Operational Plan Preparation at Schiphol Airport

Improving Effectiveness of Operational Preparation through Collating Partnered Stakeholder Data

Thesis

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This thesis concludes my four-year Aviation studies at the Amsterdam University of Applied Sciences (2017-2021). In this document I have tried to provide insight in operational preparation for KDC's partners as well as in concepts on how to better anticipate and evaluate airside processes in a collaborative manner.

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Abstract

The joint investigation group KDC focusses on researching innovative and promising airport concepts that might benefit the KLM, LVNL and RSG stakeholders at Amsterdam Airport Schiphol. With the approved implementation of airport-collaborative decision making [A-CDM] at the airport it is eyeing implementation of the next EUROCONTROL concept of total airport management [TAM]. This holistic approach to preparing, managing and evaluating both air- and landside operations shows great potential at several other European airports, with the airport operation centre [APOC] at the core of its operation.

The airport has already commenced the set-up of their APOC, currently solely configuring a daily plan [AOP] aimed at providing insight in tomorrow's operation [D-0]. Stepping up to a more collaborative functioning of airport stakeholders, the partners are interested in finding the potential benefits that might arise when preparing operation more collectively and finding out how this process of joint planning could be synchronised.

For an eventual merge of stakeholder preparations, it is necessary to map out current individual stakeholder processes on planning for D-0 together with information during the day. Through evaluating various preparatory documents, attending briefing meetings and consulting experts of the Pre-tact Unit, APOC and KLM flow & dispatch department the process has been analysed. In addition, the current trial of cross-stakeholder plan exchange is discussed with information on useability and desired improvements. Unifying this information with the constructed process maps allows for a more collective planning framework in which all stakeholders are proposed to operate. Next to assessing and optimizing these processes, theoretical research is done into probable benefits when information sharing is intensified.

It is found that using a set order of updates into a shared database enables for better usage of information with enhanced insight in partnered decision-making on the day prior to operation [D-1], showing potential for a joint collective preparation through the AOP. Several gains are in the area of predictability of airside operation, establishment of performance baselines and insight in on-going processes. Rendering these theoretical advantages into hardened performance data does not only necessitate effective partner involvement in data sharing but also requires collective evaluation. Real-world results of intensified stakeholder collaboration are extremely scarce but are likely to be published once the ongoing EUROCONTROL research (PJ04) into TAM has finished in 2022.

However, these benefits can only be achieved and quantified if the involved stakeholders prove willing to invest time and resources, overcoming reticence towards a more integrated working method. As this requires the use of common data sources, further research should be aimed at evaluating accuracy of predictions with outcomes of decision support tools used, as well as information availability within the parties foreseen for future participation to joint preparation.

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List of Abbreviations

Abbreviation	*Definition*
A-CDM	Airport Collaborative Decision Making
A-SMGCS	Advanced Surface Movement Guidance & Control System
AAS	Amsterdam Airport Schiphol
ACC	Area Control Centre
AEMC	Airport Enterprise Management Centre
AFM	Aircraft Flow Manager
AFOS	Airport Forecasting System
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
AOP	Airport Operations Plan
APC	Apron Planning & Control
APOC	Airport Operation Centre
ATC	Air Traffic Control
ATH	Athens International Airport
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
CIAO	Collaboration Interface Aircraft Operators
CISS	Central Information System Schiphol
CMA	Capacity Management & Analytics
CPDSP	Collaborative Pre-Departure Sequence Planning
CTOT	Calculated Take-Off Time
D-0	Day of Operation
D-x	Day … before Operation
D+x	Day … after Operation
D2D	Day to Day
DCB	Demand-Capacity Balancing
DCL	pre-Departure Clearance
DLR	German Aerospace Center
DMAN	Departure Manager
DOP	Daily Operational Plan
DPI	Departure Planning Information
EIBT	Estimated In-Block Time
ETL	Extract, Transform and Load
EXIT	Estimated taxi-In Time
EXOT	Estimated taxi-Out Time
FMA	Flow Manager Aircraft
FMP(C)	Flow Management Position (Controller)
FUM	Flight Update Messages
FUM	Flight Update Messages
HvA	Amsterdam University of Applied Sciences
ICAO	International Civil Aviation Organization

ICT	Information and Communication Technology
ISC	Integrated Service Control
KDC	Knowledge Development Centre
KLM	Royal Dutch Airlines
KNMI	Royal Netherlands Meteorological Institute
KMAR	Koninklijke Marechaussee
KPA	Key Performance Area
KPI	Key Performance Indicator
LT	Local Time
LVNL	Air Traffic Control the Netherlands
NEST	Network Strategic Tool
NLR	Royal Netherlands Aerospace Center
NM	Network Manager
NMOC	Network Manager Operations Centre
NOP	Network Operations Plan
OHD	Operational Helpdesk
OPS Plan	Operational Plan
OSD	Operational Support & Development
OVA	Operational Permit Airside
PDF	Portable Document Format
PFM	Passenger Flow Manager
QRC	Quick Reference Chart
RSG	Royal Schiphol Group
SESAR	Single European Sky ATM Research
SFM	Security Flow Manager
SKV	Schiphol Kansverwachting
SUP	Supervisor
TAM(S)	Total Airport Management (Suite)
TFM	Traffic Flow Management
TMA	Terminal Control Area
TOBT	Target Off-Block Time
TSAT	Target Start-Up Approval Time
TTOT	Target Take-Off Time
UM	Unit Management
UTC	Universal Time Coordinated
VTT	Variable Taxi Time

Summary

With the ever-expanding demand by airlines and passengers – prior to covid-19 – for more aircraft movements at Amsterdam Schiphol Airport, its operation has been under reasonable stress. Currently plans for further expansion are currently put on hold at 500.000 movements, awaiting a governmental decision on its future ceiling. To utilise the available capacity to the best extent possible up and until then, RSG has commenced implementation of new concept aimed at preparing, managing and evaluating airport operation. The Airport Operation Centre is at the core of the relatively new philosophy Total Airport Management as posed by EUROCONTROL and DLR. In this concept, numerous stakeholders cooperate to better plan, execute and asses the airport's operation. The main driver behind this concept that is working together more closely provides better insight in partner processes and decision-making, eventually yielding better cross-tuned performance.

With the Airport Operation Centre as a relatively new concept at Schiphol, no stakeholders have yet been physically installed in its office. The Knowledge Development Centre has been closely monitoring these advancements and decided to enable research into intensifying stakeholder information exchange to benefit planning purposes. Since the control hub is currently only aimed at preparing an insightful plan into foreseen airport operation for RSG, investigation is aimed at assessing current partner planning processes. To see how the three parties presently prepare for tomorrow's operation, daily operational plans are analysed as well as stakeholder meetings on their configuration. With the since recently ongoing information exchange among stakeholders it is possible to flag important elements and investigate improvements that users would like to see.

To more closely align the planning process of involved stakeholders, their data updates should occur in an orderly and timely manner during the course of a day. The LVNL forecast for expected runway usage and capacity is most valuable for both the airport and KLM as they both use this given early on in their own preparatory process. The airline can start cancelling flights one or multiple days prior to operation once it becomes clear that due to decreased runway capacity the average delay will exceed 70 minutes. Since the air navigation service provider has this overview available relatively early during the day, the first submission into the shared and secured database should originate from them. Using this given – together with information on regulation scenarios – the airport can work out the geographical impact of maintenance activities based on the foreseen usage of runways. Issuing this information to KLM allows for more precise calculations on required take off times, enabling the airline to submit windows in which aircraft can taxi-in or -out. In addition, the airline could decide on submitting information regarding the valuation of a flight and onboard passenger status – a given that can be used to optimize flight scheduling. Using this sequence, involved parties send and receive relevant data for operational preparation, after which it is bundled into a collectively configured airport operational plan.

Over the course of time this plan is expected to take up more and more partnered information. Before this point is reached it is required to have the main partners agree on the contents of the airport-wide plan and use of common data sources. Where LVNL's and RSG's interpretations currently overlap on e.g., traffic forecasting, logging of maintenance activities and meteorological updates, future collective preparation should see usage of only one database or tool per plan feature. Therefore, it is advised to further research data commonality and quality for elements that will eventually be prepared in a collective manner. Further along in the future, if LVNL and KLM have chosen to physically partake in the airport operation centre, the airport could eye upon new stakeholder implementations. Integrating new partners in line with Total Airport Management requires additional examination of information availability and its structuring at these shortlisted candidates.

Alongside the proposed timeline of data updates comes insight into potential benefits that are likely to arise when intensifying the information exchange. Theoretical advancements are – among others – enhanced insight in on-going air- and landside processes, better predictability for airport operation and

a better framework for evaluating and establishing performance baselines. Since a successful implementation of Total Airport Management has currently only been fully realised at Kuala Lumpur International Airport, it proves difficult to quantify these abstract improvements due to the lack of real-world implementations. Reasons for the limited number of functioning TAM-airports have likely to do with the set-up of a large stakeholder collaboration as well as limited documentation and few examples.

Paradoxically, translating these foreseen benefits into measurable advancements first requires active stakeholder involvement and post-operation analysis to verify the anticipated influences. Here, it is found that the three researched stakeholders seem quite reticent to invest time and resources into a relatively unproven concept, worsened by the fact that benefits are made hard to quantify. The current plan exchange has shown promising potential for what more information could bring to preparatory decision-making, what rests is pro-active stakeholder participation to align views on the workings of a joint operation centre and common contents of operational planning. Here, the success of a more collective planning and managing suite at Schiphol Airport depends on all stakeholders.

1. Introduction

The Knowledge and Development Centre (KDC) consists of Royal Schiphol Group (RSG), The Royal Dutch Airlines (KLM) and the Air Traffic Control the Netherlands (LVNL), who aim to find innovative and valuable solutions for a more sustainable development of the Mainport Schiphol. Their developments closely align as closely as possible to The Single European Sky Air Traffic Management Research (SESAR) initiatives, where evolution toward a more collaborative, performance-based process of airport planning is the main driver.

KDC's stakeholders are closely intertwined with each other's operation and are mostly reliant on processes carried out by their partners. This can cause problems when companies are uninformed about decisions made by other organisations, especially when it directly impacts their own operation and is disclosed shortly prior to execution. In order to better inform all involved parties, the necessary decision support tools of these processes are being developed and improved such as Airport Collaborative Decision Making (A-CDM), the Airport Operation Centre (APOC) and the concept of Total Airport Management (TAM).

In order to provide a timely overview of available capacity with traffic demand, stakeholders prepare their operation via a planning tuned to their specification. Like mentioned before, the involved parties are quite heavily dependent on other service providers and would like to be informed about their decisions as soon as possible. The current individualistic approach might not be ideal as the three main Schiphol partners are mostly not informed about choices taken and processes running within colleague organisations. Therefore, it has been stated necessary to identify and define processes necessary for ensuring a more common planning, enhanced collective situational awareness and a combined performance framework for airport operations planning.

Currently, the main stakeholders LVNL, RSG and main carrier KLM independently prepare tomorrow's operation 24 hours prior (D-1 OPS) using their own information sources. Throughout this research the stakeholders will be named RSG, KLM and LVNL for which the APOC, Dispatch and the Pre-tact Unit are responsible for operational preparation, respectively.

The LVNL Pre-tact Unit prepares an operational plan (OPS Plan) with the aim to balance capacity and demand in the ACC (Area Control Centre) sectors, TMA (Terminal Control Area), runways and ground. Inputs for this operational plan are expected constraints due to infrastructure availability and weather predictions. The Schiphol APOC prepares the operational airside and landside processes in their Airport Operations Plan (AOP) with given capacity constraints at the airport as input. Since this plan is not yet a fully integrated AOP as outlined by EUROCONTROL in their Airport Network Integration document (EUROCONTROL, 2018) – due to its timeframe and contents – it also goes by the name of Daily Operational Plan (DOP). KLM team prepares their plan given expected constraints on weather and known available infrastructure.

As a first step to more collaboration at D-1, LVNL and RSG will share their own operational plans to test their usefulness to improve their own plans. In addition, LVNL will also share its OPS plan with KLM in the same period. This exchange has started halfway January 2021 and features weekly evaluation forms to gain insight in in which aspects or information prove to be beneficial for scheduled operation. Another interesting development comes for the team of APOC at the end its project period, meaning that from March 2021 onwards the department will consist of several full-time positions, enabling for earlier and better preparation of operation.

2 Research Outline

Current hindrance lies at the individualistic approach of preparing for the next day of operation at current time (D-1). Stakeholders prepare their operation based on the data they have available, which mostly focusses on in-house information regarding their own specific part of operation. This potentially leaves out important knowledge that the other parties might hold on their own operational limitations (e.g. scheduled maintenance, runway usage, reduced manpower), which could negatively impact total capacity at the day of operation (D-0).

The APOC prepares a daily AOP in which information is given on flight-, baggage- and passenger numbers, air- and landside maintenance activities as well as meteorological predictions. Apart from this, LVNL prepares a D-1 OPS plan in which, among other figures, sector-planning, traffic demand and runway configuration are listed. Additionally, KLM prepares operation through constantly monitoring their network for possible disruptions due to weather or Air Traffic Control (ATC) flow congestion.

In this process of preparation, there is limited exchange of information between stakeholders. LVNL's D-1 OPS plan is shared with the APOC daily between the beginning and end of the afternoon after which APOC communicates the final daily AOP to LVNL. In addition, KLM also receives LVNL's daily OPS plan at roughly the same time as shared with APOC but does not directly return data or decisions to their air traffic control provider.

2.1 Research Objective

The objective is to identify what relevant and up-to-date partner information is currently used and is needed to be shared in order to better prepare operational planning of all involved stakeholders for increasing traffic prediction accuracy and reducing delay minutes.

For achieving the above-mentioned objective, the main research question needs to be answered:

"How can KDC's main stakeholders continuously match their planning cycles by incorporating relevant and up-to-date partner information?"

To support this main question, several other sub-questions are constructed to aid answering the above:

1. *Which collaborative decision-making concepts are currently in place and are being developed?*
2. *How are preparatory roles divided within stakeholders and what do they prepare?*
3. *How is the current individual operational preparation process organised for each stakeholder?*
4. *What are deficiencies in the process of present stakeholder information exchange?*
5. *Which effect(s) do(es) the extra information bring for the stakeholders' decision-making process?*
6. *To what extent can the planning cycles of the stakeholders be combined and synchronised?*
7. *Which KPIs can be constructed to evaluate the process of information exchange?*

2.2 Research Relevance

As all stakeholders are continuously striving to optimize their decision-making process, there is constant interest in receiving up-to-date information from other partners. When informed about other's decisions and planning considerations, one is able to start working out scenarios in which these choices are taken into account. Having in-time access to relevant partner information allows for a better understanding of decisions taken on possible capacity constraints of the airport and aerodrome.

