regulate inbound traffic based on the capacity to absorb traffic.

To proactively use buffers, the supervisor requires information on the consequences of the use of buffers. Besides, the supervisor needs information on the amount of expected inbound traffic, the options available to delay and its capacity to absorb traffic, and the conditions of availability of these buffers. Only with this information, the supervisor can proactively make the consideration to use buffers. Because the decision to regulate the inbound traffic has to be made two hours prior FIR entry, the consideration to proactively use buffers is made in that particular timing.

6.2 Comparison London Heathrow and Amsterdam Schiphol

Although a different operational concept for Amsterdam Schiphol is excluded from this research, it is interesting to compare the holding concept at London Heathrow and Amsterdam Schiphol to analyse the differences. Where Hans Alders is a known name in the debate about the future of the Amsterdam Schiphol in the Netherlands, the British have Sir Howard Davies examining the requirement for extra airport capacity at London Heathrow considering the impact to the society (Martin, 2016). Both airports are operating near the limits of their capacity. The characteristics of London Heathrow and Amsterdam Schiphol are set against each other in the following table (Table 8). While the aircraft movements are comparable, London Heathrow only has two runways

and can get the most out of the runway capacity by feeding the runway from multiple stacks. Apart from the busiest hour in the morning, Heathrow uses one arrival runway to ‘provide local communities with respite’ according to the airports’ website (Heathrow, 2018). The differences in average ASMA delay in Table 8 indicate that the airlines at London Heathrow have accepted the extra track miles, fuel usage and time as a burden of the limited runway capacity.

	London Heathrow	Amsterdam Schiphol
Amount runways	2	6
Amount holding stacks IAF	4	3
Aircraft movements per 2018	475,624	499,444
Legal movement gap in 2018	480,000	500,000
Declared peak hour arrival capacity 2018	45	68
Average ATFM delay 2018 [min]	1.84	2.38
Average ASMA delay 2018 [min]	7.7	1.5

Table 7: Comparison London Heathrow and Amsterdam Schiphol (Schiphol, 2019) (Heathrow, 2019) (Alders, 2019) (EUROCONTROL, 2019d)

Considering the management of the inbound traffic, both airports use a different concept to optimise their capacity. Whereas Amsterdam Schiphol uses a system that is comparable to a push strategy (4.4.4), London Heathrow uses a concept to manage the flow into the TMA that is comparable with the pull strategy. According to the glossary of leanproduction.com (n.d.), the definition of a pull system in supply chain logistics is: ‘A method of regulating the flow of goods both within the factory and with outside suppliers and customers. Based on automatic replenishment through signal cards that indicate when more goods are needed.’ This system is also known as Kanban (leanproduction.com, n.d.). In other words, every process step takes precisely what is needed from the previous process step to operate the process efficiently. A pull strategy is the opposite of a push strategy; in a push strategy, the flow of goods between different workstations are less adjusted to one another’s actual throughput. According to Haskins (2013), the approach controllers at London Heathrow pull the aircraft out of the stack in the order of the optimal wake turbulence categories. An additional advantage of the system used at London Heathrow is that the approach controller has a more tactical overview on the available runway capacity and is able to identify gaps where the ACC controller in the Amsterdam Schiphol system does not have this overview, according to approach controller and strategy expert in a personal conversation (Appendix VI). For London Heathrow, holding stacks are an effective and efficient buffer in combination with their pull strategy. Amsterdam Schiphol has a push strategy; therefore, the use of holding stacks are less effective in the current layout than the holding stacks in the London Heathrow operation.

6.3 Holding stacks as proactive buffers in the Dutch airspace

An interview with two ACC controllers (Appendix II) results in the first insights in the bottleneck in the holding stack operation. The interviews are the basis of a simplified model to analyse the throughput times of aircraft in the holding stack when the usage would be extended during normal operations. The analysis of the throughput times is presented in 6.3.2. However, first, the current holding stack layout is explained in 6.3.1. Throughput times are the first consequence analysed to give insight into the proactive use of the holding stack operation. Nonetheless, the supervisor requires more information to visualise the consequence of a different operational balance: more traffic in the stacks means less room to absorb any adversity. To visualise how many aircraft will have to be put in a stack to decrease the amount of ATFM simulation has to be used.

6.3.1 The current holding stack layout

In the current airspace layout, the Amsterdam TMA has three IAFs: ARTIP, RIVER and SUGOL. According to the map (Figure 14 and 15), the three IAFs consist of the same levels (FL 070 to FL 240) (Luchtverkeersleiding Nederland, n.d.-b). However, because the aircraft enter the FIR on different altitudes from different routes, the actual stack capacity is not the same. According to the ACC controllers who have been interviewed, commanding aircraft to climb during the descent phase does not occur in normal operations. Therefore, when aircraft enter the FIR on a lower FL, the stack capacity is less than the maximum as visualised in Figures 14 and 15.

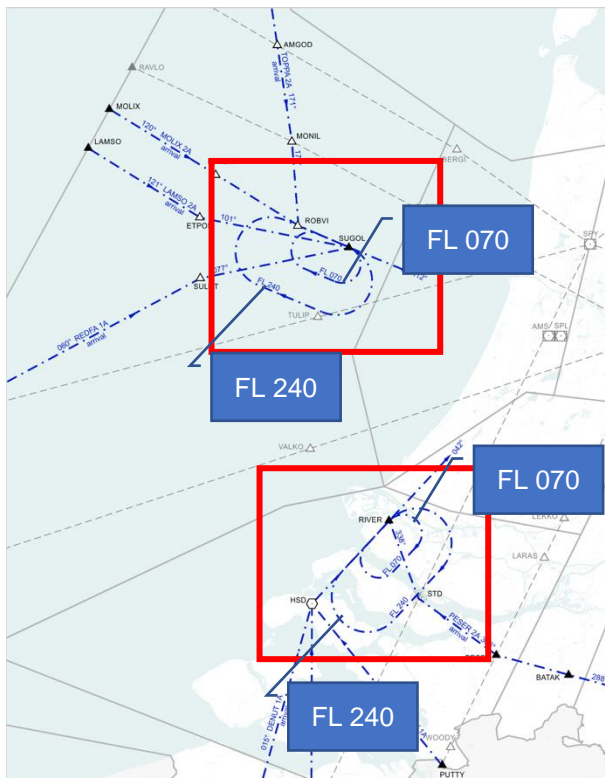


Figure 20: STARs SUGOL and RIVER (Compiled by author based on Luchtverkeersleiding Nederland (n.d.-b))

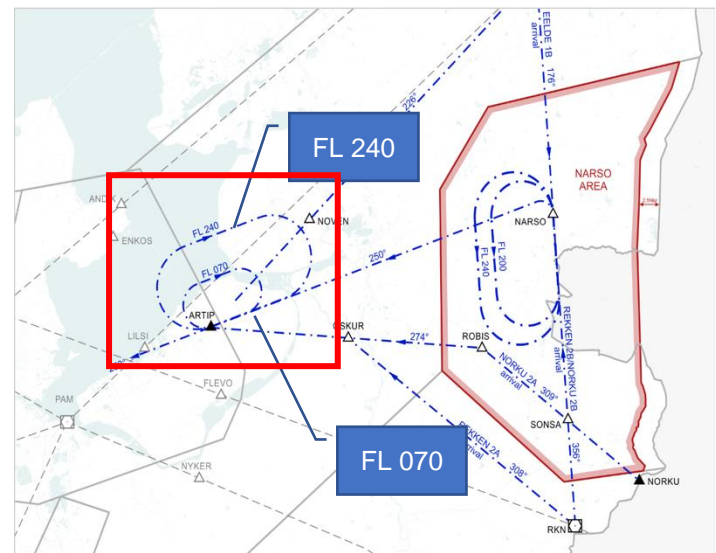
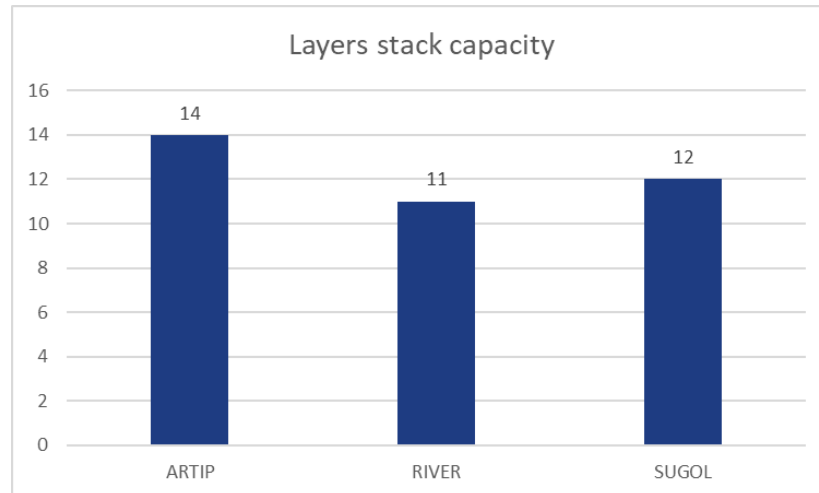


Figure 19: STARs ARTIP (Compiled by author based on Luchtverkeersleiding Nederland (n.d.-b))

The data (Table 9) shows that the average FIR entrance altitude [ft] is the highest at routes in the direction to ARTIP (FL250). Therefore, it does not seem to be a problem to use the total stack of 17 layers. The average FIR entrance altitude at RIVER is around FL210, which means the top three layers could be devious to use in normal circumstances. The same applies to the top two layers of SUGOL, where the average FIR entrance altitude is around FL220. Additionally, the altitude transfer agreements between ACC and APP are between FL070 and FL100. These layers are considered as operational resolution room and are not always available as stack capacity. The remaining available capacity is listed in Graph 4. However, even apart from the already considered operation resolution room layers, the current holding stack operation is used to absorb contingencies. How many layers required as safety margin has to be researched in a simulation model.

FIR entry	IAF	Average FL [ft]
EEL	ARTIP	24202,72
NORKU	ARTIP	26071,57
DENUT	RIVER	21982,91
HELEN	RIVER	19248,00
LAMSO	SUGOL	20311,51
REDFA	SUGOL	22595,99
TOPPA	SUGOL	22595,09

Table 8: Average altitude at FIR boundary



Graph 4: Stack capacity per IAF

6.3.2 Holding stacks throughput

A simplified theoretical model of the holding capacity is created based on qualitative data obtained by interviewing air traffic controllers. The purpose is to give the first insights into how holding capacity works when the usage would be extended. There is only a minimal amount of data available on the current use of holding capacity (maximum of two layers in the used data set); therefore, the data did not provide enough insight in what would happen if the usage is significantly increased. Interviews with two ACC controllers give insight into what the most significant bottleneck is in the holding capacity process and which patterns have been abstracted from the insights of the controllers. These patterns result in a simplified model to show what the bottleneck in the operation is and what happens if the holdings stack usage will increase. The model has been presented to three ACC controllers to validate whether they recognise what the model indicates.

The descending process in a holding stack is schematically visualised in Figure 13. The assumption is made that every aircraft has the same descending rate and reaction speed. Additionally, no variables other than the bottleneck altitude are considered in the illustration. In the first time interval, aircraft N1 is cleared out of FL100 into the TMA and aircraft N2 is cleared from FL 110 to descent to FL 100. In time interval 2, aircraft N2 has descended to FL 100, and Aircraft N3 is cleared to descent to FL 110, and so on. The result of this pattern is that aircraft N5 must wait at FL140 and can only start to descent in the time interval number 4. This illustration visualises how fast the delay time increases because of the bottleneck altitude.

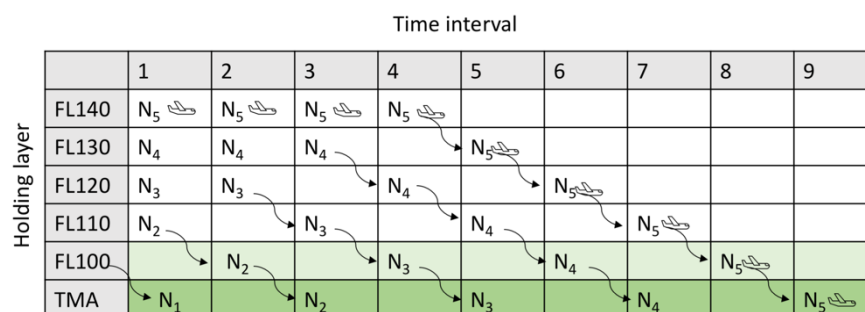


Figure 13: Visualisation of the bottleneck altitude in vertical holding

The bottleneck altitude is reflected by following theoretical Formula (3) on the descending process in a holding stack from the top level to the level of transfer:

$$t_{holding} = (N_i - 1)(t_{wait} + t_{movement}) \quad (3)$$

- $t_{holding}$ = Total time in holding of N_i
- N_i = Number of aircraft in sequence

- t_{wait} = Average descent time per stack layer all aircraft
- $t_{movement}$ = Descent time per stack layer of N_i

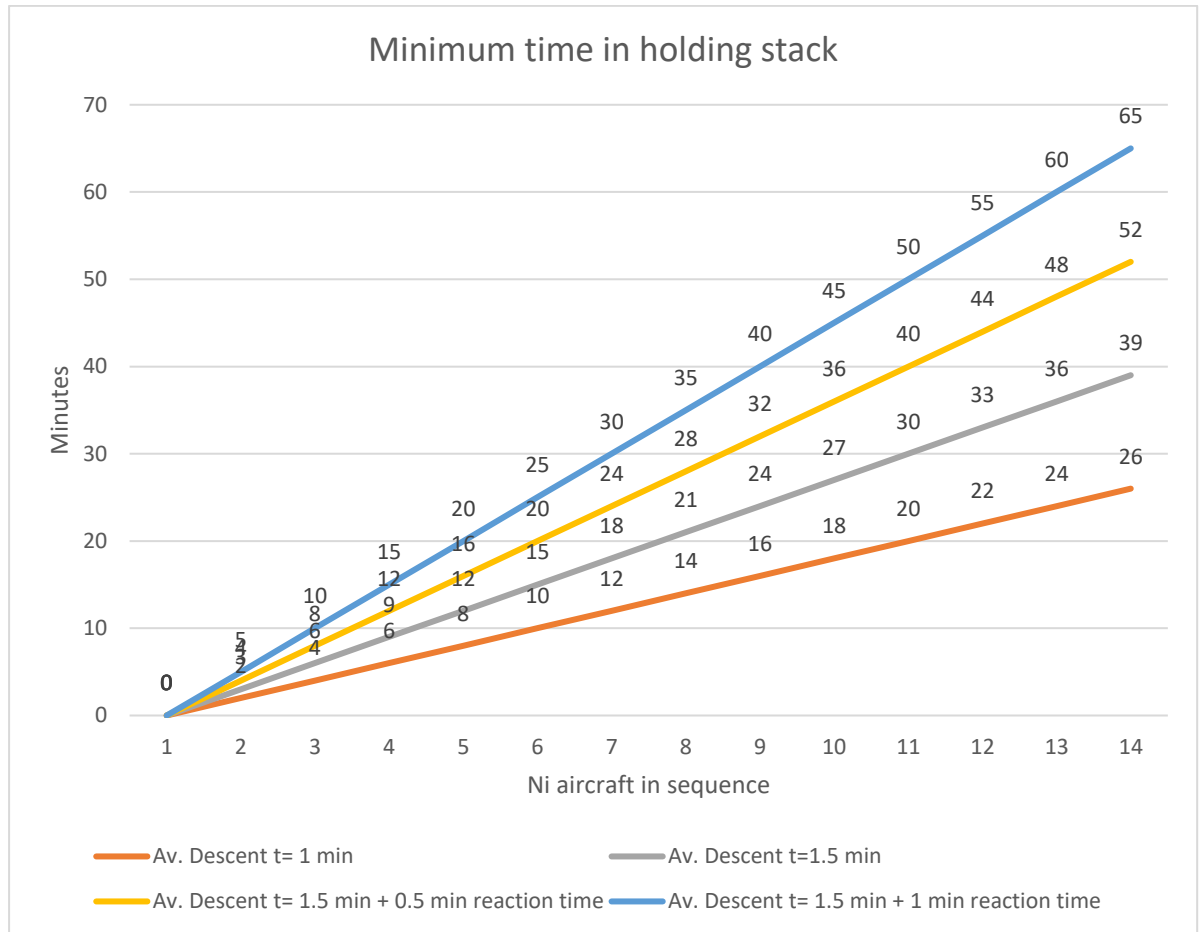
The formula is however based on static variables; there is no difference considered for aircraft types. An essential addition to Formula 3 is the reaction speed of the pilot. Once the pilots receive clearance to start the descent the pilot first must read back the clearance and then set up the descent in the cockpit, before the actual descent starts. This reaction speed affects both the t_{wait} as the $t_{movement}$ because the t_{wait} represents the average descent time per stack layer of all the aircraft in the stack. Including an average reaction time as a constant in the total holding time, results in Formula 4:

$$t_{holding} = (N_i - 1)(t_{wait} + t_{reaction}) + (N_i - 1)(t_{movement} + t_{reaction}) \quad (4)$$

Graph 5 visualises the increase in delay time in four scenarios.

