

Arrival Management Evaluation

An insight into Advanced Schiphol Arrival Planner

Thesis



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A collaboration with the Aviation Academy, Amsterdam University of Applied Sciences

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Thesis

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Abstract

Advanced Schiphol Arrival Planner (ASAP) has been implemented on November 13th 2018, which replaced the old system called Inbound Planning. The department capacity management and analytics faced the problem that, currently, insufficient operational documentation and insights into the new arrival management system ASAP are available.

This research solved the problem that insufficient documentation is available about ASAP and this research functions as a framework for further research into arrival management and/or ASAP.

The following main question was leading in solving the problem of insufficient documentation:

How does ASAP generate the arrival planning at Amsterdam Airport Schiphol, and how can the planning be adjusted by the controller and the output be measured?

ASAP generates its arrival planning at Amsterdam Airport Schiphol with eleven different inputs:

- | | | |
|-------------------------|-------------------------|----------------------------------|
| 1. Radar data | 4. Filed Flight Plan | 8. LIV + Capacity |
| 2. TMA trajectories | 5. ABI + ACT message | 9. Weather information |
| 3. Aircraft performance | 6. Runway configuration | 10. Buffer parameters |
| | 7. IAF preference | 11. Output Trajectory prediction |

All of these inputs are used to provide ASAP's calculating components with the correct information and data of each flight. The most important components to generate the planning, are the slot time planning and the trajectory prediction. All ASAP's components perform calculations which create six outputs:

- | | | |
|--------|--------------|------------------|
| 1. ETA | 3. Slot time | 5. Delay |
| 2. LIV | 4. EAT | 6. Speed delta t |

ASAP's output must be measured with monitoring the four proposed Key Performance Indicators, which relate to the correctness of the time information and an optimized arrival sequence. These requirements are critical to the air traffic controllers who work with the output (planning) of ASAP.

- | | |
|-------------------|--------------------------|
| 1. EAT adherence | 3. Holding ratio |
| 2. Slot adherence | 4. Influence of the APLN |

The Approach Planner (APLN) has five different actions to influence ASAP's planning, and the three most frequently used actions are to assign another runway to one flight, assign another slot time to one flight, and to create a new planning in ASAP.

The main recommendation is to use this document actively and to keep its information up-to-date. This document enables the facilitation for further research and makes the knowledge easily obtainable and more transferable to new students or LVNL's employees.

Keywords: Arrival Management,
Advanced Schiphol Arrival Planner,
Schiphol,
Air Traffic Management.

Preface

This thesis on “Arrival Management evaluation – An insight into Advanced Schiphol Arrival Planner”, which has been performed to clarify the elements of the arrival management system at Amsterdam Airport Schiphol. This research has been written to fulfill the graduation requirements of the Aviation Logistics program at the Aviation Academy at Amsterdam University of Applied Science. I was involved in investigating and writing this research from February to July 2019.

The study provided by the Knowledge and Development Centre, located at the accommodation of the Dutch Air Traffic Control, where I have started to do a graduation internship. My research question was formulated together with my thesis product owner André van de Groep and my thesis consultant Catya Zuniga.

I want to thank my thesis consultant, Catya Zuniga, for her guidance and support during my thesis project. She has been very encouraging, and her deadlines helped to motivate me to keep writing.

Additionally, I also want to thank Ferdinand Dijkstra for transferring his inspiring enthusiasm about arrival management and ASAP to me. I also want to mention that, without his help and the help of Gert Hans Grutter, I would not have reached this result as my final thesis report.

To the other involved Knowledge and Development Centre students and colleagues, I would like to thank you all for your motivation and creative ideas when I needed them most. And, most importantly, I want to express gratitude to Frenchez Pietersz for his professional guidance with the start-up phase of my thesis.

I hope you find my thesis report interesting and enjoy reading it!

A. (Anouk) Hollebeek
Schiphol, June 18, 2019

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List of abbreviations

AAA	Amsterdam Advanced ATC (System)
AAS	Amsterdam Airport Schiphol
ABI	Advance Boundary Information
ACC	Area Control Center
ACID	Aircraft Identification
ACT	Activation
AMAN	Arrival Management
ANSP	Air Navigation Service Provider
APLN	Approach Planner
APP	Approach Control Center
ARTAS	ATM Surveillance Tracker And Server
ASAP	Advanced Schiphol Arrival Planner
ASM	Arrival Sequencing Model
ATA	Actual Time of Arrival
ATCOs	Air Traffic Controllers
ATM	Air Traffic Management
ATO	Actual Time Over
CCIS	Closed Circuit Information System
CDM	Collaborative Decision Making
CISS	Central Information System Schiphol
CMA	Capacity Management And Analytics
CO	Controller
COP	Coordination Point
CTOT	Calculated Take-Off Time
CTQ	Critical to Quality
DCB	Demand and Capacity Balancing
DFD	Data Flow Diagram
E-AMAN	Extended AMAN
EAT	Expected Approach Time
EDD	Electronic Data Display
EOBT	Estimated Off-Block Time
ETA	Estimated Time of Arrival
ETO	Estimated Time Over
ETOT	Estimated Take-Off Time
FDP	Flight Data Processing
FIFO	First-In-First-Out
FL	Flight Level
FPL	Filed Flight Plans
ft	Feet
GND	Ground Control
HMI	Human Machine Interface
IAF	Initial Approach Fix
IBP	Inbound Planning
IFR	Instrument Flight Rules
ILS	Instrument Landing System
KDC	Knowledge and Development Centre
KNMI	Royal Dutch Meteorological Institute

KPI	Key Performance Indicator
kt	Kiloton
LAS	Last Assigned Slot
LIV	Landing Interval
LT	Local Time
LVNL	Air Traffic Control the Netherlands
MSL	Manual Slot
MUAC	Maastricht Upper Area Control
NM	Nautical Miles
NPT	New Planning Times
OIM	Operations and Instructions Manual
OLDI	On-Line Data Interchange
QRC	Quick Reference Chart
RDP	Radar Data Processing
(R)ETD	(Revised) Expected Time of Departure
RTF	Radio Telephony
RVR	Runway Visual Range
RWY	Runway
SDD	Situation Data Display
SFR	Shift Runway
SID	Standard Instrument Departure
SIPOC	Suppliers, Inputs, Process, Outputs, and Customers
SMART	Specific, Measurable, Attainable, Relevant, and Timely
STAR	Standard Arrival Route
TBFM	Time-Based Flow Management
TMA	Terminal Control Area
TP	Trajectory Prediction
TRA	Transition
UCO APP	Under Control at Approach
UDP	Uniform Daylight Period
UTC	Universal Time Coordinated
VEM	Safety, Efficiency, and Environment
WTC	Wake Turbulence Category
XMAN	Cross-Border AMAN

Definitions of terms

Term	Abbreviation	Definition
AAA	Amsterdam Advanced ATC system	AAA is a computer system which makes the operation of air traffic control possible. All LVNL's stations are linked to this system. AAA exists of a collection of hardware and software.
ETO	Estimated Time Over	The time that an aircraft is estimated to pass a specific point in airspace, calculated with nominal speeds and predefined distances from position to point.
ATO	Actual Time Over	The time an aircraft passes a specific point in airspace.
IAF	Initial Approach Fix	At the borders of the Terminal control area (TMA) are three points where the traffic from Area Control Center (ACC) is transferred to Approach Control Center (APP): at the Initial Approach Fixes (IAF).
Stack		A stack is a waiting area where multiple aircraft fly a waiting pattern. At Amsterdam Airport Schiphol, these waiting areas are the three IAF points.
EAT	Expected Approach Time	The time that an aircraft is calculated to leave from one of the three IAF points, determined from the landing slot.
EAT adherence		The difference between EAT and ATO stack. A negative adherence, therefore, means that the flight passed IAF too early; a positive adherence means that the flight passed IAF too late.
ETA	Estimated Time of Arrival	The time that an aircraft is estimated to arrive at the runway, calculated with nominal speeds and predefined distances from position to the runway.
ATA	Actual time of Arrival	The actual time that an aircraft arrives at the runway.
Slot time		The flight's landing slot. The time at which the flight is planned be at the runway by ASAP.

Summary

Due to the increasing demand for air traffic, capacity is a frequently discussed topic at the Knowledge and Development Centre. Since Schiphol has almost no growth opportunities left, it is crucial to use the airport facilities and airspace as efficiently as possible. Arrival management is one topic which relates to the efficient use of airspace capacity.

From November 13th 2018, the new arrival management system, referred to as Advanced Schiphol Arrival Planner (ASAP), has been introduced at the LVNL which replaced the old system, referred to as Inbound Planning (IBP). The main objective of these systems is to guarantee that a safe amount of arrival traffic enters the Schiphol Terminal Control Area (TMA) and that the runways are used most optimally.

CMA assesses the impact of planned changes to the Air Traffic Management (ATM) system in terms of capacity and environment. An example of an amendment to the ATM system is the replacement of the previous system IBP with ASAP. The problem which is now faced by the department CMA is that the documentation of ASAP is insufficient and not assembled nor available in one synoptic document. This resulted in the following problem statement:

There is currently insufficient operational documentation and insights about the new arrival management system ASAP.

This first argument to clarify the research's relevance is that this document functions as a complete ASAP documentation. The second argument is that, when this document is located at an open network, the knowledge becomes transferable to all employees. A third argument is that this research must function as a framework for further research into arrival management and/or ASAP.

These stated arguments, together with the formulated problem statement, resulted in the following main research question:

How does ASAP generate the arrival planning at Amsterdam Airport Schiphol, and how can the planning be adjusted by the controller and the output be measured?

To answer this question, first, an analysis has been performed on the complete arrival process at Amsterdam Airport Schiphol. This analysis provided a deep insight into the current situation. This result has been visualized with a flowchart, which clarified the conclusion that four different stakeholders act within the arrival process at Schiphol.

After the first analysis and introduction of the arrival process, an introduction to ASAP is presented. Before any further and in-depth research has been performed, it was required to understand the basic principles of the ASAP system.

All ASAP-related process steps have further been analyzed with the use of a SIPOC diagram (Suppliers, Inputs, Process, Outputs, Customers). With the SIPOC diagram, all SIPOC elements were investigated per ASAP process step to create a complete and detailed overview of the ASAP system.

The results of the second and part of the third sub-research question (*what is the input for ASAP, and how does the processing work* and *what is the output of ASAP*) is presented in a table (Table 1) because these results together answer the first part of the main research question, which is how ASAP generates its planning. The analysis of this complete result, however, has been split into two research questions.

Table 1: How does ASAP generate its planning

Inputs	ASAP black box		
	Component	Function	Specific output
Radar data TMA trajectories Aircraft performance Filed flight plan ABI + ACT message Runway configuration IAF preferences	Trajectory prediction	TMA trajectories; Nominal speeds; Actual position	ETA
LIV + available capacity Weather information Aircraft performance Filed flight plan Buffer parameters	Dynamic LIV	Entered LIV; Available capacity; Wind; WTC; Final approach speeds; Buffer parameters	LIV
LIV Output trajectory prediction	Slot time planning	ETA – Expedite margin LAS + LIV	Slot time EAT Delay
	Speed delta t		Speed delta t
	Night transition (ON/OFF)		

The other answer to the third sub-research question, of how these outputs can be measured, is advised with the aid of Key Performance Indicators (KPIs). The presented KPIs function as a recommendation and as an indication of how the output must be measured. The proposed KPIs focus on the needs of the customers, which are in this case (due to the scope of the project), the air traffic controllers. Therefore, the KPIs must concentrate on the correctness of time information and an optimized sequence. With this information, four KPIs are formulated:

1. EAT adherence
2. Slot adherence
3. Holding ratio
4. Influence of the Approach Planner

The final sub-research question focused on how the controller can adjust the planning. The only controller who can actually adjust ASAP's planning is the Approach Planner (APLN). This person can perform five different actions to individual flights, aiming to improve the overall arrival flow. The three most frequently used actions are: runway change, slot time change, and recalculate the whole planning.

Resulting from this research, different recommendations are offered. The first important recommendation is to actively use this report as a framework for other research, and as documentation, which explains the arrival management and ASAP. Additionally, it is advised to maintain this document to prevent that the material will become obsolete and that the problem of this research will originate again.

The second recommendation is to create more awareness at the Area Control Center (ACC) controllers about the operational changes of the implementation of ASAP. During the performed interview, some resistance and unfamiliarity have been identified. Therefore, the focus is required on the application of speed delta t, and which other positive effects this function has on their processes. A tool for this awareness is to create a presentation, explaining the information from this report.

The final recommendation derived from the further performed analysis between the EAT adherence and the manual adjustments of the APLN. This analysis concluded that a moderate correlation is present between the late transfer of flights and the number of manual adjustments. Therefore, the advice is to decrease the plan window (which is now ± 2.5 minutes) of a flight's transfer between ACC and Approach Control Center. A smaller plan window expectantly results in a more stable operation and therefore, fewer interventions. Additionally, further research on the origin of this relationship is required.

1 Introduction

The research institution Knowledge and Development Centre (KDC), which is an initiative from the partners KLM, Amsterdam Airport Schiphol (AAS), and ATC the Netherlands (LVNL), wants to create improvement and developments concerning capacity at the Mainport Schiphol. Therefore, to achieve these goals, the thesis research to the Arrival Management (AMAN) at AAS (from now on referred to as Schiphol) will be executed. LVNL will have the most interest in this research since they are the owner of Advanced Schiphol Arrival Planner (ASAP) and can use the framework for further study or as an informational source.

This chapter describes the introduction to the research. First, a description presents the background to the problem. Then follows a formulation of the problem statement, which defines and explains what the problem of the research is. The research objectives will clarify what the LVNL's expectations are and what kind of research is expected. Finally, the research's relevance is presented, which will indicate the importance of the study and why it is required that the problem is solved.

From November 13th 2018, LVNL has a new AMAN system, called ASAP. Deutsche Flugsicherung Systemhaus is the supplier of the ASAP application, but the LVNL has completely modified the system to the specific needs of LVNL and the operation at Schiphol. Before the implementation of ASAP, the old planning system IBP (inbound planning) was operational.

ASAP functions as a supportive planning tool for the Approach Planner (APLN) to their responsibilities, to create and monitor the inbound planning. The goal of the inbound planning is to plan the flights in such a way that the traffic flow within the Terminal Control Area (TMA) is handled safely and stable. Therefore, ASAP aims to prevent that too much traffic enters the Schiphol TMA.

The department Capacity Management & Analytics (CMA) of LVNL develops a VEM (Safety, Efficiency, and Environment) performance standard twice per year. One for the summer season and one for the winter season. These documents include the runway and airspace capacities. Also, CMA assesses the impact of planned changes to the Air Traffic Management (ATM) system in terms of capacity and environment. An example of an amendment to the ATM system is the replacement of the previous system IBP with ASAP, and the future ASAP 2.0⁴ implementation.

Until now, limited research has been conducted to the performance of the AMAN system. This applies both to the old IBP system and the new ASAP. However, CMA is expected to be able to assess the effects of an ATM change. Additionally, Dijkstra (2019) experiences the need for AMAN documentation from various people within LVNL. These people ask him for information, which is available in his head, but he cannot direct them to one clear document.

1.1 Problem statement

There are various challenges concerning the ASAP system. Firstly, ASAP is a new system, and the availability of documentation is insufficient. Additionally, the available literature is divided into various sources. Most important information can be attained from two people within the company, but from this originates the risk that when these people leave LVNL, they take their knowledge with them, which results in loss of information.

Secondly, ASAP is still being tested with different settings and iterations, which expectantly results in an improved system. These tests are based on research, but not all information from these results nor about the performed analyses has been documented sufficiently.

Finally, CMA wants to be able to analyze the effects of ASAP 2.0 and future improvements concerning the capacity and environment in the nearby future. But to be able to assess and estimate the impact, they need an ASAP framework to understand its behavior.

⁴ ASAP 2.0 is still under development and is an improved version of the recently implemented ASAP, focusing on an improved system input

With this information two problems are enumerated;

1. Documentation about ASAP is insufficient and not assembled
2. The operational and technical factors are not sufficiently analyzed nor how these factors influence the performance of the arrival process. Now, due to the scarcity of documentation, changes to the system are not based on previous analyses but deduced from experts' common sense

As a result of the two problems above, the definition of the main problem statement is:

There is currently insufficient operational documentation and insights about the new arrival management system, ASAP.

1.2 Research relevance/significance

Firstly, this research will solve the problem that there is insufficient documentation available about ASAP and how it works. When the document is created and located at an open network of LVNL, the knowledge about ASAP will become transferable and accessible to all employees.

Secondly, the research will function as a framework for further research into the subject. If, for example, this further research makes it possible to identify the relationship between input factors and the output. Then, this research indirectly functions as an essential tool to support decisions or actions.

Since the LVNL continuously wants to improve its operational performance, they are also required to improve their AMAN system furtherly. Therefore, it is essential to know which variables influence which output. With this framework as a starting point and an overview of how the input and output relate, prioritization can be given to which input or output requires improvement(s). This overview of the system's relationships or dependencies will mean that LVNL is able to make an improved estimation of the impact resulting from the changes. Better knowledge of the behavior of the system will result in faster improvements to the arrival process, due to prioritization of required developments, which additionally could save money.

1.3 Research Questions

The main research question should cover how the planning is made, the interventions of air traffic controllers, and ASAP's output, to create a complete document which describes all elements of ASAP. Therefore, with the requirement that this research, and together with the previously mentioned problems, the main research question resulted in the following:

How does ASAP generate the arrival planning at Amsterdam Airport Schiphol, and how can the planning be adjusted by the controller and the output be measured?

Sub research questions

To be able to answer the main research question, sub-research questions are formulated. If all questions are answered, a combination of these answers results in the complete solution to the main research question. The answers to these questions are presented in the findings.

1. How is the arrival process to Schiphol organized?
2. What is the input for ASAP, and how does the processing work?
3. What is the output of ASAP, and how can this be measured?
4. How can the Air Traffic Controllers and Approach Planner influence ASAP's planning?

Background questions

Background questions do not function as an answer to the main research question, but they are required to provide a better understanding of the topic. The answers to these questions are provided during the analyses in the analysis chapters. The following background questions are added to the sub research question:

1. How is the arrival process to Schiphol organized?
2. What is the input for ASAP, and how does the processing work?

- a. How does ASAP work?
 - b. Which aspects have been affected after the implementation of ASAP?
3. What is the output of ASAP, and how can this be measured?
 - a. Which KPIs are defined by the LVNL?
 - b. What are the minimum/maximum tolerated values of these KPIs?
4. How can the Air Traffic Controllers and Approach Planner influence ASAP's planning?
 - a. Which air traffic controllers work directly with ASAP, and why?
 - b. Which decisions or circumstances trigger the controller to intervene in ASAP's planning?

1.4 Research scope

This research will focus on the arrival process, from an aircraft sending an Advance Boundary Information (ABI) message to runway threshold; this is the range where ASAP is active. Additionally, concerning all data analyses, the influence of weather is left out of scope. Runway usage and differences between Initial Approach Fix (IAF) entries are also left out of scope during the data analyses.

In this research, the terminology of Air Traffic Controller (ATCO) refers to the executive ATCOs and does not include the APLN. This distinction is due to the different interaction they have with ASAP.

The scope of the first research question, about the organization of the arrival process at Schiphol, will be from ABI-message until arrival at the gate. All KDC stakeholders (plus ASAP) are implemented within the flowchart. However, all further information within this research only focuses on LVNL's perspective to ASAP. The reason for this scope is because both KLM and AAS are not a direct customer of ASAP's output.

The performance difference between IBP and ASAP is executed by CMA and will be added to the research; the researcher will not additionally perform this data analysis. This data analysis left weather and runway usage out of scope.

The second research question, about ASAP's inputs and processes, will scope around the presented input and suppliers shown in the SIPOC diagram (Suppliers, Inputs, Process, Outputs, Customers). The process will be explained through the functions of the components. The algorithms behind the calculations of the planning times will be left out of scope.

The third research question presents the output of ASAP and how this should be measured. The output will be invested with a SIPOC diagram. The information about the KPIs will be focusing on the arrival process and ASAP. However, if no ASAP Key Performance Indicators (KPIs) are determined, the research will investigate which KPIs might be required to monitor to track the performance of the system. These KPIs will be presented as advice to monitor the system; they will not function as an analysis to measure the current performance of ASAP. Due to the previously mentioned scope, the customers of ASAP are focused on the LVNL ATCOs and APLN.

Because the Approach controllers (APP) do not always operate according to the planning, an explanation and further research to the relationship of the slot adherence and manual interventions of the APLN will be out of scope.

The final research question will be focused only on the controllers who directly work with ASAP. Because the APLN can influence ASAP's planning the most, the focus of this chapter will be on the APLN. Additionally, how the influences can be implemented via the system, is left out of scope. This document only discusses the possible actions and not the corresponding procedures.

To conclude, the research will cover an analysis of the inputs and the outputs (together with KPIs) and a study of the behavior of the ATCOs and APLN who are required to work with ASAP.

1.5 Assumptions, Limitations, and Delimitations

Due to the scarcity of documentation, the assumptions must be made that the available documentation from LVNL is correct and that the knowledge from the ASAP experts is correct. The unavailability of documentation, therefore, creates the limitation to be able to question the correctness of the sources used within this research. This limitation occurs because this specific system is only operating at Schiphol.

Another assumption in this thesis research is that the ASAP algorithm is available and performing sufficiently. The focus of the report will be on the operational perspective.

The last assumption that was required to make is the assumption that the by CMA performed data analysis is correct.

One of the limitations is that the sample group of the interviewed ACC controllers is sufficient. Due to the scarcity of their availability, the small sample size is considered to be an adequate representation of the whole group.

Another limitation is the scope of the formulated KPIs. These are not tested nor analyzed (except for one KPI) due to time limitations of this thesis research. Additionally, to formulate the required KPIs, it is assumed that the retrieved Critical To Qualities (CTQs) are still in line with ACC's perspective and are therefore assumed to be correct.

The final limitation is the availability of data. Since ASAP is operational since November 13th, the amount of data is not much. However, it is assumed that this data offers a correct representation of the current situation.

Delimitation is the scope of the arrival process: from ABI-message until runway threshold.

1.6 Thesis structure

The structure of the thesis is as follows:

- Abstract and summary
- Introduction
 - o Background
 - o Problem statement
 - o Research questions
- Literature review
 - o Definition, benefits, and elements of AMAN
- Methodology
 - o Why which decisions are taken, which assumptions, and why this method
- Analysis
 1. Arrival process at Schiphol & An introduction to ASAP
 2. ASAP pre planning
 3. ASAP's planning is fixed
 4. Adjustments by the Approach Planner
 5. Flight at IAF and under control at approach
- Results
 - o Per sub-question
- Conclusions
 - o The answer to the main research question
- Discussion
- Recommendations
- References in APA style
- Appendices

2 Methodology

The methodology describes how this research is carried out, and it explains how and why this research is performed with the used methods. The descriptions are elaborated per sub-research question. For each sub-question is explained why and which research instrument is used.

However, before the first research question was investigated, a preliminary literature review has been performed. The goal was to research why an Air Navigation Service Provider (ANSP) would implement an AMAN system, and what the general procedures or guidelines of AMANs are. This information has been achieved through websites of EUROCONTROL, NATS, and many other sources.

2.1 Sub-research question 1

How is the arrival process to Schiphol organized?

A flowchart is created to visualize the complete arrival process, with the five available stakeholders⁵. The flowchart visualizes the arrival process from ABI-message until arrival at the gate. The reason for this scope is because ASAP is not operative before the ABI-message.

The flowchart includes information flows and process flows. The process flows are visualized in the correct time and moment of happening. However, due to the complexity of time within the information flows, their moment of happening is not represented within this diagram.

The arrival process is described in detail next to the visualized information within the flowchart. This flowchart offers a framework to clarify the complete arrival process at Schiphol. This overview is required to understand before the report zooms into the operation of ASAP.

After the analysis of the complete arrival process, but before it was possible to answer a specific ASAP related research question, an introduction to ASAP was required to understand the essential elements. This general information was retrieved through the available literature from LVNL.

Within this chapter, a small sidestep has been taken to the differences between the previous system (Inbound Planning, IBP) and ASAP. This information can be useful since the ATCOs have to get used to a new system and can, therefore, have an influence on their behavior. Both operational and technical changes have been enlightened through an interview with Mr. Dijkstra (ASAP operational specialist). The interview was conducted semi-structured, which means that questions were designed beforehand, but when an interesting or unclear statement was made, extra and in-depth questions were added to the interview.

The difference in performance between IBP and ASAP has been researched through data analysis, performed by CMA. This form of research is qualified as quantitative research. The data which has been compared is presented in Table 2.

Table 2: Performance analysis data sample size

	IBP data	ASAP data
From	19/11/2017	18/11/2018
To	26/03/2018	25/03/2019

The investigated days contain flights with an Actual Time of Arrival (ATA) 05:00 – 22:00 UTC.

After the introduction to ASAP, the SIPOC diagram is presented. A short description clarified the subsequent structure of the report, resulting from the information within the diagram. The research questions are discussed according to the SIPOC diagram. A diagram like the SIPOC investigates the complete overview of ASAP and clarifies dependencies and interactions within the system and its processes. A SIPOC diagram is a tool in process management that helps to identify and characterize key driving influences on a process (Sayer & Williams, 2012).

⁵ ASAP, Adjacent Center, ATCOs, Airline, Airport

2.2 Sub-research question 2

What is the input for ASAP, and how does the processing work?

This research question focussed mainly on the supplier, input, and processes. The information about the suppliers and input was achievable via desk research and conversations with ASAP experts. Documents and websites which were consulted are from EUROCONTROL, ICAO, and through the documents of the LVNL.

Then, to visualize the relationship between input and supplier, a Data Flow Diagram (DFD) has been created. This diagram is designed together with Mr. Grutter, the ASAP technical specialist.

With the knowledge of the suppliers and input, the process of how ASAP is creating its planning is clarified. This has been explained per component, with the information from the LVNL documents. This subchapter has been verified by different ASAP experts.

All these methods (the DFD, conversations, and desk research) are qualified as qualitative research since it is not based on data analysis.

2.3 Sub-research question 3

What is the output of ASAP, and how can this be measured?

Since most input elements and its suppliers have been mentioned and described in the previous analysis chapter, this analysis chapter focused on the output and customer of ASAP.

First, a description per output is explained. Then, to assess whether the output meets the desires and requirements of the customer, CTQs have been investigated. The formulation of CTQs helps to focus on the customers' requirements (Morgan & Brenig-Jones, 2014). The CTQs for the ACC controllers have been formulated within the ASAP requirements, which have been researched before the implementation of ASAP. Therefore, it was not necessary to perform this research again through an interview with ATCOs

To create the link between ASAP's outputs and its customers, KPIs have been researched. KPIs will clarify which performance must be measured within the process and which possible improvements are imaginable (Morgan & Brenig-Jones, 2009).

Since LVNL monitors the performance of the complete arrival process and ASAP is an element within this arrival process, the formulated KPIs for ASAP must be in line with the arrival performance KPIs of LVNL. Therefore, this information has been retrieved through literature. The investigated LVNL annual report originates from 2018.

The formulated ASAP KPIs are derived from the analyzed CTQs plus the general LVNL KPIs. An example of this method is presented in Table 3.

Table 3: Substantiation of formulated KPIs

LVNL KPIs	CTQs	Formulated ASAP KPIs
a.	1.	a + 1 = KPI1
		a + 1 = KPI2
	2.	a + 2 = KPI3
		a + 2 = KPI4

Which ASAP KPIs were formulated also depended on which data was available. Therefore, a data dictionary was created to investigate this. This dictionary presents which information is available through all data columns. This clarification also prevents misunderstanding of how the data results will be interpreted in the future. Since ASAP is only operational since November 13th 2018, the available data is from November 18th to December 29th 2018.

The formulated ASAP KPIs have been validated by the ASAP experts and colleague of the CMA department.

After the formulation of the different KPIs, all proposed KPIs have been visualized (with the available data) through graphs to clarify how the KPIs can be monitored.

2.3.1 The extra result from the research to the KPIs

Based on the available data (18-11-2018 to 29-12-2018, attained from department CMA), a possible relationship was encountered. Therefore, further research was executed to the relationship between the following elements:

1. EAT adherence (deviation between EAT and ATO stack) and manual adjustments of the APLN
2. Slot adherence (deviation between slot time and ATA) and manual adjustments of the APLN

The first step to investigate these relationships was the calculation of the IBP_TOTAL ⁶, which is:

$$IBP_{PRE} + IBP_{POST} = IBP_TOTAL$$

Equation 1: Calculation IBP_TOTAL

Then, the summation of the number of IBP_TOTAL is produced. To clarify how the sum of these numbers is generated, an example is presented:

Table 4: Example calculation sum IBP_TOTAL

<i>EAT or slot adherence (s)</i>	<i>IBP_TOTAL</i>
60	1
60	0
60	2
60	0

With the information of the table above, the result of the example's calculation is:

$$Sum\ of\ IBP_TOTAL\ for\ adherence\ 60 = 1 + 0 + 2 + 0 = 3$$

Equation 2: Sum of IBP_TOTAL

The second step was to calculate the weighted average of IBP_TOTAL . The formula of this calculation is:

$$Weighted\ average = \frac{Sum\ IBP_TOTAL}{Count\ EAT\ or\ slot\ adherence}$$

Equation 3: Calculation of the weighted average

In SPSS, the statistical analysis of Spearman's rho has been applied to the data. Spearman's rho is best to test the correlation since the results are not linear and not normally distributed.