This research is in line with LVNL's corporate vision and strategy, in particular sub target six: striving for seamless operation, with better predictability throughout all weather conditions, with the eventual goal of reducing delay minutes with five to ten per cent (LVNL, 2021). In order to achieve this the focus is, among others, on improving A-CDM by sharing more information in the European network and better stakeholder coordination by preparing for the day of operation. Other stakeholders have not publicly specified their interest in investigating fields of research with promising technological implementations but are keen om improving the collaborative decision making as visible from the ongoing information exchange project of KDC's partners.

The relevance of this research becomes apparent after analysing the stakeholder's individual preparation, already said to have been built on in-house information and data. For stakeholders to give off information can make them feel reticent at first, but when shown the collective benefit it will make them realise the system works both ways. This research is therefore also aimed at demonstrating the benefits of sharing information prior to operation, indicating what collective good it can do.

2.3 Research Scope & Limitations

This research focusses on three stakeholders, LVNL, RSG and KLM. Although there are many more partners within the daily operation such as ground handlers and other carriers, only KDC's partners are included as they have set up a trial of information sharing. Since these partners hold most information regarding the operational planning of traffic at and around Schiphol, they are in the best position to potentially change their planning preparation process. Other parties could hold useful information that might aid the planning preparation, but since the roll-out of the AOP has only commenced recently from August 2020 onwards, it is still in the start-up phase. Once the main stakeholders have agreed upon what data to use and have established a collective preparation process, they can start looking at incorporating other information coming from other handlers.

Next to limiting the initial number of analysed stakeholders, narrowing the time frame for analysis is also beneficial for this research. Since preparing for operation via a structured manner is relatively new within APOC, the current focus is mostly aimed at one day prior to operation. As the team has recently expanded, so has the timeframe for which they prepare by up to seven days in advance. Ideally operating APOCs also evaluate operation the day after, meaning the analysed timeframe for this research will be D-7 to D+1. The process-map timelines to be created will be indicative of actions, information and process currently running and necessary for better operation 24 hours prior to execution.

This research will deliver an advice on what information is useful for collective decision making and presents which benefits can result from a synchronised form of information exchange. It will not entail a constructed environment or application for the sharing of information, but a plan purely indicative of available data and associated sharing benefits. In addition to the advisory, several KPIs are suggested regarding the measurements on data sharing and its effect on operation.

2.4 Research Methodology

The conduction of this research is structured according to several main phases. These phases each aim to answer one of the sub-questions to eventually tackle the main research question. The following chapter not only lists the phases of which this research will consist, they also indicate what will be done and how this can be achieved. Parallel to these phases lies the process of writing and reviewing the thesis document, but since this is a continuous process, it is not distributed over the phases. Figure 1 shows the phases in a scheduled overview, indicating the order of execution.

Figure 1: Research's methodology in a phased build-up

Phase 1
Firstly, relevant literature and terminology is researched to get an understanding of how information exchange should be handled as stated by EUROCONTROL or by other mature information-sharing airports. The different roles and activities for the various stakeholders regarding operational preparation as explained in documentation will also be discussed. Next to this, important and often mentioned terms such as A-CDM, TAM, APOC and AOP are investigated. Of particular interest for these concepts is what elements are required for successful implementation and what their specific objective is.

This phase aims to answer which collaborative decision-making concepts are currently in place and are being developed. Resulting from this phase is a literature review that holds all background information regarding terminologies and information sharing within initiatives.

Phase 2
The second phase in this research is to map the preparation currently done by the involved partners. This starts by defining and describing definitions of (to be) implemented concepts, as well as individual stakeholder expectations and wishes regarding the responsibilities of others involved. The concepts investigated in this phase are: A-CDM, TAM and APOC/AOP. View of stakeholders will be compiled via conducting informative interviews with representatives of these organisations. In addition to compiling these stakeholder views, preparation will be investigated through analysing the contents of the planning they have in place. This second phase will also see the mapping of roles with their associated tasks.

This phase aims to answer how preparatory roles are divided within stakeholders and what they use to prepare operation. Resulting from this phase is an overview of stakeholders' vision, as well as several team organograms and analysis of preparatory work.

Phase 3
After having commonly agreed upon the deliverable, current feedback on the AOP and OPS plan is analysed. Both plans have been shared with others with the request for submission of constructive feedback on their content. By studying the feedback that has been received for both, it should become increasingly clear which things can be improved regarding the plan's configuration and contents. Feedback should be retrieved from LVNL and RSG as these actors are currently involved in the exchange of information. Since LVNL will publish a report on the evaluation of the exchange-period at the beginning of May 2021, the results of this research's analysis could be incorporated.
This phase aims to answer what the deficiencies are in the process of present stakeholder information exchange. Resulting from this phase are findings on analysed feedback and areas of interest for researching the process of plan preparation.

Phase 4
Fourthly, individual stakeholder preparation for tomorrow's operation is investigated. All partners have a process in place to configure an individual planning at D-1 (or even further ahead), which can be analysed to look for possible improvements and eventually linked to performance indicators. By holding consultations with several stakeholder experts and employees on the AOP, OPS plan and KLM's preparation, the configuration of the plan-assembly process will be dismantled. These processes are desired to be mapped for all three stakeholders. Using standardized process mapping techniques the

timelines will be constructed. These contain steps in the preparation process, list used information and indicate (intermediate) deliverables.

This phase aims to answer which information is regarded individually and/or collectively relevant for the stakeholders and how the process is currently configured. Resulting from this phase are timelines on the process of operational preparation of stakeholders.

Phase 5
Now that the processes of preparing for operation have been mapped, the focus can be laid on its most relevant aspects and features best indicative of providing a good planning. For the timely and correct transfer of information to take place it is necessary to indicate what data is of relevance for which decision. Next to this, stakeholders are interested in being shown the benefits of improved information-sharing, clearly indicative of what good it yields them.

This phase aims to answer which effect(s) the extra information brings for the stakeholders' decision-making process. Resulting from this phase are an overview of relevant planning data and an indication of the advantages associated with data sharing prior to operation.

Phase 6
Having researched the effects of information sharing it is possible to analyse preparation cycles and see where data exchange occurs or should take place. With the four timelines it becomes possible to construct a master track in which relevant information can be made available in a timely and structured manner. Following this step will be a recommendation on how the planning can possibly be brought in closer alignment, both timewise and information-wise.

This phase aims to answer to what extent the planning cycles of the stakeholders can be combined and synchronised. This phase will yield a recommendation on collation and synchronisation, indicative of where improvements lie for operational preparation of stakeholders.

Phase 7
Lastly, several performance indicators are constructed to be able to evaluate the realisation of set parameters and standards. Having used the feedback forms gave post-operational insight but establishing Key Performance Indicators (KPIs) enables for almost real-time monitoring of the data sharing principles. This stage also focusses on which aspects can be quantified and how they can be measured to provide an accurate representation of data-sharing's adherence and quality. Since stakeholders make use of other data sources, there has been pointed the need to analyse both commonalities and differences regarding the origin of information and their quality. This is particularly aimed at the predicted traffic volume versus the actual traffic volumes. Here, the LVNL Pre-tact Unit utilises PREDICT data from EUROCONTROL to form their traffic predictions on Schiphol traffic. Although forecasting the same parameter, the APOC makes use of the Central Information Sharing System Schiphol (CISS) to fund its prediction. Comparing the accuracy and precision from both predictions versus the realised traffic should indicate which data source and prediction is best indicative of the process.

This phase aims to answer which KPI's can be constructed to evaluate process predictability, efficiency and robustness. Resulting from this phase are several KPIs to measure information sharing and an indication is given on the quality of the traffic demand data from CISS the compared to EURONCONTROL's Predict data.

3. Airport Management Concepts

To frame the problem clearly and tackle it accordingly, relevant information is extracted from available literature and documents. The research focusses mainly on the improvement of information sharing within air traffic management and aims to eventually align planning cycles of involved stakeholders. For this, it is first necessary to clarify related terminologies (chapter 3.1) of various concepts in existence for airport management. To benefit from previous implementations of earlier mentioned concepts, several instances are discussed of airports that have implemented relevant concepts (chapter 3.2). It is looked into how these concepts are being applied to Amsterdam Airport Schiphol and what this brings in daily operation (chapter 3.3). Lastly, the view on these concepts is sketched by several experts from included stakeholders to how they go about the implementation of these terminologies (chapter 3.4).

3.1 Terminology

In order to line up views on roles and responsibilities, it is of great importance to collectively come to an agreement on various concepts that are used within preparing for operation. The following summation of principles holds detailed definitions as documented by various sources and explains their scope and target. Although the next step in airport operation – managed by an Airport Enterprise Management Centre (AEMC) – has already been defined (Aviation Strategries International, 2018), it is still very much in its infancy, making it currently irrelevant for this research. In a later stage of the research stakeholders will be asked to share their own view on responsibilities and goals of below-mentioned concepts.

3.1.1 Airport Operational Plan

The Airport Operation Centre's (APOC) responsibility is to compile a daily Airport Operation Plan (AOP) that contains all relevant information to provide an overview of scheduled capacity and possible disruptions. This plan can come in the form of a hard-copy report but is mostly represented in an interactive dashboard, containing various aspects of air- and landside operation. By utilizing inputs from multiple stakeholders, the APOC combines the information and provides a holistic view of foreseen airport operation – to be shared with all involved parties. Individual stakeholders share their data and are provided with a detailed overview of the total process in which they operate. Depending on the scope of the airport's AOP, several phases are in place with their own functionality (EUROCONTROL, 2018).

Phase 1: Planning for the AOP commences at D-180+ at earliest, where early exchange of information that might impact scheduled operation takes place and preliminary identification of available capacity is done. In addition, the available slots are published by the airport coordinator and medium/seasonal planning are exchanged by involved stakeholders.
Phase 2: The next phase commences at D-179 up to D-60 and performs the first Demand-Capacity Balancing (DCB) cycle. This process compares demand with available capacity and next determines potential bottlenecks with possible mitigation measures while minimising costs and delays. Once the involved partners have collectively agreed upon the DCB, the initial AOP will be configured.
Phase 3: Hereafter, the third phase is put into effect where the goal is to assure and check that the initial AOP is continuously being updated. The scope of this phase reaches from D-59 to D-7 and oversees that involved actors are issuing updates, preferably via an automated process. Resulting from this intermediate phase is an even more updated and precise version of the AOP.
Phase 4: The fourth phase focusses on the week prior to operation with D-6 to D-1. In this period, another DCB check is performed while taking into account the forecasted weather, scheduled events at or around the airport and available resources & equipment. Having verified the capacity planning with foreseen meteorological conditions, the APOC can collaboratively define selected scenarios which could occur on the day of operation.
Phase 5: One day prior to operation phase five starts. Similar to the previous step, the selected scenarios are verified but now based on more reliable information due to the smaller time horizon. Added to that, this phase also sees assessment on possible Air Traffic Flow Management (ATFM) measures

to be shared with EUROCONTROL's Network Manager Operations Centre (NMOC) for reviewing network impact.

Phase 6: On D-0, the day of operation, the AOP is executed as planned while following the selected scenario. The airport's performance is monitored closely after which possible tactical adjustments might be made. These are always done in close coordination with involved stakeholders to ensure the best collective outcome.

Phase 7: After the plan's day of operation, the AOP is evaluated on its quality. Important factors to look at are: KPI adherence, applicability of the chosen scenario(s) and feedback from stakeholders. These evaluations are converted to reviews to improve future handling and preparation. At the moment, Schiphol has no system in place for actively reviewing prior day's operation, apart from sporadic stakeholder feedback.

3.1.2 Airport Operation Centre

This centre aims to improve the control of logistic airport processes through close cooperation with other stakeholders to eventually ensure more aircraft depart in time and delay is being minimized. Within the APOC, ideally all relevant stakeholders are physically present to enable fast communication between, at least, essential actors: airport operator, (main) aircraft operator and air traffic control. Next to these stakeholders, other operators, ground handlers, de-icing personnel and meteorological experts are of great value when compiling an APOC team. The concept originates from EUROCONTROL and is currently being adopted at ten European Airports: Frankfurt, London Heathrow, Paris Charles de Gaulle, Paris Orly, Amsterdam Schiphol, Barcelona - El Prat, Madrid - Barajas, Palma de Mallorca, Brussels and Stockholm Arlanda (EUROCONTROL, 2017).

Establishing rolling airport operational plans allows the control centre to prepare up to 180 days prior to operation, hereby timely indicating possible capacity issues. On the day of operation, the team also manages airport processes and steers on pre-defined performance indicators, collaboratively established via stakeholder consultation. In addition to looking forward in operation and executing their planning, the APOC also evaluates its performance the day after operation (D+1) and incorporates findings in their upcoming operational plans. This airport control centre prepares multiple scenarios which could occur during the scheduled day of operation, taking into account numerous land- and airside factors that could influence airport capacity. Benefits from this scenario-thinking become visible once real-time disruptions occur and actions have been defined pre-operation, only to be implemented without the need for extensive inter-stakeholder meetings.

As seen in Figure 2, the APOC forms the foundation of strategic planning within Total Airport Management (TAM), reaching out over three main sectors: ground access, landside and airside. These sectors all have associated stakeholders that operate on increased level of detail when seen from operational perspective. As mentioned before, the APOC should house as many relevant stakeholder representatives as possible to enable for quick changes in planning considerations.

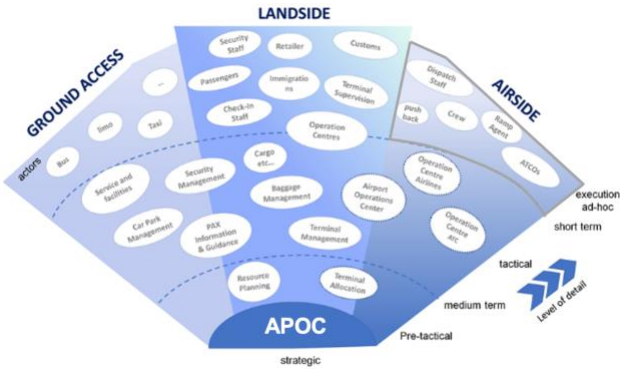


Figure 2: APOC's location in Total Airport Management (IBG, 2020)

3.1.3 Total Airport Management

Where Airport Collaborative Decision Making (A-CDM) mostly only manages short-term and ad-hoc airside decisions, TAM is comprised of all three aspects of airport control (airside/landside/ground access) and features a greater level of detail, ranging from pre-tactical to ad-hoc execution. This requires many more stakeholders to collectively operate and schedule their workings, with the APOC at the heart of operation. Benefits of TAM include, but are not limited to, an increase in capacity, efficiency and passenger comfort as well as being more beneficial to the environment (DLR, 2012). Via monitoring all airport flows (passenger/aircraft/ security/check-in etc.) through KPIs and flow-charts, the APOC should have a clear overview of potential bottlenecks and can foresee where capacity needs to be scaled up or can be reduced. Timely communicating disturbances allows other parties involved to anticipate a sudden surge or dip in passenger numbers.