- Scenario 1 is a scenario with all fast-descending aircraft (average of 1000 ft per minute) and no reaction time.
- Scenario 2 is the scenario as described as realistic by the air traffic controllers during the interview; all aircraft need 1.5 minutes to descent to the next layer, however, no reaction time is considered.
- Scenario 3 is based on scenario 2; only this scenario adds 0.5 minutes' reaction time into the calculation.
- At last, the slowest scenario 4, also based on scenario 2, only this scenario takes an average reaction time of 1 minute into account.

As a result of the simplification of the holding stack delay time, Formula 4 represents a theoretical linear relation as visualised in Graph 5. The simplification does not include the differences in aircraft performance, human behaviour and weather condition, nor the position of the aircraft in the holding pattern; nonetheless, the simplification does visualise a minimal time in the stack, and these other factors will not result in a decrease in throughput time.



Graph 5: Total time in holding stacks of 4 scenarios [min]

6.4 Linear holding as proactive buffer option

Next to vertical holding, it is also possible to use linear holding in the last phase of flight with the use of Point Merge. As explained in 3.2.3, linear holding has a more positive impact on fuel consumption and is a more suitable pairing with AMAN than the use of vertical holding; nevertheless, the amount of delay linear holding absorbs depends on the available airspace. According to EUROCONTROL (2016b), already seven control centres have implemented Point Merge, among which London City Airport and Paris ACC. With the use of Point Merge the STARS can be extended to include the buffer in the route instead of using vectoring. Whenever the buffer is not necessary, the controller can give a direct to the aircraft. This way, the airline has beforehand knowledge on the realistic arrival time in case the buffer capacity is necessary and will not be surprised with extra vectoring time.

6.5 Conclusions on how LVNL can use buffers to manage inbound traffic

LVNL can use vertical holding stacks and lateral holding as proactive buffers to manage the inbound traffic. The definition of proactive buffers is the anticipation to absorb traffic to prevent gaps in the arrival sequence to optimally use the runway capacity two hours prior FIR entry considering the amount of regulations necessary. London Heathrow has four holding stacks to feed one arrival runway optimally. Besides, Heathrow uses a pull strategy in which the APP controller pulls the aircraft out of the stack in the most optimal wake turbulence category. This way, the vertical holding stacks are an effective buffer for the Heathrow operation. Nevertheless, as described in 3.2.3, NATS is researching less fuel-intensive ways to buffer inbound traffic to Heathrow.

The characteristics of Amsterdam Schiphol are different from London Heathrow. Schiphol has holding stack possibilities at the three IAFs (ARTIP, RIVER, and SUGOL). During inbound peaks,

Schiphol operates two arrival runways. And as an opposite to the Heathrow operation, the ACC controller transfers the aircraft into the TMA with a push strategy. Because of these differences, the use of holding stacks in the current operation is a less effective tool for Amsterdam than for London Heathrow. The total capacity of the holding stacks depends on the altitude of the aircraft in the sectors, as the aircraft will not climb during the descent phase in normal operations. Therefore, the ARTIP stack has the most capacity of 14 layers compared to RIVER (11 layers) and SUGOL (12 layers) based on average FIR entrance altitude in July 2018. When one holding stack is used to feed one runway, the delay time increases rapidly with the increase of aircraft in stack. With the use of one stack, a time interval is lost because of minimal separation and descent performance. The time interval is determined by the average rate of descent of the aircraft and the reaction speed. Although the delay is absorbed near the airport, which could make it easier to resolve delay with individual flights; in general, holding stacks take time to resolve because of the altitude of the aircraft. According to the analysis, the minimal throughput time of 14 aircraft is 52 min, considering a scenario of an average descent rate of 1.5 min per 1000ft and a reaction speed of 0.5 min.

Next to vertical holding stacks, an increasing number of European airports makes use of linear holding with Point Merges. Point Merge is a less fuel-intensive way to delay traffic than vertical holding stacks. Additionally, according to the literature is Point Merge a more suitable pairing with AMAN (EUROCONTROL, 2010). The amount of delay that linear holding absorbs however depends on the available airspace, which is a scarce resource in the Dutch airspace. To determine what the actual proactive linear holding capacity is, more research is necessary on the physical characteristics of the sectors to define the maximum extension of a route. The maximum extension can be used as a linear hold. Nonetheless, the effectiveness of linear holding is dependent on the size of the air space and according to Nicolaon (2002) linear holding in the airport area only has the capacity to absorb *reasonable* delays of 6 to 7 minutes. Nicolaon (2002) has not based this conclusion on the capacity to absorb delay in the Dutch airspace.

7 Research Findings

This chapter consists of a presentation of the research findings according to the analysis chapters. Paragraph 7.1 explains how the current inbound traffic operation of LVNL is arranged according to LVNL ACC manuals, observations in the ACC and interviews with air traffic controllers. Paragraph 7.2 provides the results of the current capacity of the (speed) vectoring inbound buffers. At last, paragraph 7.3 presents in what way LVNL can make use of buffers proactively, based on a comparison between London Heathrow and Amsterdam Schiphol. Additionally, paragraph 7.3 presents the results of a mathematical representation of extending holding stack usage in the current layout.

7.1 How is the current operation of LVNL arranged regarding inbound traffic?

The responsibilities of inbound traffic from the boundary of the Dutch airspace to the runway threshold are split up between the ACC, APP control and TWR control. ACC is responsible for the traffic in the sectors from the moment the aircraft enters the Dutch airspace until the aircraft is transferred to APP control in the TMA. APP control is responsible for sequencing the traffic to the ILS intercept, where after the aircraft is transferred to TWR control.

APP control uses an AMAN system to create an optimal sequence flow towards the runways. Approximately 15-30 minutes before the aircraft enters the Dutch airspace, the aircraft will pop up on the screen of the approach planner, and the aircraft receives an EAT slot to pass the IAF into the TMA. Although Amsterdam Schiphol is level 3 coordinated airport, previous research concludes (Moll, 2019) (Riebeek, 2019) that flights often arrive in accumulated chunks instead of even distribution, as a result arriving traffic has to be delayed to sequence it towards the runway. The ACC controller is responsible for delivering the aircraft at the IAF within the EAT window and can use (speed) vectoring and holding stacks to de-bunch the traffic and adjust the timing of individual aircraft.

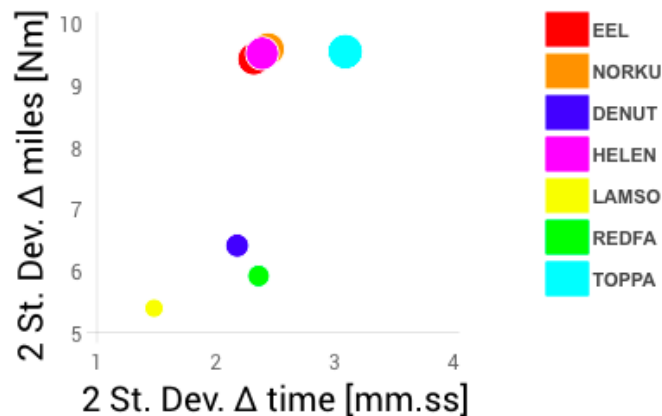
Based on the observations and the interviews, the advantage of (speed) vectoring is the flexibility and accuracy. However, the room to absorb delay with vectoring depends on the available room in the sectors and is limited. When longer delays must be absorbed, holding stacks can be used. However, the exact timing in the holding stack is hard to predict, and this makes the tool rigid and often inaccurate in combination with the ASAP slots.

ACC uses (speed) vectoring and holding stacks to absorb the difference between the EAT window and the approach timing without interference and does not use these tools pre-tactically to determine capacity. When the traffic demand exceeds the capacity in the pre-tactical phase (three hours before the aircraft enters the FIR), the ACC-SUP regulates the inbound traffic with (EUROCONTROL) ATFM slots on outstations.

7.2 What is the current capacity of the inbound traffic buffers?

This sub-question presents the current capacity in (speed) vector buffers, the most often used tool to delay traffic in the current operation.

To determine what the current vector capacity is, first, a Levene's test is conducted to see if all the routes have the same capacity. The test concluded that the routes are significantly different. The assumption has been made that the capacity used to vector is representative to the capacity available. The range of two standard deviations (95%) has been calculated for the Δ time and Δ miles of every route to analyse what the used vector capacity is in July 2018 (20,000 flights). As illustrated in Graph 6 below, the routes EEL, HELEN and NORKU have a comparable used capacity. The route TOPPA is similar to these three routes in Δ miles; however, TOPPA has the highest distribution in Δ time. At the routes LAMSO, DENUT and REDFA vectoring is used the least.



Graph 6: Δ miles and Δ time combined

According to interviews with air traffic controllers, the difference between the routes is a combination of multiple factors. First, the vector capacity is constraint by the physical characteristics of the sector. The layout of the arrival routes (Appendix V) concerning the departure routes, determines how much space there is to deviate from the routes. Moreover, when there are multiple segments in the standard arrival route (which is the case for EEL, NORKU, DENUT and HELEN), it is an easier decision to extend the first leg of the route compared to routes with only one straight segment to the IAF. Besides, the altitude at the FIR boundary and the distance from the FIR boundary to the IAF determine the steepness of the descent, this must be considered with the vectoring because it affects the descent performance.

An additional factor to the capacity is the weather. Apart from weather situations such as (thunder) storms affecting the operation, the weather should also be considered in the capacity planning of the different routes. In the Amsterdam Schiphol operation, westerly wind is usually the case. The result of westerly wind is a higher ground speed at the routes originating from the west (this applies the most for LAMSO, but also REDFA and TOPPA), which decreases the available time to vector at these routes.



Figure 21: Additional factors affecting capacity

Furthermore, the complexity of the sectors is different. Especially sector 3 (DENUT and HELEN) has much other traffic next to the inbounds for Amsterdam Schiphol. In a complex and busy air space, it is not desirable to deviate from the arrival route with vectors because it can create conflicts with other traffic. However, this no longer applies when the buffers are included in extended arrival routes as with linear holding. Next to complexity, the amount of traffic influences the amount of vectoring necessary to sequence the traffic. In the analysis, most traffic was handled via NORKU and EEL.

7.3 How can the LVNL operation use buffers proactively to manage inbound traffic?

LVNL can make use of (speed)vectoring and vertical holding stacks to buffer traffic in the current operation. The options LVNL has to buffer traffic proactively are presented in 7.3.1. Where after, sub-section 7.3.2 presents the results of increased use of vertical holding stacks and the effects to the peak hour capacity.

7.3.1 Different options to buffer inbound traffic proactively

As a result of a literature review, the proactive buffer possibilities LVNL has to manage inbound traffic in the Dutch airspace are the use of vertical holding stacks and linear holding. The definition created for the proactive use of buffers is: The anticipation to absorb traffic to prevent gaps in the arrival sequence to optimally use the runway capacity two hours before FIR entry. Proactive use of buffers is a result of the supervisor's consideration to regulate inbound traffic based on the capacity to absorb traffic.

London Heathrow uses mainly vertical holding stacks but recognises that vertical holding is a fuel-intensive tool to optimise runway capacity and is researching more environmentally friendly tools to buffer inbound traffic. One of the less fuel-intensive tools is Point Merge as linear holding. An increasing number of European airports already makes use of linear holding with Point Merges. The use of linear holding is comparable to (speed) vectoring. Thus, the amount of delay that linear holding absorbs depends on the available airspace and which is a scarce resource in the Dutch airspace. It is possible to extend the amount of absorbable delay with the use of Extended Arrival Management (XMAN). XMAN is an effective tool for de-bunching and sequencing traffic without excessive extra fuel use; the delay that can be absorbed depends on partnerships with adjacent ANSPs.

7.3.2 The effects to the peak hour capacity of holding stacks

How the LVNL operation can use vertical buffers also depends on the Amsterdam Schiphol characteristics, hence differently than with linear holding. London Heathrow is very effectively sequencing traffic in the most optimised order towards the runway by using four stacks to feed only one runway. On the contrary, the Amsterdam Schiphol operation uses only three stacks to feed two runways, and the aircraft enter the TMA in order to EAT slot. The comparison has been made between the production management push/pull strategy and the strategy as used by the airports to enter aircraft into the TMA. The strategy London Heathrow uses is comparable to the pull strategy because the APP controllers take the aircraft out of the stacks to efficiently sequence the aircraft to the runway. At Schiphol, the ACC controllers transfer the aircraft into the TMA according to the ASAP planning; this strategy is comparable to the push strategy.

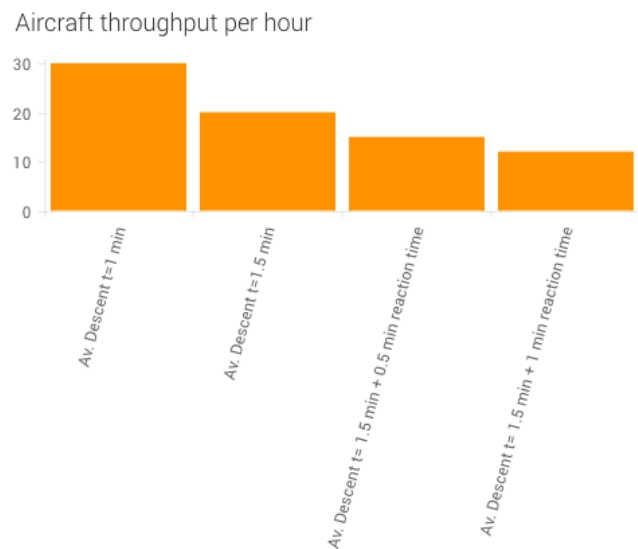
Based on interviews with air traffic controllers, to visualise the effect of holding stacks to the Dutch arrival operation, a representation (Formula 4) (Figure 15) of the most significant bottleneck is created. The bottleneck in the usage of holding stacks is mainly the altitude of the aircraft and the time to descent to the next stack layer. Besides, the reaction time of the pilot also affects the performance of the stack.

$$t_{holding} = (N_i - 1)(t_{wait} + t_{reaction}) + (N_i - 1)(t_{movement} + t_{reaction}) \quad (4)$$

With this Formula (4), four scenarios have been created to demonstrate the effect of using one stack to one runway (Graph 5). With these scenarios, it becomes visible that the delay time increases rapidly with the increase of aircraft in stack. The reason for this is that the aircraft must wait until the aircraft below is cleared on the next level, before the aircraft can start its descent. As a result of the waiting, one time interval gets lost. According to the air traffic controllers who have been interviewed, 1.5 minutes is a reasonable time interval for an average aircraft to descent 1000ft in a holding stack. Based on this scenario (Av. Descent t = 1.5 min), a stack can process 20 aircraft in 1 hour. When 0.5 minutes is added to this scenario for the pilots' reaction time, this figure decreases to 15 aircraft per hour as can be seen in Graph 7. Graph 7 visualises

the aircraft throughput per hour according to the four scenarios used to analysis the throughput times with the use of one stack. According to this analysis, when considering the scenario experienced as reasonable by the air traffic controllers, holding stacks are not effective enough to realise the declared peak hour capacity of 68 inbound movements in the current layout.