For both results, the summation and the weighted average of IBP_TOTAL , a statistical analysis has been performed. The adherence values are split into negative values (flight is too early at IAF or runway) and positive values (flight is too late) to create a better result. Together with the ASAP specialist is determined that the EAT adherence values <-300 and 300> are considered as outliers.

Because the APP controllers do not always operate according to the planning (since the planning primarily focuses to the transfer on EAT at IAF), an explanation and further research to the slot adherence and IBP relationship were out of scope. Therefore, the outliers of these values have not been determined by experts, and two ranges have been used; -500 to +500 and -300 to +300.

⁶ The number of IBP_TOTAL refers to the individual manual interventions of the APLN, measured before and after IAF

For the reliability of the data analysis and further analysis of the relation of EAT adherence and manual changes, extra available data was necessary to exclude the possibility that the implementation of ASAP has influenced this relationship. Therefore, three additional months (data of 01-01-2019 to 24-03-2019) has been analyzed separately and is presented in another table within this sub-chapter. This data became available later and is therefore added into the research later.

2.4 Sub-research question 4

How can the Air Traffic Controllers and Approach Planner influence ASAP's planning?

This final research question aimed to get a grip onto the different controllers who work with ASAP. However, before the executive controllers' practices were analyzed, the possible actions of the APLN have been discussed.

Then, an analysis was performed to create an overview which ATCO is responsible for which area and which actions can they take to influence ASAP's output. Resulting from the information of the first research question, a division of the ATCOs was made. The terminology of ATCO refers to the executive ATCOs and do not include the APLN, due to the different interactions they have with ASAP.

Then, it is crucial to investigate which circumstance or decisions trigger the APLN to apply changes within the system. Since APLNs are people and not machines, it is possible that some decisions are made by expert judgment instead of procedures. With the use of an interview and observation, these decision-making factors have been investigated and mapped.

The chosen interviewee is an APLN who has been involved in the development of ASAP and was intimately familiar with its operation. The involvement to the development of ASAP ensures that this APLN has extensive knowledge and understanding of the system. Because this person has in-depth knowledge, the decision-making was analyzed in much detail. The objective of this research is to investigate ASAP, so together with his experience, the best insights and results have been obtained.

This interview was unstructured, and no questions were designed beforehand. This interview was conducted based on the issues arising during the operation and his manual interventions.

After the APLN was interviewed, four ACC controllers were interviewed. These four people were randomly chosen, and no appointment was made in advance. The sample size of these four people is presented in Table 5. These ACC controllers were interviewed in couples; controller 1 and 2, and controller 3 and 4.

Table 5: ACC controllers sample size

Reference	Experience as ACC Controllers	
ACC controller 1	< 5 years	
ACC controller 2	Between 20 and 25 years	Also ACC supervisor
ACC controller 3	More than 25 years	Also ACC supervisor
ACC controller 4	Between 15 and 20 years	

Because this interview was unprepared, the interview was held unstructured. It was essential to analyze their influence on the system, and an excellent addition was the ability to question their opinion about ASAP. The controllers are anonymized, so they felt able to free their mind and to discuss their idea about the system openly.

3 Review of the Literature

To get an insight into the necessary information of this research, the first analysis is a literature review. This literature review focusses on the origin and purpose of an AMAN system and why this system would be recommended to use or implement. The literature review will provide the necessary information which enables the reader to understand the next chapters of this research better.

EUROCONTROL (2010), presents a description of the implementation guidelines of an AMAN. The detailed information within this chapter is obtained from this source unless stated otherwise. As this document additionally states, very little available documentation about AMAN exists. The last significant literature about AMAN, then, was published in 1999.

3.1 Definition of an AMAN

The meaning of arrival management, in aviation terms, is as follows: *“The general term given to the process of safely and effectively arranging arrivals into a smooth, efficient flow for landing at a destination airport”* (EUROCONTROL, 2010).

Various aid and tools are available to assist in this arrival management process. An example of these tools are:

- Printed flight-schedule
- Flight-progress strips on board
- Electronic aids

The best electronic aid is one which not only assists in sequencing and optimizing the flow of arrival aircraft but additionally provides information to the Air Traffic Controllers (ATCOs) on what is required, to create and maintain the best arrival sequence. Therefore, when people talk about AMAN systems, they are usually talking about the type of software which is designed to provide assistance in sequencing arrival flows of traffic, but also which gives all the time management and other information required to implement efficient arrival management.

For many years, AMAN systems are developed in Europe. These systems have evolved independently and without a standardized approach. The independent development created that the systems now are used in different ways in different locations. These various implementations created that now, the arrival management support can be differently categorized. Some AMANs are used and regarded as an essential sequencing aid which provides robust support for the ATCOs. Other AMANs are used primarily for regulating the traffic flow into the TMA. And yet other AMANs only occupy a background role and are not used.

The AMAN is usually managed and controlled by a dedicated controller, like a supervisor or an approach manager. The information from AMAN can be distributed in approach sectors, and upstream to area control sectors, and other centers.

According to EUROCONTROL, the general objective of an AMAN is: *“To provide electronic assistance in the management of the flow of arriving traffic in a particular airspace, to particular points, such as runway thresholds or metering points.”* They continue: *“Its main aims are to assist the controller to optimize the runway capacity (through aircraft sequence) and/or to regulate/manage the flow of aircraft entering the airspace, such as a TMA. It also aims to provide predictability for its uses (both ground and air) and at the same time minimize the impact on the environment, by reducing holding and low-level vectoring”*⁷ (EUROCONTROL, 2010). To be able to meet these aforementioned objectives, AMAN must provide a sequence for all and each aircraft heading to the runway, an estimate time of arrival at the runway (ETA) or when a flight flies over different fixes.

⁷ Radar vectors can be required for spacing and separating aircraft (FAA, n.d.)

Table 6 shows an overview of the correct interpretations and the misperceptions about an AMAN, together with a short explanation.

Table 6: What AMAN is, and what it is not (EUROCONTROL, 2010)

	AMANs are	AMANs are not
1	Planning tools	Full trajectory monitoring tools
2	Metering traffic to metering points	Conflict detection and resolution tools
3	Support for controller decisions	A replacement for controller decisions
4	A traffic flow awareness distribution	The ultimate solution in ATM

The statements from the table (Table 6) clarify that AMAN can monitor and process radar information (based and acting on the flight's longitudinal path), but it is not a full trajectory monitoring tool⁸. The second statement explains that AMAN is designed to assist in metering traffic, but it will not act as a conflict detection or resolution tool. AMANs' advises are not automatically conflict-free, and it even requires from the controllers that they can guarantee that the sequences are safe and conflict-free. The third statement underpins the fact that the controller is still an unmissable element of arrival management since it is not possible to design the software capable of considering all factors that a controller needs to consider. The final statement should underpin that AMAN is a tool to provide situational awareness among the controllers. Even though an AMAN can support the controllers, it is not the ultimate solution for all problems in aviation or ATC.

3.2 Benefits of an AMAN

Four different improvement areas of an ATM system are identified (EUROCONTROL, 2010):

- Safety
- Capacity
- The environment
- Efficiency

However, these four improvements can often be seen as contradictory when they are required for being achieved at the same time. For instance, an increased capacity mostly influences the environmental impact. But, AMAN systems aim to assist in balancing and combining these improvement factors. This balance can be achieved with a reduction of holding aircraft before their arrival and creating linear delay absorption instead. Another goal of AMAN is to reduce the ATCOs workload, mainly when a disturbance occurs.

These four improvements can also be seen as the most critical expectations and argumentations to implement an AMAN. The elements capacity and efficiency are most important for this research, so these will be furtherly enlightened.

3.2.1 Capacity

Runway throughput can be beneficially impacted by two aspects of an AMAN, to improve the traffic flow at the airport (Harris Orthogon, n.d.):

1. Optimized metering ensures that all available runway slots are used effectively
2. Average separation between runway movements are reduced by sequencing

These two aspects result in the improved capacity of the operation since more aircraft can be handled within the same time and with the same resources. An enhanced capacity can only be attained with the additional improvement of AMAN, which is that the ATCOs' workload will reduce or be equal with the same amount of flights.

⁸ It will not monitor every aspect of the flight's lateral or vertical movements

3.2.2 Efficiency

The benefits can also be expressed in terms of money, or savings on the use of fuel. The economic benefits of an AMAN are described for the three stakeholders:

- The Air Navigation Service Provider (ANSP): human resources are used more efficiently
- The airlines: improved flight efficiency and a reduction of fuel consumption (due to less holding)
- The airport: enhanced predictions of arrival times and related services on ground

The link of the different benefits of an AMAN is presented in Figure 1.

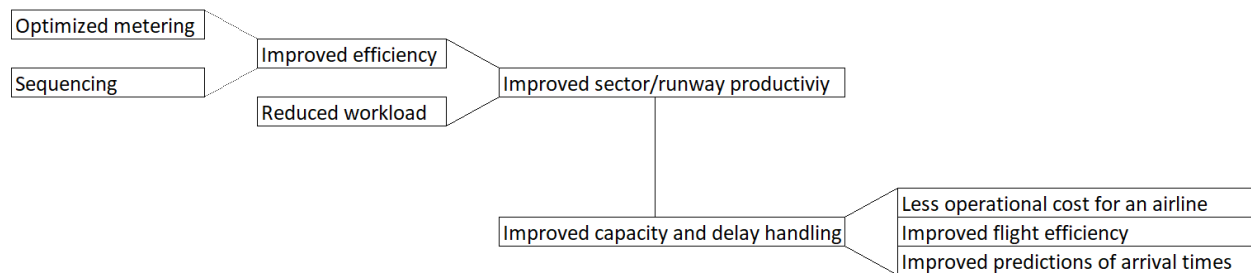


Figure 1: Benefit linkage of AMAN (EUROCONTROL, 2010)

An analysis of the impact of AMAN at Oslo Gardermoen Airport underpins these benefits above. AMAN helped to create a more optimized arrival sequence, which resulted in fewer TMA delays. An additional result was, from less waiting times for arrival aircraft, that the fuel consumption has been reduced (Harris Orthogon, 2015). These benefits are recognized at London Heathrow Airport too. The first two months in 2017 were analyzed, which indicated a fuel burn saving to 4kt fuel, which would be around £2million per year (NATS, 2017).

3.3 AMAN elements

According to the Tezpur University, the definition of a system is as follows: *A system is an orderly grouping of interdependent components linked together according to a plan to achieve a specific objective* (Tezpur University, 2017). From this definition, five characteristics are identified:

1. Order and structure, to achieve the users' objectives
2. An interaction of how the components function with each other
3. An interdependence of one subsystem and another
4. Integration of the complete system
5. One central objective of the whole system and all its components

The following elements are the critical elements in a system (R.C. Mishra & Simant, 2009):

- | | |
|---------------------|-----------------------------|
| 1. Input and output | 4. Feedback |
| 2. Processors | 5. Environment |
| 3. Control | 6. Boundaries and interface |

Because the research will only be focusing on the first critical element, the literature review will therefore solely be focusing on this element; Input and output.

The inputs are elements that enter the system for processing. These elements can be divided into human resources, materials, and information. The output must be in line with the expectations of the user; the system has to produce a valuable output (R.C. Mishra & Simant, 2009).

3.3.1 AMAN's input

This subchapter will implicate a high-level perspective on the general AMAN input. Further research and a deep-dive into these input factors will be executed and explained in Chapter 5.

According to EUROCONTROL's document, the primary input sources for an AMAN are:

1. Flight plan data (source: flight data processing system (FDP))
2. Radar data (source: radar data processing system (RDP))

Other input elements are (EUROCONTROL, 2010):

- Weather data
- Aircraft performance model
- Airspace and flight constraints
- Wake turbulence category information
- Manual inputs
 - o Landing rate separation
 - o Slots to block a runway for a particular time

Pirard (2002) has also formulated a description of the parameters required for the sequencing formulas (input for AMAN). These are similar to the elements above, but defined more specific:

- Aircraft type with a distinction between Light, Medium and Heavy; which requires different separation values
- Airborne and ground equipment which indicates the trustworthiness of information⁹
- Runway capacity and configuration, because when two (or more) runways are used, procedures can have an impact on the operations
- Sector capacity, which is defined by the ACC supervisor
- Weather data
- Military sectors, whether they are activated or not, since less airspace can influence the routes
- Vectoring and holding phases

3.3.2 AMAN's output

This subchapter will provide a high-level and basic perspective on the general outcomes of an AMAN system. Again, further research into the output of the AMAN at AAS will be executed and explained in the Chapter 6.

The Aircraft Sequencing Model (ASM) is the precursor of an AMAN. In the research of Andersson, Hall, Atkins & Feron (2003) is a visualization presented, which states the input and output factors of this model. This figure (Figure 2) is a valid starting point to create an analysis of the in- and outputs of an AMAN.

However, the ASM only produce decisions for one airline at one airport within a time horizon of 3 to 4 hours. Therefore, this model is not to be considered as equal and requires that other literature has to be researched additionally.

⁹ If accurate and precise equipment is being used, a smaller separation can be allowed

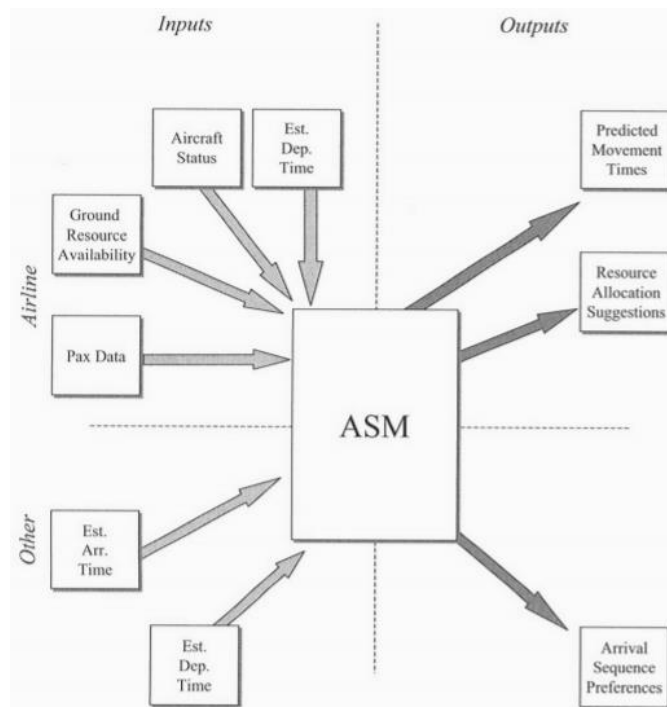


Figure 2: Arrival Sequencing Model (ASM) information flow (Andersson, Hall, Atkins, & Feron, 2003)

To obtain a complete impression of the output, the implementation guidelines written by EUROCONTROL (2010) is a valid source. In this document is a description of the output from an AMAN, which will be presented on the supervisor's screen:

1. Different time information
 - a. Delay information
 - b. Estimated time at a particular point
2. Optimized sequence
3. Delay management advisory
 - a. Time to lose
 - b. Time to gain
 - c. Speed advisories
 - d. Turn advisories

From these output results, combined with the defined KPIs from the research from Ástþórsdóttir (2013), two different KPIs are formulated to measure the arrival performance:

1. Arrival delay
2. Runway rate, arrival aircraft per hour

An image, most in line with the AMAN systems of today, is presented in Figure 3. It is expected that this thesis research will be able to add some elements to the already stated elements within this figure. This expectation derives from the fact that when the figure with information from 2003 (Figure 2) will be compared with the figure with the information from 2010 (Figure 3), many elements are added.

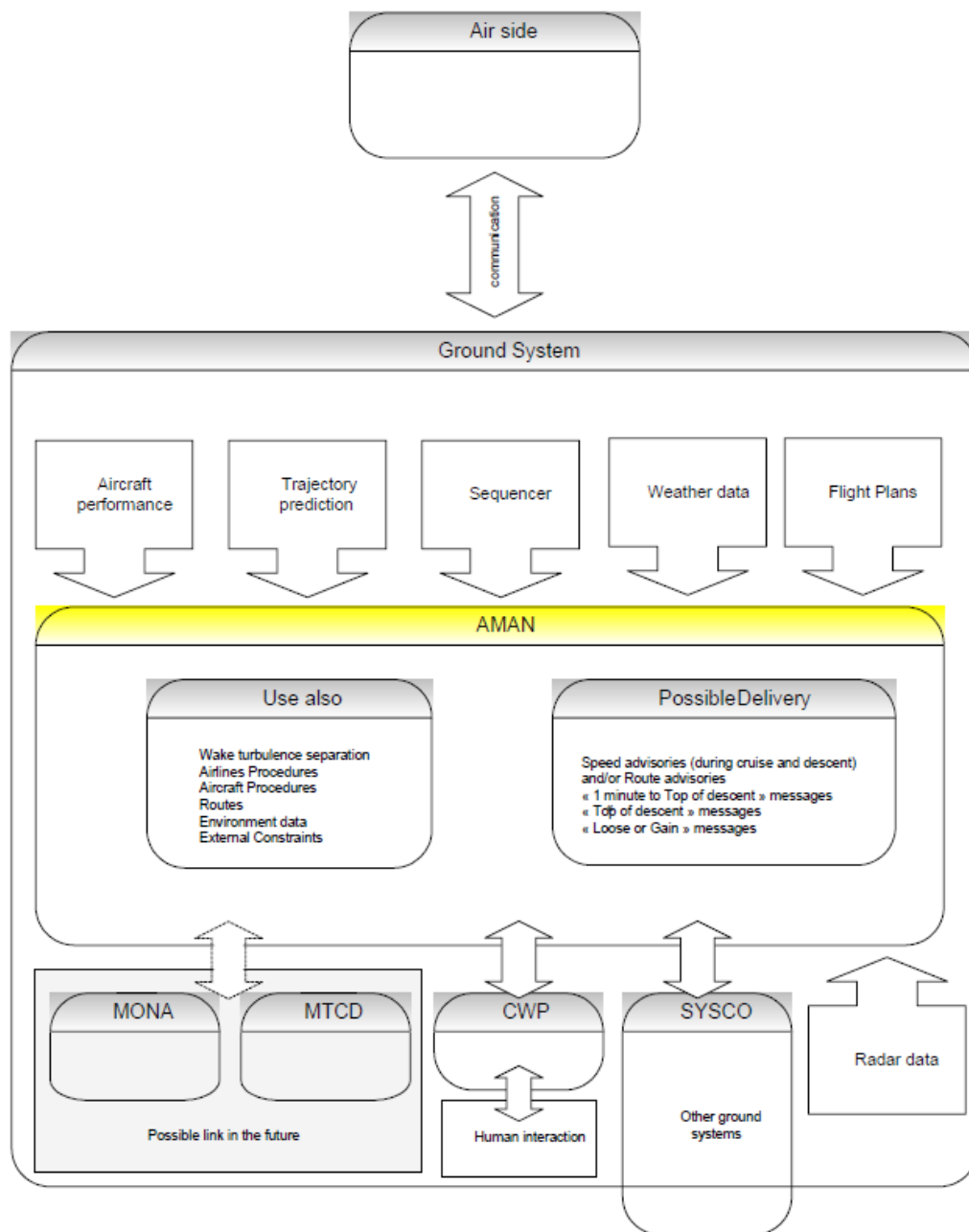


Figure 3: Possible elements of a system embodied with an AMAN (EUROCONTROL, 2010)

3.4 AMAN around the world

In the United States, the arrival management system is not referred to as AMAN, but it is known as Time-Based Flow Management (TBFM) (SESAR Joint Undertaking, & Federal Aviation Administration, 2016). This TBFM system is operational at all en-route ATISs in the contiguous United States (NextGen, 2016).

However, due to the many different ways to refer to a system like AMAN, it is challenging to find an exact answer to the question how much and which airports operate with a system comparable to an AMAN.

It is reasonable to presume that most developed and busy airports around the world are required to have a comparable system implemented and in operation, both for the workload of the ATCO and to improve the airport capacity.

3.5 AMAN in the future

The future of AMAN can be seen in the form of an extended AMAN or also referred to as E-AMAN (Extended AMAN), or a cross-border AMAN (XMAN). In April 2014, the first XMAN trials started at London Heathrow airport (EUROCONTROL, 2019). Deriving from these XMAN trials, the goal of SESAR is to implement an E-AMAN within 24 European airports across Europe by 2024 (SESAR, 2015).

The goal of an E-AMAN is to extend the AMAN range, up to 550 nautical miles (NM). This increased range provides a more consistent arrival sequence. Based on different trials, the benefits are (ICAO, 2017):

- A better predictability
- Reduction of noise and fuel emission
- Better sequence planning
- Improved adherence to the planning

Flight trials have already been taken place in Rome, Malmö, and London. The results of this trial have shown that holding-time of the aircraft have been reduced (SESAR, 2015).

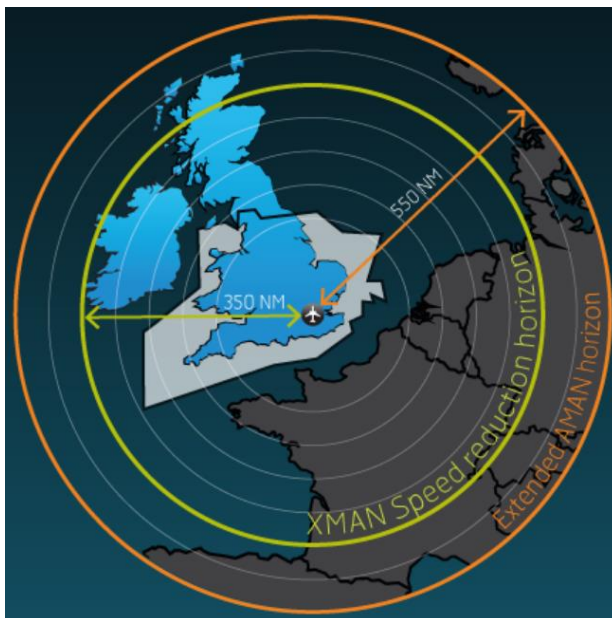


Figure 4: Range XMAN and E-AMAN (NATS, 2014)

3.6 Conclusion

As EUROCONTROL (2010) already mentions, little documentation is available about AMAN. This problem is also recognized by LVNL and therefore defined as the problem statement of this thesis report. Because little documentation is available, the reviewed literature is a bit outdated.

AMAN, or how other ANSPs refer to this system, still serves the same goal; which is to assist the ATCO in the sequence planning and to create an efficient and safe arrival flow.

The information about the input and output will be useful and an excellent point to start the research. However, because the retrieved literature is from around eight years ago, it must be considered to be not updated. Technological improvements probably create that, today, some input and/or output probably requires to be added for a complete overview.

4 The arrival process at Schiphol

Before the research to Advanced Schiphol Arrival Planner (ASAP) will start, an analysis of the arrival process at Schiphol is executed. This explanation provides an impression of in which environment ASAP functions. It also creates an understanding of all elements which are present in the arrival process.

The arrival process, with five different stakeholders, is presented through a flowchart in Appendix III. This flowchart is created to visualize the ASAP interactions and to research for which parties it is responsible. Therefore, ASAP is represented as one of the involved parties. Below, a 27complete description is presented to explain the overall arrival process.

When an aircraft is heading towards Schiphol, the aircraft enters the Dutch airspace via the so-called Flight Information Region (FIR) boundary. A visualization of the FIR-boundary and the five ACC sectors are presented in Appendix II.

The Schiphol Terminal Control Area (TMA) entries are visualized in Figure 28, presented in the same appendix. This figure displays the three Initial Approach Fixes (IAF) (alias stacks¹⁰): ARTIP, RIVER, and SUGOL. Via one of these IAFs, the aircraft will fly in sequence to the runway. In normal operations, the IAF is where ACC controllers transfer the responsibility to the Approach (APP) controller at the Expected Approach Time (EAT) with a margin of plus or minus 2.5 minutes. The ACC controllers are required to transfer the flight at the EAT to prevent that too much traffic enters the Schiphol TMA.

When the aircraft has to hold (within the stack), the transfer happens when the aircraft has received a clearance to exit the stack, and leaves the stack.

Below, short descriptions explain the arrival process from the different perspectives of each involved party.

Schiphol

The gate planning is available at 18.00hr, before the day of operations. However, due to different circumstances and changes within the operation, the actual gate planning can vary from this planning. Therefore, the exact gate allocation becomes fixed after a Collaborative Decision Making (CDM) message is received.

Then, the assigned gate will be communicated via CISS (Central Information System Schiphol)¹¹ updates, which is possible during all flight phases. This gate allocation is essential for APP and runway (RWY) controllers because they need to guide the aircraft to this gate; they can choose to assign another runway or taxi routes to the aircraft, to create a more efficient flow to the gate.

Airline

The aircraft's position will continuously be communicated via radar systems. This radar information is used by ASAP, Schiphol and the Air Traffic Controllers (ATCOs). The ATCOs guide the aircraft to the runway with an instructed height, speed, and route.

Air traffic controller

After the adjacent center transfers the responsibility of the flight, the ACC controller guides the aircraft until IAF. The goal of the ACC controllers is to transfer the flight to APP at the EAT, within a margin of ± 2.5 minutes. When the aircraft is placed into a holding stack, the stack controller will control this part of its operation. In the normal situation, a holding will only be required to transfer the flight at the EAT from the planning, when it indicated more delay than can be absorbed by speed reduction. If the aircraft is not instructed to start holding, the responsibility is transferred to the APP controller.

After APP has guided the aircraft, they transfer the flight to RWY when the aircraft flies at the Instrument Landing System (ILS) intersect. After the landing clearance from the RWY controller,

¹⁰ Definition of stack: a waiting area where multiple aircraft fly a waiting pattern (EUROCONTROL, 2016)

¹¹ CISS is the CDM system of Schiphol

the aircraft is allowed to land on the runway. After landing, ground (GND) controllers guide the aircraft while it taxis to the gate.

Adjacent center

Upstream center from an adjacent center is in control over the aircraft before ACC of LVNL takes over. Different agreements have been made (these agreements differ per sector) about the transfer of flights.

The upstream center is also responsible for the ABI and Activation (ACT) message to ACC. This message usually happens, based on a time trigger (when all requirements are met) (Dijkstra, personal communication, 2019).

Around the Dutch airspace, six different adjacent centers are operational. These centers are presented in Figure 5.

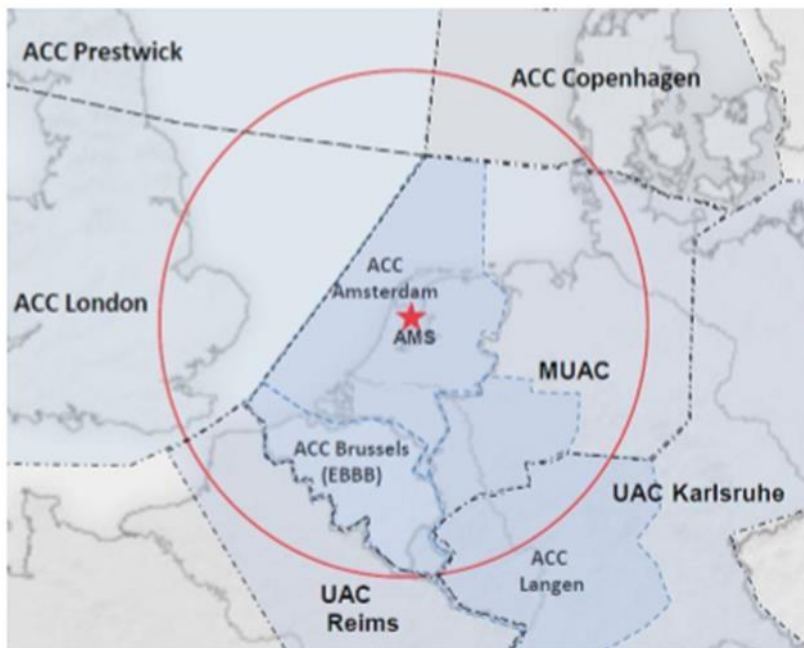


Figure 5: Different adjacent centers around the Dutch airspace (LVNL, 2019)

ASAP

As mentioned above, ASAP is visualized within the flowchart to visualize the dependencies and relations it has within the complete process. For instance, ASAP will only start planning after an ABI and ACT message is received (around 20 to 8 minutes before entering the FIR-boundary). Then, when the flight's position is Estimated Time Over (ETO) stack¹² – 14 minutes, the planning is fixed and a frozen EAT and slot time are shown on the APLN's Electronic Data Display (EDD). When ASAP's planning is fixed, only the APLN can make adjustments to this planning. These changes will be communicated to ACC via their radar display.

When the flight is at IAF, the ACC controller transfers the flight and APP controller is in control. Then, ASAP's planning (concerning that flight) will not be used anymore. The APLN only uses this information to monitor traffic within the TMA.

¹² ETO stack represents the time when an aircraft is estimated to fly over an IAF. When the flight actually flies over this point, this is called Actual Time Over (ATO).

After this explanation of the complete arrival process at Schiphol, the following chapters will concentrate on the planning system ASAP. From this point, the other stakeholders will be left out of scope since these parties do not directly operate according to ASAP's information or output. This independence of the other stakeholders towards ASAP is also concluded from the flowchart. The flowchart visualizes that no process flow nor information flow direct from ASAP to another party than the ATCOs.