The concept features a holistic view of the ongoing airport processes and investigates how they interact. Since the importance is on ensuring predictable and punctual performance, a highly synchronized way of working is expected from involved stakeholders. It was first introduced by the German Aerospace Center (DLR) in 2006 and has since been up and running solely at Kuala Lumpur International Airport (Malaysia Airports, 2019). Currently, EUROCONTROL is eyeing European implementation as it is has conducted several trial simulations for airports with multi-layered stakeholder interaction in Paris, Oslo, Madrid and Bratislava (SESAR, 2019). The project's main goal is to see how TAM can be implemented and what advantages it can bring alongside it.

Their first research focused on performance planning & monitoring which involved live-trails validating landside A-CDM implementation and analysing APOC's post operation performance. Key results from the study [PJ.04-01] include improved accuracy and predictability of airside operations, refined mechanisms to establish performance baseline and enhanced usage of information. It was found that these functionalities addressed stakeholders' needs and showed insight in Key Performance Areas (KPA).

The second study [PJ.04-02] scopes to performance management in enhance airport collaboration. Accomplishments from this research are validation of performance dashboards based on machine learning-aided decision-making, real-time simulation of DCB while including meteorological assessment and implementation of what-if parameters on configured AOPs. Concluded was that this results in enhanced air- and landside performance management, better assessment of meteorological impact and pro-active collaboration on predicted performance deterioration.

The DLR has been one of the upfront organizations regarding research into TAM concepts for over fifteen years. One particular area of interest for which quantitative results have been published is for the implementation a Total Airport Management Suite (TAMS) – a software package that enables for (pre-operational management by connecting various subsystems within the APOC. While validating the TAMS on an artificial airfield based on Hamburg Airport's layout, the researchers found significant improvements for various important operational indicators (DLR, 2012). It showed a 6.6% decline in the number of passengers left behind with a massive decrease of 22.2% for aircraft delays, increasing the punctuality by 11.8%. In addition to these gains the engine running time was cut by over 12%, hereby reducing harmful emissions.

Although this research does not yet incorporate human-machine interaction present at airport control centres, the observed benefits are most likely to be slightly compromised due to human interference. Nevertheless, these results show promising potential for a more integrated management of both air- and landside processes through TAM with the APOC at the heart of operation.

3.1.4 Airport Collaborative Decision Making

A well-known principle in collective aviation management is A-CDM. Involved parties are airside operators such as ground handlers, air traffic control and pilots who all strive to increase collaboration on taking important decisions mostly during the turnaround. As well as abovementioned concepts, this principle has also been brought forward by EUROOCONTROL – albeit it already originated in 2004 (ICAO, 2017) – and now has been fully implemented in 30 European airports (EUROCONTROL, 2021). If airports desire to implement the concept, six elements need to be implemented that each utilize their predecessor's functions.

Information Sharing: This forms the foundation for all other elements and needs to be implemented first. The principle is used to achieve common situational awareness and is done via collecting and distributing information and predictions, together with generation of flight advisories and alerts. It is also of importance to enable data recording for activation purposes and later analysis.
Milestone Approach: This describes the progress of a flight from initial planning to take-off. The principle is used to predict forthcoming events for each flight and is achieved via a timely linking of performance with real-time updating and monitoring of the aircraft's status. As visible in Figure 3, EUROCONTROL recommends implementation of sixteen individual milestone updates on inbound, turnaround and outbound processes.

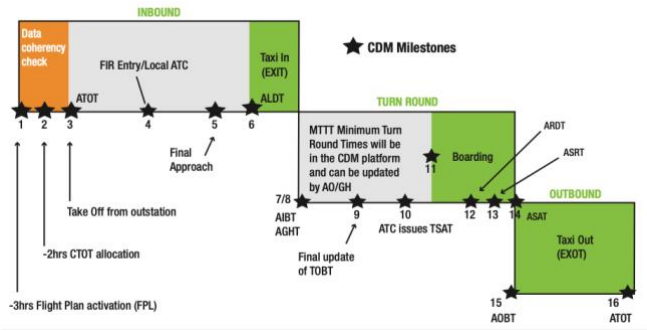


Figure 3: A-CDM Milestones for Flight Segments (EUROCONTROL, 2017)

Variable Taxi Time (VTT): This indicates the time that aircraft take between parking and the runway. The principle is used to enhance the milestone approach's predictions and is achieved by using an Estimated taxi-In Time (EXIT) and an Estimated taxi-Out Time (EXOT) that both provide for a more realistic Calculated Take-Off Time (CTOT).
Pre-departure Sequencing: This shows in which order that aircraft are planned to depart from their stands. The principle is used to streamline the process of giving departure clearances and is achieved via optimizing throughput by Departure- and Arrival Managers (DMAN/AMAN) in combination with an Advanced Surface Movement Guidance & Control System (A-SMGCS) that tracks ground movements.
Adverse Conditions: This enables collaborative management when there is a situation of reduced capacity. The principle is used to prepare for operation in non-standard situations and is achieved through preparing plans that contain actions and responsibilities of involved parties in the case of a crisis event.
Collaborative Management of Flight Updates: This concept exchanges flight updates between A-CDM airports and the Network Manager (NM). The principle is used to improve slot management for departing flights and is achieved via sending Departure Planning Information (DPI) messages to the network operations plus receiving Flight Update Messages (FUM) in return.

The role of A-CDM within the total system as portrayed in Figure 2 becomes clear when realising this concept primarily focusses on ad-hoc execution aimed at airside operation. In the upper right of this figure the concept is outlined in grey where it incorporates, among others ATC, ground handlers, dispatch personnel and push back services. Although it might seem as if A-CDM has the potential to

manage the airport as a whole, it is only a fraction of the total system, which requires participation and active information-sharing of almost all stakeholders present at the airport.

3.2 Use Cases of Intensified Information Sharing

Now that is defined and explained which elements are important for this research, real-world applications will be reviewed to see how other airports have set up their control centre. The gross of sources for analysis of previous research mainly comes from case-studies conducted by EUROCONTROL or individual airports, combined with expertise from universities. As the main focus of this research lies on the information-sharing between ATC, the airport and the aircraft operator prior to operation, of the concepts mentioned in chapter 4.1, the APOC is most of importance.

3.2.1 London Heathrow APOC

Investigation into the working of the APOC has been done at London Heathrow by a joint research group of the UCL School of Management, the University of Virginia and EUROCONTROL. The two main objectives were to review the roles within the control centre and see how processes could be improved by incorporating data-driven predictions together with machine-learning techniques. (EUROCONTROL, 2016). For this study, the team has identified eight important roles within Heathrow's APOC that oversee all seven areas of flow management. At the heart of the operation is the airport operations manager, overseeing all seven process delegates as visible in Figure 4: the aircraft flow manager (AFM), the security flow manager (SFM), the passenger flow manager (PFM), the operations lead coordinator, the engineering help centre advisor, the airport control engineer and the baggage service manager.

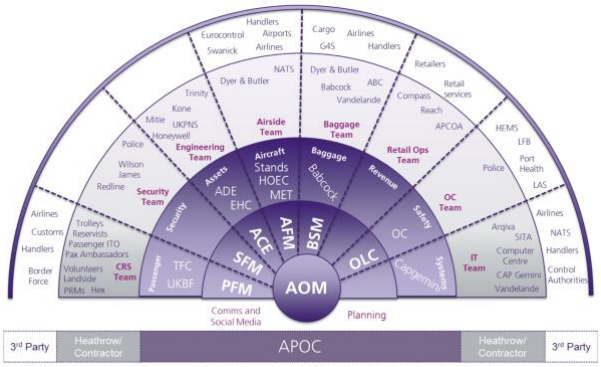


Figure 4: Heathrow APOC's Stakeholder Implementation (EUROCONTROL, 2016)

Since the research mainly focusses on enhancing the passenger process, only three relevant flow managers have been described in detail. Here, the AFM's role is to maintain a constant stream of aircraft while balancing capacity and demand. In this process, it is of importance to pay close attention to global air traffic volumes and meteorological conditions. The SFM's role is to manage security's daily resource planning to minimize occurrences of exceeding service level times drawn from regulation. While doing so, it is important to pay close attention to real-time individual terminal demand. Lastly, the PFM is tasked with reducing passenger delay minutes while making most efficient use of resources. Another aspect is to provide a pro-active response to potential problems and deploy mitigation measures.

Combined with reviewing the roles of the APOC was the implementation of a data-driven passenger-flow model that more accurately predicts the number of arriving passengers and their probabilistic connection time. Advantages of their research range from generating a more accurate and stable Target Off-Block Time (TOBT) to improved passenger experience thanks to a reduction in queuing activities.

3.2.2 Nice Côte d'Azur APOC

As of September 2020, Nice Airport has received A-CDM accreditation within the APOC framework, making use of entirely new *surface manager* (Goldnadel, 2021). This provides the airport with a detailed

and holistic image of air- and landside, vehicle movements and state of infrastructure. It saw the introduction of a hypervisor which indicates hazard criticality, allowing the team to quickly assess its impact. The deployment of a new resource management system enables optimizing the use of resources, together with improved security camera coverage.

Within the APOC, the role of the airport duty manager is to warn the NMOC about possible disturbances and monitor own airport operations, as well as those from which aircraft are arriving. The team currently has real-time overview of important KPIs and can steer accordingly, as almost all relevant stakeholders have joined the on-site decision-making room (manager/airlines/ground handlers/air navigation service/ weather service/border police). Benefits from implementation have been better decision making while considering multiple interests, more detailed insight in on-going air- and landside processes and improved passenger experience. This shows that the APOC does not only bring improvements to the internal process, but also results in better managed process on air- and landside, yielding better passenger feedback.

3.2.3 Helsinki-Vantaa APOC

Helsinki Airport has also seen the introduction of a small-scale APOC in 2014 (Alanne, 2017). It is tasked with providing actors with reliable, up-to-date and analysed information about the airport processes. The team has access to a large surveillance camera system, monitoring passenger flows in and around the airport. In addition, it also makes use of MeteoCroup's weather predictions together with their own Airport Operation Status system. This oversight allows the team to closely monitor the ongoing operation and contact involved parties when capacity is hindered. Most data entries still have to be submitted by hand, meaning the process is not yet fully digitized and automated.

One difference when compared to other operation centres is that Helsinki's APOC does not bring stakeholders physically closer together, since they operate mostly based on telecommunications. This in contract with London Heathrow, where all stakeholders are present within the operation room. The Vantaa Airport team does compile a weekly report which summarises last week's operation, evaluating exceptional situations and operational statistics. Likewise, it compiles passenger and weather forecasts with impact evaluation of maintenance activities.

3.2.4 Athens International Airport ICARUS

Athens International Airport (ATH) has been trialing an intensified information sharing concept under the name of ICARUS as part of the like-named European investigation effort (SILO, AIA, PACE, ISI, CELLOCK, 2019). After having reached its first capacity threshold in 2008, several revisions of the master plan have been done, resulting in additional facilitating infrastructure. During peak hours the airport sometimes finds itself with a lack of capacity to meet the demand as late departures or arrivals occasionally make for significant delays. Mitigating these capacity deficiencies in all weather conditions has been the objective of the ICARUS project at ATH, as well as ensuring most efficient use of available infrastructure. Since the project is run up and until June 30th, 2021, it is expected to have a roundup report with all acquired benefits in the very near future.

For this, several airport stakeholders have brought together their data silos via the airport operations database onto the online ICARUS platform where numerous aspects are addressed such as capacity modelling, airport traffic forecasting, flight delay prediction, and position and slot allocation/scheduling. As the airport itself only owns five to twenty percent of the data generated by the overall aviation process it is required to supplement it with relevant information from the airlines, air traffic control, meteorological service and main ground handlers. For this it is of importance to have the airport provide gate open times and available infrastructure, have the airlines provide flight schedules/plans and possible delays, have the ANSP provide their handling capacity, have the meteorological service provide weather updates and have the ground handlers provide updates on handling processes. Although this might

seem like a typical A-CDM implementation, the ICARUS project looks beyond the scope of in-airport operation and focusses on assessing and scheduling resources multiple days prior to operation.

3.3 Airport Concepts at Amsterdam Schiphol

For Schiphol, a partial APOC concept has been in place since the beginning of 2020. During the start-up of the project there have been several roles and preparatory activities, albeit only a selection of phases in the implementation manual (EUROCONTROL, 2018). Up to and including February 2021 there were four different *clusterleads* who prepared the AOP, with separate focus on: passenger, aircraft, landside and baggage processes. These individuals responsible for entering their expertise's information for the operational plan did so as side activity. As of March 2021, the APOC holds several fixed full-time positions that allowed the project's scope to be enlarged to up to D-30 and should give capacity for analysis of executed plans at D+1. This means the airport is currently working on implementing part of phase 3, phase 4 and 5 in addition to phase 7. Schiphol's APOC is currently only preparing and evaluating operation, as the actual execution of the AOP is done by another department: the D2D-operations team. For a full overview of the functions and responsibilities of the APOC, a detailed analysis is provided in chapter 4.2. During this new phase, the Royal Netherlands Aerospace Centre (NLR) has completed a study into the construction of an improved initial decision-making model for the APOC in the case of foreseen disruptions. This research pointed out several areas of improvement for collaborative preparation and brought forward a new model to tackle predicted obstructions (Poland & Grosmann, 2021).

The TAM concept within Schiphol is currently solely aimed at the implementation of the APOC. Reading from Figure 2, it is mainly aimed at the upper right corner where the focus is on incorporating airside activities and setting up data transfers. Before other landside and ground access stakeholders are to be incorporated in the operation centre, it is first desired to have main carrier KLM and ANSP LVNL on board. In addition, since research is still ongoing at EUROCONTROL for various European airports on TAM, results and guidebooks on its implementation are likely to be brought out soon and can therefore be awaited.