Besides, when the demand stays equal to the current demand, and the time it takes to process the demand increases with the use of holding stacks in the current system; as a result, the peak hour spreads out over a more extended period of time, and the operation will have less time to recover in between peaks. Also, when the peak hours are more spread out, the actual demand in between peaks will be higher, which might require a different runway strategy and more use of 2+2 runways to cope with the demand. However, according to the current political debates, increasing the amount of 2+2 runway usage is not possible. Also, flattening out the peak hours will affect the hub-efficiency for KLM and partners.



Graph 7: Aircraft throughput per hour according to four scenarios

8 Discussion

Both quantitative and qualitative research has been used to investigate which operational possibilities LVNL has to buffer inbound traffic in the Dutch airspace and to what extent these buffers can be used in managing the operational inbound peak capacity. To determine the current linear buffer capacity, 20,000 flights from July 2018 were analysed. Because July is the busiest month of 2018, the range of Δ time and Δ miles between the FIR entrance and the IAF is considered a fair representation of the available room to buffer. The vertical buffer capacity is based on interviews with two air traffic controllers due to the scarcity of the time of the air traffic controller; nevertheless, the controllers chosen were familiar with capacity analytics. The patterns are verified with another air traffic controller to validate this research.

The current investigation provides insights for the supervisors at LVNL in what the effects are of using buffers in the current layout of the Dutch airspace. The objective is to be able to issue less ATFM slots. Although insight is provided with this research, the capacity of the buffers within in the current layout of the Dutch airspace is limited and might not be enough to be able to decrease the issuing of ATFM slots. An underlying cause for this result is the size of the Dutch airspace. The Netherlands has relatively small, but complex airspace and the capacity to buffer within the boundaries of the FIR is limited. The research set-up was broad, and because the research encountered several sub-topics which all required a detailed investigation, it was challenging to result in solid conclusions.

8.1.1 How is the current operation of LVNL arranged regarding inbound traffic?

The overview of the current LVNL inbound operation has been created based on ACC and AMAN documents (Luchtverkeersleiding Nederland, n.d.-b) (LVNL, n.d. –b), observations in the ACC and interviews with two ACC controllers. This was an effective method to provide a broad overview of the current operation. Nonetheless, air traffic control is a very peculiar job, which requires a high amount of intellectual flexibility of the controller. This makes the results highly dependent on human behaviour. To provide more insight in the decision-making process, it is necessary to increase the sample size of air traffic controllers, because during the observations the air traffic controllers had a different perception on the complexity and difficulty level of situations.

8.1.2 What is the current capacity of the inbound traffic buffers?

The results of the data analysis concerning the capacity to buffer in the current operation suggests a room to linear buffer of two to three minutes in the Dutch airspace. This result is in line with the expectations according to the literature, because linear holding capacity is dependent on the size of the airspace (Nicolaon, 2002). To determine the linear buffers more research is necessary on the physical characteristics of the sectors. This research has analysed historical data, which indicates what buffer capacity air traffic controllers have been using. The actual linear buffer capacity, however, could be different than what the perception of the air traffic controllers is. It is interesting to see whether the perception of the air traffic controllers on the available capacity is different than the actual capacity and what the reason for this is.

8.1.3 How can the LVNL operation use buffers proactively to manage inbound traffic?

Another option to buffer traffic is with the use of vertical holding stacks. According to the literature holding stacks can be used to absorb longer delays (Nicolaon, 2002); however, a comparison with London Heathrow operation results that holding stacks in the current airspace layout are not effective enough to realise the desirable peak hour capacity. This expectation is confirmed with a theoretical analysis of the holding stack throughput times in the current layout. It must be taken into account that the throughput times of the holding stacks are only based on the most significant bottleneck, the altitude. The altitude is one variable affecting the throughput times. To give a more solid conclusion, several other variables must be considered as well: The position of the

aircraft in the stack, the aircraft performance, human behaviour of the pilot and the controller, weather and incentives affecting the pilot's performance. Once these variables are included in the research, the results could end up differently. Nonetheless, the altitude is the most significant bottleneck; therefore, it is unlikely that the throughput time decreases when these factors are considered. Besides, it is essential to determine how much capacity is necessary to absorb contingencies to determine the actual available number of stack layers to use proactively.

The advice for further research is to investigate the possibilities of buffers traffic in cooperation with neighbour ANSPs and through FABEC. The stakeholder analysis indicated that predictability is essential for all stakeholders and increasing the controllable area increases the predictability for all stakeholders. Moreover, when determining the approach on how to manage inbound traffic, the effects to the different stakeholders should be considered. At the beginning of the research, the different objectives of the stakeholders should have been included in the methodology set-up. Developing methods to cope with the uncertainty and incomplete information is relevant throughout the whole industry, and more integration of arrival management information in systems as A-CDM could open a whole range of new research possibilities.

To answer the main-question, the consideration has been made to investigate the different buffer possibilities in shallow. To be able to result with more solid conclusions the research question was too broad, and it is essential to split up the research question to investigate multiple smaller subjects in more detail.

9 Conclusions

The research investigated the research question “Which operational possibilities does LVNL have to buffer inbound traffic and to what extent can these buffers be used in managing the operational inbound peak capacity? Literature is used to determine the operational possibilities to buffer within the Dutch air space. The first sub-question is used to provide an overview of the current operation to be able to test the applicability of the different operational possibilities. After which sub-question two results in the capacity of the currently used buffer strategy based on historical data. The third sub-question investigates a buffer scenario distracted from the London Heathrow operation and provided insight in how this buffer scenario can be used into managing the operational inbound peak capacity.

9.1.1 Conclusions on the current operation of LVNL arranged regarding inbound traffic

There are several possibilities to deal with the unpredictability of air traffic. In 2018, Amsterdam Schiphol had the most Air Traffic Flow Management (ATFM) delays of all European Airports to be able to cope with the traffic demand, especially around and during peak hours. When traffic arrives in bunches at the border of the Dutch Flight Information Region (FIR), LVNL must delay the traffic to be able to control the traffic safely. The results of the literature indicate that the possibilities to buffer traffic within the Dutch air space are linear holding and vertical holding. Besides ATFM delays, LVNL uses mainly (speed) vectoring in combination with an AMAN system (ASAP), which is a flexible tool and is a form of linear buffering. The effectiveness of linear holding is dependent on the size of the air space, and according to Nicolaon (2002), linear holding in the airport area only can absorb reasonable delays.

To be able to deal with more substantial delays or complex sectors, LVNL uses three holding stacks areas to buffer traffic vertically. According to the air traffic controllers who have been interviewed, the holding stacks are used on a lesser extent than vectoring is used, which makes the ACC controllers more proficient with the use of vectoring.

9.1.2 Conclusions on the current capacity of the inbound traffic buffers

To manage the operational inbound peak capacity, linear holding can be used by (speed) vectoring to deviate from the arrival routes or the arrival routes can be extended to include the buffer into the routes.

In the current operation, the capacity to buffer is dependent on how much the air traffic controller can deviate from the standard arrival routes. The data analysis indicates a difference in buffer usage per arrival route. According to the air traffic controllers who have been interviewed, these differences have their roots in multiple factors. For one, the physical characteristics of the routes are different in terms of shape and steepness. Also, the traffic, the complexity, and external factors as the wind direction affect the buffer capacity. Table 10 indicates how much air traffic controllers deviate from the standard arrival routes (in two standard deviations (95%)) to linearly delay traffic in the current (standard) operation. The analysis indicates a maximum of three minutes (route TOPPA)

FIR-entry	2 St. Dev. Δ time [hh:mm:ss]	2 St. Dev. Δ miles [Nm]
EEL	00:02:32	9.41
NORKU	00:02:44	9.57
DENUT	00:02:18	6.40
HELEN	00:02:39	9.50
LAMSO	00:01:48	5.39
REDFA	00:02:36	5.91
TOPPA	00:03:09	9.53

Table 9: Currently used vector capacity Dutch airspace

9.1.3 Conclusions on how the LVNL operation can use buffers proactively to manage inbound traffic

To absorb longer delays, vertical holding can be used. Vertical holding takes place on the holding stack areas near the airport at the IAFs (RIVER, SUGOL and ARTIP). The IAF is the transfer point between ACC and APP and connects the sectors to the TMA. Literature suggests that holding stacks can effectively be used to maximise runway capacity when multiple stacks are used to feed one runway. The use of holding stacks has the disadvantage of rapidly increasing delay times when the use of stack layers is increased. Besides, when the increased delay in the stacks causes increased arrival delays, this could cause an increase in disruptions in the ground operation, which affects the departure on-time performance. In other words, increased delay times has a butterfly effect on the complete airport operation.

According to the interviews with air traffic controllers, the most significant bottleneck in the operation of holding stacks is the altitude of the aircraft. A simplified representation is created of holding stacks throughput. Table 11 presents the results of four scenarios with the holding stack throughput Formula (4), in which scenario 2 and 4 represent a realistic average pace according to the interviews. The analysis of the holding stacks throughput concludes that with the use of holdings stacks in the current layout capacity is being lost. The results indicate that the stacks are, as expected according to the literature, not sufficient enough to realise the desirable peak hour capacity without multiple stacks to feed one runway.

Scenario	Average Descent t [min]	Average reaction t [min]	Throughput/hour [aircraft]
1	1	0	30
2	1.5	0	20
3	1.5	0.5	15
4	1.5	1	12

Table 10: Aircraft throughput per hour according to four scenarios (2)

The research investigated the research question “Which operational possibilities does LVNL have to buffer inbound traffic and to what extent can these buffers be used in managing the operational inbound peak capacity? The combination of quantitative and qualitative analysis results in two operational possibilities to buffer traffic in the Dutch airspace. The first possibility is linearly and can be used to absorb small delays. The second possibility is with the use of holding stacks. Holding stacks can be used to absorb longer delays; however, in the current layout, this tool is rigid and does not perform efficient enough to get the maximum out of the inbound peak hour capacity. To decrease the number of ATFM delays, LVNL must investigate buffer possibilities outside of the Dutch air space, because the Dutch airspace is small and complex. Besides, the use of buffers is not the solution to the root cause of the problem, which is the unpredictability of air transport.

10 Recommendations

Within the Dutch airspace, LVNL has two buffer possibilities, linear holding and vertical holding. Both require a revision of the airspace structure to be effective.

10.1 Create a predictable linear holding strategy

The first option is to create a predictable linear holding strategy, the linear buffer capacity must be part of the arrival routes, by extending the routes or by changing the shape of the routes. Research is required on the physical characteristics to determine what the actual buffer margin is, apart from how the air traffic controllers experience the room to buffer. When more knowledge on the physical characteristics is collected, a simulation model should be created to analyse the effects on the peak hour performance. Furthermore, a larger sample size of flights than used during this research is required to be able to analyse the routes that have been excluded from this research. The assumption was made that the minimum sample size representative to conclude equals or is greater than 1% of the total flights observed. Because of this assumption, the sample size of RKN (164 flights), PUTTY (10 flights) and MOLIX (182 flights) were not large enough to conclude. When these routes would be included, it is possible to create a more solid conclusion on the total buffer capacity on the routes and where in the Dutch airspace the most capacity is.

During simulations already performed at different ACC sectors in Europe, Favennec et al. (2010) found that the workload is significantly reduced with the implementation of linear holding because the aircraft does not deviate from the standard routes. Besides, Favennec et al. (2010) report a better view of the arrival sequence and an effective combination with AMAN slots. Not only will the predictability increase for the ANSP, but the predictability of arrival management for the airline and airport operator will increase as well. Because of these benefits, the recommendation is to further investigate the linear holding strategy as one of the possibilities within the revision of the Dutch airspace (Ministry of Infrastructure and Watermanagement, 2017).

Nonetheless, linear holding requires space to absorb delays, which is a scarce source within the Dutch airspace. Implementing linear holding will not increase the buffer capacity directly, but will result in a reduced workload and increased predictability. To increase the buffer capacity, linear holding has to be expanded in collaboration with adjacent ANSPs.

10.2 Create an effective stack holding operation

The second option is to use vertical holding to buffer traffic. In the revision of the Dutch airspace of which the problem assessment has started in 2018 (Ministry of Infrastructure and Watermanagement, 2017), an additional stack to use vertical holding efficiently must then be considered. The effects of an additional stack to the peak hour capacity should be investigated with the use of a simulation model. The simulation model should consist of several elements affecting the stack operation: Aircraft performance, stack characteristics, human performance (pilot and controller), weather, runway capacity and arrival pace. Additional holding stacks will not increase the peak hour capacity, because this is runway restricted; Additional holding stacks increases the handling efficiency to realise the current available runway capacity. Because vertical holding is fuel-intensive, the effects on the environment and the costs for the stakeholders must be taken into account in further research. However, increased use of vertical holding stacks requires substantial revisions of the operation before the stacks can be effectively used to increase the handling efficiency. How many layers required as safety margin has to be investigated with the use of simulation. Besides, the increased use of holding stacks affects the efficient use of fuel during flight. The recommendation is, therefore, to first further investigate other buffer possibilities: Path-stretching and Extended Arrival Management (XMAN) outside the FIR.

10.3 Increase predictability, stability and efficiency by expanding the area of influence

Both linear holding and vertical holding in the Dutch airspace are rather a type of symptom control and are both not the optimal solution to deal with the unpredictability of air traffic. These tools will always be necessary to deal with the capriciousness of inbound flow. Nevertheless, to create a more predictable inbound flow, partnerships with neighbour ANSPs and initiatives such as SESAR to delay air traffic en-route will decrease the root cause for the need of ATFM delays. Therefore, to increase the capacity to absorb traffic en-route without increasing the fuel consumption and decreasing the peak hour performance, streamlining the inbound traffic outside of the Dutch airspace makes an exciting research possibility. As a result, the streamlined traffic flows benefit the predictability, stability and efficiency for all stakeholders. As part of the European network, airspace borders should not be constraining the efficiency of the operation. Increasing the controllable area can be realised by partnerships such as FABEC with surrounding countries to be able to use XMAN with inbound traffic. Besides, within SESAR, LVNL should investigate to possibilities to extend the Schiphol STARS across the border of the Dutch FIR, including linear holding as a buffer. Nonetheless, the effectiveness of partnerships demands a whole new approach and depend on intensive information sharing.

10.4 Investigate the root cause of unpredictable air traffic flows

LVNL aims to be the best ANSP in the world considering safety, people and reliability (LVNL, n.d.). However, to be the most reliable ANSP, it might not be the most meaningful aim to be the best ANSP. A more specific and effective aim would be: To be the best partner to the surrounding ANSPs, EUROCONTROL, the airlines, and Schiphol; to benefit from shared knowledge and systems to create a predictable, reliable, and efficient operation throughout Europe. To realise this, arrival management should be part of A-CDM, because all stakeholders benefit from sharing information and with this: Increased predictability.

In order to get to the root of the problem, a root cause analysis including all stakeholders of the complete departure/arrival chain is required. Philosophies as lean can be used to identify the root cause of the inefficiencies in the operation and to be able to create the maximum value for the airline as an ANSP, with as little as possible waste (in terms of time, miles and complexity). As seen in the analysis in this research, the strategies used are not very different from supply chain strategies used in a production environment. The recommendation is to investigate the flow from the take-off to the landing to identify inefficiencies in the complete process and between the stakeholders.