4.1 An introduction to ASAP

From a broad perspective and with a clear understanding of the arrival process at Schiphol, the following information focuses on the broad explanation of ASAP. These sub-chapters will provide the required general knowledge to understand the subsequent chapters. Therefore, ASAP's horizon will be discussed, how the APLN sees ASAP's planning, and it will clarify the changes since the implementation of ASAP.

An AMAN system is a support tool for the ATCOs, and it functions as a planning system. This description also applies to ASAP.

ASAP is the planning system for all Instrument Flight Rules (IFR) inbound flights to Schiphol. The goal of this system is to (Luchtverkeersleiding Nederland, 2012):

1. Create a stable traffic flow in the TMA of Schiphol
2. Use the available runway capacity most optimally
3. Generate realistic and stable EATs

Dijkstra (2019) also describes ASAP as a Demand and Capacity Balancing (DCB) tool, with the core function to finding the right balance between capacity and demand. This means that ASAP aims to realize an as high as possible capacity, at a specific declared capacity, while the TMA will be sufficiently protected. Which means that there will be no overload.

To create these goals mentioned before, from an operational perspective, ASAP can be divided into two elements:

1. Electronic Data Display (EDD): which visualizes the ASAP output
2. Approach planner (APLN): who acts on the ASAP output

In a normal situation, the APLN functions are executed by the APP supervisor. However, when this person is not available, the tasks should be transferred to an APP controller.

The APLN sees the ASAP output through the EDD. The EDD is a screen with a visualization of the arrival sequence. Information about the EDD and how the APLN works with it will be described later in this chapter.

ASAP's horizon

ASAP starts planning when it receives an ABI-message from the upstream center¹³, for example, Maastricht Upper Area Control (MUAC).

When this ABI-message is received, the flight will be displayed on the EDD as a pre-planned flight. Based on the information from this ABI-message and the flight's correlated radar data, ASAP will calculate the following times (Luchtverkeersleiding Nederland, 2012):

1. The Estimated Time of Arrival (ETA): The time a flight can land on the runway, not taking other arrival flights into account.
2. The flight's slot time: The moment the aircraft is allowed to land on the runway, this time calculation does take other arrival flights into account.
3. The Expected Approach Time (EAT): This is the expected time the flight will leave one of the three IAF points, derived from the calculated slot time.

¹³ Upstream center is the party who transmits the flight to ACC

When the ACT-message is received, this is considered as a confirmation to ASAP that the flight will certainly come. This message is also received from the upstream center and will be sent after the ABI-message. A reason that an ACT message is not received is, for example, when a flight is canceled, or it diverts to another airport. When the flight has not sent an ACT message 2 minutes before it reaches the Coordination Point (COP), the flight will be removed.

The information concerning a pre-planned flight is not fixed, due to uncertainties during the significant timespan between ABI-message and arrival. During this pre-planned flight phase, ASAP is continuously calculating the three times (ETA, EAT, and slot time). Therefore, the slot time¹⁴ is not definitively planned. The EAT, however, will be displayed on the EDD, but the APLN cannot make any adjustments. The ETA, EAT, and slot time will be fixed at the moment that the flight is planned.

A pre-planned flight will change into a planned flight at ETO stack – 14 minutes. This is also referred to as the ASAP freeze horizon. This means that ASAP will freeze the slot and EAT, 14 minutes before the flight is expected to be flying over the IAF. From that “frozen” moment, the APLN can change elements of ASAP’s planning.

When the flight enters the TMA, the flight changes from planned to under control at APP (UCO APP). It is ACC’s task to transfer the flights to APP at the EAT within a margin of ± 2.5 minutes, planned by ASAP. When APP is in control of the flight, the use of ASAP becomes less relevant. Nevertheless, the APLN is still able to monitor the traffic flow within the TMA from the information of the EDD and possibly make adjustments.

To support the previous information about the ASAP process, Figure 6 has been created to visualize this information.

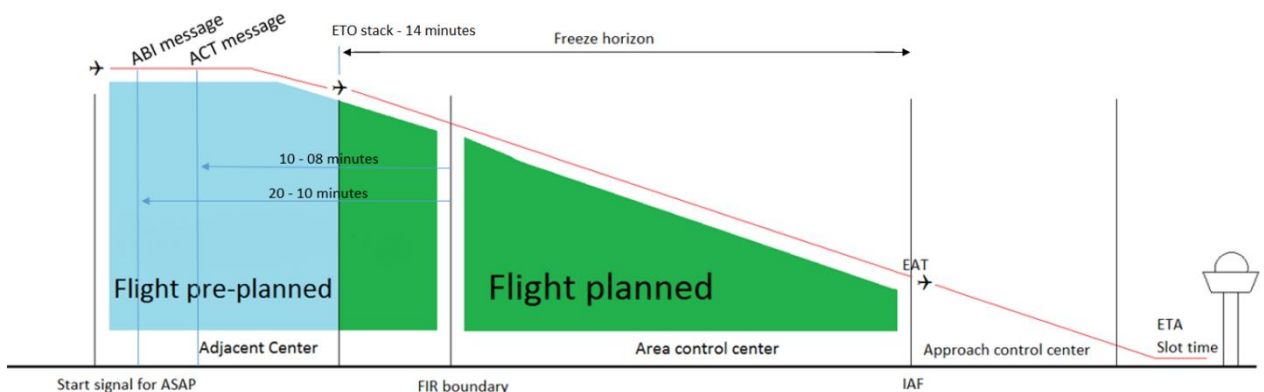


Figure 6: Visualization of ASAP's inbound process at Schiphol

4.2 Working with ASAP

This subchapter describes how the information of ASAP is displayed to the APLN. However, this chapter will not describe the procedures of how changes are applied via this display. After the explanation of the EDD, a description of flights from nearby and TMA airports is presented. These airports require extra attention from the APLN and are therefore important to mention within this chapter.

4.2.1 The Electronic Data Display

ASAP presents its information through the EDD on the APLN's position. This display is divided into four bays:

1. Two lanes for the main arrival runways
2. One for the phased out arrival runway(s)
3. One for other arrival runways and traffic in the hold phase (awaiting weather improvement)

¹⁴ The slot time is the time at which the aircraft is at the runway; runway slot time

In Figure 7 is visualized that the flights are represented in a flight strip, which have different colors. These flight strips' colors represent different ASAP phases.

Blue color: The flight is pre planned, which means that the planning is not fixed

Green color: The flight is planned, only the APLN can adjust this planning

White color: The flight is UCO APP, the planning cannot be adjusted anymore

A screenshot with a complete overview of the EDD is presented in Figure 7.



Figure 7: Screenshot of the ASAP EDD (OIM2 – Schiphol APP controllers , 2012)

Within this figure, the numbers refer to the information which is presented:

- | | |
|--|---|
| 1. Runway usage | 5. Expedite margin ON/OFF |
| 2. Which IAF is coupled to that runway | 6. Time display of the timeline ¹⁵ |
| 3. Landing interval (LIV) | 7. Actual time (in UTC) |
| 4. Updated LIV | |

¹⁵ This can be 65, 90 or 150 minutes from actual time

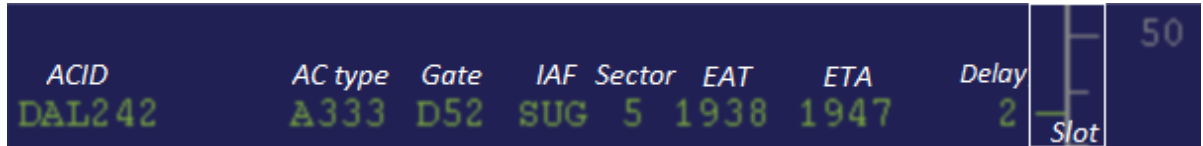


Figure 8: Flight strip in main arrival runway bay (OIM2 – Schiphol APP controllers, 2012)

A flight strip which is presented in the main arrival runway bay contains (from left to right) the following information:

- Aircraft indication (ACID)
- Aircraft type
- Gate assignment
- IAF entry
- ACC sector
- EAT
- ETA
- Planned delay
- Slot time (visualized by time bar)

An ACID may be presented in the color red. This means that the flight has departed from a nearby airport (see chapter 4.2.2) and the APLN needs to check whether the slot time is within the sequence. After a manual adjustment or confirmation to the slot time, the ACID's color changes to orange.

Phase-out bay

When the APLN establishes a runway change, the flights (which still need to land) will change from the bay of the main arrival runway to the phased-out runway bay. Within this bay, it is not possible to intervene with these displayed flights displayed.

The flight strips presented in this bay can have two different colors.

- Grey: The flight is planned
- White: The flight is UCO APP

A visualization of the phased-out runway bay is also presented in Figure 7.

Several reasons can be described when runway changes are required. Below, some examples are presented:

- Change of weather/wind
- Runway maintenance
- Bird control check
- Distribute noise nuisance to the environment
- Change of departure runway

Other & holding bay

Three different kinds of flights are presented in the other & holding bay (Luchtverkeersleiding Nederland, 2012):

1. Flights which ASAP cannot assign to a runway, because it has no IAF (see chapter 4.2.2)
2. Flights which are assigned to another runway than the main arrival runway
3. Flights which are placed by ACC to indefinite holding¹⁶



Figure 9: Flight strip in Other & Holding arrival bay (OIM2 – Schiphol APP controllers ,2012)

¹⁶ Definition of indefinite delay: delay not determined (Office of the Federal Register, 1950). Therefore, indefinite holding means that the holding delay is not determined or known. Usually for flights awaiting weather improvements.

The timeline

The range of time on the timeline from actual time (UTC)(number 7 in Figure 7), is presented on top of the timeline (number six in Figure 7). Within this timeline, two horizontal lines can occur:

1. Green line: When the APLN made a runway or stack preference change
2. Blue line: When the APLN changed the LIV. The entered LIV will be shown above this line, and the previous LIV will be shown below the blue line.

4.2.2 Flights after the planning horizon

Flights from nearby & TMA airports are flights that, after the planning horizon, appear in ASAP and are planned. Because they appear after the planning horizon, these flights require to be continuously monitored by the APLN to assign an (optimal) slot. Figure 10 visualizes this inbound difficulty.

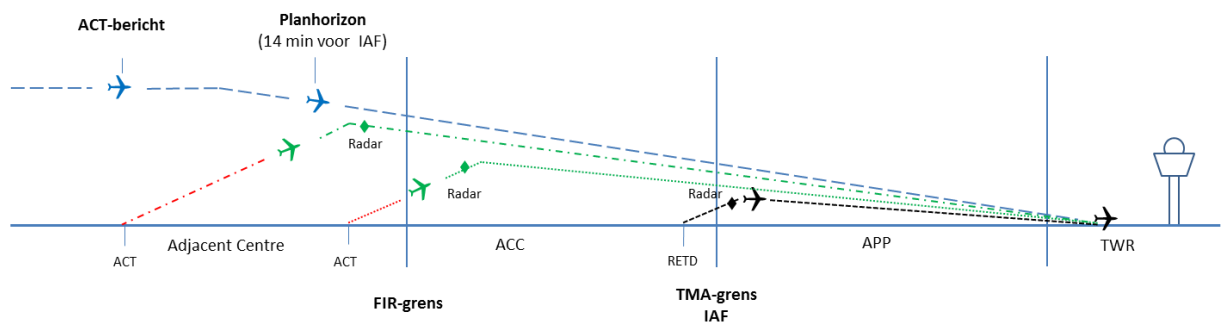


Figure 10: Pop-up flights Schiphol (Advanced Schiphol Arrival Planned design document, 2018)

Flights from nearby airport

A nearby airport is an airport from which an inbound to Schiphol does fly over an IAF, but is not planned before the planning horizon. Some example of airports which are classified as nearby airports are:

- EBAW, Antwerp
- EBBR, Brussels
- EGSH, Norwich
- EEH, Eindhoven

With these flights, ASAP (most of the time) has an ABI-message available earlier than the radar data. In this ABI-message is mentioned when the flight will fly over the COP. The flight is then planned, only with the information from the ABI-message, which creates an inaccurate planning due to the unavailability of radar information. This flight will be planned by ASAP and visualized at the EDD, shown in green on the main arrival runway bay, except for the red ACID.

These flights are also referred to as 'pop-up flights'¹⁷, and the occurrence of these flights have much negative effect on the arrival management (Vanwelsenaere, Ellerbroek, Hoekstra, & Westerveld, 2017).

The reason why these flights are called 'pop-up flights' is that there's no communication or knowledge about their arrival to Schiphol beforehand. They suddenly "pop-up" on the EDD, with sometimes a wrong spot within the sequence. This situation happens around 5 to 10 times per day (Dijkstra, personal communication, 2019).

Flights from TMA airport

For Schiphol, three airports are within the Schiphol TMA, and therefore TMA airports:

1. EHRD, Rotterdam
2. EHKB, Den Helder
3. EHLE, Lelystad

¹⁷ Definition of pop-up flight: "Flights that depart within the horizon of the AMAN system, implying that these flights still need to join the arriving traffic stream when the sequence has already been established" (Vanwelsenaere, Ellerbroek, Hoekstra, & Westerveld, 2017)

An airport within or very close to the Schiphol TMA does not enter the TMA through an IAF. For these flights, the Revised Expected Time of Departure ((R)ETD) is determined with the estimated off-block time (EOBT). Because no runway has been assigned yet, ASAP will calculate the ETA based on the (R)ETD and the flight duration to point SPL. This calculated ETA is the earliest time at which the flight could land at the runway.

These flights will be presented in the other & holding bay on the EDD, with runway indication 'NON'. When the flight is assigned to an arrival runway, the flight must be positioned at a (created) free slot. It is required to place this flight within the arrival sequence, to get the planning back in order. These flights are announced to the APLN beforehand, so they are not referred to as 'pop-up flights'.

4.3 From the previous system to ASAP

ASAP has been implemented on November 13th 2018. Before this new system was implemented, the operational system was IBP (inbound planning).

The initial goal of the first version of ASAP was to transfer the functionalities of IBP directly onto the new platform. However, ASAP has a new Human Machine Interface (HMI), and small improvements are implemented (Molenaar, 2018). This is confirmed by Dijkstra (2019), who explains that the system is mainly the same on algorithmic perspective, but small details are added and applied. The complete interview with Dijkstra relating to these system changes presented in Appendix XI.

A more detailed description of the operational and technical changes will be presented in the following sub-chapters.

4.3.1 Operational changes

As mentioned before, the HMI has improved. Within ASAP, the overview of arriving flights is improved, which creates that its support for the APLN has improved. This positive result is also experienced by the interviewed APLN (more information about his opinion is presented in chapter 7.4). This improvement is established by the implementation of the EDD as it is now (visualized in Figure 7). Before, the EDD showed a tabular list with number rounded to minutes.

Now, the flights are visualized with a thermometer which shows the aircraft sequence and the APLN can interact with these flights, by drag-and-drop them (in case of a runway change) (Dijkstra, 2019).

4.3.2 Technical changes

Besides the operational changes, many technical changes are implemented as well (Dijkstra, 2019):

1. Implementation of speed delta t

Before the implementation of speed delta t, delta t was operational. This was a function from AAA (Amsterdam Advanced ATC system)¹⁸ which represented the difference between EAT and ETO stack. However, this time did not take the instructed speeds from the ACC controller into account. Speed delta t does take this speed into account. Further information about the speed delta t function is presented in chapter 5.2.

2. Approach route allocation

This function was available before, however, the quality is improved. It is more accurate and flexible. This means that new TMA routes can easily be adjusted or modified without requiring major rework in the system tuning.

3. Runway allocation

Now, ASAP is the source of the runway configuration. Before, this was entered into AAA. Therefore, the information is the same, but the source is shifted from AAA to ASAP. Especially the HMI to enter this information is considered an important improvement.

¹⁸ AAA is LVNL's computer system, existing of a collection of hardware and software

4. Trajectory prediction (TP)

The TP still calculates with fixed trajectories and nominal speeds, but the output of the TP has improved. Newly implemented into the TP is (Molenaar, 2018):

- Better descent profile in the ACC work field
- Speed input has an effect on ETO stack (for speed delta t use only)
- Routes within the TMA are optimized

4.3.3 Performance changes

The data analysis which clarifies the AMAN performance changes is performed by CMA. Since weather, runway configuration and days with regulations are out of scope, any changes or effects cannot directly be assigned to the implementation of ASAP. Therefore, this sub-chapter will only provide the results as observations.

CMA is required to assess the impact of changes to the ATM system at the LVNL, concerning capacity and environment. Therefore, they have analyzed two KPIs related to capacity and environment, which are EAT adherence and aircraft's flight time in Dutch airspace.

EAT adherence is the difference between EAT and ATO stack. It is best to have an EAT adherence of zero because then, the planning is executed most efficiently. If the EAT adherence is negative, it implies that a flight has been transferred by ACC to APP at IAF too early. If the adherence is positive, it means that a flight has been transferred too late.

The first result which is presented visualizes the impact to the EAT adherence (Figure 11).

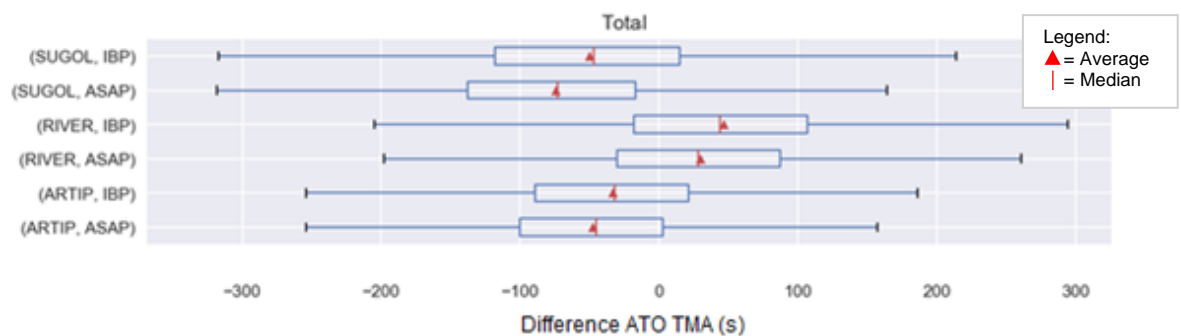


Figure 11: EAT adherence (s) per different stacks

From the information within the boxplots, three interesting observations are made:

1. Only the adherence of flights arriving over RIVER has improved because this adherence moved more to zero. The boxplots of SUGOL and ARTIP show that these adherences shift even more away from zero, which is an undesired result
2. All average EAT adherences have decreased, which is in the case of SUGOL and ARTIP an unfavorable result
3. All boxplots are more concentrated

Another result from the data analysis shows the flown time in the FIR, operated by ACC (Figure 12), and flown time in the TMA, operated by APP (Figure 13). These figures only contain data from two winter inbound peaks (06:20 – 08:00 UTC and 17:20 – 19:00 UTC).

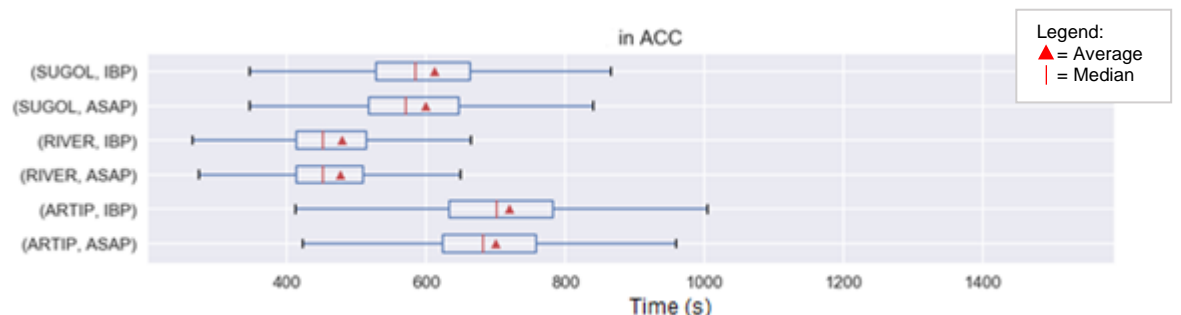


Figure 12: Time (s) aircraft fly in ACC area per different stack

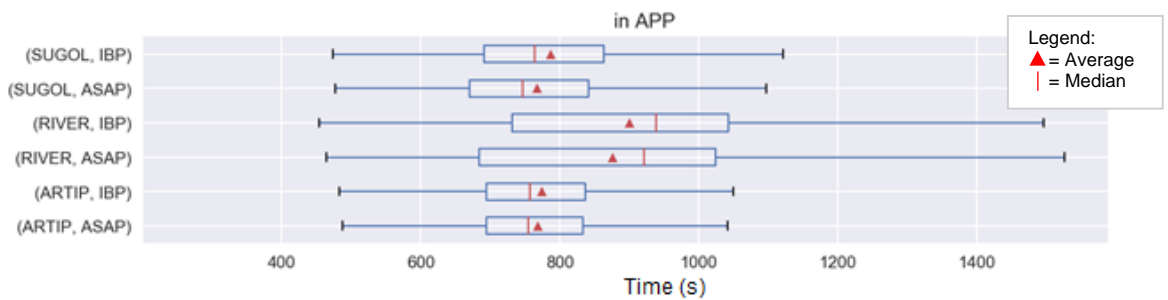


Figure 13: Time (s) aircraft fly in APP area per different stack

These two boxplots present the result that all average values have slightly decreased or have remained the same. No other observations can be noted, due to insignificant differences.

From the observations of the presented boxplots, two conclusions are drawn. First, the EAT adherence has decreased for two of the three IAF points. This worsened adherence is an undesired effect since early TMA entries can increase the workload of the APP controllers. The second conclusion is that the average flown flight time in the Dutch airspace has slightly decreased, which is a positive effect concerning the environmental impact. However, again, whether these two conclusions arise from the implementation of ASAP cannot be concluded due to the scope of the data analysis.

4.4 ASAP analyzed through the process steps

The four broad process steps of ASAP are visualized through a SIPOC diagram (Supplier, Input, Process, Output, Customer)(Figure 14). This diagram shows, per process step, which input and supplier are required to create the output(s) for the customer(s). The complete SIPOC diagram is presented in Appendix IV.

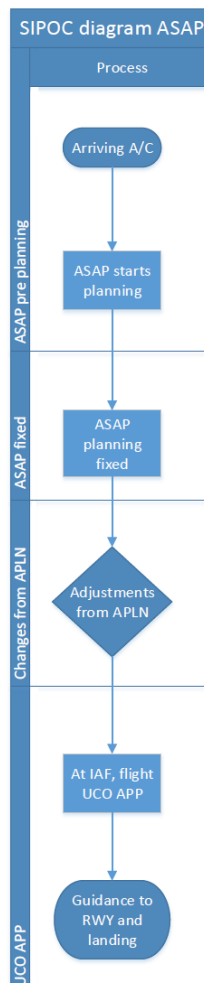


Figure 14: SIPOC ASAP's process steps

Figure 15 visualizes the process phases from the SIPOC diagram next to the previously presented figure from chapter 4.1. The next chapters will provide an in-depth analysis of these phases according to the SIPOC diagram and its elements.

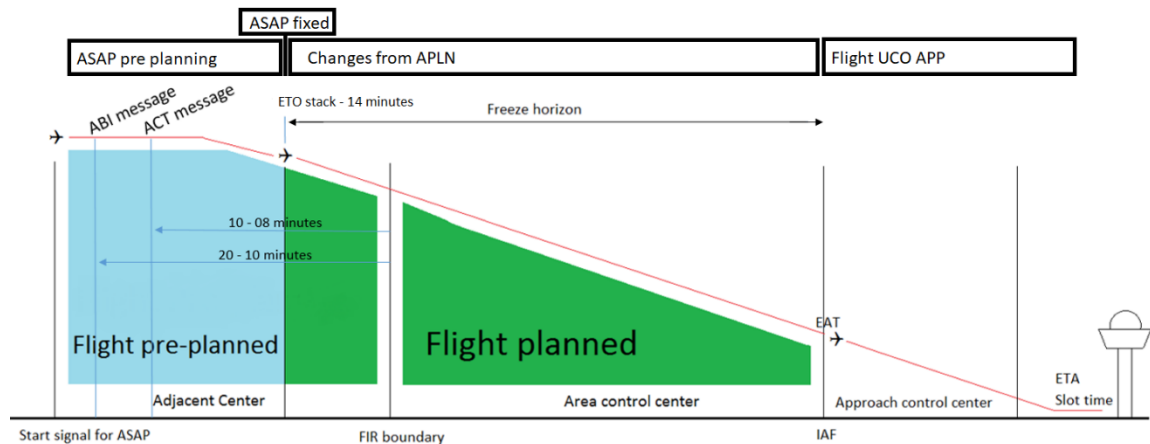


Figure 15: ASAP's SIPOC diagram in relation to ASAP's horizon

As explained in the previous sub-chapters, ASAP starts planning after receiving messages about an arriving flight to Schiphol, and when it receives radar correlation. Then, ASAP starts calculating the planning. This process step is presented in chapter 5. Chapter 5 focusses on the suppliers and inputs because all required elements for ASAP's calculations are introduced within this process step. Also, the planning sequence is calculated within this process step. Therefore, this chapter also covers how and with which input elements is the planning created.

The following process step occurs when the ASAP planning is fixed, at ETO stack – 14 minutes, which is described in chapter 6. This chapter is focusing on the outputs and customers, deriving from ASAP's planning. An additional and enlightened analysis within this chapter is the link between customer and output, which are visualized through Key Performance Indicators (KPIs).

Another result of the fixed planning is the process that the APLN can make adjustments to this planning, within the freeze horizon. These possible changes are explained in chapter 7. Since all preceding information covered systematical elements, this chapter is focusing on the human side of the system. Therefore it is concentrating on the decision-making process; why and under which circumstances does the APLN make which adjustment to the planning, and how can other ATCOs influence it.

The final process step begins when the flights pass IAF, and the flight is UCO APP. This process is described in chapter 8. The final step in the SIPOC is, concerning this thesis project, not part of the core planning function because it is only functioning as a monitoring part. Therefore, the process will shortly be described to ensure a complete view of ASAP is presented, but it will not contain an in-depth analysis.

All these aforementioned chapters firstly show the section of the SIPOC model it will discuss. These figures visualize all suppliers, inputs, outputs, and customer that are elements of the process step.

5 ASAP pre planning

The first step in the ASAP process starts when, due to the arriving aircraft, ASAP starts planning individual flights into the arrival sequence (Figure 16). Therefore, this chapter discusses the analyses which focus on the various input elements and the different functions of the calculation processes within ASAP. However, to have a complete idea of this process step, the chapter will highlight all five SIPOC elements which are involved in this step.

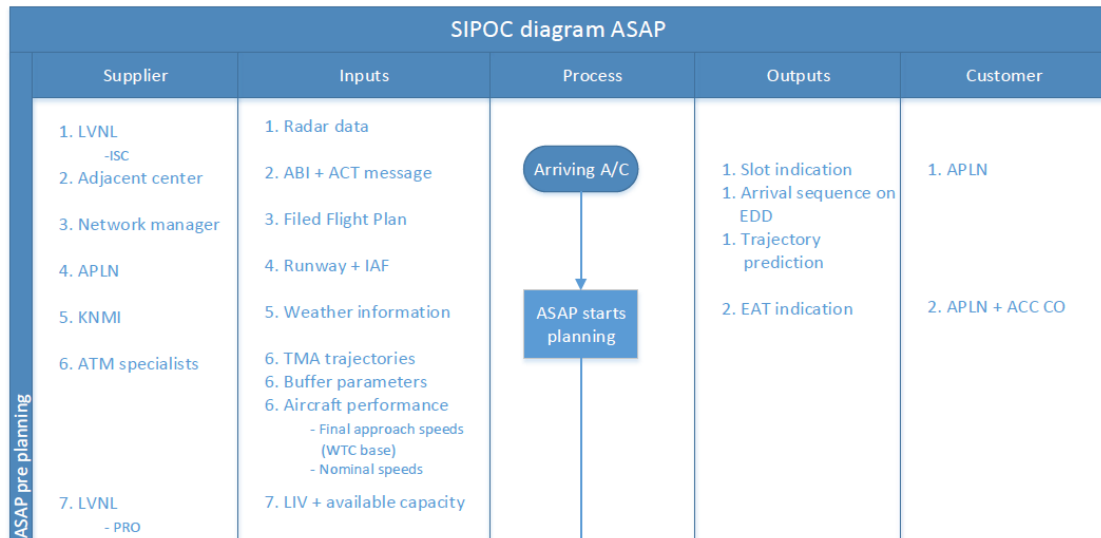


Figure 16: First SIPOC process step

5.1 Suppliers and their input

To start the first process step ASAP requires different inputs which are received from various suppliers. Below is a presentation of all input elements and the suppliers, ordered according to the SIPOC diagram.

1. Radar data

The radar data, obtained by the system ARTAS (ATM surveillance tracker and server), is monitored by LVNL's department ISC (integrated service and control). ARTAS is the main system that presents and processes the radar data for ASAP. ARTAS receives information from different radars and processes all individual radar information. The combination of the individual data will create an improved image, which will be sent to the Radar Data Processing (RDP). The RDP is a component of AAA which will, via AAA, send the radar information to ASAP.