Of all airport management concepts, A-CDM has been implemented to the greatest extent at Schiphol Airport. For the first element, information sharing is done in the CISS which gathers all data for inbound, turnaround and outbound traffic. The airport uses the milestone approach, as second element, to trigger the decision-making progress but has herein chosen to leave out the Actual Take-Off Time, Actual Ready Time and Actual Start-Up Request Time – milestone three, twelve and fourteen, respectively. Thirdly, the VTT component has been made available in Schiphol's ATC tower where LVNL uses the variable times for calculating the Estimated In-Block Time (EIBT), Target Start-Up Approval Time (TSAT) and Target Take-Off Time (TTOT). For incorporating pre-departure sequencing, Schiphol Airport has implemented a Collaborative Pre-Departure Sequence Planning (CPDSP) module which can provide for accurate TSATs and TTOTs. It is however currently working on the implementation of the proposed DMAN to better coordinate departing traffic. To tackle adverse conditions Schiphol has appointed a Flow Manager Aircraft (FMA). Next to this, the A-CDM portal provides for an airport status which is indicative of capacity: green, orange or red. For the last A-CDM element regarding the collaborative management of flight updates, Schiphol is connected to the Network Management Operations Centre (NMOC) via a DPI connection where the airport's information can be used to assist the network planning as of the 16th of May 2018 (Schiphol, 2019).

3.4 Stakeholder Views on Airport Concepts

To map the visions of stakeholders regarding several aspects of the terminology mentioned in chapter 3.1, informative interviews were conducted with involved individuals for LVNL, Schiphol and KLM. The goal here was to extract ideas on the partners' current and future vision for the APOC/AOP, TAM and A-CDM. Comparing these stakeholder visions should allow for indicating areas of alignment as well as

possible misalignments. The following stakeholder views were formed after partners had been asked to explain their objectives, responsibilities plus ideal partner-involvement configuration and aims to answer the first sub-question.

It should be noted that all concepts have been presented to three parties, but KLM could not comment to advancements on TAM and the APOC since these concepts have not yet been brought into focus at the airline. Transcripts come from written or oral correspondence and are only altered by the slightest amount for the sake of textual flow.

3.4.1 LVNL

The following answers resulted from written correspondence with an expert from the Strategy & Capacity Management/Capacity Management & Analytics department at LVNL (D. Zwaaf, personal communication, March 16, 2021).

View on APOC/AOP

What is the current (and future) objective of the AOP within your organisation?

"Eyed objective is working together more closely to improve the (pre-)tactical flight planning at the airport, hereby reducing delays and cutting costs. It is of great importance to indicate benefits from each step taken in a more collaborative work-process. Continuously adapting and improving the decision-making is more of an evolutionary process than taking a clearly pre-defined path."

Who should be responsible for and tasked with compiling the AOP?

"The central responsibility for the AOP is with the airport. In order to keep this plan up-to-date, stakeholders should take and be given responsibility of their data sources."

Which partners/positions definitely need to be included in the APOC?

"Partners and positions to be included in the APOC depend on its organisation and may not all have to be physically present. It is preferred to have the ANSP and ground handlers take up a role, where the challenge is aimed at finding the relevant resources to be involved in the process. Other helpful skills for the APOC include post-operation analytics and operational input when management commences at D-0."

View on TAM

What is the current (and future) objective of TAM within your organisation?

"The current aim for TAM is exploring the cooperation between the LVNL Pre-tact Unit and Schiphol's APOC. Possible other objectives should be driven by airport or airline input."

Which partners definitely need to be included in TAM and which should be excluded?

"This concept should see the same stakeholders involved as mentioned priorly at A-CDM."

What roles and responsibilities do you expect of KLM and RSG in TAM?

"Of KLM and the APOC compliance to procedures is expected. They should use the constraints in the planning at D-X to update their own operational planning. The APOC should also host the chair in the decision-making process on capacity decisions and facilitate stakeholder participation to come up with capacity scenarios and the conditions of executing them accordingly."

View on A-CDM

What is the current (and future) objective of A-CDM within your organisation?

"LVNL's future objective within the concept will be to replace the current sequencer by Q4 of 2021. This module is named the DMAN and is aimed at improving the flow of departing flights."

Which partners definitely need to be included in A-CDM and which should be excluded?

"Partners ideally involved in this process are the airport, the Air Navigation Service Provider (ANSP), ground handlers, airlines (pilots & operation centres) and the EUROCNTROL NM."

What roles does your organisation have in A-CDM and what responsibilities do you expect of KLM and RSG in this concept?

"The role of the ANSP here is to manage the outbound planning, whereas KLM is to comply with A-CDM processes. This means setting correct and accurate TOBTs as well as de-icing times. RSG is there to support a smooth operation of the processes, lead the development, ensure that stakeholders are informed what is expected of them and provide the main interface to the NM."

3.4.2 RSG

The following answers resulted from oral correspondence with an expert from the Airport Operations department at RSG (Y. Alexopoulos, personal communication, March 16, 2021).

View on APOC/AOP

What is the current (and future) objective of the AOP within your organisation?

"Current and future objective of the AOP closely aligns with that of TAM and is focused on involving multiple stakeholders via a more integrated planning."

Who should be responsible for and tasked with compiling the AOP?

"Here, the APOC should be responsible for compiling the AOP after closely coordinating with the involved stakeholders. Next to the task of constructing the plan, it should also distribute this accordingly."

Which partners/positions definitely need to be included in the APOC?

"More subjectively determined are the involved partners and positions which are ideally physically present at the APOC. This preferred team is comprised of an LVNL representative with authorisation over regulations, one KLM ground handling agent and one KLM flight handling agent. For further in the future, larger ground handlers as Menzies, Aviapartner, Swissport and Viggo can be implemented in the APOC. Albeit no preference for physical presence, also a KNMI weather representative and an EUROCONTROL network manager are desired."

View on TAM

What is the current (and future) objective of TAM within your organisation?

"The short-term objective is to deliver a daily, integrally AOP that is approved by all involved stakeholders. For the long-term, D-0 operation should be handled by the APOC within the concept of TAM, as well as evaluating the operation on D+1 based on constructed KPIs."

Which partners definitely need to be included in TAM and which should be excluded?

"Involved partners ought to be the airport itself, LVNL, larger airlines that operate a multitude of flights, ground handlers and the Royal Netherlands Meteorological Institute (KNMI). In addition, terminal handlers like security and baggage handling should have agreements regarding the sharing of information."

What roles and responsibilities do you expect of KLM and LVNL in TAM?

"The role of KLM within TAM must be to cooperate in compiling the AOP, as well as keeping a direct line of contact with the APOC regarding progression of flights and possible cancellations. For LVNL the role shifts to matching their available capacity as closely as possible with the demand originating from the AOP. Next to this, it is desired to more collectively coordinate sector regulations."

View on A-CDM

What is the current (and future) objective of A-CDM within your organisation?

"The objective is to continuously improve A-CDM performance through several initiatives. One of them is the implementation of the DMAN to increase stability and predictability of TOBTs, as well as enhancing the prediction of the inbound process."

Which partners definitely need to be included in A-CDM and which should be excluded?

"The partners who should be incorporated in this concept are RSG, LVNL, airlines and ground handlers since they should all provide information or important procedures."

What roles does your organisation have in A-CDM?

"Direct tasks of A-CDM are mainly for airlines and ground handlers, whereas RSG only acts on facilitating systems and processes. Eyeing towards the more integrated concept of TAM the role of airport should be to more actively monitor how the TOBTs are set and inform handlers about the importance of updating their schedules."

What roles and responsibilities do you expect of KLM and LVNL in A-CDM?

"KLM is the owner of the TOBT, which is outsourced to the ground handler. Therefore, the airline should be responsible for improving their on-time performance and instruct their pilots for a timely start up call within the TSAT. LVNL should be responsible for providing a system that is capable of handling pre-covid-19 traffic volume as well as optimizing capacity utilization."

3.4.3 KLM

The following answers resulted from written correspondence with an expert on A-CDM at KLM (H. Kelder, personal communication, March 9, 2021).

View on A-CDM

What is the current (and future) objective of A-CDM within your organisation?

"KLM's objective lists several elements that it deems important to the concept of collaborative decision making. Here, the maximum use of resources regarding airspace, runways, ground handling equipment and gate allocation together with a minimal delay is of relevance. As well as achieving improving situational awareness and reducing emissions & non-performance costs. At the heart of this lies a stable and predictable operation."

Which partners definitely need to be included in A-CDM and which should be excluded?

"Ideal partner inclusion for this concept is comprised of other airlines, main ground handlers, Schiphol operations, LVNL operations and EUROCONTROL. Stakeholders to best be left out are subcontractors that are managed by Schiphol."

What roles does your organisation have in A-CDM and what responsibilities do you expect of RSG and LVNL in this concept?

"The role that KLM holds in the A-CDM process is that of airline and main ground handler. They expect the APOC and LVNL to strive for continuous improvement of procedures and systems through post-

operation analysis. Other desired actions taken by LVNL and the APOC include discussing non-performance with airlines and ground handlers while supporting improvement plans, as well as acting as entry point for questions and issues that might arise during operation."

4 Operational Preparation

All involved stakeholders currently prepare their operation on an individual basis. These plans consist of different elements but show some form of overlap. More importantly, some elements are dependent on other factors present in partner's plans e.g., runway configuration or capacity. Breaking down the elements of these plans allows for individual feature evaluation. By clearly indicating where specific features originate from it becomes possible to identify and foresee potential bottlenecks in the flow of information. This also allows for other stakeholders to more specifically state features of interest which can be taken into account for their own operational planning. This chapter focusses on the deliverables and process of stakeholder preparation for LVNL (chapter 4.1), RSG (chapter 4.2) and KLM (chapter 4.3) and aims to answer the second and third sub-question.

Each section first gives an overview of the stakeholder's preparatory plan currently in place. The main users of the document are discussed, as well as the format in which the plan is delivered and which main elements it is comprised of. Finally, the authors responsible for configuration are listed together with the timestamped process they are involved in.

4.1 LVNL's OPS Plan

Since June 2020 LVNL configures a daily operational plan for tomorrow's operation, the OPS plan. The Pre-tact Unit does so on Monday to Friday, meaning that Tuesday to Saturday sees full operational planning preparation. As the team does not work during the weekends, smaller operational plans are configured for Sunday and Monday during Friday. Because plans are configured one day prior to operation, there is a one-day shift in preparation. The plans for these days are so called 'mini OPS-plans' and contain less information than regular plans prepared during weekdays. The smaller plans are specifically pointed at highlighting special events and mostly exist of two to four pages.

Deliverable

The method of deliverance is through a clickable PDF-document that is uploaded daily to the SharePoint of the LVNL Pre-tact Unit. As well as being uploaded to the online environment, the plan is also forwarded to the mailing inboxes of the abovementioned addressees. The size of the OPS plan varies by day, but mostly consists of twelve to fourteen pages.

Pre-tact Unit's SharePoint page both outlines the current OPS plan and an archive for past operational plans. Alongside the most up-to-date version is a guide that informs readers about the contents of the plan, which is useful for individuals less known with the subject.

Contents of the plan is structured in several chapters and consists of numbers, text and graphs:

- General
- Traffic Supply ACC
- Analysis Regulations
- Remarks / NOP
- Weather Forecast
- Maintenance / OHD
- Runway & Capacity

The full overview of the included aspects, their data structure and their sources can be found in tabular representation in Appendix I. Next to indicating which input and output features are present in the plan, the table also lists who is responsible for the feature (in the case of an output feature) or where the information is sourced from (in the case of an input feature).

Authors

Two bodies responsible for compiling the OPS plan are the Operational Support and Development (OSD) and the Capacity Management (CMA) departments, making up LVNL's preparational unit named the Pre-tact Unit. The authors of the preparatory plan alternate occupation on a daily basis with the ratio

being two to one, with the team always made up of three persons in total. The reason for the constant rotation of positions within the daily meetings is that there is too little time available within the team to have three functions with fulltime focus on the preparation of the plan. By spreading the workload through alternating turns, an individual only has to partake in the meeting on a (bi-)weekly basis, allowing for more time to be allocated for other work and projects he or she is involved in.

During the meeting, the authors collectively discuss the elements in the PowerPoint which mostly have been automatically generated and inserted into the presentation. Another important actor in the process of compiling the OPS plan is the KNMI, providing weather updates with possibly restricting conditions. All involved actors and their roles for the preparation are shown in Figure 5 below.

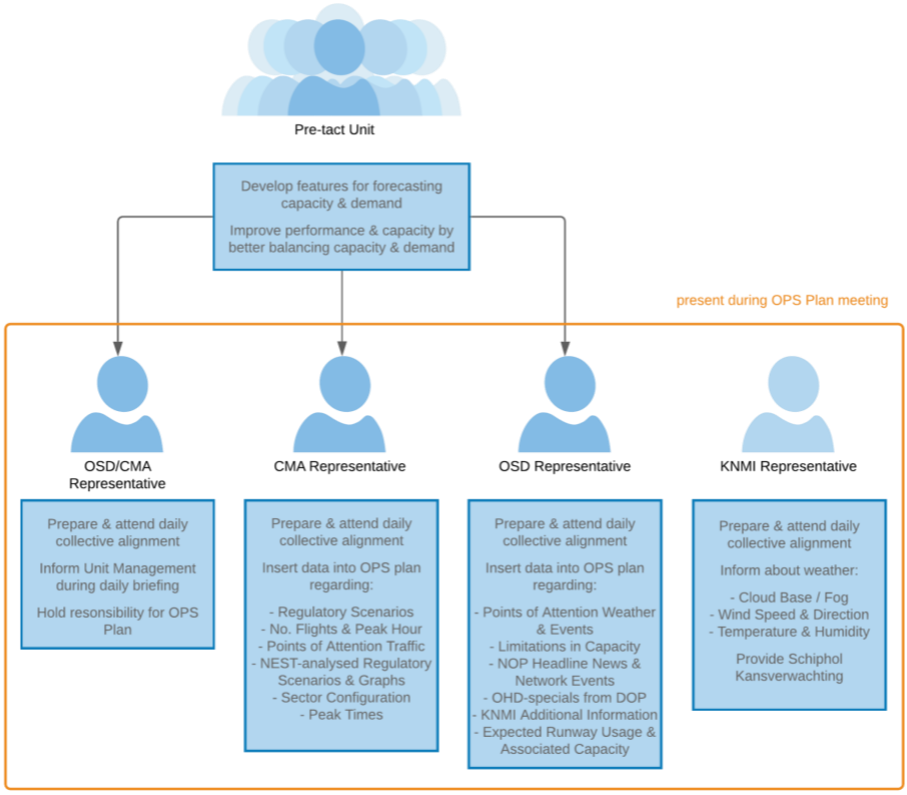


Figure 5: Actors involved for preparing the OPS Plan

Timeline

Daily preparation for the OPS Plan on office days commences before 10:30LT (Local Time) where the three individuals scheduled for the D-1 get-together of the Pre-tact Unit prepare information to be discussed during the meeting at 10:45-11:30LT (see Figure 6). The OSD department forecasts the runway usage and capacity based on the Schiphol Kansverwachting (SKV) – a meteorological forecast on airport-specific parameters – from the KNMI provided earlier on in the morning (6:50UTC), as well as announcements on maintenance, network updates and special activities provided by the Operational Helpdesk (OHD). Similarly, the CMA department uses the SKV and EUROCONTROL's Predict data to prepare the expected traffic and sector configuration, as well as working out possible regulation scenarios if demand is foreseen to exceed capacity. Here, both teams might decide on configuring a regulation scenario for operation.