List of References

According to APA style

- Alders, H. (2015, January 29). Brief van dhr. Alders over de groei van Schiphol [Parliamentary paper]. Retrieved May 16, 2019, from https://www.omgevingsraadschiphol.nl/wp-content/uploads/2015/03/Brief_van_dhr._Alders_over_de_groei_van_Schiphol.pdf
- Alders, H. (2019, January 30). Brief van Alders aan de Minister [Parliamentary paper]. Retrieved June 6, 2019, from <https://www.bewonersomgevingschiphol.nl>
- Barnhart, C. (2012, 1 juni). Demand and capacity management in air transportation. Geraadpleegd op 25 november 2018, van <https://link.springer.com/article/10.1007/s13676-012-0006-9>
- Basora, L., Courchelle, V., Bedouet, J., & Dubot, T. (2018). *Occupancy Peak Estimation from Sector Geometry*. Retrieved from https://www.sesarju.eu/sites/default/files/documents/sid/2018/papers/SIDs_2018_paper_23.pdf
- Boekhout, J. (2018, February 2). THE INFLUENCE OF ATFM DELAYS ON AIRSPACE CAPACITY. Retrieved May 16, 2019, from <https://www.kdc-mainport.nl/index.php/nl/docman/pdf/99-kdc-final-thesis-joep-boekhout-1/file>
- Bowman, C., & Ambrosini, V. (2002, December 16). Value Creation Versus Value Capture: Towards a Coherent Definition of Value in Strategy. Retrieved March 12, 2019, from <https://onlinelibrary.wiley.com/action/cookieAbsent>
- Caccavale, Maria Virginia, Iovanella, A., Lancia, C., Lulli, G., & Scoppola, B. (2014). A model of inbound air traffic: The application to Heathrow airport. *Journal of Air Transport Management*, 34, 116–122. <https://doi.org/https://doi.org/10.1016/j.jairtraman.2013.09.004>
- Cook, A. (2007). *European Air Traffic Management*. London, United Kingdom: Ashgate.
- Cook, A., Tanner, G., Williams, V., & Meise, G. (2009). Dynamic cost indexing – Managing airline delay costs. *Journal of Air Transport Management*, 15, 26– 35. <https://doi.org/10.1016/j.jairtraman.2008.07.001>
- Cook, A. (2016). *European Air Traffic Management: Principles, Practice and Research*. London, United Kingdom: Routledge.
- Christien, R., Hoffman, E., Trzmiel, A., & Zeghal, K. (2018, June). An extended analysis of sequencing arrivals at three major European airports. Retrieved June 16, 2019, from <https://www.eurocontrol.int/sites/default/files/publication/files/aiaa-atio-2018-eurocontrol-sequencing-analysis.pdf>
- Curtis, D. (2016, May 20). Is this the end of stack holding? - NATS Blog. Retrieved April 16, 2019, from <https://nats.aero/blog/2016/05/is-this-the-end-of-stack-holding/>
- Delay. BusinessDictionary.com. Retrieved May 30, 2019 from <http://www.businessdictionary.com/definition/delay.html>
- Delgado, L., Cook, A., Cristóbal, S., & Plets, H. (2015). Controller Time and Delay Costs. Presented at the Fifth SESAR Innovation Days. Retrieved from https://www.sesarju.eu/sites/default/files/documents/sid/2015/SIDs_2015_paper_44.pdf

EUROCONTROL. (2000, November). COSTS OF AIR TRANSPORT DELAY IN EUROPE. Retrieved May 30, 2019, from

<https://www.eurocontrol.int/sites/default/files/content/documents/single-sky/pru/publications/other/cost-of-air-transport-delay-in-eu-ita.pdf>

EUROCONTROL. (2005). *Report on Punctuality Drivers*. Retrieved from

<https://www.eurocontrol.int/sites/default/files/publication/files/airports-report-final-cover-page.pdf>

EUROCONTROL. (2008). Airport CDM Cost Benefit Analysis. Retrieved from

https://www.eurocontrol.int/sites/default/files/content/documents/sesar/business-case/airport_CDM_CBA_2008.pdf

EUROCONTROL. (2010, December 17). Arrival Manager. Retrieved May 19, 2019, from

<https://www.eurocontrol.int/sites/default/files/article/content/documents/nm/fasti-aman-guidelines-2010.pdf>

EUROCONTROL. (2010a). Point Merge Integration of Arrival Flows Enabling Extensive RNAV Application and Continuous Descent. Retrieved from

<https://www.eurocontrol.int/sites/default/files/content/documents/sesar/point-merge-osed-v2.0-2010.pdf>

EUROCONTROL. (2012). Airport CDM implementation manual. Retrieved June 5, 2019, from

<https://www.eurocontrol.int/sites/default/files/publication/files/2012-airport-cdm-manual-v4.pdf>

EUROCONTROL. (2014). Additional ASMA time. Retrieved from

<https://www.eurocontrol.int/sites/default/files/events/presentation/140219-ans-ops-performance-add-asma.pdf>

EUROCONTROL. (2016, November 24). What is air traffic management? Retrieved March 24, 2019, from

<https://www.eurocontrol.int/articles/what-air-traffic-management>

EUROCONTROL. (2016a). A guide to the Network Manager Operations Centre.

EUROCONTROL. (2016b, November 15). Point Merge: improving and harmonising arrival operations. Retrieved June 8, 2019, from

<https://www.eurocontrol.int/services/point-merge-concept>

EUROCONTROL. (2017). Performance Review Report. Retrieved from

<https://www.eurocontrol.int/sites/default/files/publication/files/prr-2017.pdf>

Eurocontrol. (2018a, October 23). Report on Complexity Metrics for ANSP Benchmarking Analysis. Retrieved February 26, 2019, from

<https://www.eurocontrol.int/publications/report-complexity-metrics-ansp-benchmarking-analysis>

EUROCONTROL. (2018b). Performance Review Report 2017. Retrieved from

<https://www.eurocontrol.int/sites/default/files/publication/files/prr-2017.pdf>

EUROCONTROL. (2019). Top 20 airport delay locations during 2018. Illustration. Retrieved from

<https://www.eurocontrol.int/publications/annual-network-operations-report-2018>

EUROCONTROL. (2019b, May 2). ATFCM Users Manual. Retrieved May 16, 2019, from

<https://www.eurocontrol.int/publications/atfcm-users-manual>

- EUROCONTROL. (2019c, April 5). About the Network Manager. Retrieved June 5, 2019, from <https://www.eurocontrol.int/articles/about-network-manager>
- EUROCONTROL. (2019d). Performance Review Report 2018. Retrieved from <https://www.eurocontrol.int/sites/default/files/publication/files/prr-2018.pdf>
- European Commission. (n.d.). Extended Cross Border Arrivals Management optimising arrivals for London Heathrow Airport [Illustration]. Retrieved May 7, 2019, from <https://ec.europa.eu/transport/sites/transport/files/modes/air/ses/ses-award/projects/doc/dsnaxmaninfographie01gb.jpg>
- FAA. (2018, September 27). Reference Guide. Retrieved February 5, 2019, from <https://www.faa.gov/nextgen/snapshots/guide/>
- Favennec, B., Rognin, L., Trzmiel, A., Vergne, F., & Zegha, K. (2010). POINT MERGE IN EXTENDED TERMINAL AREA (PMS-TE 2009-2010) (No. 2010-011). Retrieved from https://www.eurocontrol.int/sites/default/files/library/012_Point_Merge_in_extended_TMA.pdf
- Gill, C. (2014). New ATC procedures - unintended effects on the flight deck? Retrieved May 18, 2019, from <https://skybrary.aero/bookshelf/books/2927.pdf>
- Haskins, P. (2013, August 7). Infographic: Why do aircraft hold at Heathrow Airport? - NATS Blog. Retrieved June 6, 2019, from <https://nats.aero/blog/2013/06/infographic-why-do-aircraft-hold-at-heathrow-airport/>
- Heathrow. (2018, January). HEATHROW AIRPORT Operations Handbook. Retrieved June 4, 2019, from https://www.heathrowconsultation.com/wp-content/uploads/2018/01/2887-HRW-3R-AIRSPACE-Operations-Handbook-A4_V11.1.pdf
- Heathrow. (2019). Flight movements | Noise | Heathrow. Retrieved June 6, 2019, from <https://www.heathrow.com/noise/reports-and-statistics/operational-data/flight-movements>
- Holding Pattern. (2019). In Merriam-Webster's online dictionary. Retrieved on March 24, 2019, from <http://www.merriam-webster.com/dictionary/holding%20pattern>
- Kanis, K. (2017, February 20). *Impact of runway changes on the capacity of Amsterdam Airport Schiphol*. Amsterdam. Retrieved May 16, 2019, from LVNL internal documents
- Hopp, Wallace J., and Mark L. Spearman. "To Pull or Not to Pull: What Is the Question?" *Manufacturing & Service Operations Management* 6, No. 2 (April 1, 2004): 133–48. doi:10.1287/msom.1030.0028.
- KDC. (n.d.). Centre of Excellence | KDC Mainport. Retrieved May 30, 2019, from <http://kdc-mainport.nl/centre-of-excellence/>
- KDC. (n.d.). Samenvatting KDC resultaten 2017. Retrieved February 20, 2019, from <https://www.kdc-mainport.nl/index.php/nl/resultaten/311-samenvatting-kdc-resultaten-2017>
- Keul, J., & Veldhuis, J. (2014). *Lange termijn verkenningen voor de Mainport Schiphol*. Retrieved from http://www.seo.nl/uploads/media/201402_Lange_termijn_verkenningen_Schiphol.pdf
- KLM (2011). Fact Sheet Network and Hub Systems. Retrieved from:

https://www.klm.com/corporate/en/images/008372%20Factsheet%20network_tcm729-342204.pdf

Kok, R., Tielrooij, M., & Dijkstra, F. (2019). *Cross Border Arrival Management (XMAN) Trial Reims - Amsterdam*. Retrieved from LVNL intern

leanproduction.com. (n.d.). Glossary – Lean Manufacturing Definitions | Lean Production. Retrieved June 8, 2019, from <https://www.leanproduction.com/lean-glossary.html>

Luchtverkeersleiding Nederland. (n.d.-a). LVNL DOCS. Retrieved May 6, 2019, from https://docs.lvnl.nl/saml_login

Luchtverkeersleiding Nederland. (n.d.-b). OM AMS ACC. Retrieved May 6, 2019, from https://docs.lvnl.nl/saml_login

LVNL. (n.d.-a). Corporate Visie & Strategie | LVNL. Retrieved April 24, 2019, from <https://www.lvnl.nl/over-lvnl/corporate-visie-strategie>

LVNL. (n.d.-b). Advanced Schiphol Arrival Planner. Retrieved May 17, 2019, from https://docs.lvnl.nl/saml_login

spsshandboek.nl. (n.d.). Met de independent t-test bezig? Afstudeerbegeleider helpt je verder! Retrieved June 1, 2019, from <https://spsshandboek.nl/independent-samples-t-test/>

Martin, S. (2016). Strategic Airport Capacity Management at Heathrow. *Impact*, 2(1), 7–12. <https://doi.org/10.1080/2058802X.2016.11963988>

Mobility and Transport European Commission. (2017, February 23). Extended Cross Border Arrivals Management optimising arrivals for London Heathrow Airport - Mobility and Transport - European Commission. Retrieved May 6, 2019, from https://ec.europa.eu/transport/modes/air/ses/ses-award-2016/projects/extended-cross-border-heathrow_en

Moll, C. (2019, April 30). *Capacity analysis of airport slot planning and air traffic demand. Amsterdam*. Retrieved May 16, 2019, from LVNL internal documents

Mind Tools. (2018, October 2). Kano Model Analysis - Creativity Tools From MindTools.com [Illustration]. Retrieved March 13, 2019, from https://www.mindtools.com/pages/article/newCT_97.htm

Ministry of Infrastructure and Watermanagement. (2017, December 19). *Plan van aanpak Luchtruimherziening*. Retrieved July 4, 2019, from <https://www.rijksoverheid.nl/documenten/rapporten/2017/12/18/bijlage-1-plan-van-aanpak-luchtruimherziening>

M2P consulting. (2015, September 1). Hub Structures – How Airlines bank their hubs around the world [Presentation slides]. Retrieved May 30, 2019

NATS. (2017). ATFM Delivering Performance. Retrieved from [https://www.icao.int/Meetings/ATFM2017/Documents/2-Stuart MacBride - ICAO ATFM Conference ATFM in delivering Performance.pdf](https://www.icao.int/Meetings/ATFM2017/Documents/2-Stuart%20MacBride%20-%20ICAO%20ATFM%20Conference%20ATFM%20in%20delivering%20Performance.pdf)

NATS. (2019a, March). eAIP AIRAC EGLL. Retrieved March 18, 2019, from http://www.nats-uk.ead-it.com/public/index.php%3Foption=com_content

- NATS. (2019b, May 23). London Heathrow - EGLL AIS. Retrieved June 6, 2019, from http://www.nats-uk.ead-it.com/public/index.php?option=com_content
- Nieuborg, A. (2014, February 20). Additional ASMA Time. Retrieved May 17, 2019, from <https://www.eurocontrol.int/sites/default/files/events/presentation/140219-ans-ops-performance-add-asma.pdf>
- Nicolaon, J. P. (2005, November 5). HOW TO SAVE FUEL BY LOSING TIME? Retrieved March 26, 2019, from https://www.icao.int/Meetings/AMC/MA/2002/env_operationalmeasures/jean_pierre_nicolaon.pdf
- O'Byrne, R. (n.d.). Supply Chain Glossary of Terms. Retrieved June 8, 2019, from <https://www.logisticsbureau.com/supply-chain-glossary/>
- Payne, V., Pena, R., Tisdall, A., Ratcliffe, S., Byus, G., & Fucharoen, S. (n.d.). Implementing Air Traffic Flow and Collaborative Decision Making. Retrieved April 3, 2019, from <https://www.canso.org/system/files/Implementating%20Air%20Traffic%20Flow%20Management%20and%20Airport-Collaborative%20Decision%20Making.pdf>
- Proactive. (2019). In Cambridge Academic Content Dictionary. From <https://dictionary.cambridge.org/dictionary/english/proactive>
- Proactive. (2019). In Merriam-Webster Dictionary. From <https://www.merriam-webster.com/dictionary/proactive>
- Pronk, K. (2019, January 6). Fixed Approach Routes. Retrieved February 20, 2019, from LVNL internal documents
- Reactive. (2019). In Cambridge Academic Content Dictionary. From <https://dictionary.cambridge.org/dictionary/english/reactive>
- Riebeek, M. (2019, April 9). *Analysis of deviation to arrival airport slots in planning stage at Amsterdam Airport Schiphol*. Amsterdam. Retrieved May 16, 2019, from LVNL internal documents
- Schiphol Group. (n.d.). Feiten en cijfers | Jaarverslag 2017 | Schiphol. Retrieved November 6, 2018, from <https://www.jaarverslagschiphol.nl/over-ons/feiten-en-cijfers>
- Schiphol. (2019). Schiphol | Jaarlijkse Traffic Reviews. Retrieved June 6, 2019, from <https://www.schiphol.nl/nl/schiphol-group/pagina/traffic-review/>
- Skybrary. (n.d.). Basic Controller Techniques: Vectoring - SKYbrary Aviation Safety. Retrieved March 24, 2019, from https://www.skybrary.aero/index.php/Basic_Controller_Techniques:_Vectoring
- Skybrary. (n.d.-b). Holding Pattern - SKYbrary Aviation Safety. Retrieved March 24, 2019, from https://www.skybrary.aero/index.php/Holding_Pattern
- Skybrary. (n.d.-c). Airport Collaborative Decision Making (A-CDM) - SKYbrary Aviation Safety. Retrieved June 5, 2019, from [https://www.skybrary.aero/index.php/Airport_Collaborative_Decision_Making_\(A-CDM\)](https://www.skybrary.aero/index.php/Airport_Collaborative_Decision_Making_(A-CDM))

statisticsshowto.datasciencecentral.com. (2019, June 4). Central Limit Theorem: Definition and Examples in Easy Steps - Statistics How To. Retrieved June 11, 2019, from <https://www.statisticsshowto.datasciencecentral.com/probability-and-statistics/normal-distributions/central-limit-theorem-definition-examples/>

Stephen M. Rutner, C. John Langley, Jr, (2000) "Logistics Value: Definition, Process and Measurement", *The International Journal of Logistics Management*, Vol. 11 Issue: 2, pp.73-82, <https://doi.org/10.1108/09574090010806173>

The International Warehouse Logistics Association. (2010, February). SUPPLY CHAIN and LOGISTICS TERMS and GLOSSARY. Retrieved May 20, 2019, from http://www.iwla.com/assets/1/24/2010_Glossary_of_Terms_10.7.11.pdf

Van Horsen, M. (2017). *Cross-Border Arrival Management to reduce traffic bunching at Schiphol Airport*. Retrieved from LVNL internal documents

Vanwelsenaere, A., Ellerbroek, J., Hoekstra, J. M., & Westerveld, E. (2017). *Analysis on the Impact of Pop-Up Flight Occurrence when Extending the Arrival Management Horizon*. Retrieved from http://www.atmseminarus.org/seminarContent/seminar12/papers/12th_ATM_RD_Seminar_paper_61.pdf

Winkel, J. (2011). *Downloads*. Retrieved from Project Management: http://hoadd.noordhoff.nl/sites/7294/_assets/7294d07.xls

Xu, Y., & Prats, X. (2017a). Effects of linear holding for reducing additional flight delays without extra fuel consumption. *Transportation Research Part D: Transport and Environment*, 53, 388–397. <https://doi.org/10.1016/j.trd.2017.04.027>

Xu, Y., & Prats, X. (2017b). Including Linear Holding in Air Traffic Flow Management for Flexible Delay Handling. Retrieved May 18, 2019 from <https://core.ac.uk/download/pdf/132528595.pdf>

Zuidberg, J., & Vinkx, K. (2018, May 23). Capacity demand at Schiphol Airport in 2030. Retrieved February 26, 2019, from <https://www.rijksoverheid.nl/documenten/rapporten/2018/05/03/capacity-demand-at-schiphol-airport-in-2030>

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Appendix I Reflection

This last year has been a rollercoaster in many ways and with a lot of trial and error, I was able to prove to myself that what does not kill you really does make you stronger. During the reflection of the last year, I came to realise that the growth during the honours programme was almost equivalent to the growth during the first three years of my bachelor, and the amount growth during my thesis was equivalent to those years AND the honours programme. As a result, the measurement scale of the competences used during the mid-terms is not representative to reflect on my current competences, because a five then is absolutely not the same as a five now. The competences I focused on during the last year are: Confidence, problem analysis, and for the honours management programme specifically, team work. I found out that within confidence, communicating expectations is a vital element in the early stages of a project. Besides, although I always thought I was a very stress resistant person, my final thesis this last semester has really challenged me on coping with stress.