ARTAS provides continuous aircraft radar data to the ATCOs, with the data from an extensive area network. The type of data that is provided is (EUROCONTROL, 2019):

- Position
- Speed
- Mode-of-flight

2. ABI + ACT message

The Adjacent center sends, per individual flight, an OLDI-message. An OLDI message may concern ABI and ACT messages. This information will be presented to the flight data processing (FPD) within AAA. From this AAA's component, the information will be sent to ASAP.

The ABI and ACT message is obtained through the network manager. These messages are also referred to as OLDI messages. The primary purpose of an ABI message is to (ICAO, 2014):

- Provide advance boundary information
- Provide and update missing flight plan data
- Facilitate early correlation of radar tracks (not used in ASAP or AAA)

The ACT message is quite similar to the information of the ABI message, but it serves another purpose. The most crucial difference is that an ACT message (ICAO, 2014):

- Constitutes a contract between two centers, for example, if a flight will not be transferred a cancellation needs to be sent by the transferring unit
- Enables establishment of correlation in the receiving ATC unit
- Provides transfer conditions to the receiving ATC unit

3. Filed Flight Plan

The network manager delivers Filed Flight Plans (FPL). The information from the FPLs also enters the FDP and will be sent to ASAP. The information which is used from the flight plans, by ASAP, is:

- The type of aircraft and corresponding Wake Turbulence Category (WTC)
- Route from FIR to IAF (standard arrival route (STAR))

Examples and formats of both ABI, ACT, and FPL messages are presented in Appendix V. This appendix also contains the required information of these messages.

4. Runway + IAF

ASAP is the primary source for the runway and IAF preference. The APLN can enter which runway(s) are used (both departure and arrival runways) and the preferred IAF for each runway. When the APLN has updated one of these settings, ASAP will send this information to AAA which will be subsequently received and implemented by the tower.

This input of the APLN will be applied through the whole ATM system, since ASAP is the primary input source for runway configuration. The APLN can enter the runways in ASAP, both the arrival runway and departure runway. The APLN selects the arrival runway with (Luchtverkeersleiding Nederland, 2012):

- The associated preferred IAF
- Possible transitions
- Departure runways with associated preferred Standard Instrument Departure (SID)

The runway configuration is chosen according to several factors, for example:

- Wind
- Visibility/cloud base
- Runway combination
- Arrival allowed at required time

The IAF preference will depend on the in-use runways. The IAF preference is also input of the APLN. The geographical location of the stacks¹⁹ plays a significant role in the choice of IAF preference. The presented IAFs (Table 7) are the most preferred with the following frequently used runways.

Table 7: IAF preferences (Dijkstra, personal conversation, 2019)

Arrival runway	IAF preference
18C + 18R	18C: ARTIP 18R: RIVER AND SUGOL
18R + 27	27: ARTIP 18R: RIVER AND SUGOL
36R + 06	36R: ARTIP 06: RIVER AND SUGOL

5. Weather information

The Royal Dutch Meteorological Institute (KNMI) updates the Closed Circuit Information System (CCIS) with the different winds and temperatures aloft. These winds are measured over five levels per sector, plus five for the TMA. So in total, there can be 30 different winds aloft at the time.

The weather information of ASAP is directly obtained from the CCIS. CCIS contains various weather reports, but ASAP only uses the information about the winds and temperatures at different levels within the different sectors (Grutter, 2018).

¹⁹ ARTIP is situated at the east from Schiphol, RIVER at the south, and SUGOL at the west

An example of the input is presented below:

WIND ZONE	FL050			FL100			FL160			FL220			FL280		
	Dir	Spd	Tmp	Dir	Spd	Tmp	Dir	Spd	Tmp	Dir	Spd	Tmp	Dir	Spd	Tmp
sect 1	215	020	+07	220	030	-02	225	040	-11	230	050	-23	235	060	-35
sect 2	215	020	+07	220	030	-02	225	040	-11	230	050	-23	235	060	-35
sect 3	215	020	+07	220	030	-02	225	040	-11	230	050	-23	235	060	-35
sect 4	215	020	+07	220	030	-02	225	040	-11	230	050	-23	235	060	-35
sect 5	215	020	+07	220	030	-02	225	040	-11	230	050	-23	235	060	-35
WIND ZONE	FL010			FL030			FL050			FL070			FL090		
tma	Dir	Spd	Tmp	Dir	Spd	Tmp	Dir	Spd	Tmp	Dir	Spd	Tmp	Dir	Spd	Tmp
tma	210	020	+15	210	020	+11	215	020	+07	215	020	+03	220	030	-01
QNH	TRL														
1013	045														

Figure 17: METEO data input ASAP (Luchtverkeersleiding Nederland, 2019)

6. TMA trajectories

The ATM specialists have designed the buffers and aircraft performances within the ‘adaptation’ of ASAP. The TMA trajectories are defined for every IAF to every runway. By historical data, the most common flown route is analyzed and implemented into the system.

6. Buffer parameters

The buffer parameters function as an extra distance, apart from to the already implemented distance due to the WTC of an aircraft. This extra distance is specified for each WTC possible pair. However, this buffer only functions when the LIV is between 3 NM and 4 NM.

6. Aircraft performance

The specialists also contribute to the predefined aircraft performance. The two main elements which are part of the performance of an aircraft are:

1. Wake turbulence category (WTC)
2. Nominal speeds

The WTC is categorized, based on the maximum start-up mass of the aircraft (except for the A380).

Table 8: WTC categorization (Luchtverkeersleiding Nederland, 2019)

WTC	Maximum start-up mass or aircraft type
SUPER (J)	A380
HEAVY (H)	≥ 136,000 kg
MEDIUM (M)	> 7,000 kg and < 136,000 kg
LIGHT (L)	≤ 7,000 kg

Together with these four categorizations, the minimum horizontal separation is determined. This separation depends on what the sequence in aircraft is, which fly in front of each other. The following regulation is applicable for this separation minimum: the required horizontal wake turbulence radar separation minimum, when a flight is at the same height or less than 1,000ft below the other flight must be:

Table 9: Required minimum separation between aircraft (NM) (Luchtverkeersleiding Nederland, 2017)

Sequence	Radar separation minimum (NM)
HEAVY behind SUPER	6
MEDIUM behind SUPER	7
LIGHT behind SUPER	8
HEAVY behind HEAVY	4
MEDIUM behind HEAVY	5
LIGHT behind HEAVY	6
LIGHT behind MEDIUM	5

For the other possible sequence combinations, it is required to apply a minimum separation of 3 NM. These separation minima are also used when both aircraft use the same landing runway.

Besides the WTC, the nominal speeds are taken into account to determine the inbound planning. To define all different nominal speeds, the arrival process is divided into six parts. Each part has for all different kind of aircraft predefined nominal speeds:

1. Mach/Calibrated airspeed cruise
 2. Mach descent
 3. Calibrated airspeed descent
 4. Calibrated airspeed terminal
 5. Calibrated airspeed intermediate
 6. Calibrated airspeed final
- ATO IAF

7. LIV + Available capacity

The Landing Interval (LIV) is determined by the minimum required distance between two aircraft, depending on winds, runway combinations, time of day, and visibility. However, the actual minimum distance between two aircraft can be greater than the LIV, due to the WTC separation minima (discussed above). The available capacity is also depending on the same criteria as the LIV and expressed in the number of arrival aircraft per hour.

Changes to the LIV or capacity are applied into ASAP by the APLN via its EDD window.

The supplier of the minimum LIV and available capacity is the LVNL division called PRO (procedures). They have described all these regulations in the file called QRC 8 (Quick reference chart). This chart is the source of the regulations concerning the allowed LIV during various weather conditions. For every runway (combination) is calculated which separation is required, with all possible wind strengths and directions.

This document contains an overview of the LIV and capacity with all different runway combinations and visibility. This document also covers the distinction between inbound and outbound peak.

An impression of this document is presented in Table 10. This example displays that the landing capacity with runway 06 + 09, good visibility and Uniform Daylight Period (UDP) is 20 aircraft with a separation of 3.0 NM on runway 06 and 6.0 NM on runway 09.

Table 10: Example of the information presented in QRC8

Inbound peak							
Runway combination		LIV (NM) / Capacity					
Landing	Starting	Good visibility		Bad visibility	Limited visibility circumstances		
		UDP	Not UDP		A*	B*	C*
06 + 09	09	3.0+6.0/20					
06 + 18C	09	3.0+3.0/37	4.0+3.0/32				
06 + 18C	18L	3.0+3.0/37					
06 + 18R	09	3.0+3.0/37	4.0+3.0/32	4.0+3.0/32	4.0+4.0/24	6.0+6.0/22	8.0+8.0/23

*A, B, and C refer to the different possible runway visual range (RVR) which may create (extra) limitations

In practice, the implementation of QRC8 is by the use of a Capacity Forecast Schiphol form. This form is completed after an operational briefing, which is organized four times per day. At this briefing, the following parties are present:

- LVNL APP and ACC supervisor
- KNMI
- KLM OCC and HCC
- Flow Manager Aircraft Schiphol

After the briefing is the capacity forecast Schiphol being sent by the APP supervisor (also functions as the APLN) to the ACC supervisor and other external stakeholders.

The previous explained system information is additionally displayed with a Data Flow Diagram (DFD). This diagram (Figure 18) provides a complete overview of the systematical structure. The speed and route instructions from the ACC controller is processed by the Situation Data Display (SDD). This display is the AAA radar display. The influences of the ACC controllers and APLN will be further discussed in chapter 7.

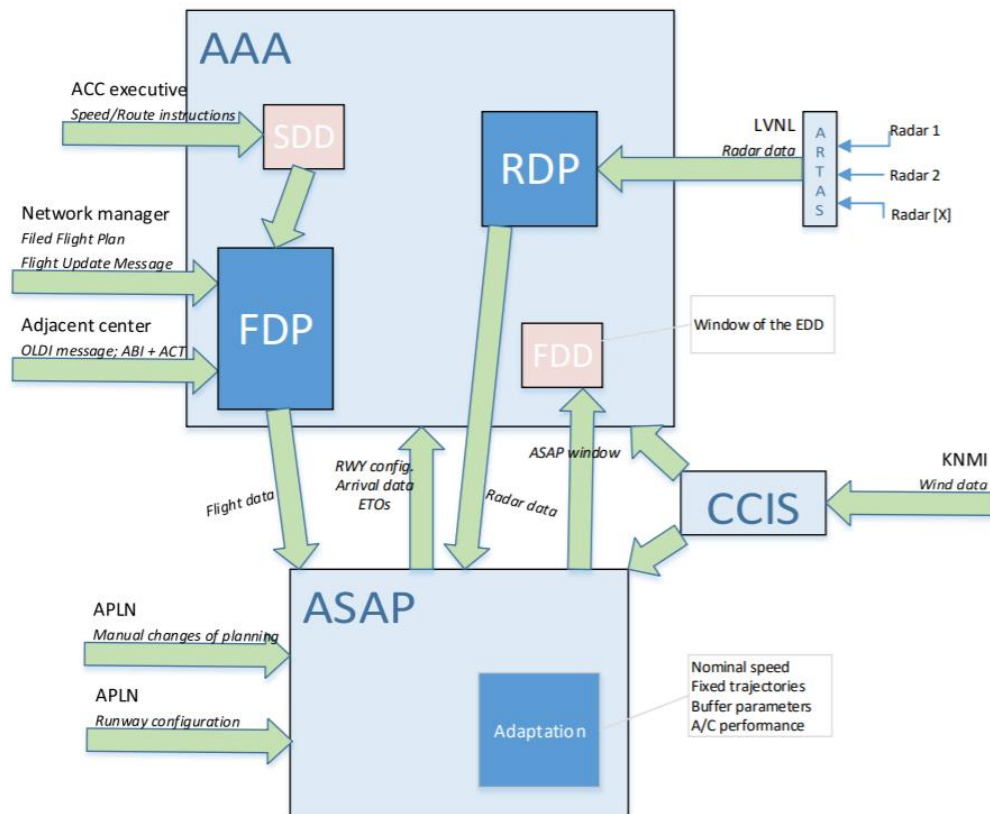


Figure 18: Data flow diagram ASAP & AAA

5.2 The process behind the planning

ASAP uses different components to process the following three times:

1. ETA
2. EAT
3. Slot time

To be able to calculate these three times ASAP contains the following components (Luchtverkeersleiding Nederland, 2012):

- Trajectory prediction (TP)
- Landing Interval (LIV)
- Expedite margin
- Slot time planning
- Speed delta t
- Night transitions
- Approach routes

Trajectory prediction (TP)

The TP is a calculating module within ASAP which calculates the ETA and ETOs. To calculate the ETA and ETOs, the TP uses (Luchtverkeersleiding Nederland, 2012):

1. Flight routing and TMA trajectories
2. Nominal aircraft speeds
3. Actual aircraft position

When an aircraft passes the IAF, which means that the Actual Time Over (ATO) is determined, the TP will not be updated anymore. This means that when the flight has passed the IAF, ASAP will stop updating the ETA. To put this information into a formula, the following function is established:

$$f(TP) = TMA \text{ trajectories; nominal speeds; actual position}$$

Equation 4: Function of the trajectory prediction

Landing Interval

The LIV must be manually entered into the system. This separation is based on a minimum procedural separation (in nautical miles (NM)) between two aircraft. The variables which must be taken into account are:

- | | |
|--------------------------|-------------------------|
| 1. Visibility | 3. Peak-hour, yes or no |
| 2. Runway combination(s) | 4. Day or night |

These minimal required separation distances are described in the file called QRC 8²⁰.

The minimum LIV is displayed on the EDD. ASAP, however, can increase the distance between two aircraft which creates that the LIV is dynamic, based on two actual factors (Luchtverkeersleiding Nederland, 2012):

- | | |
|------------------|-----------------------------------|
| 1. Wind on final | 2. Wake turbulence category (WTC) |
|------------------|-----------------------------------|

This dynamic LIV is not shown at the EDD to APLN.

There is a direct relationship between the LIV and available capacity of the particular runway. When the capacity increases, the LIV decreases; when the capacity decreases, the LIV increases (Luchtverkeersleiding Nederland, 2012). The APLN can manually change both values to the actual circumstances. The function of the dynamic LIV, created with the retrieved information, is:

$$f(LIV_{dynamic})$$

= Entered LIV; Available capacity; Wind ; WTC; Final approach speeds; Buffer parameters

Equation 5: Function of the landing interval

Expedite margin

The expedite margin is created because Schiphol inbound flights usually can land earlier than the nominal ETA. When a flight arrives at the beginning of a peak or a bunch of traffic, the inbound planning can be made more efficient by expediting traffic at the front of the peak. Therefore, the expedite margin is a function in ASAP to make the planning more realistic. The goal is to plan flight(s) earlier than ASAP would do, to use the runway more efficiently and to prevent delays. This action and method (to plan flights earlier) are called front-loading.

The reason this margin is required is that (Molenaar, 2018):

1. The TP is not perfect, and ACC let aircraft sometimes fly other routes than the TP calculates with
2. Aircraft fly with different speed into the TMA, which can be different from the speed which is used by the TP
3. Aircraft can also fly with different speed in the ACC-area, which can differ to the speeds which are used by the TP

The following formula shows the explanation of this method:

$$Slot = ETA - Expedite margin$$

Equation 6: Formula of explanation expedite margin

The expedite margin function is, today, always enabled. And the expedite margin is set to 1.0 minute because this margin shows the best results (Luchtverkeersleiding Nederland, 2012).

²⁰ This document can be found at the LVNL-intranet

Table 11: Effect of the expedite margin (Molenaar, 2018)

Expedite margin	Effect
No margin	Many flights had to be front-loaded manually
1 minute	Realistic slot times and prevention of delays
2 minutes	Too much traffic may enter the TMA

Besides the expedite margin that is activated to all flights, a specific expedite margin can be applied to individual flights. This is also referred to as manual front-loading because it is a form of expediting the traffic.

All flights in ASAP can be moved forward manually, with a maximum of 4 minutes. The result from this action is that a flight can be assigned to a slot time, which is 4 minutes prior to ETA. The reason that a flight may arrive earlier than the scheduled slot time can be caused by ACC guiding the aircraft over another route, with a higher speed than the nominal TP's speed. The ACC controller does this in coordination with the APLN to front-load traffic. Further information about actions to adjust the planning is enlightened in chapter 7.

Slot time planning

According to the ASAP experts, the planning of the landing slot is calculated with three variables:

1. ETA
2. LAS (last assigned slot)
3. LIV

The LAS is the time at which the last planned flight is required to land. This information is retrieved from the algorithms within ASAP. With the information from the three variables, the following function is created, which shows how the calculation of the slot planning is established:

$$f(\text{Slot time}) = \max(\text{ETA} - \text{Expedite margin}, \text{LAS} + \text{LIV})$$

Equation 7: Function of the slot time planning

This max function implies that the greatest of the two values will be the slot time; or the ETA – Expedite margin or the LAS+LIV.

From the calculation of the Slot time, the calculation of delay is executed, which is:

$$\text{Delay} = \text{slot time} - \text{ETA}$$

Equation 8: Delay calculation runway

A derivative from this slot time planning is the result of the EAT:

$$\text{EAT} = \text{slot time} - \text{TMA flight time}$$

$$\text{TMA flight duration} = \text{difference in time between IAF and RWY}$$

Equation 9: ASAP's calculation of the EAT

Another way to calculate the delay is:

$$\text{Delay} = \text{EAT} - \text{ETO stack}$$

Equation 10: Delay calculation IAF

In ASAP, there is no difference between both described calculations of the delay.

Speed delta t

Speed delta t is an aid for the ACC controller to transfer a flight on EAT to APP more accurately. The controller enters a speed instruction in ASAP (which will also be instructed to the aircraft's pilot) and ASAP will return an indication of in how much time the flight will fly over IAF, and whether this meets the EAT. With this speed control method, they can improve the accuracy of transition to APP. This function uses the instructed speed (rather than the nominal TP speed mentioned before) to calculate the ETO stack. This function sends feedback directly to the ACC controller when they enter a speed instruction. This information put to a function results in:

$$f(\text{speed delta } t) = \text{EAT} - \text{ETOstack}$$

Equation 11: Function of the speed delta t

An example of what an ACC controller sees while using this function is presented in Figure 19.

ETO	EAT	DELTA T			
1240	.39	-1:00	SWR73G	HLN	18R
1234	.36	.33	2:25	AFR74AN	DNT 18C
1228	...			PHDAM	DNT 22
1229	.27	-3:08	VLG83HX	DNT	18R
RIVER					

Figure 19: Example speed delta t for stack RIVER

Night transition

The night function in ASAP can be activated via the inbound-window in the EDD. This function is only available for two arrival runways: 06 and 18R. When this function is activated, ASAP takes the following actions (Molenaar, 2018):

- Available capacity is changed to 24 (maximum night arrival capacity)
- The LIV changes to 5.5 NM
- Based on the runway and IAF, a transition is assigned
- Slot time and EAT are calculated based on the assigned transition

When the night function is deactivated, the LIV will automatically changed back to 3 NM.

Approach routes

The APLN can, if applicable, choose for several arrival route options in the Schiphol TMA (Molenaar, 2018):

- No fixed route
- Night transition
- Day transition, ARTIP to runway 36R
- Parallel approach route (36C/36R)

5.3 Output of the pre planning phase

The output of this process step will be enlightened briefly because only when the output becomes fixed, the APLN actively reacts on the information. The fixed output will be discussed in chapter 6, and the interactions possible from the APLN is presented in Chapter 7.

The APLN, however, does use the output of the pre planning phase. The main purpose of this output is to function as a monitoring tool to prevent or limit delays. The information is also used to monitor whether it is required to open an extra runway (during an inbound peak) and when to close the extra runway (after an inbound peak).

Table 12: Output clarification of pre planning phase

Output	Use for customer
Arrival sequence on EDD	When the ABI-message is received, the flight will be presented on the EDD. These flights are visualized in blue and represent the arrival sequence which is continuously calculated and updated by ASAP.
EAT indication	The EAT is presented on the EDD, and later (just before the planning freezes) the EAT will be visualized through the flight's label to the ACC controllers
Slot indication	The slot time is also presented to the APLN on the EDD. This output is used to monitor and realize a stable traffic flow. The APLN can influence the pre-planned slot times, by adjusting slot times of planned flights.
Trajectory prediction	The TP uses the actual aircraft position to determine which runway and IAF are best to assign the aircraft to.

6 ASAP's planning is fixed

During the first process step, ASAP is continuously calculating to find the most optimal arrival planning. Then, when the flight is ETO stack – 14 minutes, ASAP stops calculating the flight's slot time and EAT. This moment is referred to as the 'freeze horizon'. Now, the planning from ASAP is fixed, and only the APLN can make adjustments to this output (see Chapter 7).

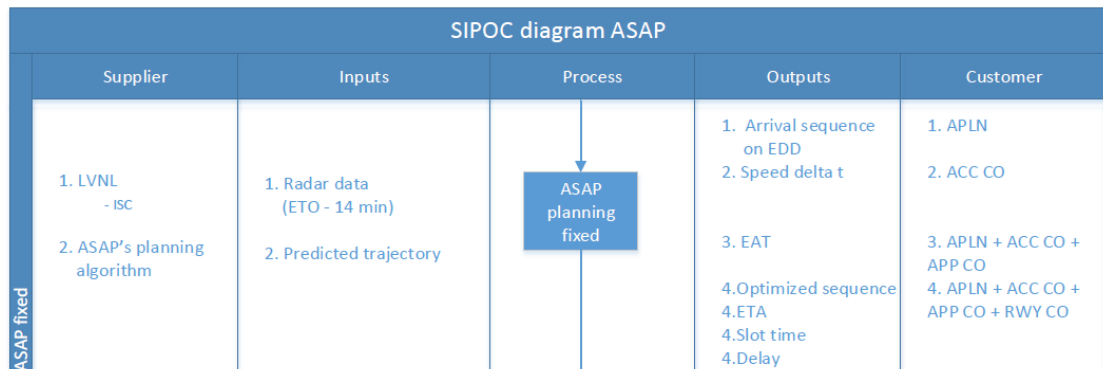


Figure 20: Second SIPOC process step

This chapter will mainly focus on the output of this fixed planning since most of the input was already presented in the first process step, discussed in the previous chapter. Therefore, the presented information addresses the focus on the output of ASAP and how this output must be measured.

Table 13: ASAP's output explanation

Output	Formula/Explanation	
ETA	$ETA = Actual\ position + \frac{Distance\ to\ RWY}{Nominal\ speed}$	
Slot time*	$Slot\ time = ETA - Expedite\ margin$	$Slot\ time = LAS + LIV$
EAT	$EAT = Slot\ time - TMA\ flight\ time$	
Delay	$Delay = EAT - ETO\ stack$	
Speed delta t	The output speed delta t is also processed by the speed delta t function within ASAP. The information is presented to the ACC controller. When this function is used, the output is an indication of the remaining delay.	
Arrival sequence on EDD	The arrival sequence is an output of the FIFO (first in, first out) rule, implemented to ASAP. The aircraft, presented through an ABI message, which can land first (measured from its current position until runway) will be placed first into the sequence. The complete arrival sequence is presented on the EDD of the APLN.	
Optimized sequence	Resulting from different algorithms and calculations, ASAP will create an optimized planning to ensure a smooth and safe arrival flow.	

*The output of the slot time depends on which time value is higher: ETA – Expedite margin or LAS + LIV.

With the description of all output values, the output is linked to the customer, and an analysis will be executed to which ways are best to measure these outputs.

6.1 Which output is critical to the Air Traffic Controllers

To assess whether the output meets the desires and requirements of the customer, the Critical to Quality (CTQ) elements can be essential to investigate. Measurements of CTQs can be between:

1. The process and inputs (own CTQs)
2. The customer and outputs (CTQs of the customer)

The KPIs which will be formulated in the next sub-chapter focus on the output of ASAP. Therefore, the CTQs which are formulated between 'customer' and 'outputs' are investigated in this subchapter.

During the creation of the SIPOC diagram, four ASAP customers are identified

1. The APLN
2. ACC controller
3. APP controller
4. RWY controller

These four customers, however, do not all use the same output from ASAP. Which output is used by which customer, is presented in Table 14.

Table 14: ASAP output used by which customer

	ASAP output	APLN	ACC	APP	RWY
	Optimized sequence	x	x	x	x
	Speed delta t		x		
	Arrival overview on timeline	x			
Time information	ETA	x	x	x	x
	EAT at IAF	x	x	x	
	Slot time planning	x	x	x	x
	Delay	x	x		

From this overview, and considering that output usable for most customers is the most important, two essential CTQ categories are formulated:

1. Optimized sequence
2. Time information

The customers' requirements have been taking into account while designing ASAP. The fact that not all customers use the output as much as others is taken into account during the formulation of the CTQs. For instance, the ACC controllers actively use the ASAP output to ensure that the aircraft is at IAF on EAT. On the other hand, RWY controllers do not have to act to the time information and sequence.

Therefore, the procedural design requirements define the customers' demands, mainly from an ACC perspective, to ASAP (Molenaar, 2018):

Table 15: CTQs from ACC towards ASAP

Critical for ACC Controller	Justification
Stability within the ASAP planning	Late EAT changes create less time to accommodate these changes
The trustworthiness of the ASAP planning	ATCOs sometimes have to verify planned times. This decreases their trust in the system
Timing and coordination between ACC and APP	To keep the radiotelephony (RTF) pressure low; communication
Realistic EATs	
Stable EATs	
Early availability of the EAT	
APLN is required to stay in control	

The requirements from Table 15 are also in line with the two formulated CTQs mentioned before. Therefore, this table functions as an extra statement to prove that these CTQs are crucial to the customers.

6.2 Performance indicators of the arrival process

To evaluate how the output must be measured, KPIs will be formulated. These formulated KPIs function as an advise to the LVNL, and they create an indication of which ASAP output is important.

The definition of KPIs is as follows: “*KPIs are a set of quantifiable measures that a company uses to gauge its performance over time*” (Twin, 2019). So, to conclude this definition, a KPI must be formulated as a SMART²¹ goal.

The LVNL has two main KPIs concerning the arrival process, which are reported to the board of directors (v.d. Groep, personal conversation, 2019):

1. Sustainability of inbound capacity (for inbound peak 1 and 5)
A percentage of the time (peaks) the declared capacity was available
2. Airport ATFM delay
Difference between ETOT (estimated take-off time) and CTOT (calculated take-off time)²², which means that an aircraft is delayed at its airport of departure

In 2018, the sustainability of the capacity was in the first peak 96.8% and the fifth peak 97.8%, above the required minimum of 95%. The Airport ATFM delay was 2.20 minutes against the target of a maximum of 2.0 minutes (Luchtverkeersleiding Nederland, 2019).

From the CTQs, described in the previous sub-chapter becomes visible that most customers use the CTQs ‘time information’ and ‘sequence optimization’. Therefore, the KPIs must be in line with these CTQs.

The LVNL KPI ‘Airport ATFM delays’ cannot be related to ASAP’s performance. However, the most direct influence of ASAP is to the KPI ‘sustainability of capacity’. When an optimized sequence can be realized, the most efficient operation can be executed, and more flights can be handled. Therefore, the formulated KPIs must also be relatable to the sustainability of capacity since a good arrival flow should result in a sustainable operation.

Before the KPIs are defined, the available ASAP data is analyzed. With this evaluation becomes known which data information is available, which makes it able to create measurable KPIs. CMA has performed a data analysis about ASAP, from November 17th 2018 until December 19th 2018. From this analysis, various measurement values came available. The data which is existing about ASAP is described in the data dictionary, presented in Appendix VI.

While formulating these KPIs, it is crucial to keep the focus on the overall goal of ASAP; which is to create a safe and on time sequence. Now, with the CTQs and LVNL’s overall KPI, these valuables are formulated into KPIs specifically for ASAP to measure its performance concerning optimized sequence and time information.

Two important KPIs concerning time information, which are already being monitored, are

1. EAT adherence:

$$EAT\ adherence = EAT - ATO\ stack$$

2. Slot adherence:

$$Slot\ adherence = ASAP's\ planned\ slot - ATA$$

Besides these two KPIs, no KPIs are formulated nor monitored at this moment.

From this point, two new KPIs are formulated. The goal of these KPIs is to propose a standard measurement to gauge the performance of the system. Since ASAP is a continued development from AAA’s IBP, the results can, for example, be further analyzed by a comparison with IBP to evaluate the impact of the implementation.

²¹ Specific, Measurable, Attainable, Relevant, and Timely

²² ETOT derives from the flight plan; CTOT is from the network manager

How many aircraft enter the FIR, and how much of these aircraft end up holding?

This first KPI monitors the flow from FIR entry to the runway. The most desirable result would be that all aircraft can directly fly to the runway. However, aircraft sometimes must start holding to prevent that too much traffic enters the TMA. Another reason for holding can arise due to the variable aircraft mix or due to bunches, which occur before the FIR boundary.

$$\text{Holding ratio} = \frac{\text{Number of aircraft in holding}}{\text{Total number of aircraft at IAF}} = \frac{a}{b}$$

Equation 12: Calculation KPI Holding ratio

To leave the ratio as a fraction creates a better visualization of the result since it is more appealing to see two actual numbers, which have more meaning than a decimal. This KPI can be monitored in different ways, for example, per hour or per day. The most desired use of KPIs is when the KPIs are being used as a tool to proactively act on the information. When the KPI is monitored over a longer time, more relations can be detected, but actions to the KPI becomes reactive. The visualization of this KPI (Appendix VIII) presents the KPI with data from one day per hour.