Their preparation is put together in PowerPoint, where the concept OPS Plan is discussed during the daily meeting at 10:45LT. During this meeting, one KNMI meteorologist attends to inform about the predicted weather at around 11:00LT. This weather briefing elaborates on the earlier provided SKV and elaborates on expectedly significant weather, where after the OPS Plan is adjusted accordingly.

If new updates come in regarding restricted airspace after 10:00LT, the OHD is responsible for including these updates in the plan by manual insertion whereas normally these updates come in via the pre-tact unit's mailbox, to be included by the team working on compiling the OPS plan.
Then the plan is saved and exported, after which an external version – containing no information on sector configuration and internal announcements – it is automatically sent to RSG as part of the project of collective plan-sharing. Once the preparatory plan has been compiled, one appointed representative briefs the UM at 12:45-13:00LT.
This representative is responsible for finalizing the OPS Plan before 13:30LT by checking for OHD updates and converting the PowerPoint file to PDF-format and store the file in a correct manner, after which it is distributed to non-tactical operations within LVNL. Automatic distribution of the plan occurs at 15:00LT when it's sent to the D-1 distribution list with KLM and RSG inclusive. Finally, at 16:30LT, it's forwarded to ACC SUP and the Flow Management Position (FMP).

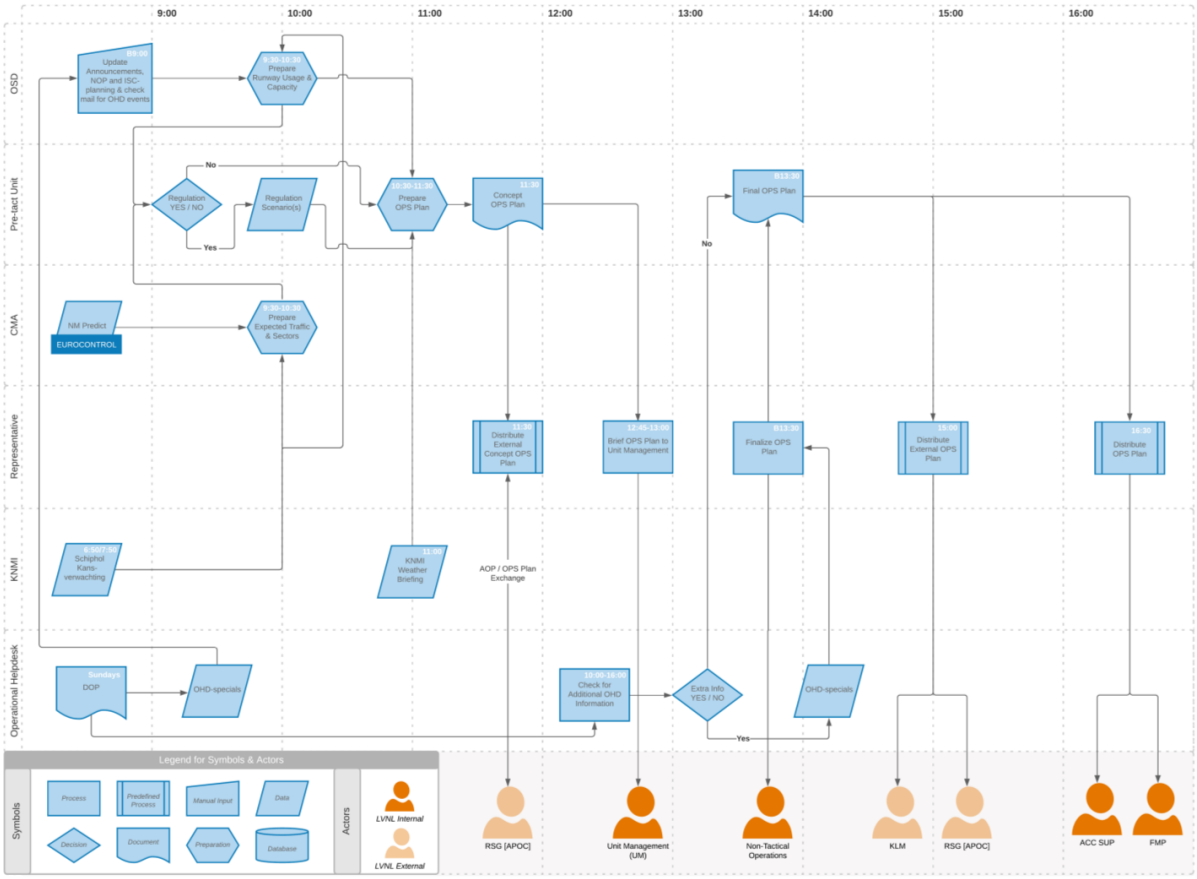


Figure 6: Process map for LVNL's OPS Plan on D-1

Remarks

Since the configuration of the preparatory plan is done by different individuals during the week, the exact contents and manner of compiling could differentiate. Although there is a reasonably clear guidebook on the construction of the OPS Plan, some earlier-made agreements might have faded in the minds of the authors. For instance, adhering to set thresholds when working out regulations due to possible weather limitations as predicted by the KNMI. The guidebook states several conditions for including regulation scenarios when windy or low visibility conditions occur, mostly in the form of a probability threshold. Since some authors might not recall this agreement, the plan could end up with an included scenario while it shouldn't have been worked out as per guidebook arrangements.

During the two-week period of virtually attending the daily D-1 meetings, there proved to be several more instances in which rules for the notation or contents of elements regarding expected traffic or

runway usage were too vague, allowing for multiple interpretations and reasonings. In order to prevent future occurrences, it has been noted to arrange a meeting regarding further formalization of agreements for the guidebook.

4.2 RSG's AOP

Amsterdam Airport Schiphol has also been configuring a daily operations plan from August 2020 onwards, named the AOP. The APOC team that is tasked with compiling the plan does so every day, also during the weekend. Similar to LVNL, it is prepared one day prior to operation and features various aspects regarding capacity and demand. Where the OPS plan is exclusively aimed at airside operation, the AOP also features many indicators and predictions for landside processes.

Deliverable

The AOP is constructed in Microsoft Power BI which presents it as an interactive dashboard. This allows for filtering for parameters or scrolling through text messages. When forwarded to partners outside the Schiphol environment the plan is flattened in PDF-format, hereby losing its interactive abilities and some of the 'critical path' features. Length of the exported AOP is mostly 33 pages, which could feature sections with no data – depending on input from other sources.

Contents of the plan is structured in multiple chapters and consists of numbers, text, graphs and maps:

- Integral Overview
- Aircraft
  - In- & Outbound
  - APC (Apron Planning & Control)
  - NOP
  - Maintenance
  - Memo's
- Passengers
  - Action Plan
  - Departure Hall
  - Departure Filters
  - Transfer Filters
  - Arrival Filters
  - Capacity Forecast
  - Maintenance
  - Long-term Maintenance
  - Assets in Failure
  - Memo's
- Landside
  - Action Plan
  - Capacity & Demand
  - Maintenance
  - Long-term Maintenance
  - Memo's
- Baggage
  - Action Plan
  - Forecast Baggage
  - T-1
  - T2/E
  - D
  - T3
  - Maintenance
  - Long-term Maintenance
  - Memo's
- Weather Forecast

The full overview of the included aspects and their data structure can be found in tabular representation in Appendix II. Next to indicating which input and output features are present in the plan, the table also lists who is responsible for the feature (in the case of an output feature) or where the information is sourced from (in the case of an input feature).

Authors

Responsible for compiling the AOP is the APOC team of which 4 positions are tasked with a daily assembly of the preparatory plan. At the lead of this team is the day coordinator who is responsible for the coordination of the general daily operation and submission of the airport plan to the D2D-department. Alongside this position are three topic-specific *clusterleads* who are tasked with inserting forecasted data regarding their expertise and mitigating potential capacity deficiencies possibly foreseen in tomorrow's operation. Next to this team of authors is a development team which is tasked with adding

new functionalities to the airport operational plan and configuration of the APOC at Amsterdam Airport Schiphol. All involved actors and their roles for the preparation are shown in Figure 7 below.

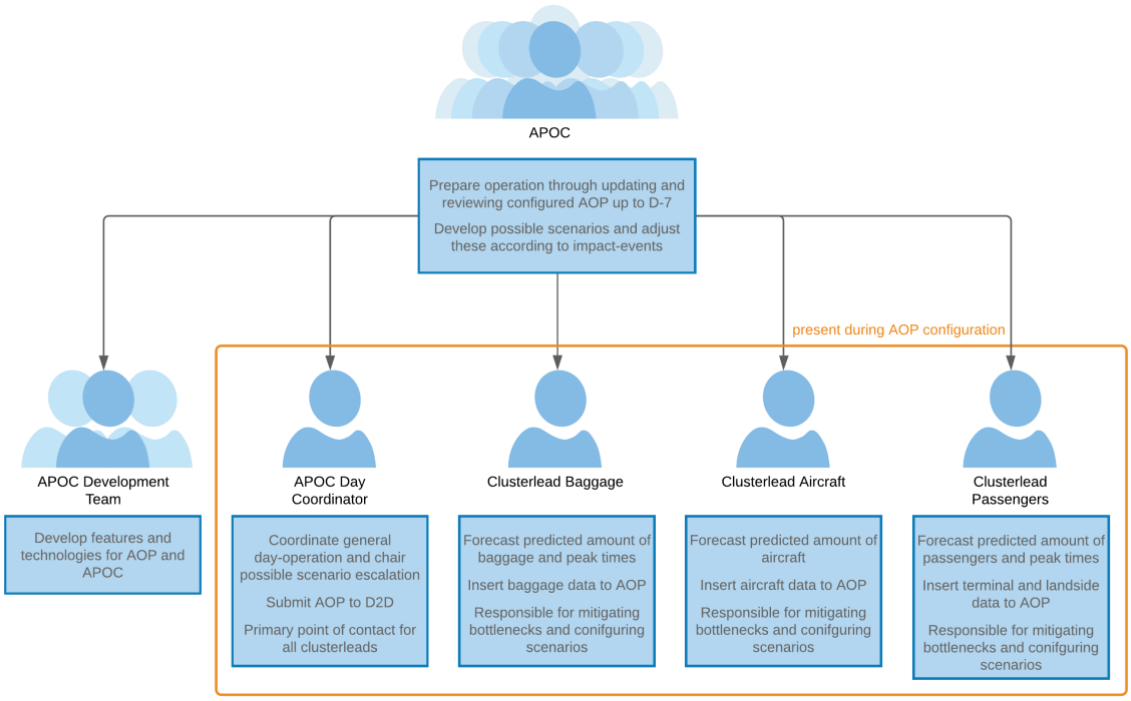


Figure 7: Actors involved for preparing the AOP

Timeline

Tasks of the APOC commence at D-7 where, according to EURONTROL, a DCB-check is performed. Working towards the day of operation, the APOC keeps a close eye on foreseen airport traffic and potential hiccups that could arise due to a lack of e.g., terminal or apron capacity. Every morning, the *clusterleads* prepare their part of operation (see Figure 8). The flow forecasts for passenger throughput are configured with the help of Flow4cast, a modelling tool that maps the stream of people through the terminal over the course of a day. The baggage information comes from various sources and also contains information on points of attention at security and the Koninklijke Marechaussee (KMAR). The APOC also prepares analysis on aircraft processes using data from CISS and TAF, together with scheduled maintenance activities from the Kermit database. A daily meeting is held prior to 10:30LT in order to discuss the elements configured by the *clusterleads* and evaluate the impact of foreseen weather conditions. Around 10:30LT, the team publishes the concept AOP into the PowerBI dashboard, after which the concept becomes available to authorised users. During the course of the day, several checks are performed to ensure that new advancements have been covered in scenario configuration. These what-if scenarios work out potential situations that might occur on D-0 and help to mitigate capacity constraints. After completion, the definitive plan is made accessible in Schiphol's SharePoint environment to the D2D-operations department, who are responsible for the execution of the plan, at 16:00LT as well as several other users who have insight in the planning.