Communicating expectations

To start with explaining the situation of the KDC. KDC is a research and development centre of Mainport Schiphol, financed by the Ministry of Infrastructure and Water management, and with the aim to solve issues concerning the different parties in the Dutch aviation Industry (mainly Schiphol, KLM and LVNL). The expectations of the researchers are to perform excellent independent research while including the stakeholders equally. First of all, the word excellent created pressure and increased stress levels to begin with. Because excellent for me is an almost unreachable state of perfection. Although I just figured this out near the end of my thesis, the most important lesson learned was that excellent for me is not the same as excellent for others. Especially, while working with different stakeholders with different objectives and performance indicators. Before starting a project, matching expectations is the most important thing to do. Although I say I have to communicate expectations very often, I found out that I did not do this very well in the beginning of my thesis. Once expectations are not clear, there is room for different interpretations and discussions. Especially, while working with different stakeholders with different objectives and performance indicators this creates chaos and did not make my final semester a very pleasant experience. Nevertheless, I proved myself once again that I am very resilient and I have a lot of willpower to accomplish things while dealing with difficult circumstances. However, this time my perseverance was my weakness as well, because it might have been easier if I accepted my loss and communicated this on an early stage instead of trying to fix a situation on a weak foundation.

Problem analysis and confidence

One of my least strong competence has been problem analysis during my whole bachelor. Because I have difficulty with breaking down problems, which results in problems seeming unsolvable and then I get stuck. During the rest of the four years, there always was a team to help in this part. Especially Rachel is very good in breaking down problems (and solving them) and I worked with Rachel a lot. During my final thesis, I had to do this on my own. The research concerned air traffic management, a subject I had no experience with nor previous knowledge of. It took me almost three months to understand the complexity of my assignment and then I panicked. Because I had no idea how to solve it, let alone solve it excellently. I started to break down the problem in several sub-problems and I realised I was never going to be able to finish the assignment and my research question was way too broad. But I did not want to let anyone down so I tried it anyway. I learned that everybody wins if you stop trying to build a perfect wall; if you cannot succeed, you have to break down everything and start again. You can however lay down bricks perfectly. If one brick does not work the way you thought it would, you lay down a new brick. Laying down one brick is not hard at all and before you know you have built a perfect wall after all. And if you are not able to finish the wall, you have built a great foundation for someone else to finish it on.

My biggest pitfall has been trying to think for others. While you are the only one who knows what you can and cannot do. Letting this go, gave me so much more confidence. There is no need to stress about what other people think; When they feel it is necessary to share, they will tell me.

Different company cultures and the effect on my productivity

During this last semester, I saw the effect a work environment and company culture can have. LVNL, the company that mainly facilitated the KDC students, is a company with a lot of the same type of people. If you do not match with the way people think in a company, it is hard to have progress. I experienced that the majority of the employees of LVNL think in blueprints and predictable roadmaps. The numbers tell the tale and there is no need for motivation, relations or rewards. Why would you expect a “you are doing good” if you can prove that you are doing good with numbers. However, this becomes challenging if you are motivated to work for the “you are doing good” and you use social interactions to see new approaches. It resulted in being stuck in my thesis once again.

Stress-resistance

To again start with an aphorism: you can handle way more than you think you can handle, until you cannot anymore handle it at all. I was always under the impression that I am very calm and can perform under the pressure of time. However, this thesis really challenged me. Although every time I thought I reached my limits, I was able to continue and work harder. Until the point I had a migraine attack for a whole week. Because normally stress does not affect me that much, I did not handle the stress in a healthy way at all when it did affect me. This experience thought me a lot, especially about myself and when I need to take a moment to relax.

Common thread: communicate expectations, create boundaries and learn to say no

When I look back to the last year, I learned so much and I believe the scale of the measurement has changed because my new learning goals are so much higher than I would ever imagined during the first three years of my bachelor. My learning objectives for upcoming challenges will be to communicate expectations beforehand to create a solid scope and boundaries. To break down a problem in smaller problems and to frequently reflect on where I am standing and what other people think about this. And most importantly: I have to learn to say no more often and to guard my own wellbeing during projects.

Appendix II (in Dutch) Interview ACC controllers, 30 April 2019

Records interview AC- controllers Stefan Soede en Rutger Huiskamp

00:00:02

Kyara: Ja ik heb eerst een paar vragen over het algemeen en over het proces en het gebruik van de buffers en daarna heb ik wat vragen over het gebruik van holding stacks, waar het voornamelijk over gaat. Dus als eerste: wat is de belangrijkste KPI voor het inbound process volgens jullie (uit de blik van de luchtverkeersleider)?

00:00:24

Stefan: Het is al redelijk existentiële vraag he meteen. De vraag vanuit het oogpunt van een generieke verkeersleider of vanuit het oogpunt van acc verkeersleider?

00:00:34

Kyara: Vanuit acc

00:00:35

Rutger: Ja.

00:00:41

Stefan: Dat je een, in mijn ogen, mijn invulling een continu gemanagede stroom inbounds de TMA in hebt.

00:00:50

Kyara: Stabiel?

00:00:51

Stefan: Ja stabiel, met genoeg aanbod om ook niet zeg maar telkens te duiken tussen te weinig aanbod en heel hard moeten vliegen om wel het aanbod de TMA in te krijgen. Eigenlijk iets over aanbod om, eigenlijk in mijn ogen, mijn optiek, om een minimum stukje delay hebben om de druk in de TMA gewoon altijd stabiel te kunnen houden.

00:01:15

Kyara: En dat is dus om zo veel mogelijk uit de baan capaciteit te halen?

00:01:24

Stefan: Ja en uiteindelijk zitten wij erboor als een soort vangnet voor approach , maar het belangrijkste is dat de baan zoveel mogelijk vol gaat lopen.

00:01:28

Rutger: Mijn eerste inschatting was inderdaad landingscapaciteit, ja landingsrealisatie eigenlijk

00:01:36

Stefan: Ja landingsrealisatie met het laagst mogelijke gevlogen extra track mijlen.

00:01:40

Rutger: Ja maar dat zijn nog meerdere KPIs natuurlijk

00:01:44

Kyara: Wat is dan belangrijker vinden jullie? Landingsrealisatie of Track miles?

00:01:47

Stefan: Landingsrealisatie sowieso dat is de meest schaarse stukje van het hele process.

00:01:54

Rutger: Ja.

00:01:57

Rutger: Ja ik denk ook de weg daarnaartoe en hoe dat allemaal aankomt en dergelijke maar ik denk inderdaad dat de belangrijkste is landingscapaciteit.

00:02:08

Stefan: Ja. Dat daar soepelere en efficiëntere manieren zijn om die baan zo vol mogelijk te krijgen dat is wel een dingetje maar uiteindelijk is dat de manier waardoor erop Schiphol geld verdiend wordt. Dat de baan volgepland is.

00:02:24

Rutger: En als acc verkeersleider zal dat dan nog veranderen? Nou als je puur kijkt naar ons stukje, want dit is natuurlijk ook een beetje generiek hè.

00:02:36

Stefan: Voorspelbaarheid dan. Weinig ad hoc up dates van approach planning. Weinig ad hoc beslissingen over de TMA vulling, dat is eigenlijk hetgeen wat voor acc. Denk ik.

00:02:53

Kyara: De voorspelbaarheid voor de approach controller?

00:02:56

Stefan: Nee voorspelbaarheid voor de acc controller, voorspelbaarheid in approach tijden die uitgedeeld worden door de approach controller

00:03:02

Kyara: Waar gebruiken jullie buffers voor?

00:03:16

Rutger: En dan bedoel je gewoon veiligheids buffers of qua capaciteit te buffers?

00:03:27

Kyara: Capaciteitsbuffers

00:03:26

Rutger: Voor het onze eigen slechte kwaliteiten, dus als we zelf niet goed genoeg zijn. Voor onvoorziene omstandigheden. Voor als approach planning niet goed genoeg is. Dat ze echt even wat verkeersleider gekeken dan.

00:03:42

Stefan: Overaanbod, bunching.

00:03:49

Rutger: De algemene samenvatting is zo een beetje het iets minder functioneren van 1 van de schakels. En dan is het of de verkeersleider voor je op de verkeersleider na je of de verkeersleider zelf. Of.

00:04:02

Stefan: De externe invloeden.

00:04:04

Rutger: Ja een beetje de de vertrektijden en aankomsttijden van het vliegtuig ik denk dat dat het een beetje is.

00:04:09

Stefan: Ja en externe invloeden zoals weer. Als je geen sequence meer kan maken door weer dan dan is. Maar ja eigenlijk is buffer capaciteit gewoon een beetje dat je meer capaciteit hebt in je sector dan dat er volgende sector aan capaciteit heeft. Je wil als aanvoerende sector niet de bottleneck zijn. En dat we niet die bottleneck zijn geeft dus ook ruimte om inderdaad om dingen op te vangen, san welke kant dan ook.

00:04:39

Kyara: Buffers zijn eigenlijk in hoeverre je verkeer kan absorberen in jouw stukje luchtruim.

00:04:45

Rutger: En praktischer, je gebruikt buffers door te sturen of te houden inderdaad.

00:05:48

Kyara: Wat is voor jullie het effect van het gebruik van buffers als vectoring of speeds vectors of het gebruik van holdingsstacks?

00:05:55

Stefan: Werklastverhoging

00:06:04

Rutger: En het wordt er ook onoverzichtelijker van

00:06:05

Kyara: En daarmee ook werklastverhoging?

00:06:09

Stefan: Ja ik weet niet of dat hand in hand gaat, misschien wel. In ieder geval, Ja cognitief wordt het werklast verhogend. Om het geheel ook nog bijgescand te krijgen. Maar qua de werklast die je er in stopt in mijn ogen niet perse. Nee. Als je alles naar de 70 (FL70) laat zaken wordt heel onoverzichtelijk maar ja je hebt wel iedereen onder 70 geklaard. Maar cognitief wordt het wel lastig om bij te houden. Ziet ie daarin?

00:06:41

Rutger: Ja ik wil inderdaad niet zeggen dat als je als het onoverzichtelijk wordt dat dat betekent dat het meteen werklast verhogend is. Over het algemeen wel.

00:06:53

Rutger: Maar in ieder geval werklast verhogend / onoverzichtelijk wordt het als je veel van het sturen of van het houden gaat gebruiken.

00:07:02

Stefan: Het haalt de rek uit de rest van je buffercapaciteit zeg maar. Je hebt minder capaciteit om heel veel conflicten ergens anders op te gaan lossen.

00:07:11

Kyara: Ja, minder marges voor nieuwe conflicten?

00:07:12

Stefan: Ja

00:07:16

Kyara: En wat beïnvloedt de beslissingen omtrent het gebruik van buffers?

00:07:20

Rutger: Het weer, tenminste ik denk dat dat is wat je bedoelt. Het weer, de voorgaanden perioden, dus als je bijvoorbeeld een dag hebt dat de approach planner heel veel updates doet dan ga ik eerder gewoon naar de stack (iaf) vliegen en niet sturen of een klein beetje sturen, dan meteen de hold in omdat ik denk dat er veel vertraging is. Als er gewoon een approach planner zit die 1 keer de tijd deelt en daar niet meer aan zit en je hebt nu een kwartier vertraging, dan weet je dat dat zo blijft. Maar als je een kwartier vertraging hebt en je hebt een approach planner die constant een update doet van een paar minuutjes dan blijf ik gewoon doorvliegen naar... ja of iets op een headinkje (vector) of gewoon doorvliegen naar de iaf omdat ik toch weet dat er wel updates komen.

00:08:04

Kyara: Dat het dan vanzelf wel opgelost wordt?

00:08:06

Rutger: Ja precies dat, dus het weer en hoe de approach planner zit te plannen. Hoeveel verkeer er nog aankomt? Of ik het in mijn eentje doe of niet, of er nog iemand bij zit of niet.

00:08:18

Stefan: Wat er in de planlijst naast me staat, hoeveel verkeer ik direct aan zie komt

00:08:22

Rutger: Ja en hoeveel verkeer niet alleen inbounds er aan komen maar ook hoeveel overig verkeer er nog is. Als er heel veel andere conflicten zijn en dingetjes zijn dan kies ik voor de makkelijke oplossing.

00:08:32

Kyara: En wat is de makkelijke oplossing?

00:08:34

Rutger: Ja dat verschilt ook weer een beetje per als er weinig inbounds zijn dan kies ik voor het sturen. Omdat ik persoonlijk kan daar nauwkeurig mee kan werken, kan nauwkeurig op de tijd komen dan wanneer ik de holding draai. Mocht er nou veel verkeer zijn en ik heb ook heel veel andere conflictjes dan ga ik eerder de hold in, want dan kan er vrij weinig kapot. Dan zitten ze, draaien ze rondjes en of je dan te laat bent of te vroeg, dan maakt dat niet zoveel uit want ze draaien toch door. En als je stuurt, dan stuur je vaak op andere vliegtuigen af waardoor je veel meer conflicten creëert dat wanneer je gewoon lekker ronddraaid. Dus de hold is dan wat dat betreft in principe nog makkelijker

00:09:07

Stefan: In principe lopen de inbound routes naar de hold vrij van je overige verkeer dus als je dan gaat af gaat kijken dan kom je of je eigen inbounds tegen ergens of andere outbounds. Maar ja ga je naar de hold dan loop je in principe daar vrij dus dan hoeft je alleen nog maar de inbounds op elkaar te doen.

00:09:22

Kyara: Hoe komt het dan dat je door middel van vectoren preciezer kan sturen?

00:09:29

Rutger: Het nadeel is een beetje dat, zeker met asap, zijn we op een andere manier van werken maar je hebt niet echt controle meer over wanneer de kist met de hold aankomt en hoe de kist bij de hold aankomt. Dus een hold duurt ongeveer 4 minuten om rond te draaien en je kan natuurlijk daarbinnen wel iets eerder draaien maar die bochten zijn heel onvoorspelbaar want je moet eigenlijk met 180 graden draaien, nou de ene doet dat heel snel de andere doet het veel langzamer. En als je daar net iets te laat bent dan zit bijvoorbeeld net weer inbound en moet je of heel erg veel naar links of moeten we wachten tot die over de river (iaf) is bijvoorbeeld. En dan een 360 draaien.