When this KPI is being monitored, many different factors and variables must be taken into account before a conclusion can be drawn. Different variables which influence the number of holding aircraft are, for instance;

- Variable aircraft mix
- Weather influence
- Bunching at the FIR
- Runway usage

Other variable factors which must not be forgotten, are the influences that the ATCOs and APLN can have on the output and performance of the system. For example due to;

- Variable decision-making and influences of the ATCOs
- Manual changes from the APLN

The manual changes are measured through the data column IBP_NR_PRE/POST. However, the reason why they've made which decision cannot be derived from the data.

How much effect does the APLN have on the output of the system?

Resulting from the fact that the APLN can apply many changes to the planning, this can have a significant effect on the output, for example, to the adherence of both slot time and EAT. The number of changes applied by the APLN (in the data, these manual changes are referred to as IBP), is available through the data. With the data available, the question is transformed into the following KPI:

$$\text{Influence of the APLN} = \frac{\text{Sum of the number of manual changes}}{\text{Count EAT or Slot adherence}}$$

Equation 13: Calculation KPI influence APLN

To formulate this KPI, the trigger was an analysis of the sum of the manual changes against the EAT and slot adherence. Both figures intend to visualize a relationship between the two analyzed outputs. If a relation is found, this can be an interesting start for new research.

ASAP is designed to be hands-off, which means that the influence of the APLN to the planning must be kept to a minimum. This KPI can be monitored daily as well.

To conclude this chapter, the following KPIs are formulated to monitor the punctuality of the time information:

1. EAT adherence
2. Slot adherence

And to monitor the performance of the system, the following two KPIs are formulated:

1. Holding ratio
2. Influence of the APLN

An impression of the visualization of these KPIs is presented in Appendix VII and Appendix VIII.

7 Adjustments by the Approach Planner

As briefly mentioned within the previous chapters, when the planning of ASAP is fixed only the APLN can make any adjustments to the planning. As a result, these actions will affect the output and require to be further analyzed. Despite that only the APLN can change the planning, the other ATCOs can also have an influence on ASAP's planning. Therefore, this chapter will address how the APLN can adjust, and how the ATCOs can influence ASAP's planning²³.

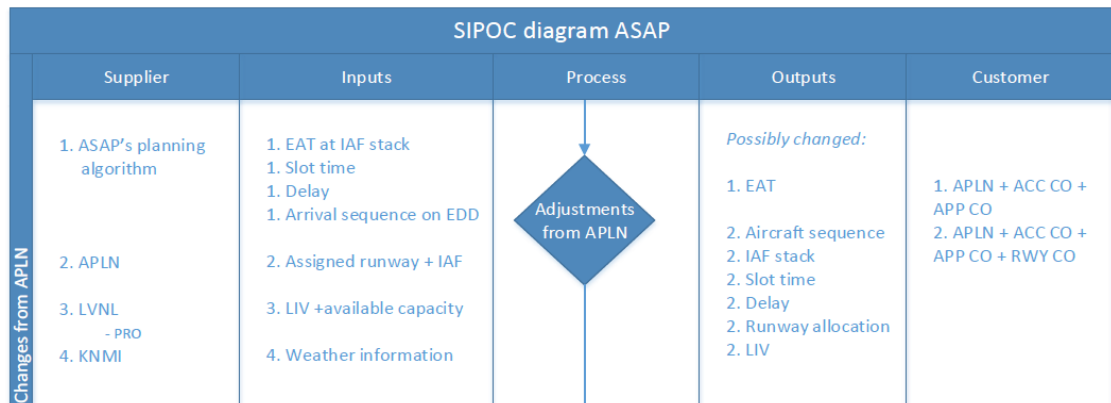


Figure 21: Third SIPOC process step

The suppliers of the inputs are already explained within the previous chapters. But the inputs of this process step are crucial information to the requirement of which adjustments are necessary and possible. These inputs are divided over two ways for the APLN to intervene with the planning:

Table 16: Division of input for APLN process

1. ASAP general settings	2. Change planning of one or multiple flights
Runway assignment	Slot time and EAT
IAF preference	Delay
LIV and available capacity	Assigned runway
Arrival sequence on EDD	Assigned IAF
Weather information	Arrival sequence on EDD
	Weather information

7.1 ASAP's general settings

The division of actions is important to distinguish, due to the effect these inputs have on the process of the manual settings from the APLN.

With the presented information and acquired planning from ASAP, the APLN can make some general adjustments or enter these settings. These adjustments affect all flights after the moment the changes are implemented. The general possibilities to change ASAP's planning are (Molenaar, 2018):

- *Runway configuration changes*
For example, from two runways to one runway after an inbound peak, or the other way around. The runway will shift from the main runway bay to the phase-out bay, and the flights on this runway cannot be affected by the APLN anymore.
- *Change the LIV and available capacity*
For example, when the visibility decreases and an extra distance is required according to QRC 8. ASAP will automatically increase the time separation within the sequence after this setting has been adjusted.
- *Stack and SID preferences*
- *Enable night transition*
This transition is required between 22.30 and 06.30 local time (LT). The consequences this transition has on ASAP is described in the previous chapter 5.2 The process.

²³ Due to this distinction of responsibilities, the term ATCOs and do not include the APLN

7.2 Change of individual flights in ASAP's planning

The APLN is also able to change the planning of one or multiple flights. Five different actions are possible (Luchtverkeersleiding Nederland, 2018).

1. *To assign another slot time to one flight* (in ASAP: MSL, manual slot)
This action does not only affect the slot time of the flight, but it also affects the EAT of the flight. Depending the change, coordination with ACC may be required. The most common reason for this action is to expedite the traffic or to decrease the amount of traffic within the TMA.
2. *To move a flight to another runway* (in ASAP: RWY, runway)
The function "EAT-indicator" shows to the APLN on the EDD where the selected flight must be positioned (on the other main runway-bay) to leave the EAT unchanged. It is also possible to assign a flight to a runway which is not operational. When a flight is moved to another runway, ASAP will automatically recalculate the subsequent flights on the runway from which the flight is removed. This action is mostly executed to balance the amount of traffic on the runway; it will be equally distributed.
3. *To assign another approach route in the TMA* (in ASAP: TRA, transition)
The arrival route can be adjusted just before, or just after, parallel approach. With this setting, a flight is assigned to the normal approach route or a parallel route. This creates a more specific detail into the operating modes. This action will only be executed when a parallel runway combination is used.
4. *Require ASAP to create a new planning* (in ASAP: NPT, new planning times)
With this function, all flights arriving on the runway bay following the selected flight will be re-planned. This function can also be executed when the flight is already UCO APP. This action will be executed when a slot or runway change has been applied and ASAP needs to reschedule the subsequent arrival sequence.
5. *Delay multiple flights all at once* (in ASAP: SFR, Shift runway)
The delay of the flights can be adjusted to +1 minute, up to +15 minutes. This function is mainly used to create extra space within the TMA. Note that when an NPT is executed on a flight before the shifted flights, after an SFR, the added delay is shifted back.

Even though ASAP is designed to be a so-called hands-off system, four cases require the actions of the APLN. Table 17 presents these action required scenarios, together with possible triggers:

Table 17: Required situation of APLN intervention, according to ASAP literature

Action-required scenario	Reason
Flights from nearby/TMA airports	- Most of the time, these flights show up after the freeze horizon. Therefore, the APLN needs to manually assign these flights a slot time
Sequence error	- TP's route does not correspond with the actual route - Inaccurate estimate from adjacent center - Heavy wind (late receive of the ABI-message)
When delay occurs	- When ETO Stack is earlier than EAT - APLN not anticipating at the right time - Opportunity for front-loading. Traffic bunches are usually preceded with periods of low traffic density
Create more efficient planning	- The goal of the five actions described above are all designed to create a more efficient and safe planning

The ATCOs have two terms, which are regularly used during conversations and are related to the realization of the creation of an efficient planning:

1. "Scharrelen" (wandering): When a flight is processed at a runway which is, in ASAP, not assigned to the IAF at which the flight will enter the Schiphol TMA. "Scharrelen" happens when a flight is moved to another runway (also the case when this runway is not a main arrival runway)

2. Front-loading: Process of planning one or more flights earlier than ASAP would do. One example of front-loading is the expedite margin.

7.3 Responsibilities of the Air Traffic Controllers

The APLN can actively intervene with the planning, reacting on the information from the EDD. However, the ATCOs do have an influence on the planning as well. To obtain the complete view of the influence of these ATCOs and ASAP, an analysis is performed of the executive ATCOs and how they can influence the planning.

Table 18: Division of ATCO interaction with ASAP

	At which part of the operation?	Possible actions	Effect on ASAP output
ACC	From FIR to TMA ±FL245 to ±FL070	- EAT swap	Swapped EAT and slot time with the other aircraft
		- Speed instruction	Effect on not-nominal ETA; function speed delta t
		- Vectoring	Effect on nominal ETA, because the ACC trajectory is adjusted
APP	From TMA to ILS intercept ±FL070 to ±3,000ft	- Tactical runway switch	A gap can arise within the arrival sequence
RWY	From ILS intercept to RWY ±3,000ft to landing		

The influence of APP and RWY controllers on ASAP is marginal because the need for the planning, as a system, is until ATO stack; to create a stable traffic flow within the TMA. When the aircraft passes the IAF, ASAP will only function as a monitoring tool. Therefore, the effect on ASAPs output when the APP performs a tactical runway switch is only to be seen in the arrival sequence.

However, both the performance of APP and RWY controllers can influence the throughput of the planning execution. This means that when the throughput is insufficient, the planning will get ahead on reality, which can result in too much traffic entering the TMA. Conversely, if actual throughput is higher than planned, the planning may get behind, and available capacity may be underutilized.

An EAT swap can be performed by an ACC controller when a sequence error occurs at the same IAF (Luchtverkeersleiding Nederland, 2017). For example, the ACC controller might have a couple of flights lined-up, in an optimized sequence. However, according to ASAP's algorithm, another flight would fit within this sequence. Then, the ACC controller swaps EATs to keep the coupled flights together and puts the other flight behind this flow.

7.4 The Decision-making process of the Approach Planner

An interview has been conducted during the APLN's shift, to understand the situation in which the APLN would decide to change something of ASAP's planning. This APLN is very experienced and has much knowledge about ASAP because he was involved in the development of the system.

According to this APLN, it is the goal of the APLN to create a general, most optimal arrival flow. In the situation when two arrival runways are operational, this means that both runways are balanced to have the most optimal arrival flow. For instance, if one runway has ten minutes delay, but the other runway operates perfectly on-time, this is not the most optimal flow.

However, if changes have no improvements to the planning it is not desired that changes are made. These changes affect the stability and predictability of the planning's operation. When the APLN decides to adjust the planning, it is best to apply it as soon as possible because the ACC controllers need to act on this changed information (for example, when the EAT has changed).

The inbound and outbound peaks are determined by a fixed schedule. The APLNs can anticipate the demand and open an extra runway within a window of ±20 minutes before this peak.

Table 19: Inbound peak (UTC)

Start inbound peak	Until
05:40	07:20
09:00	09:40
11:00	11:40
13:00	14:10
15:40	18:20

When two arrival runways are operational (this only occurs during peak hours), the APLN has much more possibilities to apply changes to the planning.

Most of the manual changes that the APLN performs to individual flights are runway changes and slot time changes. These changes are mostly resulting from two situations:

Table 20: Required action from the APLN

Situation	Peak hour		Off-peak	
	Runway	Slot time	Runway	Slot time
Delay in the planning	When the delay decreases on both runways ²⁴ and if the flight could be swapped to the other runway.	If no gaps appear within the sequence, slot time changes are not desired ²⁵ .		Change flights' slot times to influence the delay times.
Gaps within the sequence	If the gap can be filled with a flight planned on the other runway, and only when this action improves the arrival sequence.	Change flights' slot times to fill the gaps.		Change flights' slot times to influence the gaps occurring within the sequence.

Note that the described actions are only performed when it improves the arrival sequence. When a swap or switch does not have a positive effect, no measures are taken, and the planning will be unchanged.

It may appear very easy and, with the explanation above, unimaginable that the sequence is not optimal yet. However, it must be taken into account that there are various factors which influence or limit the actions described above.

Table 21: Limiting factors to the APLN's actions

Factors	Explanation
Weather/cloud base	When the ATCO has to guide an aircraft around a thunderstorm or cloud, it is more difficult to anticipate this situation.
Other traffic/departure traffic	If the arrival sequence interferes with the departure flow, this will influence the workload, and it may require another route than predicted.
Sequences/turns	The ACC controllers like to make a string with arriving aircraft, which fly behind each other. From ACC perspective, it is not desirable that the APLN or ASAP planning add another flight within their sequence.
Distance + aircraft's speed	It may occur that a gap appears on the planning. However, it may not always be possible to fill the gap because the aircraft is too far away.
Overloaded TMA	When the TMA is becoming overloaded, it is desirable for the APLN to have a (small) gap within the arrival sequence. This gap automatically will decrease the pressure on the TMA.

²⁴ The goal will remain to balance the delay for both runways.

²⁵ It is always possible to change the slot times. However, if the sequence has no gaps, changes to flights' slot times will have consequences to other flights.

To conclude the APLN's decision-making process, the APLN will take actions when this influences the arrival performance positively. When the actions do not affect the result of the efficiency, it is not desirable that the APLN will intervene and the planning must be unchanged. ASAP is a hands-off system with the goal to create a stable planning, without the interventions of an APLN.

Not interfering will appear more often during off-peak, because only one runway is operational, which creates that the APLN's actions are limited.

The interviewed APLN is very content about ASAP, and mostly about the improved HMI. It is much more intuitive and precise. The EDD better visualizes gaps in the planning, and the flights are presented earlier in the planning, which creates the possibility to anticipate early to bunches or peak hours.

7.4.1 ACC controllers' vision to ASAP

This interview merely focused on their perspective of the system; whether they have positively experienced the (much) changes. The summary of the results of these interviews is presented in Appendix XII.

Before the specific ASAP output is analyzed, the first interesting result is how they experience the implementation of ASAP.

Table 22: ACC controllers' opinion about ASAP

	Overall opinion about ASAP
ACC controller 1	Very positive
ACC controller 2	Positive
ACC controller 3	Not negative
ACC controller 4	Positive

Concerning the ACC controllers' operation, two major differences between IBP and ASAP are distinguished, which are:

1. Speed delta t
2. Earlier able to monitor traffic

The most significant change to the ACC controllers' operation, is the implementation of speed delta t.

Table 23: ACC controllers' opinion about speed delta t

	Opinion about speed delta t
ACC controller 1	Very positive, uses it actively
ACC controller 2	Positive, actively monitoring on speed
ACC controller 3	Negative, does not use it
ACC controller 4	Due to experience, function seems unnecessary

From this result, the given impression is that the less experienced controller is more positive about ASAP than the more experienced controller. The difference can be underpinned with the fact that the less experienced controller is new and has not created its own methods and personal practices yet. He may, therefore, be more flexible. The most experienced controller is used to work according to the old system, and it can be hard to change his methods, after more than 25 years of experience.

Another change, earlier able to monitor the traffic, is also experienced differently by the different controllers.

Table 24: ACC controllers' opinion about early monitoring traffic

	Opinion about early monitoring traffic
ACC controller 1	No opinion
ACC controller 2	Very positive, less communication with APLN required
ACC controller 3	Negative, just let me do my job
ACC controller 4	Negative, too much communication to the adjacent centers

About this statement, too, is a big difference in how the ACC controller experiences the impact. It may be advisable to inform the controllers about the purpose of the changes, and why these changes create an improvement to the operation, to get these results more coherent.

8 Flight at IAF and under control at approach

The final process step presented in the SIPOC diagram is when the flight passes the IAF. At this point, the flight is transferred to APP and it is referred to as UCO APP. This chapter briefly discusses this process step, to finalize the arrival process from ASAP's perspective.

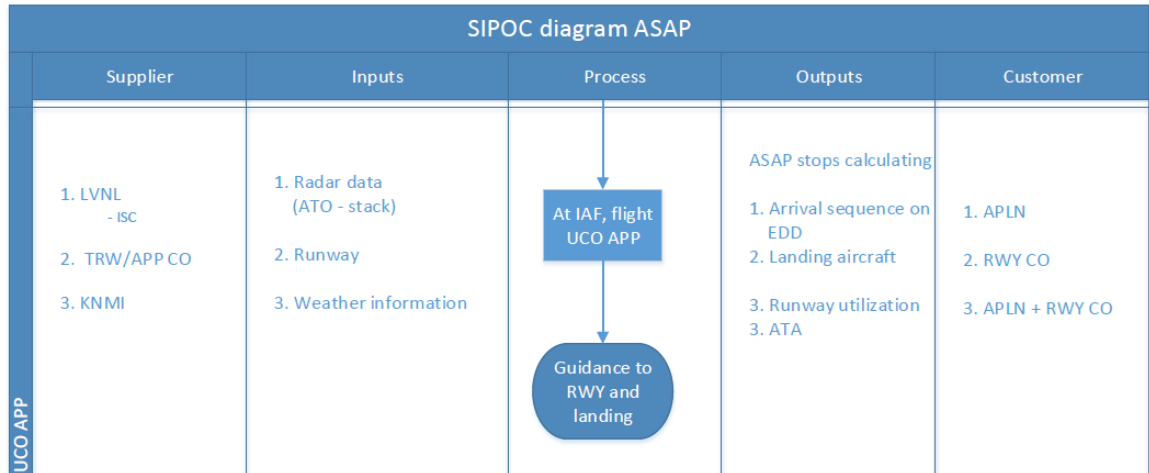


Figure 22: Final SIPOC process step

The only other not previously discussed input element is the weather information. The weather information will be used by the APLN to estimate if the LIV and available capacity are still acceptable. It could happen, for example, that the cloud base lower, which makes it necessary for the APLN to intervene with the current planning because more separation needs to be applied.

Table 25: Output clarification of final SIPOC phase

Output	Use for customer
ASAP stops calculating	When the aircraft has passed IAF (ATO stack) ASAP stops updating and continuously calculating the ETA. This is not of any use to the customer, therefore it is not linked to any.
Arrival sequence on EDD	Even though ASAP stopped updating and calculating, the flight is still presented on the EDD to the APLN. With this information, the APLN can monitor the arrival flow within the TMA. When the planning is ahead of the traffic, it can be too busy within the TMA; when the planning is behind the actual traffic, usable capacity can be lost.
Landing aircraft	As one of the main tasks of an RWY controller, the arriving aircraft will land on the runway.
Runway utilization	Due to the interactions of the APLN and the algorithms within ASAP, the runway utilization should be as high as possible. However, this is not completely under control of ASAP nor APLN because this output is dependent on the demand of aircraft.
ATA (Actual Time of Arrival)	When the aircraft arrives at the runway, this is, in LVNL terminology, referred to as the time of arrival.

The two customers presented at this final process step, are the APLN and RWY controller. The APP controller, however, is a supplier to the guidance of the aircraft to ILS interception but they do not use any of the presented output in this SIPOC process step.

9 Research Findings

The research findings present the results of the performed analyses, explained in the previous chapters. The analysis chapters have followed the structure of the formulated research questions. Therefore, the results of these analyses already start answering the research question. The results are presented and explained next to the research question it answers.

The first research finding clarifies how the APLN and ATCO can act on the planning of ASAP. It presents which actions are most commonly used, and which situations create limitations to the APLN's possibilities. The second research finding explains the output of ASAP, together with how it must be measured. Another presented finding, resulting from the analysis of how the output must be measured, is a correlation between the manual adjustments of the APLN and the EAT adherence. The third research question clarifies how ASAP processes its input elements. The final finding presents a summary of the analysis of the arrival process at Schiphol.

9.1 Results of the analyses to the Air Traffic Controller

The first findings, analyzed in the final analysis chapter, explain the results of the investigation to the following research question:

How can the Air Traffic Controllers and Approach Planner influence ASAP's planning?

This question focusses on actions to an individual flight, but the APLN also has different options to impact all flights at the same moment. For example, when another runway needs to be operational or when an extra runway needs to be opened, or when the LIV has to increase due to the change of weather. However, these actions are required for safety and are determined by regulations.

The interventions with the planning on individual flights have the goal to create a more efficient operation. The APLN can adjust the planning, but the ACC controller is also able to influence this planning. How the planning can be affected by which actor is visualized in Table 26. This description is ordered by which actions are most common to use, obtained through the interviews and observation.

Table 26: Actions from the APLN and influences from the ACC controller, ordered to most prevalent

APLN	ACC Controller
1. Move to another runway	1. Speed instruction
2. Assign another slot time	2. Vectoring
3. Recalculate the planning	3. EAT swap
4. Delay multiple flights	
5. Assign another approach route	

The APLN is acting proactively on ASAP's planning, but some situations may be limiting the APLN's possibilities of changing a flight's planning. Combining the information of the interview and observation with the APLN with desk result resulted that the most limiting factor is whether the situation occurs during off-peak hours. Runway changes are not possible because off-peak operations perform only with one runway. Therefore, it is only possible to change flights' slot times. This creates that the APLN is sometimes not able to act on the arrival sequence on the EDD, because there are no changes possible. Additionally, the system is created to be a hands-off system to keep the most stable operation of the arrival sequence. Therefore, it is not desired that the APLN intervenes much.

Since the ACC controller influences ASAP's output too, a short interview with four ACC controllers resulted in very different opinions and results. Therefore, it is difficult to point out one main result. However, the results tend to conclude that the controllers with the least experience will be most positive about the implementation of ASAP. This would be a logical result because these ACC controllers do not have their own methods and are still more flexible and amendable. This result is also underpinned by the ASAP experts, who have executed training and conversations with the ACC controllers.

Another finding, which is also related to the intervention of the APLN, is the effect pop-up flights have to the process. These flights can have a significant effect on ASAP's planning and,

therefore, require the manual interventions of the APLN. For confirmation or to place the flight in the correct spot within the arrival sequence. Since they appear around 5 to 10 times per day and are not notified to the system in advance, this is a very time-consuming and inefficient process.

9.2 Results output and customer

In chapter 6., the following sub research question was investigated:

What is the output of ASAP, and how can this be measured?

Figure 23 indicates the results of the ASAP output and the related measurements.

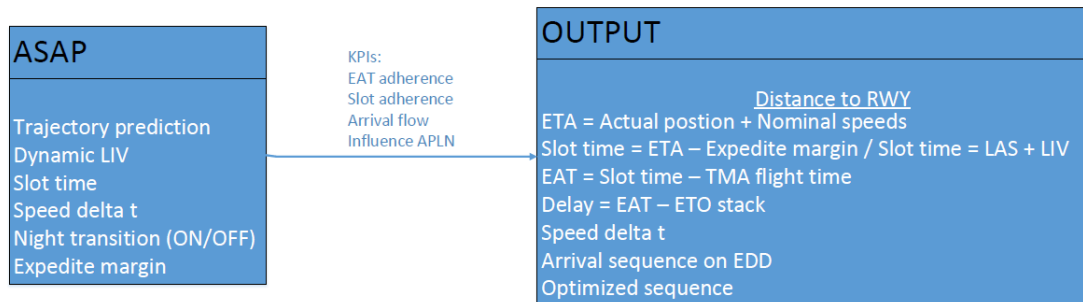


Figure 23: Result research to the output and how to measure

This diagram shows how the output relates to the processes of ASAP. These different relationships individually analyzed, created the following relationships concerning process and output:

Table 27: Relation ASAP component and specific output

Component	Specific output
Trajectory prediction	ETA
Slot time planning	Slot time EAT Delay
Speed delta t	Speed delta t
Expedite margin	Slot time
Dynamic LIV	
Night transition (ON/OFF)	

The dynamic LIV is not implemented by the APLN, but it is a result of ASAP's weather input. It does not directly have a specific output element, but it can have a significant effect on the slot time planning when the dynamic LIV increases. Therefore, the dynamic LIV can only indirectly influence the outputs slot time, EAT, and possible delay.

Neither the night transition (both ON and OFF) does directly influence one of the output elements. It does influence how ASAP creates the planning (it affects the input values) but does influence how the input elements are processed.

Resulting from knowledge about the outputs of ASAP, together with an analysis of the CTQs of the customers and the overall LVNL's arrival KPIs, the ASAP KPIs are formulated. These KPIs make it possible to monitor and measure the output and, therefore, the performance of the system.

Table 28: Result ASAP KPIs

LVNL KPIs	CTQs	ASAP KPIs	Formula
Sustainability of capacity	Correctness of the time information	EAT adherence	$EAT - ATO\ stack$
		Slot adherence	$Planned\ slot - ATA$
	Optimized arrival sequence	Holding ratio	$\frac{Number\ of\ aircraft\ in\ holding}{Total\ number\ of\ aircraft\ at\ IAF}$
		Influence of the APLN	$\frac{\sum Number\ of\ manual\ changes}{Count\ EAT\ or\ Slot\ adherence}$

9.2.1 Relationship adherence and manual changes

While investigating the KPIs for ASAP, a possible relation was found between the EAT and slot adherence with the number of manual changes from the APLN (IBP_TOTAL). In this sub-chapter, the analysis of the manual adjustments and EAT adherence is completely elaborated. The results of the analysis of the relationship between the manual adjustments of the APLN and the slot times is presented in appendix IX and X, because further explanations to this relationship are left out of scope.

The relationship between the EAT adherence and the manual adjustments of the APLN has been researched with a statistical analysis. The EAT adherence had to be split into negative (-300 to 0 seconds) and positive (0 to 300 seconds) values to be able to prove any statistical correlation. A negative EAT adherence implies that the flight has passed IAF too early, and a positive EAT adherence implies that the flight has passed IAF too late.

The first statistical analysis was applied to the sum of IBP_TOTAL. The results of all scatter plots are presented in Appendix IX. The plots of the EAT adherence and IBP_TOTAL are visualized in Figure 24. The information which is achievable from these plots, is that a correlation is present between the two values. It shows that when the EAT adherence is around zero, the number of manual changes is high, and when the EAT adherence is -300 and +300, the number of changes is low.

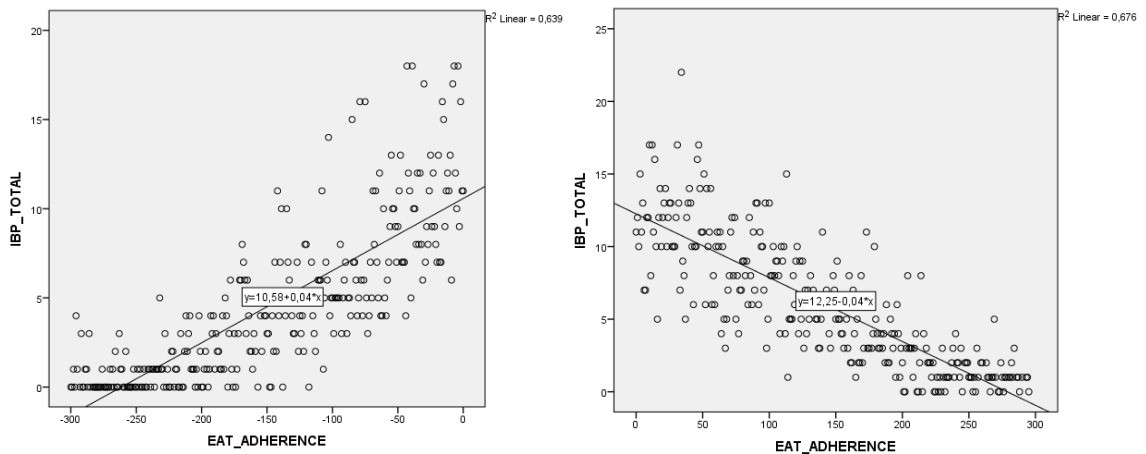


Figure 24: Scatter plots of the relation between EAT adherence and IBP_TOTAL

The data within these plots have the following relationships, according to the Spearman’s rho method in SPSS.

Table 29: Spearman’s rho results: Adherence and the sum of manual changes

		Correlation coefficient	Sig (2-tailed)	N
EAT adherence (s)	-300 to 0	.847	.000	299
	0 to 300	-.852	.000	284

These presented correlation coefficients (Table 29) imply that there is a strong significant correlation between both factors.

However, when this correlation was reviewed by experts, they had the comment that this might not be the correct way to investigate this relationship. The correlation, how it is visualized and interpreted now, implies that the APLN needs to apply many manual adjustments when the EAT adherence is more precisely executed. However, the total number of flights are not taken into account. When the number of flights increases too (like sum of IBP_TOTAL does), this conclusion of the correlation may therefore not be correct.

Therefore, another statistical analysis is performed. This analysis covered the weighted average of the sum of IBP_TOTAL. After the calculation of the weighted averages, again, a scatter plot is created and all plots are presented in Appendix X. The plots of the EAT adherence and the weighted average of the IBP_TOTAL are visualized in Figure 25. These plots show very different results compared to the plots with the summation of IBP_TOTAL. When the EAT adherence is negative, the line is almost flat, which implies that a weak or no correlation is present. However, the plot with the positive EAT adherence does visualize a relationship and shows that when the EAT adherence is high, the average of manual adjustments is also high.