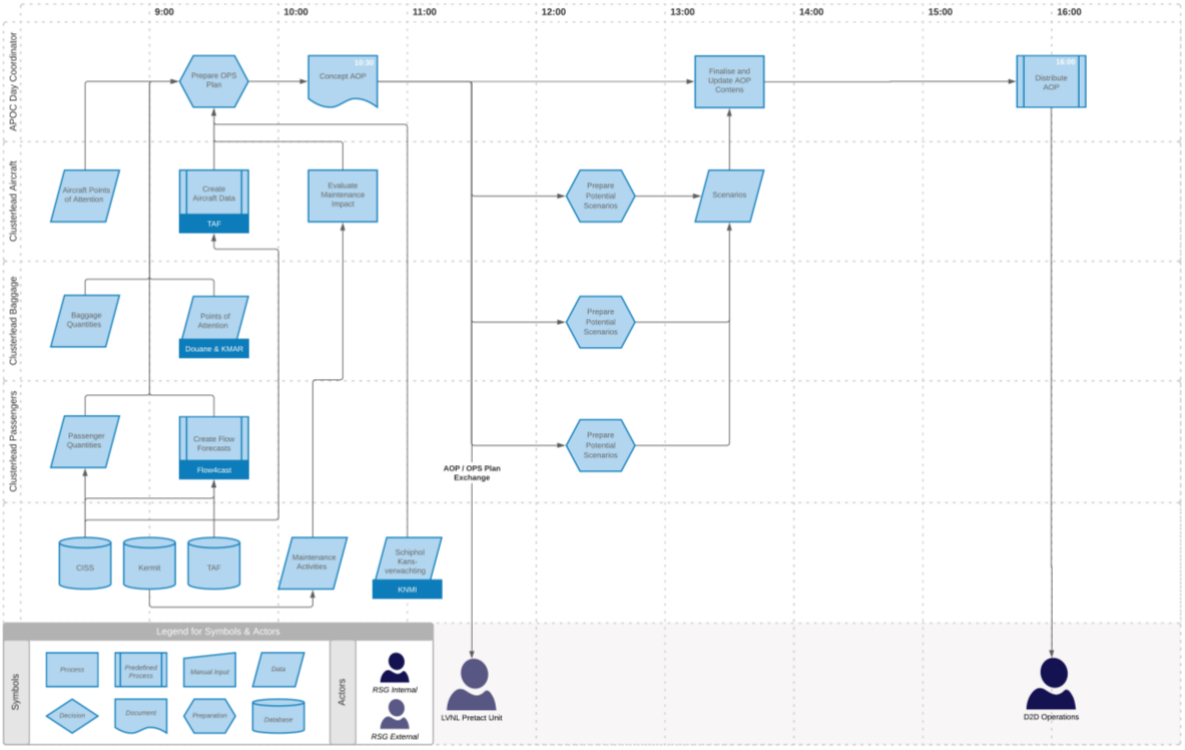


Figure 8: Process map for RSG's AOP on D-1

Remarks

As the APOC currently operating at Schiphol is still in its start-up phase, it does not yet perform all activities that it will perform when fully implemented. Now, the current scope of the team is to look ahead for a maximum of seven days, up and including tomorrow (D-7/D-1). As mentioned in chapter 4.1.2 the ideal concept implementation features an even broader horizon, commencing even before 180 days operation and evaluating performance one day after. Especially the latter part could bring valuable insights into improving the centre's preparatory work and measures its overall performance.

4.3 KLM's Preparation

Unlike LVNL and RSG, KLM does not prepare a daily preparatory plan inclusive of various aspects of operation. Since most decisions are taken on a shorter notice than for other stakeholders, they have chosen to continuously evaluate and update their flight planning, lessening the chance of using out-of-date information. The preparation is done for individual flights as well as for flight regions containing multiple KLM flights. Main focus during this process is to reduce overall delay and ensure adherence to scheduled arrival times as good as possible.

It should be noted that since there is no deliverable for the airline on operational preparation, the analysis is carried out slightly different. As the operator makes use of various decision-support tools, these will be analysed to see what information they provide and how this aids the airline personnel.

Tools

Since this team is tasked with optimizing the flow of individual aircraft movements and the collective network, it uses multiple tools to manage and predict the flow of aircraft in their network.

The Airport Forecasting System (AFOS) by To70 aids by predicting which runways will be in use for the upcoming 36 hours. This tooling provides probabilities on runway combinations and their capacity based on the SKV and the runway configuration document as provided by LVNL (QRC009 – Runway Combination & Capacity Figures & QRC025 – Baangebruik). With this prediction, the airline can steer on hourly capacity and has an early indication of the expected traffic throughput for runways in use.

Parallel to monitoring the weather and runway usage, the team also focusses on en-route delays from the EUROCONTROL Collaboration Interface Aircraft Operators (CIAO) service. If delays arise on the scheduled route, the flow controller can look up flight plans from surrounding aircraft to anticipate on expected airspace occupation. It should be said that this interface is read-only, meaning that this system does not allow for alterations to flight paths. This could however be decided upon after acquiring necessary flight and airspace insights from CIAO. In addition to the possibility of instructing aircraft to reroute, delaying departing aircraft can also benefit the network performance as this could prevent the ATC capacity from being exceeded at certain points in time.
Another decision support tool used by the airline for preparing and managing flights is Traffic Flow Management (TFM). This module holds a complete collection of flight scheduling, passenger information, crew planning, aircraft maintenance announcements and flight value. It is used by both flow managers and the dispatch team to look up flight specific data and act accordingly, especially in the case of having to delay certain flights. To ensure least is lost during operational interruptions, flights with the lowest economic value are first in line to be delayed or cancelled.

Deliverable

In the process of preparing for operation the airline does not configure a deliverable to distribute over various departments or with closely related stakeholders. Intermediate deliverables are different for each flight and include but are not limited to: flight plans, passenger lists, load sheets and crew planning. Next to these documents, there is also additional information available, but which is mostly scattered throughout various systems. This includes valuation of flights, aircraft maintenance remarks and

Authors

The team responsible for managing the flights and ensuring a coordinated flow of traffic consists of six flow controllers who are tasked with e.g., monitoring ATC delays over the network and contact with EUROCONTROL. The team responsible for preparing the flights and mitigating the risk of potential disruptions during departures consists of roughly fifteen dispatchers who are tasked with e.g., the creation of flight plans and mass & balance calculations. Further forward in the process of preparing for operation (D-90 to D-7) comes the task of creating the flight timetable alongside with the planning of routes and aircraft, for which the operational manager flight is responsible (Wouter van Miltenburg, personal communication, May 28, 2021). All involved actors and their roles for the preparation on D-1 are shown in Figure 9 below.

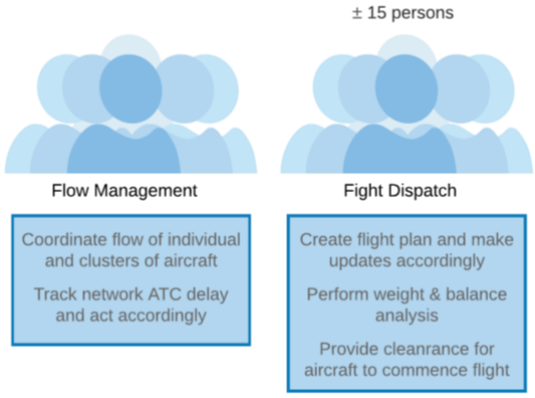


Figure 9: Actors involved in preparing for KLM's operation

Timeline per Flight

Fourteen days prior to scheduled departure of a flight the number of booked seats is checked to see whether the flight will continue as planned or cancelled due to the lack of reservations. When enough seats are booked the flight will be executed as planned and the preparatory work can commence. From here on, the flight is handled by the dispatch team who start preparing the aircraft's flight plan and paperwork. When the team has found a suitable route and other checks have been completed, the flight

is prepared and handed over to the flow control department at D-1. Six hours prior to the targeted take-off time, the first flight plan is filed to the Lido system – a system from Lufthansa Systems used by pilots to access necessary documents and tactical data for safe flight execution. Roughly three hours before take-off, a check for weight and balance is done and the expected en-route traffic is analysed. Roughly two hours before scheduled take off, the crew members discuss the proposed flight plan and can provide approval or request modifications.

Timeline per Day

There are several instances in which the airline has small briefing instances over the course of the day. Here, the first meeting occurs at 4:15LT with the operational manager flight, approach control, ACC SUP and the KNMI to discuss foreseen operation. The second briefing occurs at 9:15LT and is aimed at evaluating the inbound peak at Schiphol Airport, after which the third takes place at 14:00LT in the afternoon to assess operation until then and look forward to the possible peak traffic in the evening. Lastly, the final briefing is held at 21:30LT to review D-0's operation and look into expected nightly traffic.

Remarks

The airline does not (yet) make use of a standardized daily plan in which various operational elements are collated, which could be due its reliance on implemented tools developed by external parties. Since these predictions are mostly generated automatically without much interference of employees, organising daily meetings on preparing operation might not bring additional insights but only result in more work being brought to the table. In addition, since KLM mostly has a continuous operation of flights spread out during the day, individual preparatory phases mostly do not overlap. A flight departing at 9:00LT will see preparation in the early morning, whereas an aircraft with 18:00LT as TTOT will see preparation during the afternoon. If the team were to prepare a combined planning for all aircraft at a given time during the day, some flights would be better prepared than others due to the timeframe in between preparation and execution. Flights with a narrower timeframe have been prepared with more up-to-date information than flights departing later that day.

5 Information Sharing

The individual preparation as outlined in the previous chapter contains few instances in which information exchange between stakeholders takes place. This limited sharing of information could be due to the lack of relevancy of partner data or confidentiality of own information. However, if a collective planning agreement were to be set up, these issues are more likely to be resolved. To find what other drawbacks and limitations the current individual planning method has, conusltations will be held with experts involved in setting up operational preparation. Added to this, extracting what other information is of relevance in this process of planning and incorporating this in an improved planning could have beneficial effects. This chapter focusses on the current instances of information exchange (chapter 5.1) and investigates feedback on the trial period of operational plan interchange which has been ongoing for the last couple of months (chapter 5.2). Having seen the current usage of partner plans and wishes regarding future improvements, benefits are listed for an intensified process of information sharing (chapter 5.3).

This chapter focusses on deficiencies in the current collective planning process and effects of additional information for decision-making, hereby answering the fourth and fifth research question.

5.1 Moments of Exchange

In the process mapped timelines several instances of information exchange take place, as indicated by the orange actors at the bottom of Appendix IV and V. This might occur in various manners: through e-mail, telephone, databases, physical documentation or cloud-based solutions. Although all these do the trick of transmitting data from source to origin, the preferred route is through a centralized database or cloud-based solution. This ensures the information is be submitted in a standardized format and is accessible through a secured and organized environment. As the eventual goal is to develop a rolling AOP in which all important actors continuously insert and update relevant information, it is most likely ideal to configure a shared database accessible by trusted and involved stakeholders.

Over the course of the day, the first exchange takes place at 11:30LT when LVNL's Pre-tact Unit shares their concept version of the OPS Plan (still possibly subject to updates) with the APOC team of Schiphol. This exchange leaves out announcements and sector configurations due to confidentiality (both are separate pages in the OPS Plan), as previously explained in chapter 4.1. The information exchange takes place via e-mail by sending over a PDF-file of the preparatory document.
In return, the APOC releases the first update of their daily AOP at 11:30LT. Since this document does not hold confidential information to other stakeholders it is made fully available. The exchange occurs via an update to the APOC's PowerBI dashboard for which LVNL's Pre-tact units has login credentials.

The second exchange occurs at 15:00LT when LVNL distributes their definitive OPS Plan to both Schiphol's APOC and KLM. As with the morning update, this document also omits the confidential information. This step is also done by forwarding the OPS Plan in PDF-format to the e-mail inboxes of KLM and RSG.

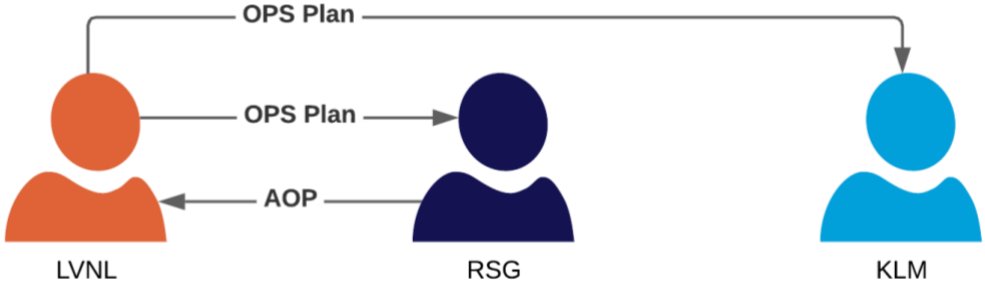


Figure 10: Preparational plan exchange between stakeholders

As seen from these interchange instances, there are only several moments during the days in which the information is transferred. What has also become apparent from this analysis is that KLM only receives data, while not providing something (excluding feedback) in return for it as seen in Figure 10. If the airline wishes to partake in the APOC it is highly likely that they will have to change their receive-only principle and must bring in some useful information regarding operational flexibility as proposed in chapter 6.1.

5.2 Feedback on Plan Exchange

As mentioned before, the exchange of preparatory plans has been ongoing from the beginning of 2021. In this timeframe the OPS Plan has been shared with both RSG and KLM, alongside the daily distribution of RSG's AOP to LVNL, exclusively. Next to bi-weekly evaluation forms, feedback sessions have been held to discuss the relevance of information present in both plans for the involved partners. The outcome of these feedback forms and sessions serves as a foundation for further development of collective preparation, tuned to individual stakeholder needs.

Resulting from the submitted feedback and expert consultation is a list of desired improvements which can be grouped together. Resultant of investigating the requirements for realising these enhancements and benefits associated with implementation will be a quick indication of which improvements require the least amount of work while yielding the most beneficial effect. If desired improvements are mentioned more than once, only its first occurrence will be analysed. To aid the more challenging-to-implement enhancements, some have been provided with a guiding question.

5.2.1 OPS Plan

RSG submitted three feedback forms on the plan's contents and delivery, all filled out via an online questionnaire in the fourth and eighth week of 2021. KLM also submitted three feedback forms but spread these out over January to March and provided the ANSP with several written responses and requests on the shared OPS Plan. A summarised overview of useful elements and desired improvements for both parties can be seen in Table 1, further details on its implications are provided in the text below. For the exact location in the OPS Plan, source and data type of the elements used by the stakeholders, refer to Appendix I where these fields have been highlighted in green.

	RSG	KLM
Useful Elements	- announcements on runway usage - points of attention for operation - regulation scenarios - runway usage & capacity - weather predictions	- regulation scenarios - runway usage & capacity
Desired Improvements	- agree on best data for predicted traffic - configure OPS Plan every day - include KNMI briefing information - include what-if scenarios - increase SKV updating frequency - participate physically in APOC - present as online interactive tool - work out impact of maintenance	- increase SKV updating frequency - indicate new weather values clearly - receive OPS Plan before 12:00LT - sort runway capacity chronologically - sort runway usage chronologically

Table 1: Summarised feedback on OPS Plan exchange

Useful Elements for RSG

Data presented in the plan regarding announcements and maintenance is mostly used to crosscheck the information that is present in the AOP, whereas regulations are used to predict possible delays and impact on gate-planning. The KNMI weather briefing combined with the SKV provides the airport with a

better insight on meteorological conditions than the stand-alone weather prediction and gives a better picture of expected meteorological conditions surrounding the airport. In addition, the airport makes use of the scheduled runway planning during the day to better align their maintenance activities with predicted runway usage.