00:10:03

Rutger: Met sturen is het gewoon als je daar 5 sec te laat bent dan stuur je en dan ben je 5 seconden te laat bij de stack en dat is niet zo'n probleem of increased (speed) nu wat dan is het probleem opgelost

00:10:12

Stefan: Zodra je de hold in bent gevlogen kan je eigenlijk alleen nog maar met 2 minuten dingen doen.

00:10:19

Stefan: En dan is het of binnen 2 minuten daar of de 3 4 5 6 (min). Maar je kan niet binnen 2 minuten weer daar zijn dus dat is wel en dat is dus ook als je er vlak voor bent

00:10:27

Rutger: als je 4 minuten of meer vertraging hebt dan kan het in de hold en als je minder dan 4 minuten vertraging hebt dan zo kom je dus te laat, ja dan is dat heel lastig nog weer te te op te lossen.

00:10:38

Kyara: Als jullie rekenen dan eigenlijk in stukjes van 2 of 4 minuten als je met holding werkt.

00:10:43

Rutger: Nee dat niet maar dat is toch wel een beetje het gevoel wat je krijgt. We rekeningen er niet echt mee maar je weet gewoon ja je kan veel nauwkeuriger sturen. Tot een bepaalde hoogte natuurlijk. En je weet gewoon dat je zodra ze in de hold de bocht omgaan, die bocht duurt sowieso 2 minuten, als ze voor de eerste van rechtdoor en helemaal 360 moeten maken en dat is 2 minuten.

00:11:04

Stefan: En daar zit nog een flinke spreiding in tussen vliegtuigtypes tussen in het ergste geval duurt die eerste bocht, die 2 minuten duurt, al 3 minuten en als je daar eigenlijk maar 1 minuut moet verliezen, dan komt dus degene die daar achteraan komt die die komt sowieso al 3 minuten later en dat werkt heel hard door. Het is waar je eigenlijk met vectoren kan je heel makkelijk, doordat je kan spelen met hoe hard je wegvliegt door de door de heading te variëren, hoe hard je wegvliegt van der stack kan je variëren met hoe snel je de vertraging eruit vliegt. Mik ik een heel klein beetje naast de stack dan loop ik de vertraging er heel langzaam uit, dus dan maakt het toch niet uit of ik zeg maar op 30 seconden of op 40 seconden terugdraai, dat maakt dan voor de tijd toch niet uit. Vlieg ik met heading oost weg van artip dan loopt ie er heel hard uit, dus dan moet ik heel snel.. dan naar luistert het heel nauw. Maar zo kun je wel heel makkelijk voor jezelf ook je werklust bepalen. Hoeveel druk zit er voor mij op wanneer ik terug moet sturen. Wanneer ik met vectors werk.

00:11:55

Stefan: En het is meestal dat de vertraging ontstaat bij de eerste kist. Zeker nu omdat je de harde overgang hebt van 2 banen starten 1 baan landen naar 1 baan starten 2 banen landen.

00:12:11

Stefan: Dus de eerste moet gewoon wachten tot de tweede baan vrij is en daarna dan loopt de vertraging wel door. Dus die eerste al door de hold in te gaan al van 3 minuten te laat komt ja dan heb je dus heel erg door werkende vertraging, want alles wat erachter als je die echt zo strak mogelijk. Het plus en min 5 seconden de tijd erover heen vectoren scheelt heel veel werklust erachteraan.

00:12:31

Rutger: Wat ook meehelpt is dat we holden niet heel vaak doen, tenminste de hold leegdraaien doen we niet zo heel vaak, dus daar zijn we niet zo geoefend in. Laatst ook weer, dan probeer je het wel heel strak maar je bent iets te voorzichtig, want je bent niet zo gewend. Maar met sturen zijn we wel gewend daar hebben we dus veel meer gevoel bij, wat het doet, hoeveel moet je vliegen, hoelang moeten nog vliegen, hoeveel moet sturen.

00:12:57

Stefan: en de standaard overdracht afspraken met approach die maken het ook dat je niet makkelijk krap kan werken in hold. De overdrachtsafspraken zijn nu uit de 100 zakken naar 70 (FL) speed 220 tot 250 (kts).

00:13:12

Stefan: Als je nou een afspraak hebt bij holden waarbij je moet wachten op een baan opening en daarna de afspraak maakt ik mag ze 708090 (FL) gestapeld overzetten en met een speed tussen de 220 250 knopen en 10 graden links of zo. Dan kun je veel makkelijker weer die efficiency daarna opbouwen, waardoor je niet enorme gaten hebt aan het begin van een peak.

00:13:35

Rutger: Wij moeten een rijtje overdragen terwijl bij Londen is het ook wel dat ze daar al 3 kisten op elkaar of binnen 5 mijl mogen doen.

00:13:40

Kyara: Want dat doen jullie niet?

00:13:42

Rutger: Nee of moeten bellen maar in principe is het gewoon dat ze een rijtje van ons willen hebben 5 6 mijl achterelkaar

00:13:47

Stefan: Voor dezelfde baan is dat een soort van not done.

00:13:49

Rutger: Ja.

00:13:51

Kyara: Oké.

00:13:51

Rutger: Dat leeft bij ons tenmniste, misschien als je met approach praat dat dat heel anders is.

00:14:00

Stefan: Lig eraan met wie je van approach praat haha

00:14:00

Rutger: Dat is ook weer zo..

00:14:00

Kyara: Want in theorie zou het ook kunnen?

00:14:04

Rutger: Ja. En zeker wat Stefan zegt, als er een tweede landingsbaan bijkomt waardoor het toch niet druk is in de TMA, dan kan het prima. Of bijvoorbeeld als toch wel de mist opklaart en wel weer flink glad kan worden dan zijn dat soort technieken prima te doen.

00:14:18

Stefan: Zoals ik heb meegekregen heb is de reden dat der gezocht wordt naar zo een holding tool is de realisatie vanuit de snel beter wordende weersomstandigheden. Of dat de baan cap onbenut wordt gelaten op het moment en dat komt mede doordat wij gewoon niet zo strak zijn, in zeker de eerste 4 kisten daar zit gewoon 10 NM tussen omdat je het gewoon niet gewend bent.

00:14:49

Kyara: Kunnen jullie een moment beschrijven waar je een hoge werkdruk ervaarde en hadden buffers hier invloed op?

00:15:03

Rutger: Ah. Vorige week. In de een de avond een keer een moment, we hadden vertraging op zuid. Ik weet niet meer precies hoeveel vertraging, maar het was voldoende om in de hold te gaan. Alle andere stacks hadden wat vertraging en waren aan het holden.

00:15:17

Rutger: En op een gegeven moment was het allemaal prima het was wel wat drukker met de overige verkeer maar dat was allemaal prima te doen want ik wist ik moet nog even 5-6 minuutjes in de hold en dan is het oké en dan is al het andere verkeer wel redelijk weg. Alleen toen werden we gebeld door approach of even we even strakke rijtjes konden maken met 6 NM. En terwijl de laatste 2-3 kisten zaten nog net niet helemaal in de hold en de eerste wel. En op dat moment had ik ook nog veel ander verkeer en door het verkeerd gebruik van de approach tijden en toch nodig hebben van de stack, en alsnog door kunnen komen op een rijtje van 6 NM. Het was behoorlijk werklast verhogend om daar nog te zorgen dat het een beetje netjes 6-7 NM werd. Al het overige verkeer ook netjes afgehandeld werd, dus niet afleevde. Dus ja dat kwam wel vooral door het buffer gebruik.

00:16:11

Stefan: Ja. verkeerd buffer gebruik.

00:16:24

Kyara: En dit was gebruik van een stack zonder dedicated stack controller?

00:16:29

Rutger: Ja.

00:16:30

Kyara: Oké. Dus dat was eigenlijk wat er voor zorgde dat de werklast hoog was?

00:16:37

Rutger: Ja. Als er een stack controller was geweest dan was de werklast appeltje eitje hè, want dan hadden we allebei: 1 had de stack met 5 ofzo of 6 en ik had de andere 6 kisten, dus dat was niet zo spannend geweest. Maar ook het belletje dat we door mochten komen, als het gewoon approach tijden was geweest dan was het ook wel beter geweest. De eerste zat volgens mij 2 minuten tussen, nou dat is een beetje 6 NM en daarnaast zat er 3 of 4 minuten tussen en dan weer een keer 3 minuten en dan was het iets verspreider geweest waardoor ik niet zo constant hoefde op te letten op wanneer ze konden indraaien.

00:17:08

Stefan: Ja het is gewoon in dit geval creëert de de ad hoc beslissing van approach creëert gewoon werklast in zichzelf, want dat je die beslissing eerder genomen dan had je met hetzelfde aantal vliegtuigen met hetzelfde aantal delay, als je overal anderhalf/ 2 minuten er tussen had gezeten dat je gewoon linksaf gaan met de hele hele pluk en dan rechtsaf en dan was het goed geweest.

00:17:27

Kyara: Dus dat is waarom voorspelbaarheid belangrijk is

00:17:28

Stefan: Ja het ligt echt in de voorspelbaarheid. Kies je voor een cut-off point van hier ga ik niet meer vectoren en als je dat gekozen hebt, dan wordt elke beslissing om ineens wel eerder door te komen (in de TMA) die wordt enorm werklast verhogend.

00:17:42

Rutger: Net te veel verkeer om het sturen, 7 of 8 minuten en dan met meer verkeer sector zuid, dan vind ik dat net iets te veel om dat er makkelijk uit te sturen, dus ja dan is de keuze de hold in maar dan zit je ook er aan vast als die keuze hebben gemaakt is. Zeker in een kleine sector dan kun je eigenlijk geen kant meer op omdat qua hoogtes en afstand tot elkaar heb je gewoon niet voldoende ruimte om daar weer wat van te maken.

00:18:09

Kyara: Hoe werkt het precies het gebruik van de stacks? Dat was voor mij best wel lastig te begrijpen want ja verkeer gaat erin en gaat eruit maar hoe snel gaat dat en beweegt het verkeer in een stack?

00:18:23

Rutger: Niet zo heel snel helaas, wil je ook de opbouw weten of gewoon als je al in de stack zit?

00:18:29

Kyara: Ook de opbouw.

00:18:31

Rutger: De opbouw is lastig omdat eigenlijk de kisten willen niet hard zakken en niet hard vliegen omdat ze vertraging hebben, want als ze weten 20 minuten vertraging, denken ze ja ik kan wel heel laag zitten maar dat kost alleen maar meer benzine en ik wil ze zo langzaam mogelijk. Maar wij willen ze eigenlijk zo laag mogelijk in de steek omdat er nog heel veel verkeer achteraan komt. Dus dat is al lastig.

00:18:46

Stefan: Want dat is je directe buffercapaciteit eigenlijk, als de eerste al halverwege erin hangt dan is de helft van je buffercapaciteit weg en als je gewoon op 70 (FL) erin zit

00:18:53

Rutger: dan heb je nog gewoon (stackcapaciteit) 16 kisten in en als je op 140 in de stack komt dan kun je d'r nog maar 9 in. Zoiets, Reken maar even na.

00:19:00

Stefan: Ja.

00:19:01

Rutger: En als je bijvoorbeeld in holding modus zit, zijn er veel mensen snel geneigd om gewoon op elkaar te zakken omdat ze toch op elkaar in de holding moeten. Het probleem is dat je bij het opbouwen van de hold moet je eigenlijk eerst zorgen dat je, als er 2 op elkaar komen of 2 binnen 4 NM vanuit Maastricht (MUAC) naar ons dan moet je eerst zorgen dat ze uit elkaar getrokken worden zodat je allebei al heel hard kunnen zakken. En daarna kunnen ze pas weer terug naar de stack. Omdat je als je de eerste zakt naar 70 (FL) en de andere zak je erop dan zit je met die tweede vaak veel te hoog omdat die gewoon niet zo heel hard zakt. En als je gewoon allebei tegelijk kan zakken dan scheelt dat en RT en je hoeft niet constant met de tweede op de eerste te zakken.

00:19:46

Stefan: De eerste die heeft dan een bepaalde descent rate dus die zakt niet zo heel hard met die dat A. niet wil en nou ik had naja maar goed dat kun je opdragen. Maar zelfs draag je hem een hogere rate op dan tweede krijgt telkens 1000 ft. Maar goed een vliegtuig gaat aanduiken dus de eerste 500 ft gaat met 250 ft per minuut omdat die eerst gaat duiken en daarna moet ie al weer af levelen dus dan gemiddeld doe je over 1000 ft zo een anderhalve minuut dan. Terwijl als je zakken 5000 ft kan zakken in 1 keer, duik je de in de eerste aan en dan zullen we de volgende 3000 ft die kan hij met 1500 ft per minuut doen en daarna gaat hij weer aflevelen. Dus groter je dat gat maakt naar beneden wat in 1 keer naar beneden kan klaren des te harder kun je zakken dus des te lager krijg je hem zonder eigenlijk problemen.

00:20:24

Rutger: En het scheelt ook gewoon heel voor RT en opletten voor jezelf want als je even niet doorzakt met constant erop dan zit die tweede dus helemaal te hoog. Terwijl als je het uit elkaar haalt en dan zakt dan hoef je eigenlijk daar even niet meer naar te kijken en dan kun je met andere dingen bezig zijn. Nou als het dan eenmaal in de hold zit,

00:20:38

Stefan: Voor dat gezegd te hebben, dan ga je dus eigenlijk al sturen dus als je dan aan de sturen bent dan kun je dus net zo goed eigenlijk gaan sturen om die delay eruit te sturen

00:20:43

Rutger: Ja maar dat hangt er van af, even vanuit gaande dat het een half uur delay is of zo en dat je echt flink wat erachter aan krijgt. Bijvoorbeeld als je dat nou eenmaal in de hold zit, d'r van uitgaan dat je gewoon vertical view kan gebruiken, je bent op zaal geweest he?

00:20:53

Kyara: Ja, ik heb dat nog niet op zaal gezien maar ik weet hoe het eruit ziet.

00:20:58

Rutger: Dat is voldoende opzich, daar zie je opzich het overzicht wel mooi alleen daar is een beetje wat Stefan zei kan elke keer maar vaak 1000 ft zakken. Als alle levels gevuld zijn en de onderste kan d'r uit, dan duurt het heel lang voordat je de bovenste kan laten zakken. Want je zakt de 1 na onderste zak je 1000 ft nou ja dat duurt een minuutje of anderhalf dan zakt de volgende, duurt weer een minuutje of anderhalf. Nou dat 7 keer/8 keer anderhalve minuut dat betekent dus gewoon dat de bovenste pas na 12 minuten nadat de eerste weg is 1000 ft moet zakken en en die moet dan dus 7/8/9/10/15 x 1000 ft naar beneden. Naja als je 8 kisten hebt dan heb je vaak wel iets meer delay dus dan wil het wel maar zeker als je niet zoveel delay hebt dan is die hoogte dan heel onhandig.

00:21:45

Stefan: Of als je ineens snel beter wordende weersomstandigheden hebt. Als je van heel veel delay naar 0 delay gaat bijvoorbeeld, waarbij de TMA gevuld moet worden, ja dat is dan onhandig als je dan een vliegtuig hebt boven de initial approach fix dei 15000 te hoog zit bij wijze van.

00:21:52

Rutger: Ja.