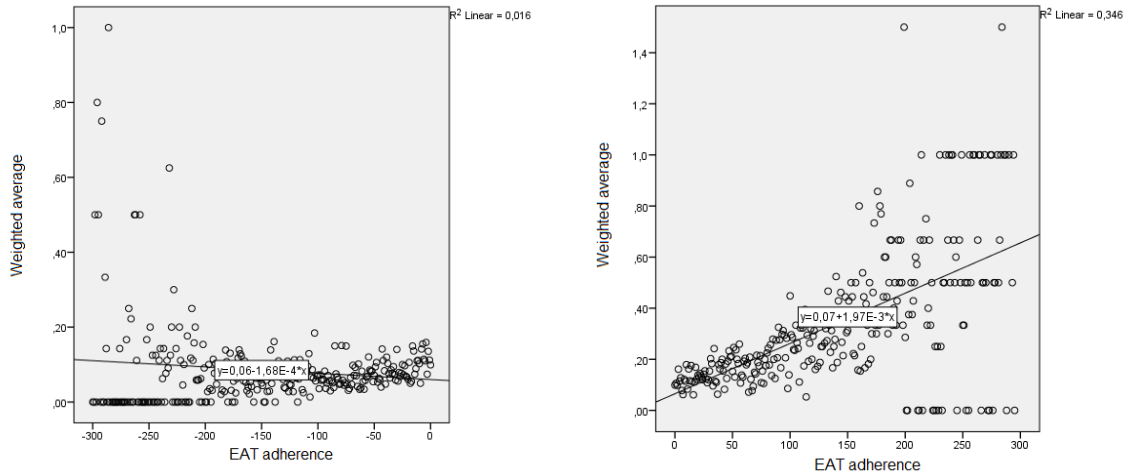


Figure 25: Scatter plots of the relation of EAT adherence and the weighted average of IBP_TOTAL

The plots have the following relationships, according to the Spearman’s rho method in SPSS.

Table 30: Spearman’s rho results: Adherence and the weighted average of the manual changes

		Correlation coefficient	Sig (2-tailed)	N
EAT adherence (s)	-300 to 0	.223	.000	299
	0 to 300	.594	.000	284

With the information from this table (table 30) is concluded that the negative EAT adherence and the manual changes by the APLN do have a weak statistical correlation like expected from the visualized plot. The results concerning positive adherence, however, results in a moderate relationship with the manual adjustments of the APLN. This conclusion derives from the number of the coefficient, which is around .5.

To underpin that these correlations are not an effect of the implementation of ‘a new system’, the same analysis is performed with the data of three additional months (01-01-2019 to 24-03-2019). This additional analysis is only executed for the relation with the EAT adherence since the slot adherence is out of this research’s scope. The results of this statistical analysis are presented in Table 31.

Table 31: Spearman’s rho results three extra months

		Correlation coefficient	Sig (2-tailed)	N
EAT adherence (s)	-300 to 0	.187	.001	300
	0 to 300	.579	.000	296

To put this information of the EAT adherence into an operational perspective, it can be concluded that when the flight passes IAF too early (negative EAT adherence) there is a weak correlation. However, when the flight passes IAF too late (positive EAT adherence), a moderate relation is found between this adherence and the manual adjustments of the APLN.

How this correlation arises has been discussed with two APP supervisors. Based on their experience, the operational explanation of this relationship is due to the plan window of the transfer on EAT. If this margin of 2.5 minutes decreases, it is expected that the correlation will decrease. When all flights are exactly transferred at EAT, the planning would be performed perfectly and the APLN is not required to intervene. However, when a flight is not perfectly transferred on EAT, little gaps can occur and, to create an efficient flow, the APLN is required to take actions.

9.3 Results input and process

The results of this chapter 5. can present an answer to the following research question:

What is the input for ASAP, and how does the processing work?

Just like the previous research question, Figure 26 indicates the results of the ASAP input and its different calculating components.

From the analysis of the inputs is found that some of these have inputs themselves. Like the runway configuration and IAF preference, which have to be manually implemented and reviewed by the APLN each time. Another of these inputs is the buffer parameters, which create more safety margins. However, when the planning creates extra margins each flight, this results in a less efficient planning. However, different iterations are still being tested concerning these buffers.

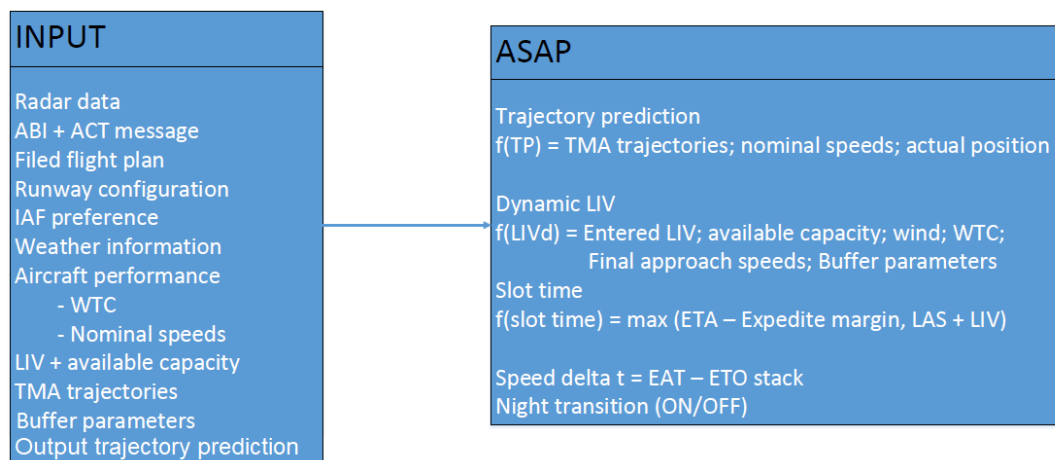


Figure 26: Result input and ASAP's components

Figure 26 visualizes how the input relates to the processes of ASAP. It also clarifies how the processing works, explained by the function of each ASAP component. Especially when the component's functions are presented next to how the components relate to the output, the explanation of how the processing works is complete (Table 32).

Table 32: Process of ASAP

Component	Function	Specific output
Trajectory prediction	TMA trajectories; Nominal speeds; Actual position	ETA
Slot time planning	ETA – Expedite margin LAS + LIV	Slot time EAT Delay
Speed delta t	EAT – ETO stack	Speed delta t
Expedite margin*		Slot time
Dynamic LIV	Entered LIV; Available capacity; Wind; WTC; Final approach speeds; Buffer parameters	LIV
Night transition (ON/OFF)		

*Since the expedite margin is a time value, this cannot be described as a function.

How the different input elements relate to the specific components has been analyzed as well. This resulted in the following relationships concerning process and input:

Table 33: Relationship ASAP component and specific input

Input	Specific component
Radar data TMA trajectories Aircraft performance Filed flight plan ABI + ACT message Runway configuration IAF preferences	Trajectory prediction
LIV + available capacity Weather information Aircraft performance Filed flight plan Buffer parameters	Dynamic LIV
LIV Output trajectory prediction	Slot time planning
	Speed delta t
	Night transition (ON/OFF)

The two components mainly execute the processing of ASAP's planning:

1. Trajectory prediction,
2. Slot time planning

These components are not only depending on the input from the suppliers, but the components need each other's output too, to create a complete and efficient planning.

9.4 Results analysis of the arrival process

Chapter 4. The arrival process at Schiphol was examining the following research question:

How is the arrival process to Schiphol organized?

The answer to this question is achievable through the information from the created flowchart diagram, presented in Appendix III. The diagram shows that five different parties are involved and play a role within this process. These five parties are divided into four stakeholders (Table 34).

Table 34: Stakeholders within the arrival process

Stakeholder	Involved party
Adjacent center	Upstream center
Air traffic control	Air traffic controllers from LVNL ASAP
Airline	KLM
Airport	Amsterdam Airport Schiphol

The arrival process of an aircraft to Schiphol starts around 20 minutes before FIR-entry; when the ABI-message is received from one of these adjacent centers. Together with radar data and the information from the ABI-message, the flight is planned within ASAP. When the flight is at the FIR-boundary, ACC will have control over the flight.

In the meantime, with the aid of CDM, Schiphol is aware of the arriving aircraft and can secure the required gate. This gate assignment will be notified to the ATCOs and ASAP, so they can take this gate into account when they determine the runway allocation and taxi route.

The moment the aircraft enters the TMA-boundary (passes IAF), the flight will be transferred from ACC to APP. The planning cannot be adjusted anymore, and the aircraft will continue descending to the runway. The ATCOs in the tower will finalize the process by arrival at the runway.

10 Conclusions

This research aimed to perform an analysis of the arrival management system at Schiphol referred to as Advanced Schiphol Arrival Planner (ASAP). The report must function as a framework to further or more profound research to this system. Therefore, to assess all elements of ASAP and to create a complete understanding of the current situation, the following main research question has been formulated:

How does ASAP generate the arrival planning at Amsterdam Airport Schiphol, and how can the planning be adjusted by the controller and the output be measured?

The results of the literature review, together with the research findings, presented that the ASAP inputs are very much equal to the outcomes of the performed literature review. However, as expected, much more detail and in-depth research were required since there was limited literature available about the use of an AMAN system.

To answer the first part of the main research question, how does ASAP generate the planning, a table is formed (Table 35). The information has been retrieved through the analysis of the second sub-question, and a part of the third. This table visualizes the following information:

1. All required input elements
2. Inputs required for the ASAP processes
3. The outputs of the ASAP processes

Table 35: ASAP's inputs, processes and outputs

Inputs	ASAP black box		Specific output
	Component	Function	
Radar data TMA trajectories Aircraft performance Filed flight plan ABI + ACT message Runway configuration IAF preferences	Trajectory prediction	TMA trajectories; Nominal speeds; Actual position	ETA
LIV + available capacity Weather information Aircraft performance Filed flight plan Buffer parameters	Dynamic LIV	Entered LIV; Available capacity; Wind; WTC; Final approach speeds; Buffer parameters	LIV
LIV Output trajectory prediction	Slot time planning	ETA – Expedite margin LAS + LIV	Slot time EAT Delay
	Speed delta t	EAT – ETO stack	Speed delta t
	Night transition (ON/OFF)		

The second part of the main research question, how the planning can be adjusted by the controller, has been analyzed on the base of an interview with an Approach Planner (APLN). Because the APLN is the only person who can adjust the planning, 'the controller' in the main research question refers to the APLN.

Because ASAP is designed to be a hands-off system, the interesting changes concern the adjustments to the planning of one or multiple flights and do not to refer to changes that affect the complete sequence. These individual and manual changes are applied to optimize the arrival sequence and subsequently increase runway utilization.

The three changes that are performed most frequently by the APLN are:

1. Shift to another runway
2. Assign another slot time
3. Recalculate the planning

The actions of the APLN, to adjust the planning, depend on two main limiting factors:

1. Is it peak hour
2. Are there gaps within the sequence

The main goal of an APLN is to create the most optimal arrival flow for all operational arrival runways. If the efficiency of the arrival sequence is not improved by an adjustment, it is not desired that the APLN will intervene. That is because the efficiency improvement that is obtained by a planning modification needs to be balanced against the negative impact it may have on the planning's stability to ACC.

The other analysis of the third sub-research question created an answer to the final part of the main research question, how can the output be measured. This question is answered by the introduction of four Key Performance Indicators (KPIs). These KPIs are based on the desired output of the customers (Critical to Quality (CTQs)), which are the air traffic controllers and compared to the LVNL's overall arrival KPIs.

Table 36: ASAP's formulated KPIs

LVNL KPIs	CTQs	ASAP KPIs	Formula
Sustainability of capacity	Correctness of the time information	EAT adherence	$EAT - ATO\ stack$
		Slot adherence	$Planned\ slot - ATA$
	Optimized arrival sequence	Holding ratio	$\frac{Number\ of\ aircraft\ in\ holding}{Total\ number\ of\ aircraft\ at\ IAF}$
		Influence of the APLN	$\frac{\sum Number\ of\ manual\ changes}{Count\ EAT / Slot\ adherence}$

Now all three parts have been answered, the conclusion of the main research question is:

ASAP generates its arrival planning at Amsterdam Airport Schiphol with eleven different input elements:

- | | | |
|-------------------------|----------------------|----------------------------------|
| 1. Radar data | 4. Filed Flight Plan | 8. LIV + Capacity |
| 2. TMA | 5. ABI + ACT message | 9. Weather information |
| trajectories | 6. Runway | 10. Buffer parameters |
| 3. Aircraft performance | configuration | 11. Output Trajectory prediction |
| | 7. IAF preference | |

All of these inputs are used to provide ASAP's calculating components with the correct information and data of each flight. The most important components, to create the planning, are the slot time planning and the trajectory prediction. All ASAP's components perform calculations which create six outputs:

- | | | |
|--------|--------------|------------------|
| 1. ETA | 3. Slot time | 5. Delay |
| 2. LIV | 4. EAT | 6. Speed delta t |

ASAP's output must be measured with the monitoring of the four proposed KPIs, which relate to the correctness of the time information and an optimized arrival sequence. These requirements are critical to the air traffic controllers who work with the output of ASAP. The KPIs are:

- | | |
|-------------------|--------------------------|
| 1. EAT adherence | 3. Holding ratio |
| 2. Slot adherence | 4. Influence of the APLN |

The controller who can adjust the planning is the APLN. The APLN has five different actions to change ASAP's planning, and the three most frequently used actions are to assign another runway to one flight, assign another slot time to one flight, and to create a new planning in ASAP.

Together with the aid and adjustments of the APLN, three ASAP goals will be reached, which is to create a stable traffic flow in the Schiphol Terminal Control Area (TMA) and to form the most optimized and efficient arrival sequence.

11 Discussion

The challenge that this research faced was that, currently, insufficient operational documentation and insights about the new arrival management system ASAP are available. This problem resulted in the main research question:

How does ASAP generate the arrival planning at Amsterdam Airport Schiphol, and how can the planning be adjusted by the controller and the output be measured?

The results of the input elements are very much in line with the results of the performed literature review. However, which was expected and explained in the conclusion of this chapter, some extra elements were required to add to obtain the complete view on the current situation. Additionally, since no recent studies were found which have been performed on any other arrival management process nor arrival systems, it is not possible to discuss the research's results about these studies.

The continuous use of the SIPOC diagram through the research was an excellent tool to assess if all ASAP's elements are analyzed. It helped to identify the critical influences on all processes. This method helped to analyze the ASAP system, which gained sufficient in-depth research.

The result of the data analysis, performed to formulate the ASAP KPIs, has identified a correlation between the manual changes of the APLN and the EAT adherence. To interpret this statement into an operational perspective: When the flight passes IAF too late (a positive EAT adherence) the number of manual changes from the APLN increases (or the other way around).

Further research to this correlation is not required because the performed research, a statistical Spearman's rho analysis in SPSS, was a good method to assess whether a relationship is existing or not. Hence, the fact that there is a moderate relation between the two elements is proved.

However, what the impact of this relation is, and which element triggers the other, remains unclear. Since ASAP is designed to be a hands-off system, this relationship is undesirable. Therefore, further research into the cause of this relationship is advisable.

The first limitation within this research, due to the scope, was the assumption that ASAP's algorithm works as it should. The calculations behind the planning, on the algorithmic level, has not been investigated. To even achieve more detailed documentation, further research into this algorithm should be executed.

The second limitation was the scope to investigate the measurability of the proposed KPIs further. These proposed KPIs are only presented based on theoretical analyses, but the results are not further analyzed nor tested (except for one KPI). To evaluate if these KPIs can monitor ASAP sufficiently, tests (over a longer period) should be executed. When these tests result in unclear outcomes, extra KPIs should be formulated to improve the overall assessment of ASAP and the arrival process.

The third limitation was the ACC controllers' sample size group, which has been interviewed to receive ACC controllers' perspective on the implementation of ASAP. The generalizability may be limited by the sample size of the ACC controllers. Four people is a minimal amount, which may not represent the actual opinion of the whole group. The whole group of ACC controllers, according to LVNL's operations department, is approximately 65 executive controllers. This clarifies that the sample is too small (6%). Additionally, these ACC controllers were randomly chosen, which may question their knowledge since they could not prepare for the questions.

The final limitation, concerning all data analyses within this thesis, was the limited amount of available data. Due to the timing of the introduction of ASAP, only the data of four winter months was available. More data, ideally from undisturbed summer months, decrease the effect of weather conditions or other special event. It additionally creates more equal circumstances, which improve the trustworthiness of the data to compare both performances.

The recommendations, based on these acknowledged limitations, are presented in the next chapter.

12 Recommendations

Since this research focused on the analysis of ASAP to create a framework for further research, the recommendations will propose which studies should be required or advised to improve the arrival management at Schiphol. Additional recommendations are provided on how ASAP itself should be improved.

1. *Monitor proposed Key Performance Indicators*

To further improve the arrival management at Schiphol, the first recommendation is to actively monitor the proposed ASAP Key Performance Indicators (KPIs) to obtain a complete view of the current situation. However, the formulated KPIs solely evaluate the performance of ASAP. Therefore, only evaluating the proposed KPIs is insufficient to assess all operational factors. This implies that, resulting in an additional recommendation, it is advisable to formulate additional KPIs, which also measure other elements to visualize the complete arrival performance. For instance, to monitor the runway usability or to measure the number of aircraft operated per air traffic controller. Additionally, all these KPIs together can be used to determine where (other) performance changes are required.

2. *Create more awareness at ACC about early transfers*

The second recommendation is to create more awareness at the ACC controllers to transfer the flights at IAF as close to the EAT as possible. CMA's performed data analysis visualized that the EAT adherence (at two of the three IAF points) becomes more negative, which means that the flights are transferred to APP too early. An early transfer could, for instance, cause that too much traffic accumulates within the TMA. This could affect the APP's workload and could lead to an undesired result.

Because the findings of CMA's data analysis show that this worsened adherence only appears at two IAF points, it is additionally recommended to do further research on why only these two points displayed a negative result in the EAT adherence. It is furthermore recommended to perform this research again when a greater dataset is available. More data reduces the effect of weather conditions or other special events, and it results in more equal circumstances to compare the performance of ASAP with the old system IBP.

3. *Reduce the plan window*

The third recommendation is based on the performed statistical analysis between the weighted average of the manual changes of the APLN (IBP_TOTAL) and the count of the EAT adherence. From this analysis is concluded that there is a correlation between the late transfer of flights and the number of manual changes. Therefore, the advice is to decrease the plan window (which is now ± 2.5 minutes) of a flight's transfer between ACC and APP.

Based on the experts' judgment, a possible explanation of the correlation could be when flights arrive too late at IAF, gaps could arise within the planning. To ensure and create an optimized sequence, the APLN will act on these gaps, and manual changes will be applied. In the situation where the plan window is smaller and closer to the planned EAT, the possibility of late transfers will decrease since the planning will be executed more accurately. The APLN will not have to intervene, and an efficient arrival flow will be ensured.

No further research into the relationship of these elements is required. However, it is still unknown what the most important cause of this relationship is, and whether the interventions will decrease when the plan window is reduced. Therefore, these unclarities must be furtherly research.

The plan window adherence has been a topic of discussion for a long time. This research confirmed current intentions for the further improvement of the adherence.

4. *Improve the predictability of the planning*

The fourth recommendation focusses on the improvement of the predictability of the planned operation by reducing the interventions of the APLN. Two methods are advised, based on the analysis of the input and required adjustments of the APLN.

The first method is to create a "smart" runway configuration system. This system must calculate and implement the LIV and required runways, based on the current situation of weather and period of the day. When such system is implemented, the APLN does not have to implement these changes manually.

The second recommended method is to improve the predictability of pop-up flights. Nowadays, these flights require a lot of monitoring from the APLN, especially since it happens 5 to 10 times

per day. When the predictability improves, less monitoring might be required because their pop-up has already been anticipated.

5. *More awareness at ACC about the positive effects of ASAP*

The fifth recommendation derives from the interview with ACC controllers. It has been recognized that the more experienced controllers are not very fond of the implementation of ASAP, due to different factors. Based on this result, the recommendation is to create more awareness at the ACC controllers about the positive effects of the implementation of ASAP.

Inform them about the positive changes ASAP has to APP controllers and especially for the APLN. Secondly, educate them about what the overall effects to the operation are, resulting from the implementation of ASAP. More importantly, focus on the application of speed delta t and the advantages this function has to their process.

Since the more experience controllers seem to be more persistent to change, due to their multiple years of experience, they are the most important people to focus on first.

The tool for this awareness can be in the form of a presentation which is enriched with the information from this report. The ACC controllers need to be more aware of various elements, which must be explained with an operational perspective and focusing on ACC's operational benefits.

6. *Use this report as a documentation of ASAP*

The final, and quickest implementable, and therefore, most important recommendation is to actively use this report as a framework for other research, or as documentation, which explains the arrival management and ASAP. Additionally, it is advised to keep this document up-to-date to prevent that the document will become obsolete and that the problem of this research will originate again.

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Appendix I: Personal reflection

This graduation research took place during an internship at the Knowledge and Development Centre, which is located at the Dutch air traffic's headquarters. This personal reflection will focus on two subjects. The first reflection will evaluate the assignment and how I've developed my personal skills and knowledge. The second reflection will assess the Knowledge and Development Centre's working methods and how that affected my results and my abilities.

1. *The assignment*

February 2019, I started my internship, which would cover the subject 'Arrival management'. However, besides an available theme, no assignment was formulated. This meant that no required results were precise, and no scope was set. This created that I had to face the process of finding a good thesis project myself, which was performed by conversations with professionals and other LVNL employees. At that time, this process felt like a waste of time, and I was very relieved when a clear assignment came into sight. On the other hand, looking back on this process, I have developed some personal skills from this process. For instance, I feel more confident to clarify what I want to do, which was required to state during all the conversations.

When I had my thesis' requirements defined, I was able to start to do the research. The assignment itself has thought me a lot of new competencies, which I had not developed during my third years' internship.

The first competence I developed is the ability to talk to other people or employees more easily. Since this research required many conversations with the ASAP experts, I was required to speak much and create an open environment.

Another part of my thesis required to do some interviews, which I had never conducted before. This got me out of my comfort zone, as well. Additionally, the interviews educated me on how to prepare and lead them, but it also made me conscious of how you can talk to another person.

The second competence I have furtherly developed is my ability to work independently and structured. During my study in Amsterdam, many assignments are required to be performed into teams. Now, the graduation assignment has to be performed individually. This requires that all thesis elements are my responsibility. A planning had to be created within the project plan, and to ensure that the finalization of my thesis would be achieved on time, I strictly followed this schedule (apart from deviations due to assignment changes).

The requirement of independently working educated me on how to prepare a planning for such big assignments, and clarified all elements involved in a thesis.

2. *The Knowledge and Development Centre*

I enjoyed doing my internship at the KDC. I was introduced to the right people very quickly, and after the assignment became clear, I could perform all analyses without many obstacles. However, due to the scope of my assignment (focusing on LVNL only), I have not so much experienced the cooperation of all Schiphol's stakeholders, and how to involve them all into my thesis.

The KDC has one method to guide all students, which is called the scrum working method. Scrum is an Agile method which results more effectively and flexibly of working, and it should create productive teams which can tackle problems quickly. However, we are not functioning in a team..

By working according to the scrum method, every week is a so-called stand-up. These are guided by an individual manager who knew nothing about my thesis progress, in which you mention:

1. What you have done
2. What are you going to do the next week
3. Do you identify any problems?

My personal experience with this weekly stand-up is that it motivated me to work productively so I could mention at least one finished element every week. However, it did not make me more flexible or effective since I am the only team member of my thesis.

Another method attached to the scrum working method is the two-weekly sprint reviews. At these sprint reviews, we were required to give a five-minute presentation about what we had done the past two weeks and what we will perform in the next two weeks. Different people of Schiphol, KLM, from the HvA, and the LVNL were available during these presentations to ask questions or to give feedback.

Again, this presentation motivated me to work hard, so I was able to present new information at these sprint reviews.

I think, due to the pressure of the sprint reviews and the stand-up, that I have worked harder and more than I would have done without these methods. However, I can imagine that people find the pressure attached to the scrum too much.

Besides the high pressure and hard-working, I liked doing my research. With the enlightenment that I liked doing research, I have realized that I want to do a master study after I graduate from the Aviation Academy.

Appendix II: Dutch airspace

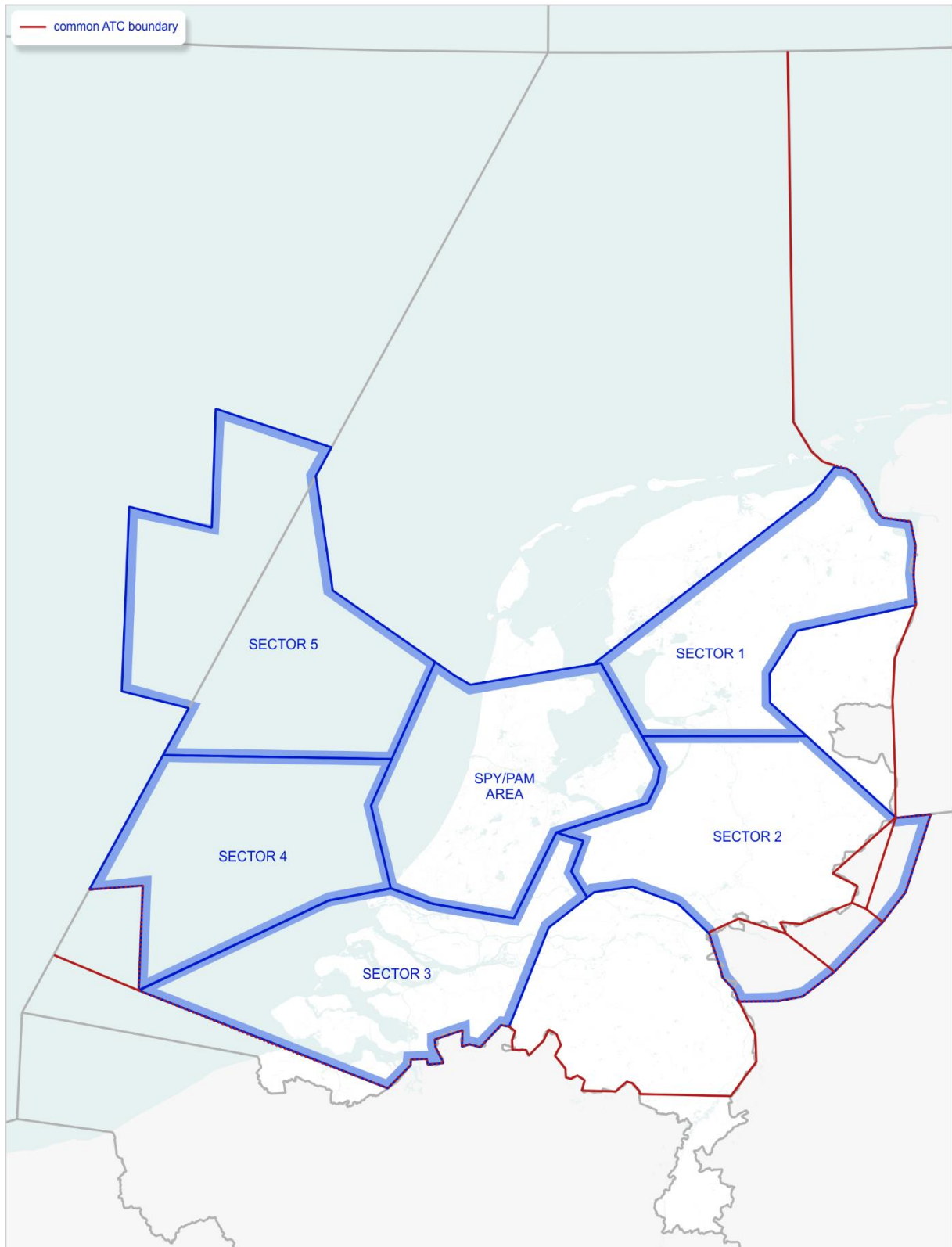


Figure 27: Dutch airspace (FIR-boundaries) and the sectors (Luchtverkeersleiding Nederland, 2017)

The space between the red lines are military airspace.