In order to optimize the contents and usage of the OPS Plan, RSG advises to increase the frequency of updating the SKV and include the information from the additional KNMI briefing. As well as including this briefing, it is also asked to work out the possibly negative impact of scheduled maintenance activities or irregularities. In addition, instead of receiving the OPS Plan from Monday to Friday, it is ideally configured for every day in during the year. Lastly, a minor addition of time-zone indication (UTC/LT) would remove possible confusion regarding listed times.
Less modest changes involve the inclusion of what-if scenarios in the case of strikes or significant weather, which could especially prove valuable when traffic numbers start to pick up again. Similar to their own AOP, RSG would like to see the OPS Plan presented as an online interactive tool, also updating during the day. The greatest improvement would be to have LVNL physically present at the APOC to collectively work on preparing tomorrow's operation. This however would mean that both stakeholders should reach a consensus on which data source to use for predicting traffic demand – either Schiphol's CISS data or the NM's Predict data.

Improvements Desired by RSG

- agree on best data for predicted traffic

This requires an analysis as presented in chapter 8, albeit more focussed at specific evaluation parameters that are most of interest when predicting traffic. Setting up specific indicators that best resemble what is of importance (inbound and/or outbound, accuracy per day/hour etc.) should allow for selecting the dataset with best prediction power.
This yields consensus on which dataset to use for predictions made within the airport control centre in which LVNL will eventually partake for preparing and coordinating airport operation. Since this installation has not yet been realised, the mild beneficiary effect for enacting this measure will only come into effect later on in the process of APOC development.
One question to ask for the implementation of this improvement could be: what is the best indicator for accuracy and precision on the traffic prediction?

- configure OPS Plan every day

This requires an adaptation into the scheduling of OSD & CMA employees, demanding them to also work during the weekend (at least for some hours). Since the configuration of the OPS Plan is not allocated to specific individuals, workload is equally distributed across the department. As there already is limited spare time available, doing so would possibly require an additional position.
This yields a steady supply of preparatory plans year-round, contributing to the continuity of LVNL's operation. Although ATC might not benefit all too much from the continued planning due to the already ongoing internal preparations, involved stakeholders could benefit from more constant documentation – especially the case if adverse weather conditions or capacity constraints are foreseen.

- include KNMI briefing information

This requires only a small adjustment to the information already present in the plan, since one individual could take minutes of the short daily KNMI weather briefing. Even if no new information is presented the summarized report brings a report on the discussion during the weather update, indicating what was spoken about.
This yields additional information in the OPS Plan concerning more up-to-date weather information since the SKV is generated earlier on in the morning. If noteworthy changes have taken place during these hours the written update can be of particular benefit for taking operational decisions.
One question to ask for the implementation of this improvement could be: how should the weather briefing be presented in the OPS Plan?

- include what-if scenarios

This requires a hefty update to the OPS Plan with more involvement of other stakeholders. Since LVNL's operation is partly dependent on other parties' decisions, the inclusion of what-if scenarios brings up need for more evaluations with more worktime allocated to it. This integrated way of preparing operation is best commenced when stakeholders have been more actively and physically involved in the APOC.
This yields several scenarios which have been worked out for specific capacity-reducing occurrences, making them easy to implement when obstructive events occur. Having these scenarios during disturbances greatly reduces workload and negative impact since the problem has already been analysed and solutions have been put up.
One question to ask for the implementation of this improvement could be: which scenarios are meaningful for inclusion in OPS Plan?

- increase SKV updating frequency

This requires more than only updating the SKV alone as the plan is only submitted once to the SharePoint environment, making it closely related to presenting it as an online interactive tool. For the improvement in specific it is necessary to set up an updating mechanism, alongside a short-written evaluation of the changes relative to the prior SKV.
This yields a more up-to-date insight in the expected weather conditions at the airport and enables for better anticipation on changing trends. It is likely that only updating the SKV would not be sufficient since this is already available to involved stakeholders, however the ATC's interpretation of it is not. If this were to be included in addition, the plan's recipients are better informed on operational implications.
One question to ask for the implementation of this improvement could be: how often should the SKV be updated and who should be made responsible for doing so?

- participate physically in APOC

This requires physical presence of one or multiple LVNL employee(s) which are involved in preparing the daily AOP, therefore likely to necessitate new functions. Before taking this step, it is of great importance to agree upon the division of activities for involved representatives in order to bring in the correct candidate(s).
This yields a more collaborative and inclusive way of airport decision making with easier inter-stakeholder communication. Since all parties are physically present in the same area the initiation of discussions is simpler, hereby saving time to focus on primary tasks.
One question to ask for the implementation of this improvement could be: who of LVNL should participate in the APOC and what should the tasks of this representative be?

- present as online interactive tool

This requires the setup of an online dashboard which is accessible to all entitled parties and in which all information is presented in an interactive manner. Since the eventual aim is to incorporate the information from LVNL's preparation into the AOP, it might not be worth the effort to set up a tool themselves but rather implement its information into the APOC's dashboard currently running.
This yields a very accessible overview of the preparatory planning which could be designed to allow for real-time updates for, e.g., weather and runway configurations. Having the preparatory plan in an online environment can enable testing for effects of what-if scenarios and further smooths the way for a data-driven airport control centre.

- work out impact of maintenance geographically

This requires a close coordination between the airport and air traffic control since the impact is dependent on the precise date & time of maintenance activities and the scheduled usage of run- and taxiways. In addition, the impact assessment requires more time in the preparatory phase of compiling the plan.

This yields an impact evaluation of scheduled maintenance activities to be used for optimizing usage of runways or other way round, scheduling repair-work based on predicted runway configuration. If the impact of maintenance turns out to be greater than previously anticipated, mitigating measures can be deployed to minimise its effects.
One question to ask for the implementation of this improvement could be: how to assess the impact of maintenance activities?

Useful Elements for KLM
The data presented in the OPS Plan provides KLM with confidence to take early decisions and create a solid legal foundation in the case of delay and passenger claims. If big disruptions are expected and mentioned in this document, it could initiate a possible sector briefing. Other use comes from the simulations present in the OPS Plan which can be useful when average delays exceed 70 minutes – an indication for the airline to start cancelling flights. Next to this, to aid newly acquired dispatch personnel, the OPS Plan also makes for a useful extension of knowledge since it provides a good overview of various aspects of operation.

To finetune the OPS Plan, KLM advises to chronologically sort the runway usage and associated capacity, instead of the peak to off-peak order. This means there is a more logical time representation, indicative of how the runway layout and capacity is expected to turn out during the day. As well as updating the flight plan, KLM also misunderstood the SKV in relation to the KNMI weather briefing. As the OPS Plan states, the briefing is supplementary to the SKV, with the probability forecast therefore seen as more important. Since the KNMI briefing occurs at a later point in time (roughly three to four hours later), the briefing forecast is more accurate than the SKV. Therefore, clearly indicating renewed forecast values in the weather prediction is of value. Similar to RSG's proposal, KLM also sees benefit of a more frequently updated SKV.
The most mentioned and desirable improvement for KLM regarding the OPS plan is to receive it before 12:00LT or even earlier, since the process of cancelling or rerouting tomorrow's long-haul transfer passengers needs to start early on in the afternoon. Eventually, this results in better decision-making for both dispatch and flow control.

Improvements Desired by KLM
- receive OPS Plan before 12:00LT
This requires only a small change in the process of information exchange. Since the OPS Plan is scheduled for delivery at 11:30LT to external parties, the only step is to include KLM in the delivery list. Important to mention during the plan-sharing is that this only yet entails a preliminary version of the document, as finalisation occurs later on during the afternoon.
This yields more insight for KLM into planned runway configurations and possible hinderances foreseen by LVNL. As flights are ideally cancelled well ahead in advance it is of great importance to the airline to have an early estimation of scheduled airport operation.

- sort runway capacity and usage chronologically
This requires a minor modification in the OPS Plan regarding the presentation of predicted runway usage. If multiple in- and/or outbound peaks are foreseen, the preferred depicted order is chronologically. Looking at more recent preparatory plans, this measure seems to have already been implemented.
This yields a more comprehensive overview of predicted runway usage and capacity, making it easier for users to form a timewise image of anticipated aircraft handling.

Improvements Desired by ACC SUP
- create sector configuration based on workload-model and improve visibility in OPS Plan
Lastly, suggested by one of LVNL's ACC SUPs (Rogier Hendriks, personal communication, June 9, 2021) was to optimize the creation of the foreseen sector configuration. Where this is currently done

based on expected aircraft demand, this should ideally be done based on the workload-model that is currently already being used for assessing the number of air traffic controllers needed for operation.
This requires a change in the process during which the prediction for the sector configurations is made, meaning that the algorithm currently used should be interchanged with another one based on the workload-model. For altering the visual representation due to an unclear layout, cross-checking new design with the OPS Plan users is recommended as they should be able to read off the charts.
This yields a better prediction for sector configurations that is likely to more closely resemble D-0's operation, allowing enhanced scheduling for air traffic controllers.

5.2.2 AOP

LVNL submitted one document containing feedback on the usability and improvements of the AOP in the seventh week of 2021. KLM was not included in the trial and has therefore not cast feedback on the airport's operational plan. A summarised overview of useful elements and desired improvements found by the ANSP can be seen in Table 2, further details on its implications are provided in the text below. For the exact location in the AOP, source and data type of the elements used by the stakeholder, refer to Appendix II where these fields have been highlighted in green.

	LVNL
Useful Elements	- aircraft process data - maintenance activities - DCL estimations de-icing
Desired Improvements	- agree on best data for predicted traffic - improve AOP accessibility via ICT-infrastructure - improve DCL-estimation visibility - include expected de-icing capacity and demand - include SKV and KNMI briefing - include snapshot function due to rolling plan - include timestamps of data insertion - work out impact of maintenance geographically

Table 2: Summarised feedback on AOP exchange

Useful Elements for LVNL

Although the team only looks at several specific sections of the plan, the data provided in the AOP mostly matches with information known to LVNL on maintenance activities and data regarding aircraft processes. Next to crosschecking the information already available to the team, information is extracted from pre-Departure Clearance (DCL) estimation for de-icing – although with no significant new insights to be used in their own operational preparation.

To further improve the contents and layout of the AOP, LVNL has listed several future enhancements of which several are relatively easy to implement. Firstly, including timestamps in the plan for when information was added allows for an indication of the actuality of the data. The team also advised to include the SKV in the AOP, alongside implementing information from the KNMI briefing. Other possibly relevant features could be the inclusion of apron capacity & demand (especially for wide-body aircraft) and de-icing capacity & demand. Regarding the access and viewing of the plan there are still some improvements to be made since it is only accessible via individual user accounts for which a lengthy authorisation process is required. If the AOP is exported and distributed via e-mail in PDF-format, some graphics prove missing and scrolling becomes impossible, limiting the number of items visible per list. The final desired layout updates entail including a snapshot functionality for accessing daily static insights and relocating the DCL estimation to a more prominent place in the plan.
Similar to the mention in the feedback on the OPS Plan, the pre-tact unit stressed the importance of identifying the best dataset for traffic predictions at the airport and reaching a consensus on which one to use. Finally, the team also wanted to investigate the possibilities of having a geographical, integral

oversight of scheduled maintenance works and their expected impact on operation – a functionality also mentioned by RSG in the reviewing the exchange.

Desired Improvements for LVNL

- improve AOP accessibility via ICT-infrastructure

This requires setting up one account per stakeholder to avoid hiccups with individual users and their permissions. Since the current AOP exchange does not yet allow other stakeholders to input data, there is no need to have different user accounts – providing one login with view-only permission is enough for now.
This yields a small improvement in the ease of logging in to see the airport's operational planning, since any accessibility issues now only have to be resolved for one account.
One question to ask for the implementation of this improvement could be: how would LVNL like to access the AOP, since individuals accounts work poorly?

- improve DCL-estimation visibility

This requires only a minor update in the AOP's layout since the feature is already present in the plan but has not claimed the most prominent place. As the feature is important to LVNL, the desired improvement would be to bring forward the element and prioritise its placement.
This yields easier access to the most important elements for air traffic control, possibly saving small amounts of time when looking for the features of interest present in the AOP.
One question to ask for the implementation of this improvement could be: where should DCL-estimation be put in operational plan?

- include expected de-icing capacity and demand

This requires the creation of a new prediction based on meteorological updates and third-party de-icing handlers. Because this would entail the creation of a new aspect, it also requires time and employee availability, as well as willingness from de-icing companies to share their personnel & equipment scheduling.
This yields better insight into potential bottlenecks when de-icing is required, possibly mitigating restrictions on airport handling capacity. As these subcontractors form an important part of operation, there should be aimed at eventual APOC inclusion – albeit only sharing their planning without being physically present at the control centre.
One question to ask for the implementation of this improvement could be: which parameters must be used to predict de-icing capacity and demand?

- include snapshot function due to rolling plan

This requires the implementation of a new functionality, possibly by automatically storing and exporting the plan once every 4 hours. By doing so, one can see what predictions were made at which time and how they have changed over the course of the day.
This yields the ability for setting up post analysis, comparing how predictions have adapted over time. It also forms a good foundation for data storage as previous plans are now easily available, one thing LVNL already does for its OPS Plan.
One question to ask for the implementation of this improvement could be: how can snapshots be exported correctly, since scrolling functionalities and graph representation is lost?

- include timestamps of data insertion

This requires an adjustment in the way the data is presented in the AOP since implementation would need additional space for timestamps. The APOC's development team also has to log the date and time at which data insertions or predictions are made, as these form the source of this feature. It should be said that not all elements require timestamps, only features whose values could change during the day.
This yields a better indication of when predictions or data insertions were made, a feature which is closely linked to the inclusion of the snapshot function. Whereas the previous improvement would

indicate a specific time for the plan in total, implementation of this update allows for the showcasing of publication moments for individual AOP elements – of which there are numerous.

5.3 Benefits of Information Exchange

Now that has been identified which information stakeholders would like to receive from each other, the positive influences on decision making are discussed. Since partners could initially be relatively reluctant to share data due to confidentiality or strategic interest, it is of great importance to bring a clear overview of the likely benefits of information sharing. Involved parties will find that not only the collective decision-making can be improved, but inter-company choices can also be aided by outer-company information. The first section investigates the theoretical benefits as found in literature studies and industry papers, whereas the second section splits out the direct and long-term benefits per stakeholder. These benefits can only arise when stakeholders actively share their data as listed in Table 3 at minimum, both providing and receiving valuable insights to and from the collegial airport partners.