00:21:57

Rutger: En dat is alleen nog maar het zakken en dan het leeg draaien van de stack dus ook de hoogte is dan vervelend maar ook om te zorgen dat het een beetje een rijtje wordt of de tijd te halen. 1 omdat we het niet zo vaak doen is het onhandig maar ook omdat, wat we net al zeiden, je vliegt gewoon 180 graden de verkeerde kant op dus elk NM je langer doorvliegt verlies je eigenlijk 2 NM hè. En elke halve minuut die je verkeerde kant op vliegt verlies eigenlijk gewoon een minuut in je hele vertragingstijd. Dat werkt op zich heel lekker ongewoon veel vertraging kwijttaken. Maar als je bijvoorbeeld hier ligt artip en je hebt zo een rondje en dan kun je vaak op de heading zo door op de outbound leg, dat wordt regelmatig gebruikt. Maar daar moet je wel echt goed opletten dat je niet te laat bent, want dat kun je gewoon niet meer inlopen en als dat de tweede of derde kist is in een hold van 10. Dan verlies je dus daar al een halve minuut en als je dat nog een paar keer doet dan loop je in plaats van netjes op de approach tijden, loop je opeens 3/4 minuten achter. En dat de reden dat we een aparte controller hebben want. En zorgen dat je de approach tijden haalt en zorgen dat het allemaal zakt is voor 1 persoon met overig verkeer gewoon heel lastig, want die moet en zorgen dat je niet te vroeg bent dus daar is hij weer erg op aan het focussen. Maar om te zorgen dat je niet te vroeg bent moet je eigenlijk de eerste 2/3 moet je al redelijk uit de hold draaien of op de heading van de andere heading en dan vergeet je even met de boot te zakken terwijl die al prima naar beneden kunnen en dus dan vallen vaak gaten in de hold. Qua hoogte. En dat kun je eigenlijk ook niet meer inlopen tenzij je ze gewoon weer een rate of descend geeft maar ja die piloten die gaan ook geen 4000 ft doen in de hold. Want dat is te veel dus je kan zo'n beetje 1500/2000 (ft) maar ja dan duurt ook rustig 2 minuutjes tot er wat levels vrij zijn voor de volgende week kan zakken.

00:23:35

Kyara: Je kunt dus niet als er eentje start zakken dan de volgende ook al laten zakken?

00:23:40

Rutger: Officieel is het volgens mij als ie 300 ft verlaten heeft dus als je van FL 100 naar 90 zakt en hij zit door de 97 mag je officieel naar 100 zakken. Maar niemand doet dat omdat je niet weet hoe hard ze zakken zakken. De 1 doet met 500 en de ander 1500ft per minuut. Dus wil eigenlijk wel zeker weten dat het level gewoon vrij is en ik zak pas, als ze echt boven elkaar zitten, als een level helemaal vrij is en als er iets ruimte in de hold zit dan wil ik nog wel eens een keertje 200ft speling nemen. Dus als de ene door 92/93 zit dan doe ik de ander van 110 naar de 100, maar dat is wel echt een beetje de max speling die ik neem. En je kan gewoon veiligheidstechnisch, als je binnen de 1000 ft komt ook al voldoe je aan de 300 ft regel, als je binnen de 1000ft moet komt dan is het gewoon fout. En niemand wil dat, zeker niet in een hold. Alles zit dicht op elkaar, piloten schrikken daar ook van als ze op TCAS een waarschuwing krijgen.

00:24:27

Stefan: En TCAS/RA in een stack is helemaal feest.

00:24:39

Kyara: Nee dat is heel onhandig.

00:24:42

Stefan: Wat dat betreft was ik met strippen echt sneller, dan hoef je niet te kijken, melden ze door de 93 "maintaining 90 roger" ja weet ik veel. Dar was een soort van blind, een beetje ouderwets, maar ik was daar echt een stuk sneller in.

00:25:07

Rutger: Nee je bouwt gewoon meer buffer in, omdat je bij die strippen zag je niet precies wat die kist deed dus dan kon je doen het was 700 ft maar ik zag t niet "hij zei dat hij er zat" hij zei dat het goed was en wat de piloot zegt dat klopt. En nu zie je gewoon op de radar dat die nog niet op de fl 90 zit dus ook al zegt ie "maintaining 90" dan ja ik zie hem door de 95 dan weet je dat het gewoon niet klopt.

00:25:33

Stefan: Je ziet ook de de dalprofielen heel goed in de vertical view, dus je ziet of er eente hard naar beneden duikt of niet dus. Dat maakt ook wel dat ik daarmee meer ruimte neem vaak.

00:25:42

Kyara: Op welke volgorde op een stack leeggehaald? Is dat telkens de onderste?

00:25:50

Stefan: In de basis ja, in de basis is de laagste altijd de eerste. Maar ja als hold gevuld is en er komt een dusseldorf outbound op 160. ja die moet ergens tussen. Ja wat leuks mee verzinnen. Of je gaat eronder door. De draait een keertje als die bijna aan de beurt en die daar boven moet erin draaide de degene die moet wachten draai je even weg van artip en die ander erin en zodra die voorbij is zak je naar 70.

00:26:17

Rutger: Hangt er vanaf welke hoogte ze binnenkomen bij de FIR grens en het wil ook wel eens zijn als 't als we bijvoorbeeld een belletje krijgen van mogen we erin of als we updates krijgen en d'r zit er net eentje te ver weg om netjes een rijtje van te te maken dat je degene die daarboven zit gebruikt die dichterbij de stack zit om dan sneller in te draaien. Ze mogen, een normale holding is 4 minuten, ze mogen ook een holding 8 minuten maken of iets dergelijks en als er dus eentje net ver weg zit dan dan kom je te laat dus dan wisselen we snel even om dan te zorgen dat het wel gewoon 6/7 NM is in plaats van 8 of 9 NM. Dat doen we niet heel veel maar het gebeurt

00:26:59

Stefan: Naja best wel, meestal zie je dat degene die door mag approach en dan zie je ze boven de stack van oh die draait oh die mocht erin ja daar heb ik niks aan dan draait hij outbound en voordat hij weer terug te draaien, dan krijg je zo een s bocht, ja dan zit je tegen de 2 minuten. Dus ik heb beter degene die nog richting de IAF vliegt op inbound track zeg maar en die in een keer door sturen.

00:27:16

Kyara: Ja. En in het maken van zo'n rijtje hou je dan ook nog rekening met wake turbulence categorieën?

00:27:25

Rutger: Ja gewoon voor de standaard separatie dus wel light achter heavy is wat is het 7 NM ofzo daar houden we dan rekening mee.

00:27:32

Kyara: Niet in het optimaliseren van je baancapaciteit?

00:27:34

Stefan: nee.

00:27:37

Rutger: Nee

00:27:38

Stefan: Nee, maar die vind ik sowieso al een heel interessante want daar is geen zinnig woord over te zeggen volgens mij, tenminste door approach die vinden dat ze heavy's moeten clusteren, maar dan moeten we naar de 4 NM separatie. Terwijl als je een heavy achter een minimum wilt, dat is dus 3 NM. Maar als je een medium voorop hebt, die gaat veel meer reduceren dan een heavy. Zeker als je een hebt die naar 115 knopen approach speed. Eeen volgeladen 777 freighter gaat naar 175, naja 170 approach speed. Ja dan moet je dus eigenlijk al 4 en een halve mijl hebben achter een medium.

00:28:19

Rutger: Buiten dat bij acc hebben we ook een redelijk eerlijkheids principe, hanteren we. Dus het is gewoon wie het eerst komt wie het eerst maalt en als blijkt dat er een medium voorop zit dan is dat niet omdat het handig is voor iets anders. Maar gewoon puur, ja die man die zit ook al 20 minuten te wachten.

00:28:34

Stefan: Buiten excessieve dingen als een light achter de super dan wil ik ook wel eens wisselen uit veiligheidsoverwegingen. Dat is ja. Ik neem het totaal niet mee naar mijn hold opbouwen.

00:28:51

Kyara: Kun je in een hold verschillende handelingen tegelijkertijd uitvoeren of is het echt stapje voor stapje?

00:29:05

Stefan: In principe van zoals een hold opgebouwd is wel, wat ik vaak doe is dat als ik zie dat de approach tijden heel erg op 1 volgend zijn dan ga ik zorgen dat mijn hold al verder uit gaat vliegen. Dan ga ik de outbound leg een beetje doortrekken zodat ze op een gegeven moment er gewoon weer laterale separatie is. Zodat ik daar wel gewoon weer vrij kan zakken want als je op een gegeven uit elkaar trekt dan kunnen ze wel in ieder geval doorzaken. En dan ga ik zo alvast een beetje spelen om wat meer vliegtuigen tegelijkertijd laag te krijgen maar in in een standaard hold daar kun je inderdaad echter maar 1 ding tegelijk.

00:29:41

Kyara: De huidige capaciteit die er is, in hoeverre is die helemaal nodig om speciale omstandigheden op te kunnen vangen zoals een weer?

00:29:53

Stefan: Volledig. Huidige cap is 17 keer 3. Plus. 4/5

00:30:07

Rutger: Het gebeurt zelden maar we hebben soms te weinig capaciteit, denk dat het 1 of 2 keer per jaar voorkomt, dus niet heel vaak, maar het gebeurt wel.

00:30:20

Kyara: Kun je daarmee zeggen dat je de huidige capaciteit nodig hebt voor het opvangen en daarmee niet structureler proactief zou kunnen gebruiken?

00:30:25

Rutger: Ja Jawel

00:30:27

Stefan: Jawel

00:30:27

Rutger: Dan begreep ik hem verkeerd, ik dacht dat je bedoelde of er minder levels in een stack konden. Of iets dergelijks en dat kan niet. Maar we kunnen veel meer in de hold vliegen of ontvangen dan wat we nu doen. Want we gebruiken nu denk ik gemiddeld per dag 3 kisten, 4 kisten. En ik denk dat het prima 40/50 zou kunnen over de hele dag heen ja.

00:30:52

Stefan: Nog wel meer

00:30:54

Rutger: Nog wel veel meer inderdaad

00:30:54

Kyara: Maar als je je goed je hold voller wil houden dan moet je dus meer verkeer laten komen, maar als je situaties hebt dat je verkeer op moet vangen door plotselingen mits en je hold al vol zit en je laat dus meer verkeer komen, dan kun je op een gegeven moment niet meer kwijt

00:31:06

Rutger: Klopt.

00:31:07

Stefan: Meerr tactisch, pretactisch beslissingen moeten maken inderdaad van nou als je meer verwacht dan heb je dus gewoon niet de mogelijkheid om meer verkeer laat komen maar als jij met aan zekerheid grenzende waarschijnlijkheid weet dat in ieder geval de eerste 15 weg zijn dan heb je daarna weer stack capaciteit.

00:31:23

Rutger: Ja.

00:31:24

Stefan: Het is een beetje het snijvlak van ja ik denk dat er veel meer hold kunnen gebruik in die zin veel meer kunnen laten komen maar daar moet wel pretactisch heel scherp op gelet te worden.

00:31:36

Stefan: Op de momenten dat we te weinig capaciteit hadden was als meteo dacht dat we schitterend marginaal zicht hadden, fantastisch weer en vervolgens bleek dat er maar 1 landingsbaan hadden. Maar goed, over het algemeen, zie dat we aankomen. Dus bij weer is het gewoon dat je ja dat weet, dat kunnen we niet dus dan komt er niet te veel. En de momenten dat je echt dus stack capaciteit zou kunnen benutten is op dagen dat het gewoon een beetje dit weer en geen regen geen laaghangende bewolking of zon. Dan heb je gewoon niet zo snel het probleem dat je je stacks vol hebt hangen en dat er toch te veel verkeer komt.

00:32:21

Kyara: Hoeveel denk je dat ze van de stacks die er nu zijn structureel gebruikt kunnen worden om extra verkeer op te vangen?

00:32:25

Rutger: 25 per uur

00:32:36

Kyara: En waar baseer je dat op?

00:32:37

Rutger: Ja. 21 per uur, we hebben 3 stacks. Ongeveer, ik vind 7 kisten per stack acceptabel want dan hoef je niet bijzonder hard je best te doen om te zakken en je hebt dan ruimte om iets nadelige effecten bijvoorbeeld als approach iets minder is of d'r is toch wat aan de hand dat ze iets meer ruimte nodig hebben, dan heb je nog ruimte over om boven die 7 nog kisten te holden.

00:33:01

Stefan: Dus er is nogsteeds veiligheidsmarge.

00:33:01

Rutger: Ja er is nogsteeds eenveiligheidsmarge.

00:33:06

Stefan: Het zit ook deels in bunch vorming. Want als je tussen de 7 tegelijk krijgt, dat krijg je nooit netjes een hold in. Dan zitten er altijd gaten van 3000ft tussen. Terwijl als je ze heel gespreid krijgt, ja dan kan mijn hele hold vol, zonder dat ik m'n krant hoef weg te leggen dan kijk ik naar de 17 kisten in the hold, ja als het allemaal achter elkaar vliegt dan is dat niet zo spannend. Werklast gerelateerd is dat nog wel een dingetje, qua wat je aan kan in een hold. Maar als je gaat kiezen voor ophogen van de uur capaciteit om die buffer dan zul je wel misschien wat stringenter op de bunch definitie moeten sturen of verlagen zelfs. Om er voor te zorgen dat je niet verrast wordt door een hele wolk verkeer die dan allemaal de hold in moeten.

00:33:47

Rutger: Ja het kan niet allemaal in het begin komen.

00:34:09

Kyara: Waar ligt de bottleneck in het leeghalen van de stack?

00:34:17

Stefan: Hoogte.

00:34:18

Rutger: Oefening.

00:34:19

Stefan: Ja oke ja buiten de mens capaciteit, maar goed die is te trainen. Als je dat elke dag doet dan

moet je daar netjes 6 NM van kunnen maken. Maar de grootste is in mijn ogen hoogte. En wat vliegtuigen performance. Als de vlieger niet meewerkt, ja dan houdt het op. Nou ofwel ik doe er eentje tussen, dat kunnen we ook wel eens doen, maar dan moet er wel zitten. Dat is menscapaciteit, maar vooral de hoogte.

00:34:48

Rutger: Ik ben het met je eens. Ik zeg niet dat het een heilige graal is maar als ik bijvoorbeeld naar Londen kijk wat ze doen. En daar hebben ze uit het is een beetje gek maar daar halen ze soms 3 kisten uit de stack dus allemaal een beetje verschillende headings en een beetje zakken. En op zich hou je dan evenveel capaciteiten en dan heb je er een plukje van 3 en dan weer even niet en dan weer een plukje van 3, alleen het scheelt dat je dan gewoon de onderste 3 in een stack kun je al meteen zakken in plaats van elke afzonderlijk 1000 ft kun je ze dan gewoon redelijk even goed hard meteen naar onderen en dan de volgende er bovenop en dat scheelt gewoon een hele hoop. In plaats van elke keer eentje, kun je elke keer 1000 ft en daardoor zorg je dat je en het probleem met dat wij niet strak kunnen sequencen en het hoofdprobleem is daarmee een beetje opgelost. Gewoon meteen bij approach, die weten hoe ze het willen, weten of er nog 1 tussen moet kunnen, dus veel beter, veel scherper, want die zitten gewoon weer normaal op een heading wat ze elke dag doen.

00:35:34

Kyara: Maar dat is dus het verschil bij London dat de stacks controlled zijn door approach.

00:35:38

Stefan: De onderste levels inderdaad inderdaad, 3/4 ja zoiets.

00:35:45

Kyara: Hoe snel keer achterelkaar vliegtuigen uit de stack halen en want is hier de limiterende factor voor?

00:35:49

Rutger: Overdrachtsseparatie. We moeten we voldoen aan de overdrachtafspraken naar approach. Ja dus dan is het gewoon elke 6 NM, dus elke anderhalf /2 minuten.

00:36:03

Stefan: Ja minimaal 5 (NM). Ja als je het elke dag doet met je speed is het 5.

00:36:05

Rutger: Ja maar dat doe je nu ook niet met het sequencen.

00:36:11

Rutger: Approach wil graag 6 NM. Ja oke als we dat even helemaal loslaten dan kun je 5 NM inderdaad dat is waar. En dan is de hoogte en oefening.

00:36:21

Stefan: Ja goed een capaciteitslimiterende factor is natuurlijk gewoon 5 mijl. Doorvoer capaciteit van je stack is 5 NM en als ze dan allemaal langzaam vliegen, ja dan gaat het gewoon langzaam. Je krijgt er dus minder per uur uit dan dat je dat doet met een lopende sterk sequence, want dan komen ze vanuit de 130 met nog 5 NM te gaan met reducerend uit de 300 (kts) dan gaan ze gewoon 70 kts hoog boven de grond harder dan dan uit de stackk waar ze eigenlijk 190 (kts) vliegen en al heel laag zitten en dan nog een soort van moeten increasen en dan naar 220 (kts) increasen vaak. Dus je mist daar ook gewoon nog een flink stuk.