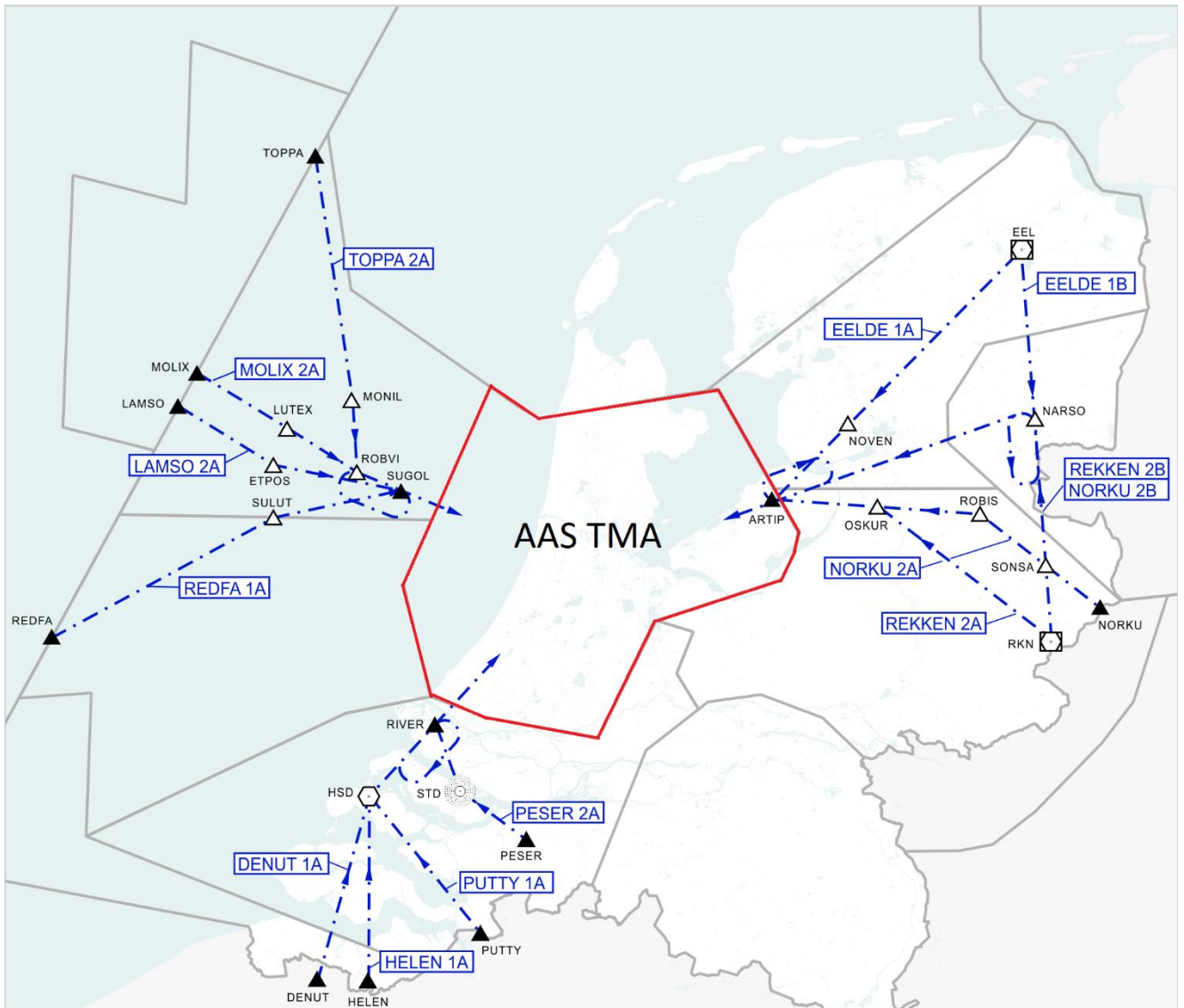


Figure 28: Schiphol TMA and the three IAF points (Luchtverkeersleiding Nederland, 2017)

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Appendix III: Flowchart arrival process

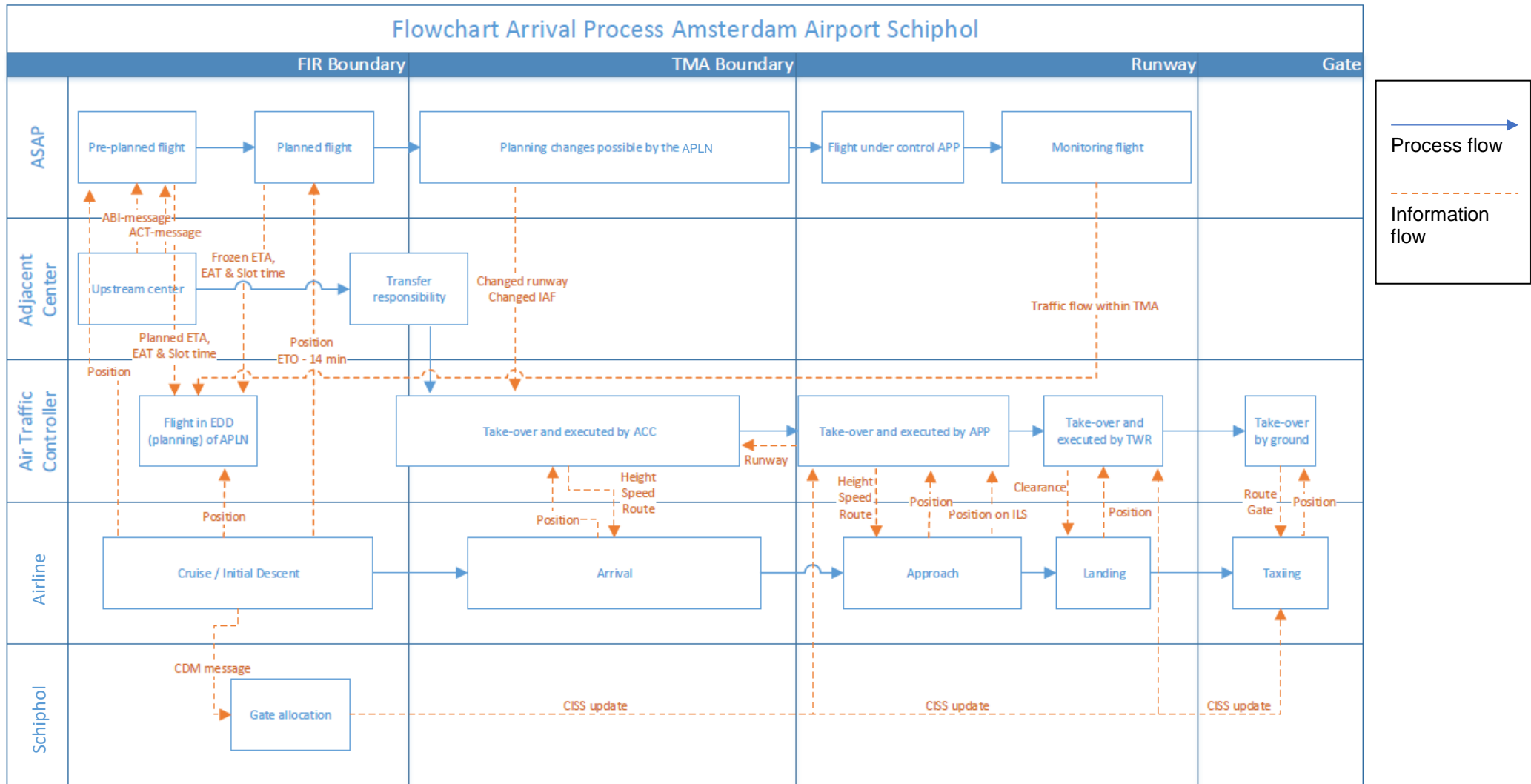


Figure 29: Flowchart (Note, the information flows are not correctly represented through time)

Appendix IV: Complete SIPOC diagram

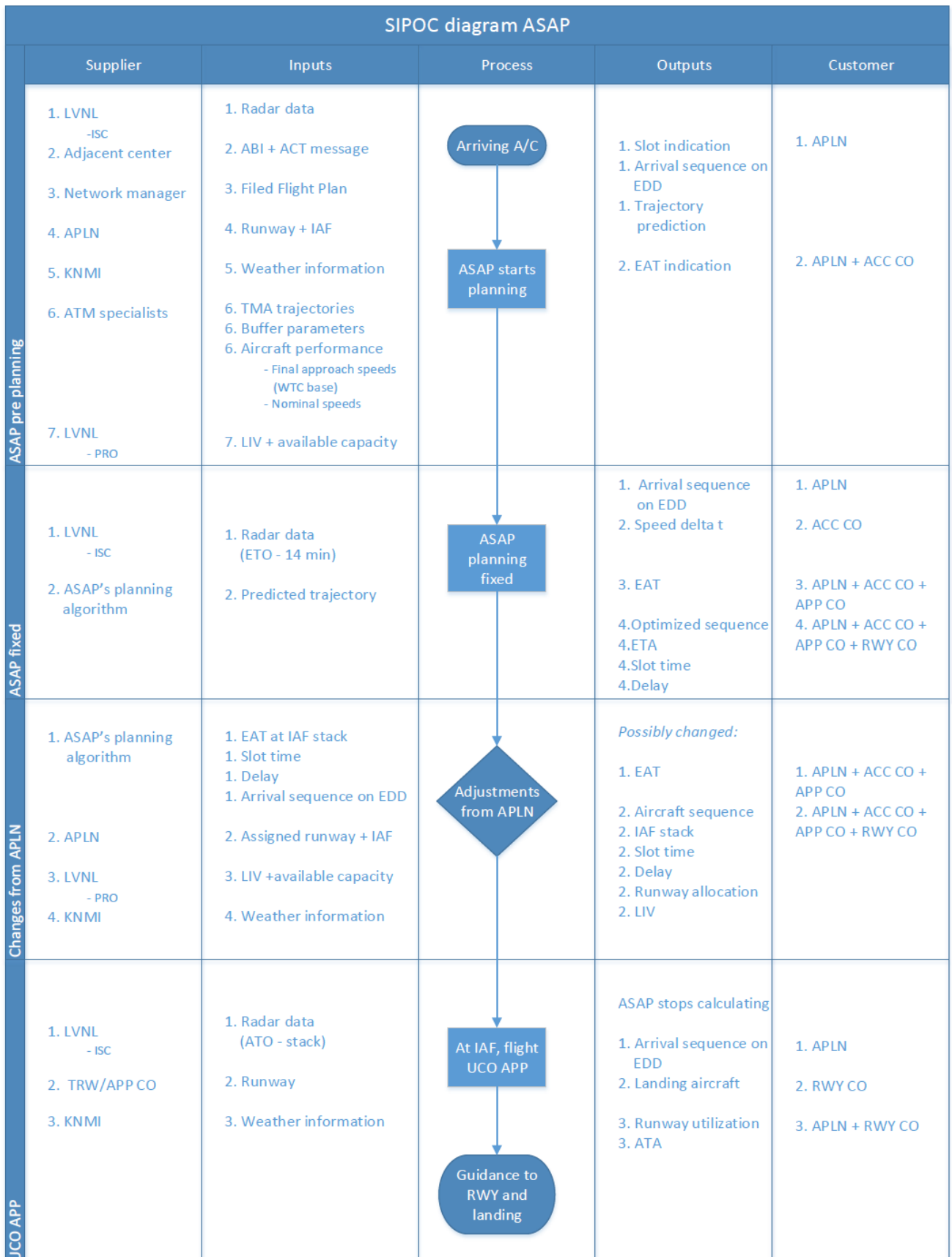


Figure 30: Complete SIPOC diagram

Appendix V: Additional information about the input

The following items of data must be presented in an ABI or ACT message:

Table 37: ACT and ABI message requirements (ICAO, 2014)

	<i>ABI message</i>	<i>ACT message</i>
Requirements	Message type and number	Message type and number
	Aircraft identification	Aircraft identification
	SSR mode and code	SSR mode and code
	Departure and destination airport	Departure and destination airport
	Estimate data	Estimate data
	Number and type of aircraft	Number and type of aircraft
	Type of flight	Type of flight
	Equipment capability and status	Equipment capability and status
Bilaterally agreed	Route and other flight plan data	Route and other flight plan data
		Actual take-off time

These items of data can be transformed to the following ABI message example (ICAO, 2014):
 (ABIOMAE/OMSJ578-ABY464/A5476-VIDP-MAXMO/0032F100-OMSJ-9/A320/M-15/N0457F360 OBDAG LUN G333 TIGER/N0454F380 G452 RK G214 PG G665 ASVIB M561 MOBET/N0409F260 A419 DARAX -80/S-81/W/EQ Y/EQ U/NO R/EQ/A1B1C1D1L1O1S1)

Or into the following ACT message example (ICAO, 2014):
 (ACTOMAE/OMSJ727-ABY604/A7306-HEBA-ALRAR/0130F110-OMSJ-9/A320/M-15/N0428F250 DCT NOZ A727 CVO/N40461F350 UL677 MENLI UN697 NWB W733 METSA UB411 ASH G669 TOKLU UP559 ASPAK/N0438F290 UP559 NALPO P559 ITGIB/N0409F230 P559 -80/S-81/W/EQ Y/EQ U/NO R/EQ/A1B1C1D1L1O1S1)

The Filed Flight Plan message contains the following information (ICAO, 2016):

Table 38: FPL message requirements (ICAO, 2016)

	<i>FPL message</i>
Requirements	Message type, number and reference data
	Aircraft identification and SSR mode and code
	Flight rules and type of flight
	Type of aircraft and wake turbulence category
	Equipment and capabilities
	Departure airport and time
	Route
	Destination airport and total estimated elapsed time, alternate destination airport(s)
	Other information

All items presented in an example of a FPL message (ICAO, 2016):
 FPL-ACA101-IS
 -B773/H-CHOV/C
 -EGLL1400 N0450F310 L9 UL9 STU285036/M082F310 UL9 LIMRI
 52N020W 52N030W 50N040W 49N050W
 -CYQX0455 CYYR
 -EET/EISN0026 EGGX0111 020W0136 CYQX0228 040W0330 050W0415 SEL/FJEL

Appendix VI: Data dictionary

All times in the data file are noted in UTC.

Pre: Before IAF

Post: After IAF

Yellow highlights: Enriched data from another LVNL database. This data could not be determined from ASAP data.

		Column name	Description	Comment	Type
		FLIGHT_ID	Flight id number		Integer
		SFPL_ID	System flight plan ID		Integer
		ATA	Actual time of arrival	dd-mm-yyyy hh:mm:ss	Datetime
		ATO_STACK	Actual time over stack	dd-mm-yyyy hh:mm:ss	Datetime
		T14	Time EAT stack < 14 minutes	dd-mm-yyyy hh:mm:ss	Datetime
Before IAF	EAT	EAT_NR_PRE	Number of EAT updates		Integer
		EAT_LAST_PRE	Final presented EAT	dd-mm-yyyy hh:mm:ss	Datetime
		EAT_AVG_PRE	Average EAT time	dd-mm-yyyy hh:mm:ss	Datetime
	ETA	ETA_NR_PRE	Number of ETA		Integer
		ETA_LAST_PRE	Final presented ETA	dd-mm-yyyy hh:mm:ss	Datetime
		ETA_AVG_PRE	Average ETA time	dd-mm-yyyy hh:mm:ss	Datetime
	SLOT	SLOT_NR_PRE	Number of slot updates		Integer
		SLOT_LAST_PRE	Final presented slot	dd-mm-yyyy hh:mm:ss	Datetime
		SLOT_AVG_PRE	Average slot time	dd-mm-yyyy hh:mm:ss	Datetime
IBP	IBP_NR_PRE	Number of manual updates		Integer	
	IBP_LAST_PRE	Last manual update	dd-mm-yyyy hh:mm:ss	Datetime	
	IBP_AVG_PRE	Average time updates	dd-mm-yyyy hh:mm:ss	Datetime	
After IAF	EAT	EAT_NR_POST	Number of EAT updates		Integer
		EAT_LAST_POST	Final presented EAT	dd-mm-yyyy hh:mm:ss	Datetime
		EAT_AVG_POST	Average EAT time	dd-mm-yyyy hh:mm:ss	Datetime
	ETA	ETA_NR_POST	Number of ETA updates		Integer
		ETA_LAST_POST	Final presented ETA	dd-mm-yyyy hh:mm:ss	Datetime
		ETA_AVG_POST	Average ETA time	dd-mm-yyyy hh:mm:ss	Datetime
	SLOT	SLOT_NR_POST	Number of slot updates		Integer
		SLOT_LAST_POST	Final presented slot	dd-mm-yyyy hh:mm:ss	Datetime
		SLOT_AVG_POST	Average slot time	dd-mm-yyyy hh:mm:ss	Datetime
	IBP	IBP_NR_POST	Number of manual updates		Integer
		IBP_LAST_POST	Last manual update	dd-mm-yyyy hh:mm:ss	Datetime
		IBP_AVG_POST	Average time updates	dd-mm-yyyy hh:mm:ss	Datetime
		SECTOR	Sector	ACC entry sector	Integer
		RUNWAY	Runway	Runway used for that flight	String
		RWCOMBINATION	Runway combination	Which other runway was used at that time	String
		EAT_LAST	Final presented EAT*	dd-mm-yyyy hh:mm:ss	Datetime
		SLOT_LAST	Final presented slot**	dd-mm-yyyy hh:mm:ss	Datetime
		T_TMA	Entry time of the TMA	dd-mm-yyyy hh:mm:ss	Datetime
		T_FIR	Entry time of the FIR	dd-mm-yyyy hh:mm:ss	Datetime
		T_STACK	Entry time of the stack	dd-mm-yyyy hh:mm:ss	Datetime
		N_HOLDINGS	Number of holdings	Number of circles that the aircraft flown in stack	Integer

FL_TMA	Flight level (FL) when entering TMA	FL at point over IAF	Decimal
EAT_ADHERENCE	Difference EAT_LAST and T_TMA	Sec	Integer
SLOT_ADHERENCE	Difference slot time and ATA	Sec	Integer
T_ACC	Seconds flight is UCO ACC; Difference between T_STACK and T_FIR	Sec	Integer
T_APP	Seconds flight is UCO APP; Difference between ATA and T_STACK	Sec	Integer

*If EAT_LAST_POST contains a value, then this time is used for EAT_LAST. Else, EAT_LAST_PRE.

**If SLOT_LAST_POST contains a value, then this time is used for SLOT_LAST. Else, SLOT_LAST_PRE.

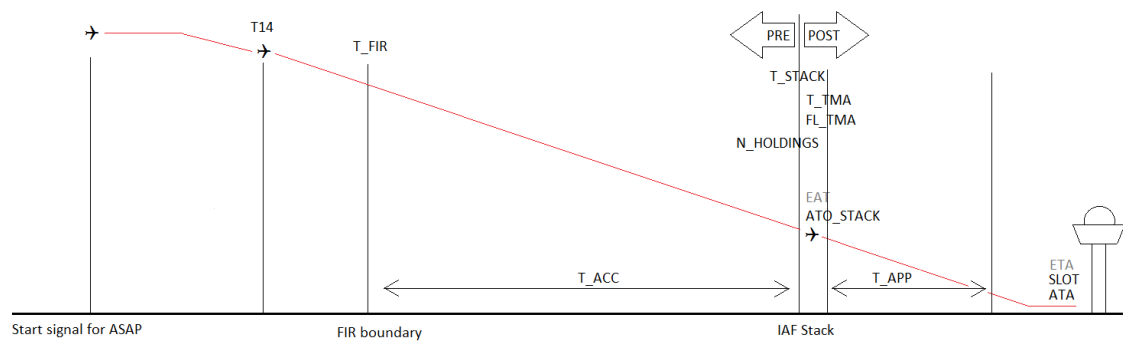


Figure 31: ASAP data points visualized through ASAP's arrival diagram

Appendix VII: ASAP KPIs time information

Slot Adherence (20-12-2018)

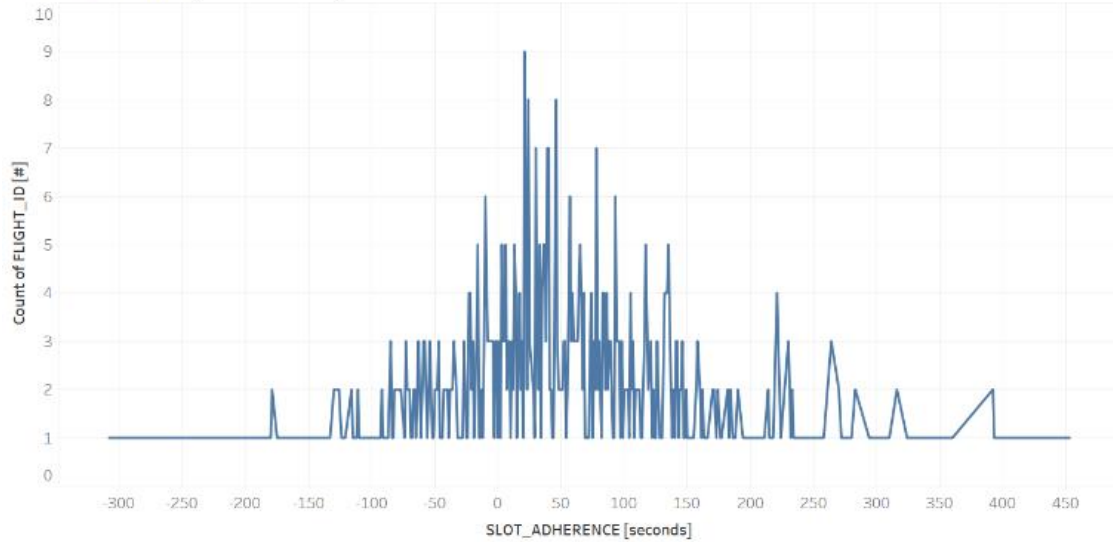


Figure 32: ASAP's slot adherence (in seconds) (20-12-2018)

EAT Adherence (20-12-2018)

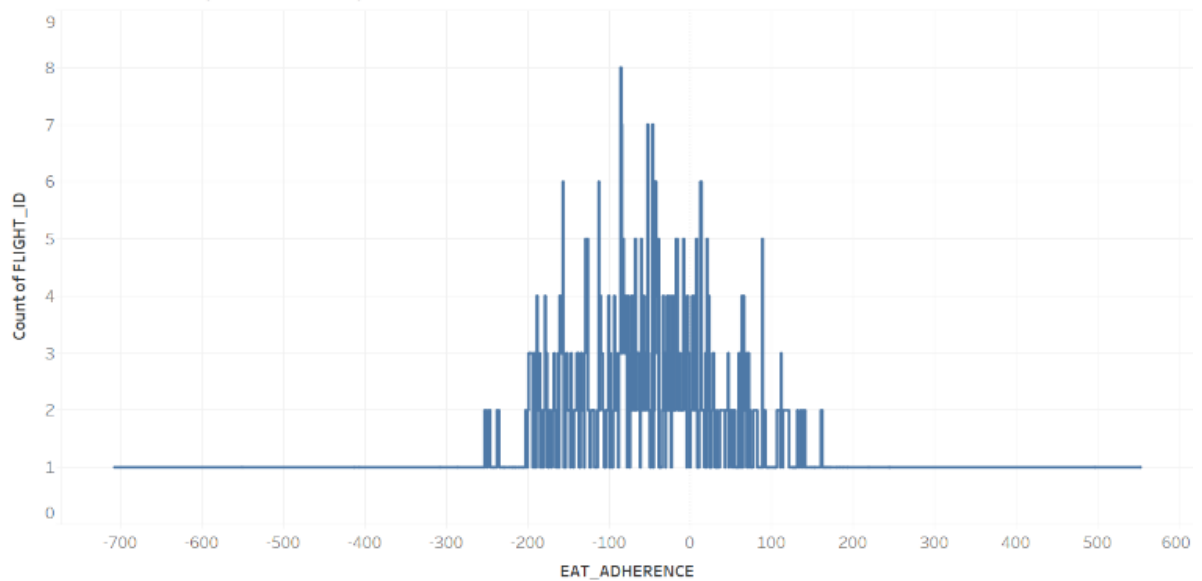


Figure 33: ASAP's EAT adherence (in seconds) (20-12-2018)

Appendix VIII: ASAP KPIs sequence optimization

Aircraft at IAF vs aircraft in holding

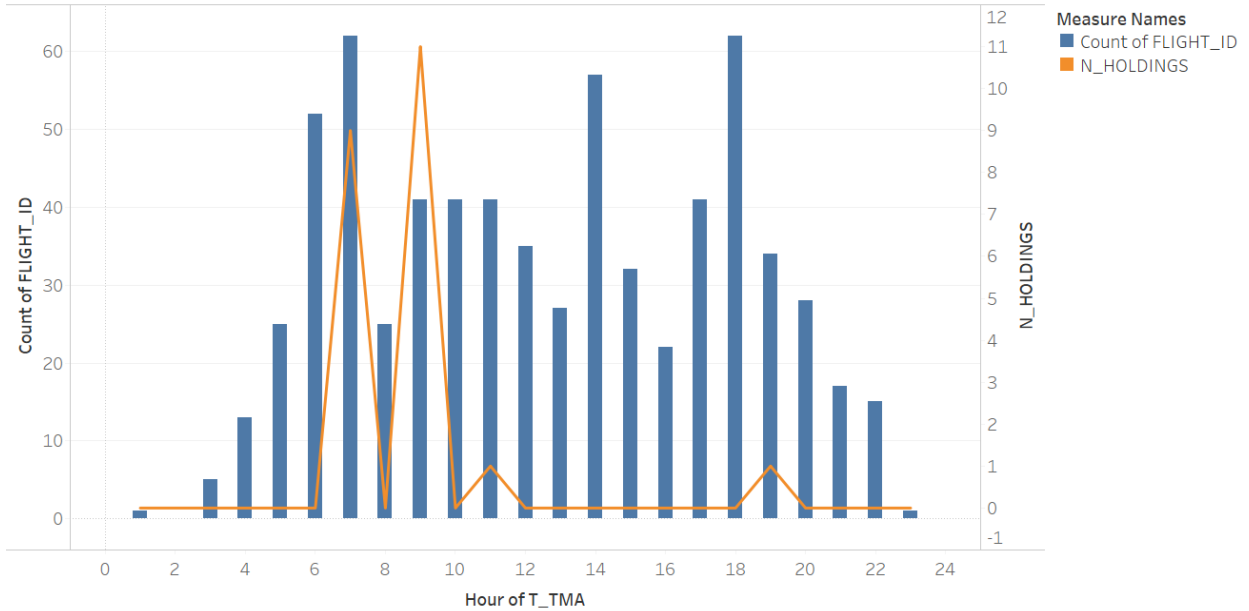


Figure 34: Number of aircraft at IAF and the number of aircraft in holding (20-12-2018)

EAT_ADH vs IBP

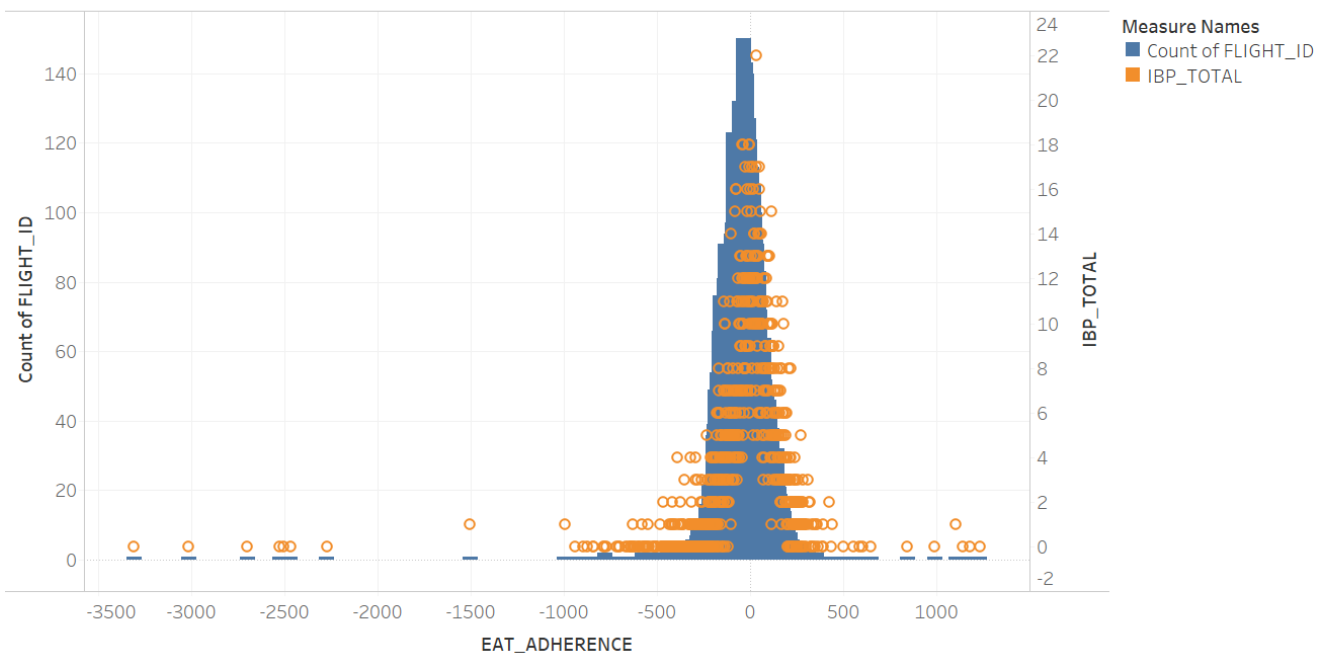


Figure 35: EAT adherence (in seconds) versus IBP_TOTAL (18-11-2018 to 29-12-2018)

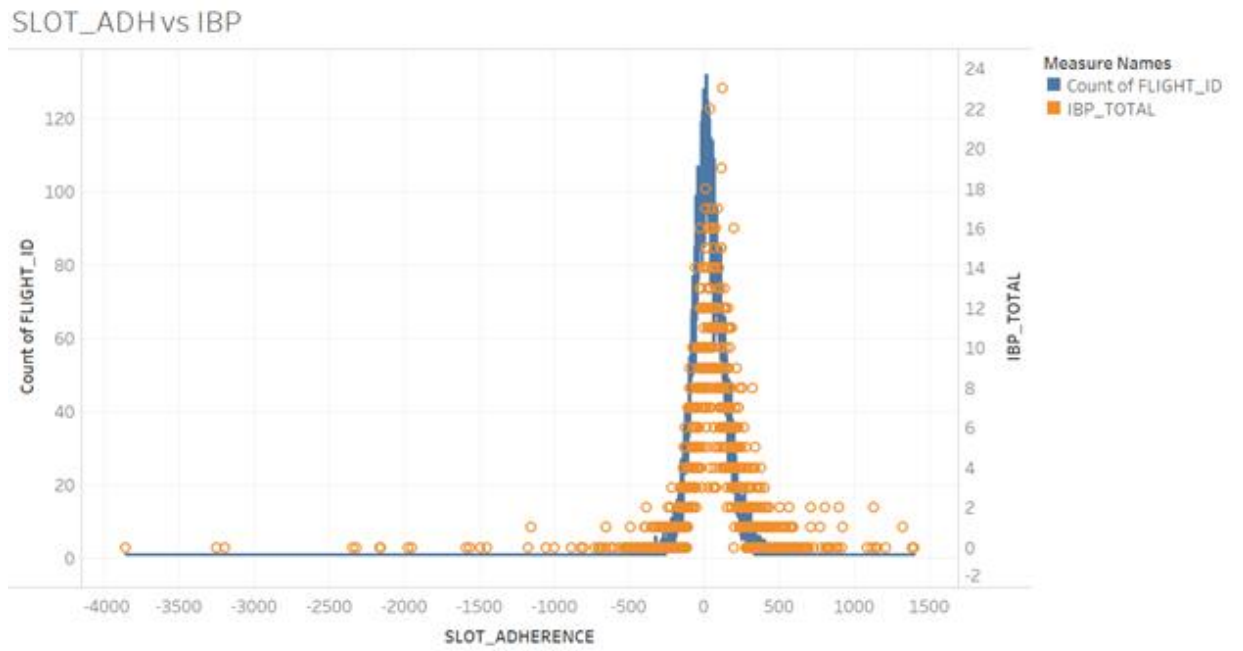


Figure 36: Slot adherence (in seconds) versus IBP_TOTAL (18-11-2018 to 29-12-2018)

Appendix IX: Relationship adherence and sum manual changes

The data used to create these figures is from 18-11-2018 to 29-12-2018.