00:37:05

Rutger: Denk ook het moment waarop je de sequence maakt. Als als ik als ik er nu over nadenk. Als je bijvoorbeeld de sequence maakt op Artip de zeg maar de eerste gaat over op Artip op 70 en dan draaien we heel strak in en pas zodra de tweede bij Artip zit heb je 5 NM anders dan kun je eigenlijk pas doorzakken naar 70. Als je dat verplaatst naar voor Artip. Dan kun je al eerder een 70 waardoor de kisten ook lager kunnen zitten. Dus volgens mij heb je dan als je.

00:37:37

Stefan: Ja maar dan zitten ze lager, lagere grondsnelheid. En ten opzichte van sequencen zeg maar.

00:37:47

Rutger: Nou ja. Ik denk dat vooral de hoogte beperkt als je heel strak op 5 NM doet dat je op een gegeven met gewoon de hoogte niet meer kwijtraakt en als je dan naar 7 kan.

00:37:56

Stefan: Nee dat ik net zei verder dat ga ik ook wegvliegen uit de stack om inderdaad te zakken zodat je nog laag genoeg komt. Maar ten opzichte van sequencen is in een hold gewoon echt letterlijk de doorvoer snelheid is gewoon lager omdat je langzaam gaat een lager zit

00:38:31

Kyara: Zou je iemand vanuit 70 (fl) eruit kunnen sturen en als je dan 5 NM separatie hebt er iemand vanuit 80 er achter aan kan sturen. Dat je ze er wel op verschillende levels uitstuurt?

00:38:40

Rutger: Als er verschillende levels eruit mogen sturen dan kunnen we het krapper binnen 5 NM en dan kan het ook sneller de stack uit

00:38:47

Kyara: En hoe snel?

00:38:49

Stefan: Hoe snel hangt ervan af hoe krap we mogen komen. En hoe hoog we mogen. Als het zeg maar als er tussen de 70 en 140 door mogen komen dan kun je de eerste 7 kisten. Binnen 4 minuten allemaal uit te stellen hebben denk ik. Want dat is gewoon de eerste had op 70 tot 80 daar al op 90 enzovoort tot 140 en dan is maar net waar ze in de zitten en een rondje in de steek doet 4 minuten dus in principe als boven elkaar mag je hoeft niet op 5 NM te letten. Dan denk ik dat je de eerste 7 kisten in het binnen 4 minuten de TMA in kan duwen.

00:39:26

Stefan: Ja dus als je ongeveer 3 NM of meer wil hebben. Dan denk ik dat je ook weer de eerste 7 kisten in een minuutje of 8 / 9 eruit kan sturen.

00:39:42

Kyara: Hoelang doe je nu ongeveer over die 3 NM of 5 NM?

00:39:46

Stefan: Ja 5 NM is een beetje anderhalf of is een beetje anderhalf / 2 minuten ongeveer. Een beetje afhankelijk van hoe hard ze vliegen, soms wat langer. Drie NM is dan iets minder. En dan heb je nog met het zakken en een draai te maken en waar ze in de hold zitten op dat moment dus dan als je ook nog qua hoogte wil een beetje de volgorde wil dus dat je niet hebt dat de eerste vliegt op 70 en de tweede op de 100 en de derde weer 90 dan heb je daar ook wel tijd voor nodig om te zorgen dat we op het juiste moment over de iaf komen. Het is een beetje pak 'm beet maar ja ik denk 8/9 minuten is zoiets dat je dan voor de eerste 7, misschien nog wel iets meer zelfs.

00:40:30

Kyara: Zou je met holding stack het gebruik van de vierde baan tussen pieken kunnen opvangen? Er wordt steeds meer naar de 4e baan regel gekeken en zeker in de zomer wordt waarschijnlijk wel een limiterende factor. Zou je die bewegingen die nu op de vierde baan binnenkomen kunnen opvangen? Dus echt structureel dat verkeer opvangen.

00:41:06

Stefan: Het zou wel kunnen. Want zo heel veel verkeer is het niet volgens mij en kun je dat prima opvangen in aantallen. Alleen het probleem is dan wat de rest van de piek gaat doen. Want als je bijvoorbeeld nu maar 34 of 32 kisten kan landen omdat je maar 1 baan hebt. En dan komen er 40 heb je 8 keer te veel, maar zodra je 2 landingsbanen hebt als er dan meteen 65 of 60 komen heb je daar eigenlijk gewoon de hele baan al mee gevuld. Plus dan nog een keer die 8 die dan hou je dus delay en

dan kom je eigenlijk nooit van die delay af tot 's avonds laat. Dat is op zich niet erg, maar dat betekent dus dat je ook de hele inbound piek door heb je gewoon constant extra delay. Dat hoeft niet erg te zijn en als je dat niet wil moet je ergens een moment hebben dat je die het overschot wat je hebt om die 8 kisten weg te werken zonder dat je terug moet naar 1 baan of zonder dat de baan vol gevlogen wordt. Stel dat je, je hebt 8 kisten te veel en in het eerste moment van de 2 landingsbanen gebruik komen er maar 60, dan kun je eigenlijk die eerste acht nog wel kwijt, of in de eerste half uur komen er heel weinig en daarna komen we pas weer veel dan kun je die 8 in het eerste stukje wel kwijt en de rest die kreeg toch al delay omdat die toch allemaal samen komen.

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Appendix III Dutch airspace

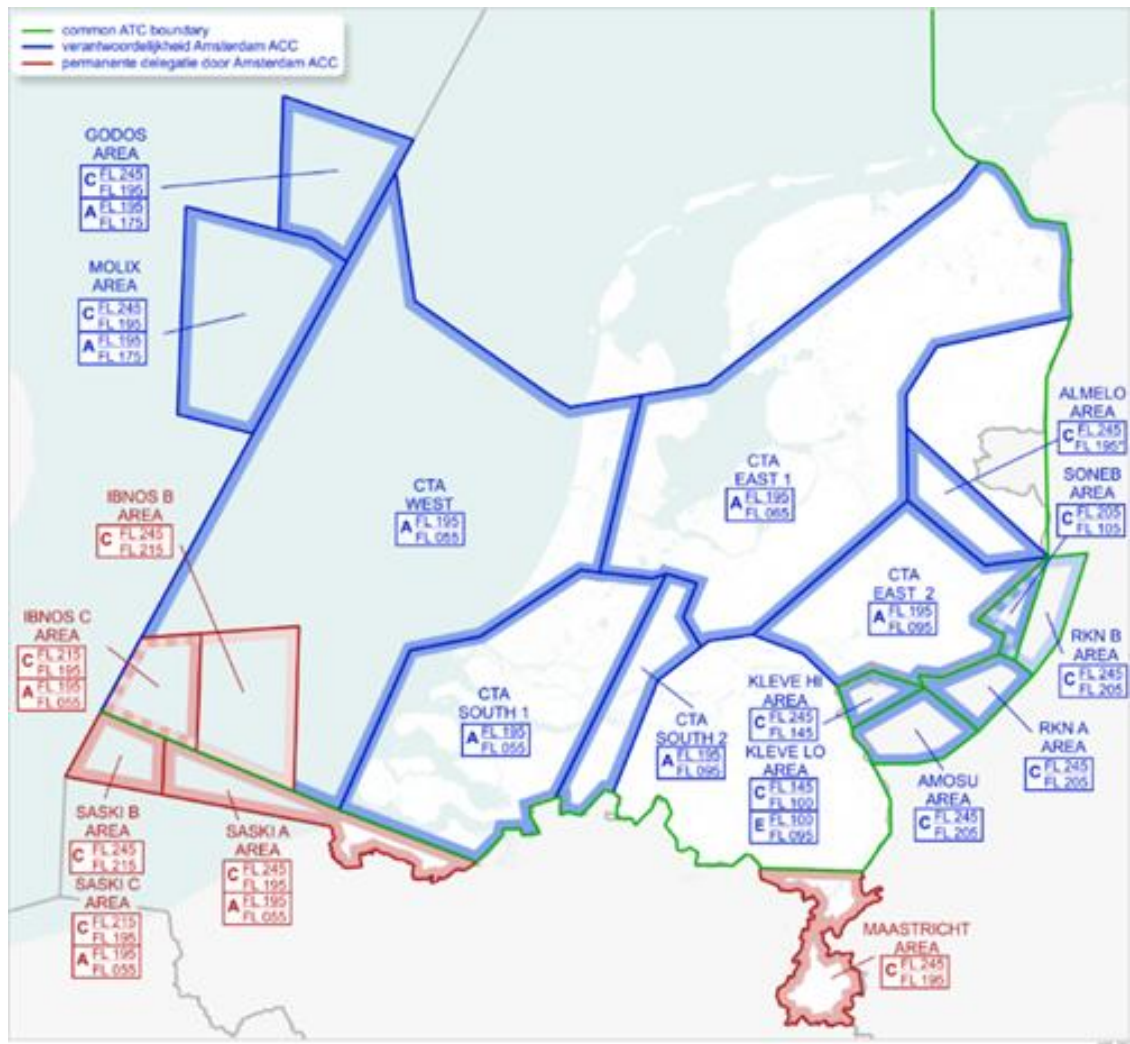


Figure 22: Responsibility LVNL Area Control Centre according to Operational Manual (OM AMS ACC) ((Luchtverkeersleiding Nederland, n.d.-b)

Appendix IV Area Control Centre Sectors LVNL



Figure 23: Sectors LVNL Area Control Centre according to Operational Manual (OM AMS ACC) ((Luchtverkeersleiding Nederland, n.d.-b)

Appendix V Arrival routes AMS TMA

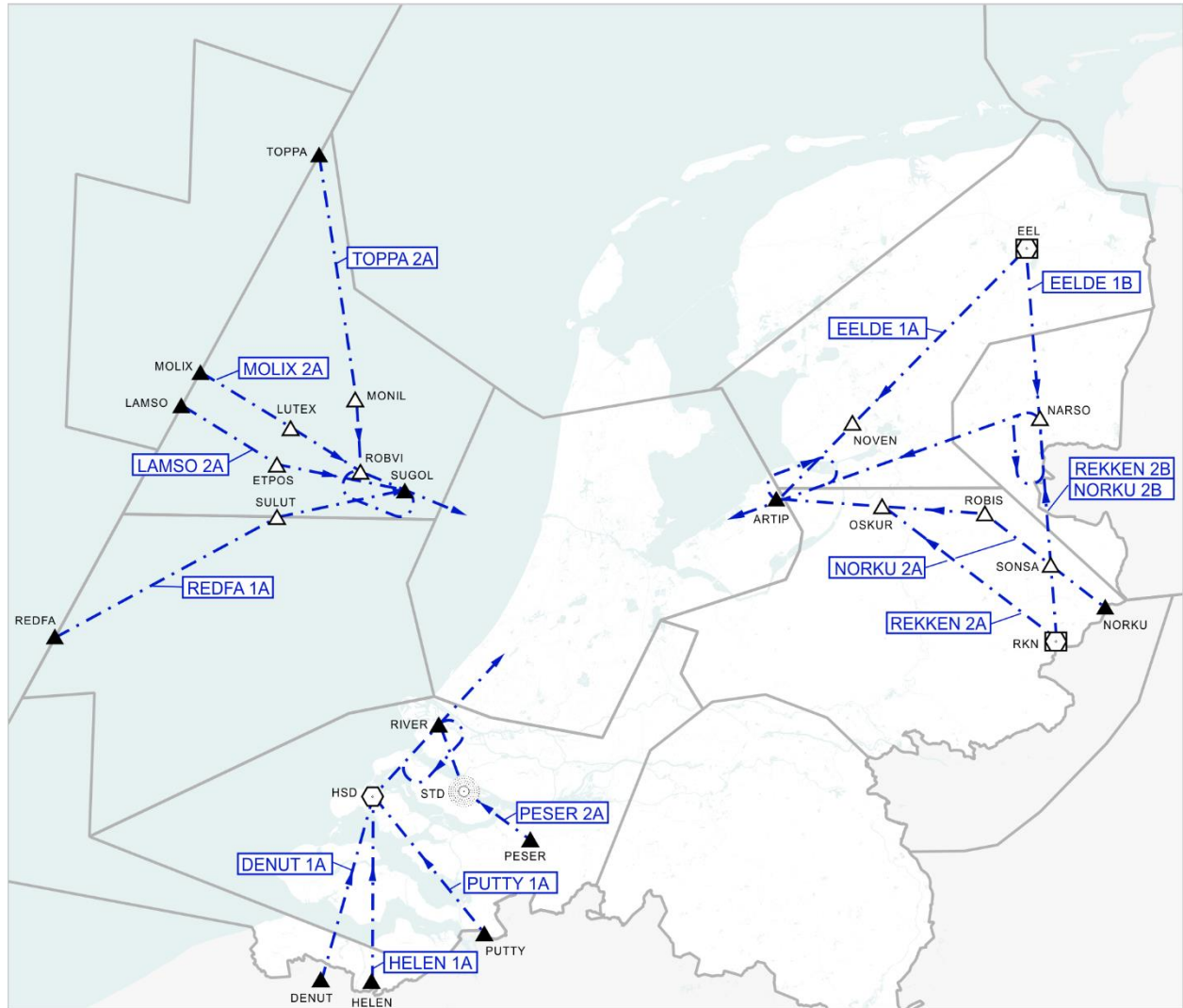


Figure 24: Standard Arrival Routes from FIR entry to TMA entry according to Operational Manual (OM AMS ACC) ((Luchtverkeersleiding Nederland, n.d.-b)

Appendix VI Summary Personal Conversation D. Noordam (Air Traffic Controller Tower/Approach and Strategy Operational Expert LVNL), 6 May 2019

First ATFM restrictions, then (extended) arrival management and at last vectoring is used as a funnel to create a streamline to the IAF. The more stable the traffic passes the IAF on the ASAP planning times, the more stable the rest of the chain becomes. Additionally, the more predictability the top of the funnel creates, the more capacity the system creates. The more accurate the ASAP planning is met, the more stable the flow in the TMA gets, which results in a more optimal realised runway capacity.

Optimally use the available runway capacity is important for LVNL. LVNL is a service provider and delivers what is asked by the sector; in other words, LVNL handles the traffic that is presented to them and their goal is to deliver capacity at Schiphol. The available runway capacity is a large factor in this and the traffic volume is adjusted to this figure. Especially with less optimal weather situations the runway capacity causes restricted traffic volumes, because larger gaps between aircraft cause a loss in capacity. However, the amount of inbound capacity is larger than the amount of outbound capacity, this makes the ground capacity necessary to *store* traffic. The available ground capacity is limited and is restricting the inbound capacity; e.g. in case of a bad weather situation such as snow, the controller will only permit as much inbounds as outbounds, because the ground infrastructure will get jammed with traffic if the outbound flights cannot depart.

The actual demand that presents itself during peak hours is higher than the available capacity. What makes the operation even more difficult is the unpredictability of the arriving inbound traffic. Especially bunching becomes very problematic. When 20 aircraft are planned to arrive in the coming 20 minutes, it is possible that the first 10 aircraft plus 5 late arrivals from the previous time slot will present themselves at the FIR boundary in the first 5 minutes. ATFM slots are not the solution for the unpredictability of air traffic; airlines can ask for directs or adjust speed to reach the airport in time for their connecting passengers, the airlines can reach the IAF earlier than planned with the ATFM slot as result.

To absorb this traffic, buffers in the airspace are necessary. However, holding is not the most ideal way to absorb bunches. Holding stacks are rigid, because there is little control on the speed of the aircraft in a hold. It is hard to minimise delays with the use of holding. Holding stacks are useful to absorb big delays. It might help when the lower levels of a hold are controlled by APP, the approach controller has a more tactical view on the sequencing for the runways and know when and how it is possible to fit in the aircraft.