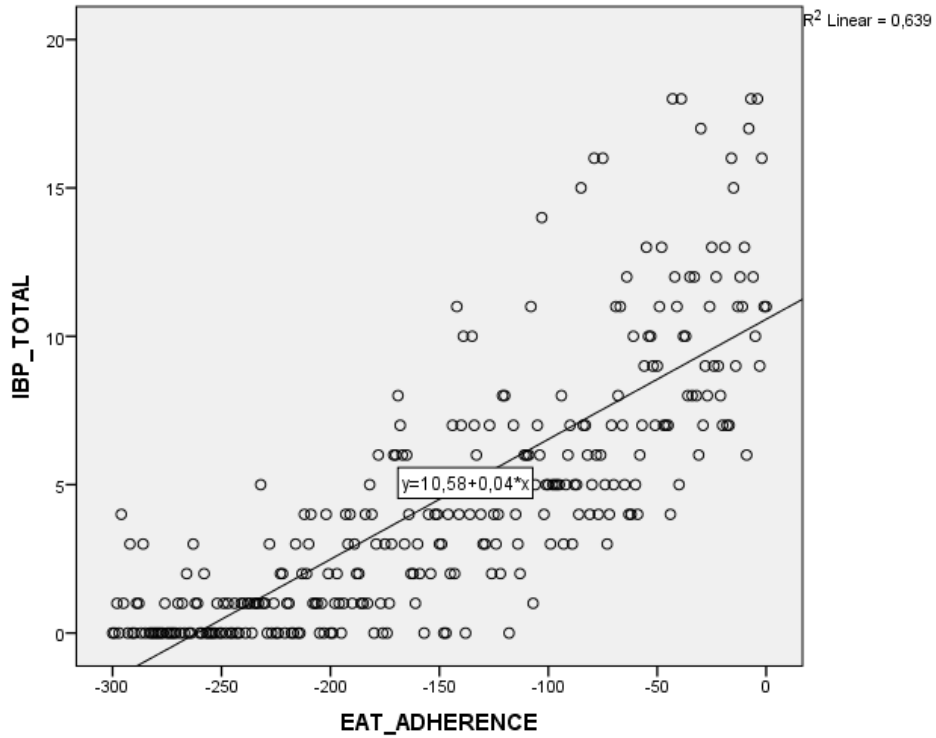


Figure 38: SPSS result of EAT adherence (-300 to 0) and the sum of manual changes

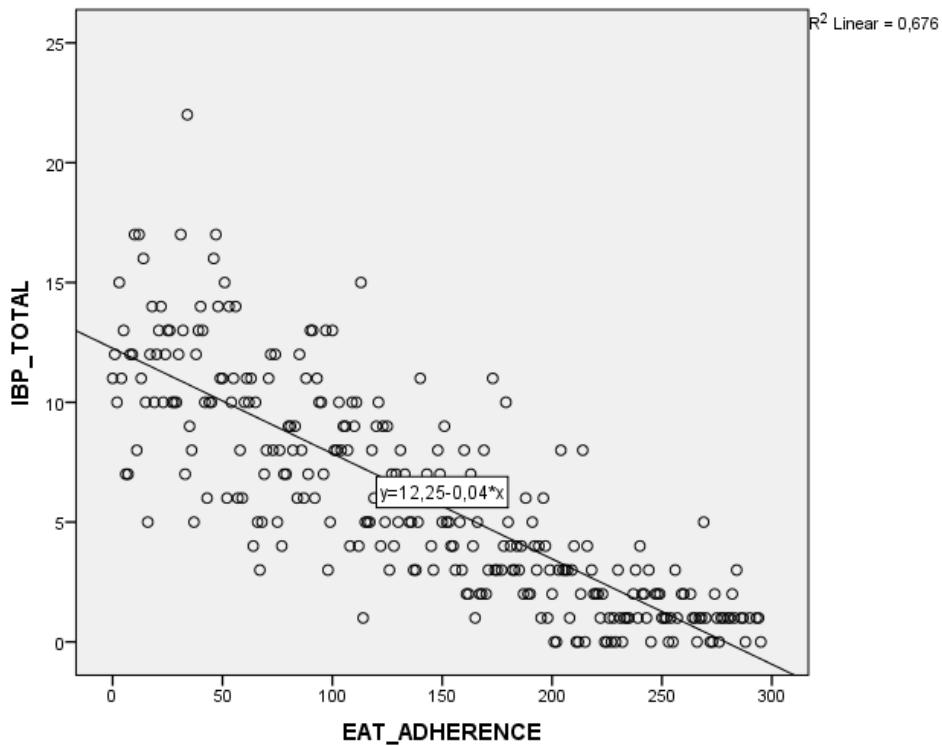


Figure 37: SPSS result of EAT adherence (0 to 300) and the sum of manual changes

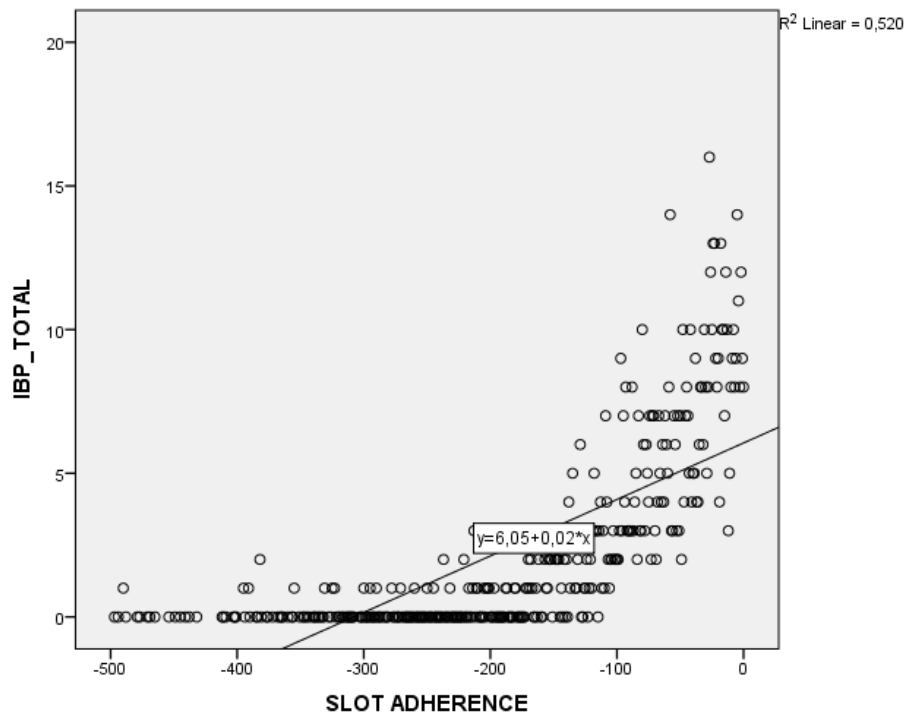


Figure 40: SPSS result of slot adherence (0 to 500) and the sum of manual changes

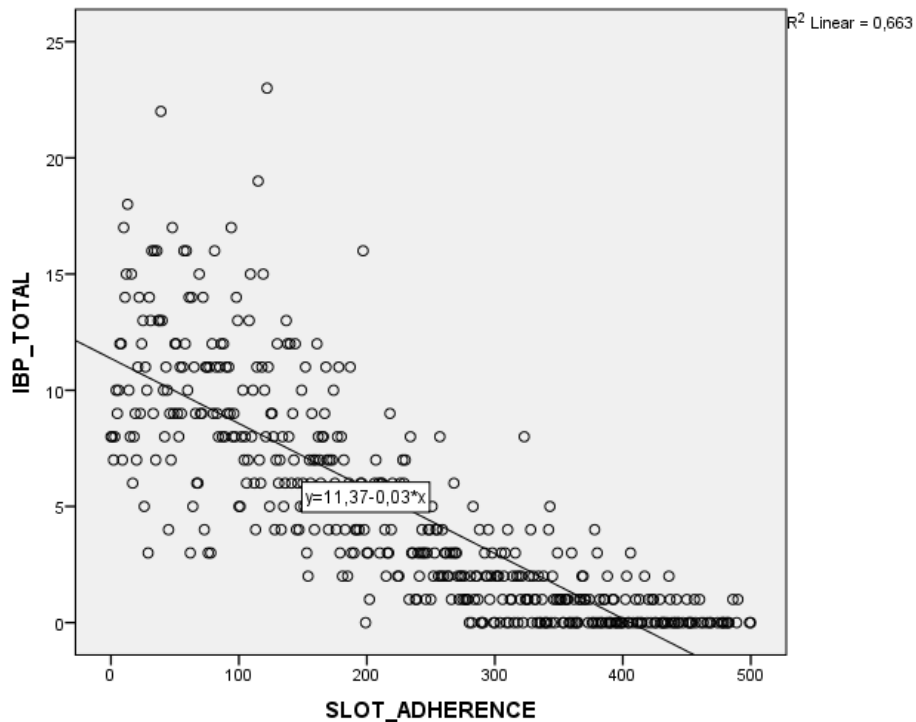


Figure 39: SPSS result of slot adherence (-500 to 0) and the sum of manual changes

Table 39: Spearman's rho results: Adherence and the sum of manual changes

		Correlation coefficient	Sig (2-tailed)	N
EAT adherence (s)	-300 to 0	.847	.000	299
	0 to 300	-.852	.000	284
Slot adherence (s)	-500 to 0	.835	.000	367
	0 to 500	-.877	.000	458

Appendix X: Relationship adherence and weighted average of manual changes

The data used to create these figures is from 18-11-2018 to 29-12-2018.

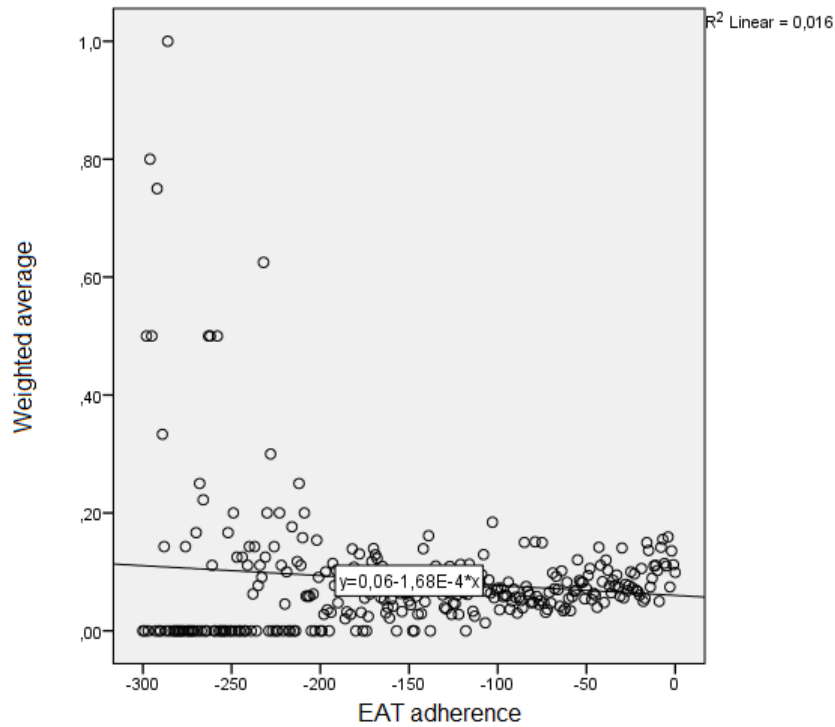


Figure 41: SPSS result of EAT adherence (-300 to 0) and weighted average

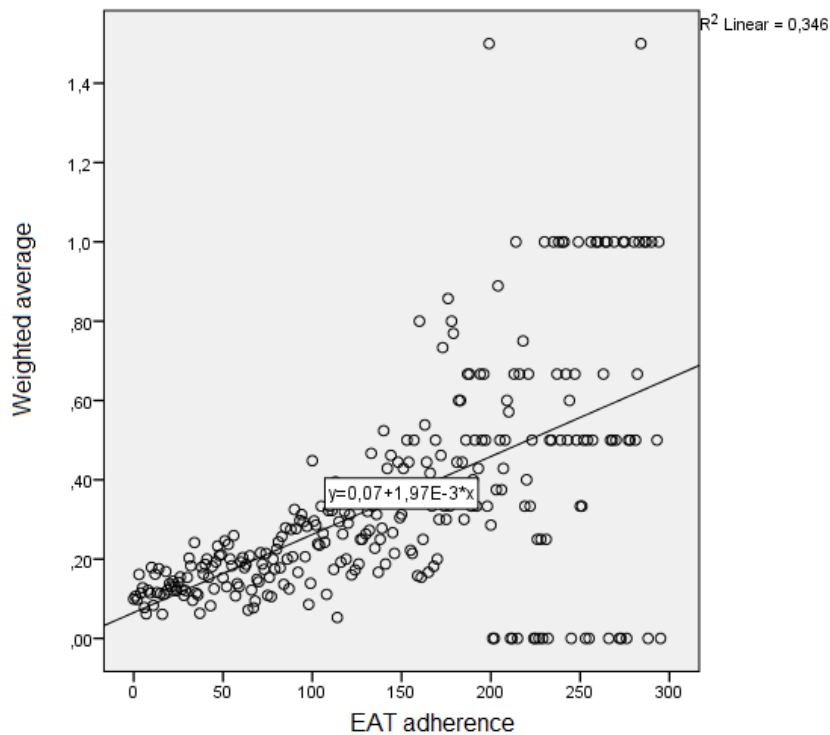


Figure 42: SPSS result of EAT adherence (0 to 300) and weighted average

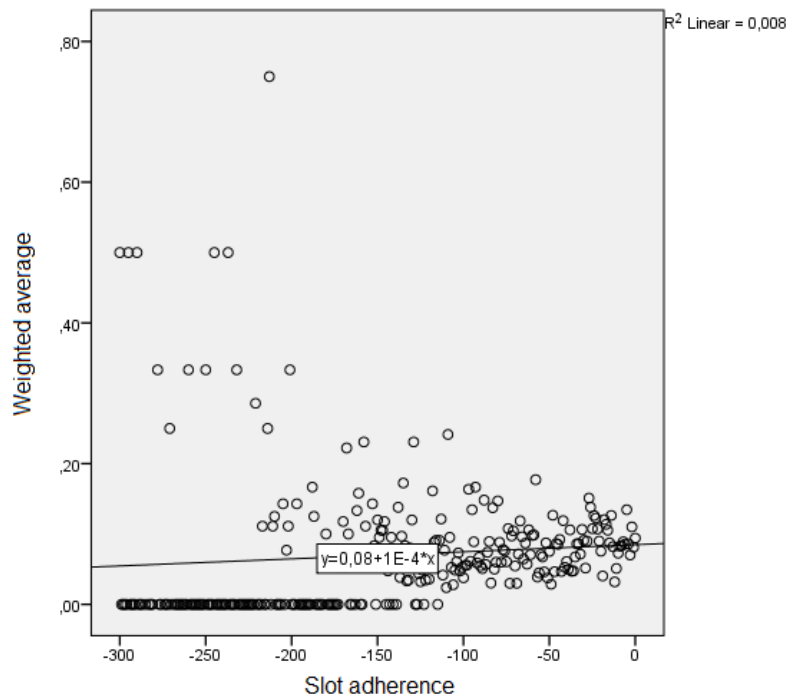


Figure 44: SPSS result of slot adherence (-300 to 0) and weighted average

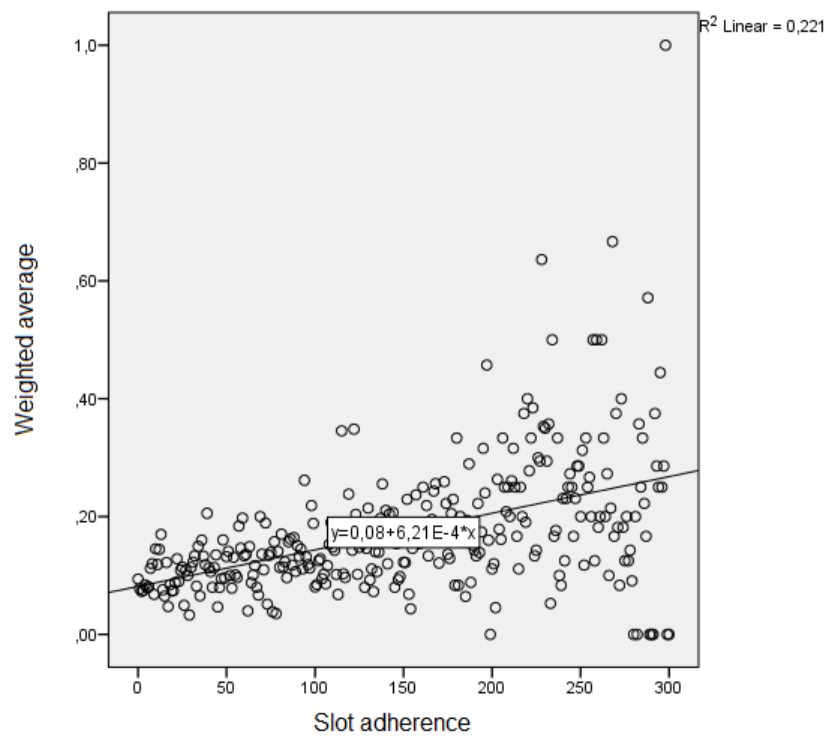


Figure 43: SPSS result of slot adherence (0 to 300) and weighted average

Table 40: Spearman's rho results: Adherence and the weighted average of the manual changes

		Correlation coefficient	Sig (2-tailed)	N
EAT adherence (s)	-300 to 0	.223	.000	299
	0 to 300	.594	.000	284
Slot adherence (s)	-300 to 0	.482	.000	295
	0 to 300	.510	.000	301

Appendix XI: Interview Mr. Dijkstra

07 March 2019, 13:30hr.

1. How many years have you been working at the LVNL?

I've started my own company in 2010, so I'm working for myself for around 10 years, but a part of that was at the LVNL. If you calculate it from my time as an intern here, because I've started at this company as an intern and after I graduated here, in total, that would be 30 years ago.

And what is your current function within the LVNL right now?

Right now, I'm a contractor, so the LVNL hires me for various jobs. I'm being hired to supervise the KDC TU students, and I do some small tasks for the HVA students, and I do some other jobs within the KDC, or directly for the LVNL or other organizations which hire me.

And what kind of jobs do I need to imagine?

Most of the time, these jobs have something to do with arrival management and trajectory prediction. For example, I've been hired by EASA to tell something in China about arrival management and that kind of stuff.

2. How many years do you work with arrival management at the LVNL?

That would be around fifteen years.

3. And have you, as you already mentioned, worked at other companies on a comparable system or to the arrival management?

Within my role as a consultant, I did. This was most of the time contracted by Boeing. Boeing ATM hired me and via Boeing, I did jobs at NAV Canada, the FAA and NASA. In the domain of trajectory prediction and arrival management research.

1. In the problem statement of my research is a description that there's too little documentation available about the AMAN system and the arrival management's process. Do you see this problem too?

Yes, indeed there's too little documentation. I've attained my knowledge over the years, so I have the knowledge by experience. The current view is that I have this information in my head, but it is nowhere written on paper. So I receive regularly, from many divisions within the company, the request if I possess a document where this is described. And then, like you've experienced too, the answer is 'no'. And that is a shortcoming.

And from which people or divisions do you notice that they miss this documentation?

From all parts of the organization. It can come from the division research, division performance, performance asked me this question once. Students who are new, like you, ask me this. Division procedures, technical. It can come from all different kind of divisions or people.

And do you have the impression that air traffic controllers miss information?

Yes, the course I gave this morning to the ACC-part makes it clear that actually, the reason to have this course is for a part to bring some unclarity under the attention about the complete working of the arrival management chain. So the answer is 'yes'. That is the reason why we do the 'spring course' the way we do it.

2. What is, according to you, the main task of an AMAN system?

That is to realize an as high as possible capacity, at a certain declared capacity, while the TMA will be sufficiently protected. Which means that there will be no overload. This can also be formulated differently, you could say: finding a good balance between capacity and demand. Sometimes, I also say that AMAN is also a demand and capacity balancing tool. Because it balances the demand, which is offered at the FIR-boundary, with the capacity available at the runway. Through all kinds of circumstances. Good visibility, bad visibility, cloud base, wind, whatever. That has to be balanced against the demand we get. This demand will be influenced by various regulations, but within the operation must be balanced again; fine-tuning. And that does ASAP, that does the AMAN process.

1. LVNL recently implemented a new arrival management system, known as Advanced Schiphol Arrival Planner (ASAP), which you recently mentioned. Were you from the beginning involved with this development?

Yes.

And what were your tasks at this development?

My tasks were, primarily to develop and specify the trajectory prediction function, which is the basis of how an AMAN system functions, the core algorithms of the planning, which calculate the planning, and I was involved with the development of the user interface, but this was not my main task. So I was mainly working on the algorithms, and partly on the user interface.

2. What was the reason that the old system had to be replaced?

The old system had to be replaced for two reasons. The first reason was that there is a desire to create more innovation and development in AMAN. Because the old system was a monolith within the AAA-system, any development was very hard to accomplish since it was competing with the resources for AAA. So this desire existed; the development-wish to increase the AMAN performance and the system support. The second reason is the fact that LVNL will switch from AAA to iCAS, and iCAS has no AMAN function. iCAS is in that sense modular, which means that the AMAN system will need to be external. Well, that was the moment when we said; if we bring AMAN externally, we can create developments and innovations external too. This means that we have freedom, because it is no longer in AAA. So now, we have a system which can be plugged in and transferred to iCAS when that will be implemented. So the implementation of iCAS was the second reason.

3. Was there, for the development of ASAP, a wish list created?

Definitely, we had a very big wish list, because many wishes are there always, and at that time, many wishes were presented, and we tried to realize these within the available time and resources.

Did the air traffic controllers show their requirements, were they taken into account?

Definitely, their wishes are all processed and they were all involved, and then we made tradeoffs. And together, we composed the package of ASAP.

4. I've read that various elements have been changed, from IBP to ASAP. Can you give an explanation to this, which elements?

The most important modification is within the user interface, so the planner gets a clear visualization of the approach sequence and how this sequence is constructed; are there any gaps, is it too tight, whatever. So the planner has an improved view on the current situation, which makes it able to monitor better and, if necessary, he or she can intervene. This is very important, it was probably the most important purpose, functionally, to achieve this. On the algorithmic perspective, the system is mainly the same, because I specified this for the old system, and now I've specified this for ASAP, but I did apply some details. I've introduced more knobs which can be turned for the load/pressure within the TMA. Since it's a demand and capacity balancing tool, and to be able to tune the balance better, I've introduced extra knobs. It's a new system, it had to be set up again, and now it literally has another setup. We're still working on this iteration, at the end of this month will be using a new one.

What do you mean with knobs?

With knobs, I mean the buffer parameters. Everywhere are buffers, an air traffic controller keeps buffers, the planning system must have buffers. The planning system must also work with average numbers, because every day the traffic is different which requires certain margins. This is no hard science, and choices need to be made. I've created knobs to tune the available choices and the variability within these choices and then finally we can say 'this is a sufficient setting, this is a good average'. Does this change, for any possible reason, we can keep track of reality with these knobs.

So actually, the changes are mainly focused on the human-machine interface, the looks and the finetuning within the system? Are these changes the biggest changes?

Yes, the finetuning of the balancing, because it is a balancing act. These two are the most important changes.

And nothing has changed to the controls of the approach planner?

There has been changed a lot because the HMI is very different. It has become more visual and graphical. Before, it was just a tabular list with number rounded to minutes. Now, it became a thermometer which shows the aircraft and they can drag. This has become completely variable and visual. Also, the interactions concerning runway changes and how these are scheduled and processed have changed. So the interaction with the system is, due to the changed HMI, majorly influenced and changed. This also had its effect on the performance of the first months, because the people had to get used to the new system.

5. You've started about it a bit yourself, in which ways would this change be reflected in the performance of the AMAN and the AMAN system?

As I already told you, AMAN is yet another demand and capacity balancing tool which is in the phase, in the last 30 to 40 minutes of the flight. If this balancing act, which arrival management is, if something changes there, it could be that the balancing act is not sufficiently balancing. Well, how can this insufficient balancing be recognized, for example that too little capacity is being realized. "Because I had 65 flights which occur at the FIR boundary in one hour, but I've put 60 on the ground. What happened to the over 5 aircraft? Yes, they've been moved to the next hour with a delay". That could happen, that is an example.

But, there are no concrete answers to this question yet?

No, that is being researched as we speak. For the next weeks and months, CMA is busy getting these insights.

And have you already gotten feedback from the air traffic controllers about the new system?

Yes, ACC is reporting that the balance is quite incorrect, they say that the balance has changed in such a way that they gave a high workload and that approach has little work to do anymore. And that little delay will be handled in the TMA. These aircraft can go *tjoek* straight to the runway, where before these flights had to make a pattern. Now they can all fly straight in, like ACC says now. And before more buffering occurred in the TMA, that is now gone because the system is tuned carefully. Such an example, that kind of feedback came back again this morning in the spring class, that experienced very strongly at ACC at this moment. And indeed, it had happened and many explanations can be given and are given to them. The approach planner has to get used to his new interface, which is different and new. I say 'it's like you've driven a FIAT car for your whole life, and now, they've put you in a Tesla, how do you cope with that, with such a power horse!?' The tuning is more carefully, because we have started very consecrating to be able to scale it up. I say 'that's what we all want, because otherwise the system would have been thrown in the Ringvaart at its first day and it would have never gotten out'. So, nobody complains then, everybody agrees. But the consequence is then that it may be not optimal in the beginning, because that is the development road. That's what we call growing pains, and yes pain hurts. But they are growing pains, teething problems.

So, hopefully next month when the fine-tuning has sharpened, we can expect that the performance has improved?

Yes, then everything will improve. Well, the performance is still good, but the complaint how I've just mentioned them, will, as I would say, decrease.

Appendix XII: Interview ACC controllers

Below is the summary of the interview with the ACC controllers.

06 May 2019, around 10:00hr.

- ACC controller 1: This controller is very positive about the implementation of ASAP. The speed delta t function is now more logic and clear, while this was much more instinctive at the old system.
- ACC controller 2: This controller is also positive about ASAP, but mainly because of his ACC supervisor's perspective. He notices that the APLN can better monitor when it is required to open an extra runway. With the old system, more communication between ACC and the APLN was required to assess the demand for inbound. Also, ACC is now better able to operate with speed reduction, also already at the adjacent centers.
- ACC controller 3: This controller thinks that ASAP is not a degradation, but much human activities are still required. Not much notable differences with the old system.
This controller does not use the new speed delta t function because, due to experience, he is able to estimate the required speed instruction. However, it is stated as a hindrance when the colleagues force this controller to use the speed delta t function.
Additionally, that the APLN is now able to monitor the traffic earlier is not a result from ASAP because this was also the situation before ASAP.
This controller also has the feeling that ACC is now acting too much beforehand, and calling with adjacent centers to anticipate on speed reduction. *"Let me do how I do it and let's stick to the flight plan. What will be, will be"*.
- ACC controller 4: This controller has also mixed feelings about ASAP. He notices the advantage of speed delta t but due to his experience, too, this function seems unnecessary. And when a holding pattern must be flown, the whole speed delta t function becomes useless. This controller also experiences that ACC is now more active on communicating with adjacent centers about flights' speed. *"If there is no work to do, don't go looking for it"*.