Theoretical Benefits

Although theoretical benefits from general information sharing have been widely researched, limited studies on benefits regarding collective operational preparation have been both conducted and published. Currently, EUROCONTROL is conducting a study (PJ04) into the broader concept of TAM to clarify its benefits and implications it brings to stakeholder collaboration of which results are expected at the end of 2022. Since basic benefits from information are mostly relatively generic and straight forward, it is best to extract proven advantages from research linked to relevant terminologies (APOC/TAM/AOP) and see how they would apply to Schiphol Airport. For this, earlier mentions of studies and articles in chapter 4.2 can be further summarized by filtering out advantageous effects:

- improved passenger experience due to a reduction in queuing activities (EUROCONTROL, 2016)
    - This study has been carried out at Heathrow Airport in 2016 where passenger flows were more accurately predicted using machine learning with information from multiple stakeholders and sources, resulting in a better experience of level of service. Since Heathrow handled roughly as many passengers as Schiphol – 75.7 million versus 63.6 million (ACI Europe, 2017), respectively – the implementation of enhanced passenger flow prediction could also see enhanced passenger experience at AAS.
- better decision making with more detailed insight in on-going processes (Goldnadel, 2021)
    - When collating multiple information sources from stakeholders into one operational centre the airport would see a more centralised and holistic view of ongoing processes. Bringing together these flows of data with representatives from involved stakeholders allows for more data-supported decision making and smoother communication between parties.
- improved predictability of airside operation with enhanced usage of information (SESAR, 2019)
    - Making more information available to other trusted parties allows them to base decisions on additional data and indicators, enabling potential to better manage operation. Bundling all incoming data from Schiphol, KLM, LVNL, ground handlers, security and eventually other actors provides transparency and improves predictability.
- refined mechanisms to establish performance baselines (SESAR, 2019)
    - Once the APOC at Schiphol Airport has been up and running for some time with several relevant stakeholders actively involved, its performance can be assessed via analysing important parameters after operation. Collectively evaluating past performance can yield agreed-upon benchmarks to which all parties strive to achieve.
- enhanced air- and landside performance management (SESAR, 2019)
    - With more data available to involved parties the collective configuration of KPIs is within reach. If real-time data exchange and evaluation were to be set up, Schiphol Airport

could see an enhanced insight into air- and landside processes. Combining data from multiple stakeholders into a single overview allows for a complete and holistic overview.

- sustained increase in throughput performance under all modes of (non-)routine operations (Papagiannopoulos, 2021)
    - Through more actively interchanging information in the days prior to operation, less unforeseen situations occur on D-0, improving collective handling of in- and outbound based on A-CDM principles. With the currently in-development what-if scenarios at Schiphol Airport, non-routine situations are worked out to mitigate their operational impact.
- better assessment of meteorological impact (SESAR, 2019)
    - The APOC setup for Schiphol ideally holds a KNMI representative to better assess and timely communicate weather conditions that could jeopardize operational capacity. With stakeholders physically present, meetings could be initiated almost instantly.
- pro-active collaboration on predicted performance deterioration (SESAR, 2019)
    - Data sharing benefits the configuration of what-if scenarios – situations in which disruptions have been foreseen and adequate measures have been put in place to mitigate its impact on operational capacity – since it facilitates for scaling up the level of detail to which the scenario is worked out. The configuration of these scenarios is done prior to operation and therefore makes for a more pro-active working method to minimise impact of airport disruptions.
- significant decrease in delays and left-behind passengers & less engine running time resulting in significantly lower reductions (DLR, 2012)
    - As research by DLR pointed out, effectively implementing TAM yields large gains for several areas of performance. Although Schiphol is still far from having implemented this concept, the setting up of the APOC provides a good start as it's at the core of operation for total airport management as previously shown in Figure 2. During the process of TAM implementation, stakeholders will join the control centre one by one bringing in more information along with them. This stepwise process is likely to see KPIs shift towards improvement as more and more partners join the airport's APOC.

Direct benefits for LVNL

- Better insight in infrastructure availability and condition of e.g., runways, taxiways and gates/aprons
    - Although the air navigation service provider already has an overview of scheduled maintenance works on airside infrastructure, malfunctions or deteriorated terminal assets could impose unforeseen delays to the airport operation. Since RSG more actively monitors these air- and landside systems, valuable information can be extracted to benefit the assessment of infrastructure availability in an early stage.
- Earlier identification of de-icing requirements allowing for better allocation of aircraft clearances
    - As one of the elements in the AOP entails a section on foreseen de-icing conditions, the ANSP will receive an early insight into the predicted procedures for D-0. As this requires an additional step in the process of getting the aircraft from gate to runway, it is desired to get an indication of expected de-icing demand. If data sharing were to be intensified between the three stakeholders, LVNL would get a better indication of potential capacity constraints regarding ice mitigation procedures.

Long-term benefits for LVNL

- More efficient throughput of aircraft movements due to reduced airport and airline delays
    - Once the information sharing has intensified over the course of time, partners are highly likely to see reduced delays originally caused by a lack of information in various aircraft and airport processes. As the total number of delay minutes has decreased, more aircraft arrive and depart on time meaning that there is stricter slot adherence. This

hereby enhances the predictability of aircraft-specific process times, allowing for a more efficient throughput of traffic at Schiphol Airport.

- Less noise pollution as usage time of second runway is decreased due to more stable planning
    - The same is true for this long-term benefit where inaccuracies in process times causing delays are smoothed out. Also being part of the 'Minder hinder Schiphol' project, research is done into improving predictability of outbound traffic (Schiphol, LVNL, 2021). This can limit the necessity for the time of using or movements handled on a second runway, reducing the total amount of noise produced by an optimised handling of flights.

Direct benefits for RSG

- More complete image of stakeholders' intentions and limitations for operation on D-0
    - The main benefit that will immediately arise is enhanced insight into operational intentions and limitations of both LVNL and KLM. Knowing what these two important partners have planned for D-0 will provide a more holistic image of airport processes. Receiving pre-operational insight is good for assessing potential limitations resulting from combined partner intentions, enabling the possibility to tackle these shortcoming before they arise.

Long-term benefits for RSG

- Enhanced passenger experience due to reduced delay from mitigation measures on what-if scenarios
    - Once the data sharing has been matured, what-if scenarios are likely to be implemented to a great extent. This allows airport partners to configure operational scenarios which are unlikely but have a substantial negative impact on capacity throughput. By pre-defining actions to be taken during such 'unforeseen' disruptions, a quicker response is possible which limits the impact of such events. The passengers will see less delay and can be better informed about ongoing situations, improving their travel experience.
- Less air and noise pollution due to less on-ground waiting time for aircraft and handling equipment
    - As mentioned above, stakeholders are likely to see reduced delays and less unnecessary waiting instances due to process bottlenecks. If aircraft can be handled in such a way that the turn-around and taxi times are minimised, this reduces the required engine-on time. This will therefore result in reduced noise at the airfield, as well reduced fuel consumption for aircraft and handling equipment – reducing the total harmful emissions of carbon oxides, nitrogen oxides and particulates.
- Higher level of service to increased passenger throughput, yielding more space per passenger
    - When the stakeholders have eventually combined their planning efforts and carry joint responsibility for most of the airport's operation, they will have a detailed insight into ongoing processes. This allows them to collectively coordinate and pro-actively steer on passenger throughput on common bottlenecks such as check-in and security. By doing so the stream of travellers is spread out evenly across the terminals, increasing the room available in each area for individual space-occupying passenger – one aspect currently crucial for safe functioning with adherence to the 1,5m-measure.

Direct benefits for KLM

- Receive runway configurations and associated capacity directly from LVNL instead of AFOS predictions
    - This is very beneficial for the main carrier at Schiphol Airport as the predictions on runway usage and capacity need not be used anymore, while the data can now be

directly sourced from the responsible authority: LVNL. Since the AFOS tool bases its predictions on historic information, which mostly includes data on near-peak capacity, its forecasts in time of non-normal operations (e.g., a pandemic) are not all too reliable. For KLM this means that this information is more reliable and less likely to deviate all too much from D-0's realisation, enhancing the airline's ability to (re)schedule or delay flights.

- Better insight in infrastructure availability and condition such as runways, taxiways and gates/aprons
    - Similar to the benefit for LVNL regarding improved insight in infrastructure's state and usage, this is also true for the airline. KLM can use the further insight to look for possible assets in maintenance or with degraded performance to mitigate hinderance to their flight execution and handling. For future intensification of data sharing the airline might also deliver information on aircraft's and handling equipment's availability and condition.
- Earlier insight in possibly imposed regulation scenario(s) that decrease(s) capacity and form delay
    - One of the wishes for the airline during the exchange trial was to have the OPS Plan delivered earlier since this allows them to decide sooner on whether to delay or cancel flights. Gaining well in-advance insight into (a) LVNL-imposed regulation scenario(s) allows to airline to better prepare flight execution and assess its impact on their own network.

Long-term benefits for KLM

- Enhanced passenger experience due to reduced travel delays with better information provision
    - Over a given amount of time the information sharing has been integrated to such an extent that delays are less frequent, due to better stakeholder collaboration and merging partner-specific data silos. If delays do still occasionally occur, the airline is able to inform passengers about the causes of flight-specific delays, as well as a better time indication of incurred delay.
- Lower fuel consumption due to less on-ground waiting time for aircraft
    - Similar to the benefit for RSG regarding reduced noise and air pollution, this benefit amounts to a lower fuel consumption for KLM. As aircraft are better managed in the in- and outbound process with less waiting time, the engine- and auxiliary power unit-on time are lowered meaning less fuel consumption. Since fuel mostly makes up for the largest part of operating costs (depending on trip distance), saving here really pays off.

6 Merging and Measuring Preparation

Having seen the work that goes into preparing for individual operation and the possible improvements that could still be implemented, the focus shifts towards a more inclusive and collaborative working method. Since the preparatory phase is structured differently for each stakeholder, merging these cycles is likely to be more difficult. To achieve a synched-up preparatory planning on D-1 for three stakeholders requires dedicated cooperation of all involved members but is highly likely to yield a better cross-tuned planning. Finding out which elements are required from which stakeholder and in what moment in time is done via comparing individual preparation (chapter 6.1). Hereafter measuring the data sharing on behalf on this collective preparation is done via several proposed KPIs (chapter 6.2). To arrange for a more integrated and fine-tuned APOC in this process, it is incentivised to agree on appointing common data sources for planning purposes (chapter 6.3).

This chapter focusses on the merging of individual operational preparation and poses a framework of metrics to evaluate its collective performance, hereby answering the sixth and seventh research question.

6.1 Collective Planning

As the previous chapter has indicated, collating partner information can yield numerous benefits for involved stakeholders. However, synching up all three planning cycles proves difficult in practice. Therefore, it is useful to first analyse collective preparation on bi-stakeholder level after advancing to tri-stakeholder breakdown.

Linking LVNL – RSG

Since LVNL and the airport both already prepare tomorrow's operation by documenting a planning, setting up a coordinated exchange and collaboration should prove relatively doable since most important aspects have already been put on paper. As the trial with the OPS Plan – AOP exchange has pointed out, there are definitely some potential benefits that arise when the interchange is done more frequently and becomes more of an integrated functionality. The synching between the airport and ATC has already been partly initiated since both partners have agreed to share/update their planning on a given time. Although this currently only occurs at (around) 11:30LT, working towards a more synchronized preparation would require updates and information exchange more frequently.

Working towards integrated information sharing will see the important information being collated into one document or dashboard. If both stakeholders would decide on merging the data into the airport operations plan, most elements of LVNL's plan could be included. The downside of merging all of the elements into one planning is that the internal users of the OPS Plan are left with an AOP that offers an overload on information, of which only a small part is useful for both the ACC SUP and FMP. Therefore, the Pre-tact Unit could look into what data is of importance to internal LVNL users and tune the OPS Plan accordingly.

Linking LVNL – KLM

These parties have worked via a mostly unilateral exchange, with the airline receiving a daily copy of the OPS Plan. Although KLM did not return data or information to LVNL, they have provided feedback on its contents and applicability for the airline's operation as seen in chapter 7.2.1. As the flow of information only came from one side the combining of planning cycles has not yet been brought into play. The airline has ongoing – therefore overlapping – preparation for each of its scheduled flights whereas the air traffic control prepares its servicing per day, meaning that both stakeholders prepare operation clearly different. This does complicate the process of synching up planning cycles as the airline is more likely to have updates on non-standard times throughout the day, while LVNL has already established fixed times of information publication.

The eventual inclusion of KLM's operational data brings in more elements to the collective plan, which would once again lessen the percentage of useful information to be used by the airline internally. Updates on flight movements from KLM are likely to provide a pretty complete operational image since the airline carried over half of the passengers travelling from and to Schiphol (Royal Schiphol Group, 2021).

Linking RSG – KLM

Of all three lines of contact, the cooperation between the airline and airport in preparing for operation proves to most modest. Since there has not yet been an exchange period in which these stakeholders share preparatory documents or information, setting up the data transfer will be most difficult. Added to this complexity comes that KLM does not prepare a deliverable in the form of a daily planning, leaving the information scattered throughout various operational systems. This does ease the synching of planning cycles between the ANSP and the main airport carrier since KLM can link up with the updating sequences from Schiphol.

If KLM were to partake in the APOC on future occasion it would have to bundle its available data with comprehensible insight on a daily basis. The data from the airline can be shared to be included in the AOP, yielding a better insight for Schiphol on KLM's scheduled operation. This plan is shared with the airline in return, providing a holistic view of planned airport actions. Unlike with the LVNL-exchange this cooperation does not interfere with internal preparation and is only likely to bring in more information into the airline's preparation phase.

Linking LVNL – RSG – KLM

Of these three stakeholders, two have already started synching up their planning cycles – albeit being in early phase of implementation. With the TAM-concept in mind, working towards an inclusive APOC with the setting up of a holistic AOP is seen as the best way forward. Effectively, this means that both the airline and the ANSP will have to be involved in transferring their data and information updates to the pre-existing AOP by RSG. Since the cycles for LVNL and the airport already coincide on several instances during the day, the exchange coming from and directed to KLM should ideally be tailored accordingly.

Aligning the contents of the AOP should also be a point of focus when including all three stakeholders since the main focus should lie on overlapping areas of operation. Elements that are relevant to all stakeholders and therefore should definitely be included in the collective plan are: weather forecast and impact, maintenance impact analysis, runway configuration & associated capacity and possible regulation scenarios. To tackle the hassle for involved parties of still having to configure an internal plan for their own usage, several partner-specific elements might be appended lastly to the airport operations plan – given that stakeholders prove willing to share these data.

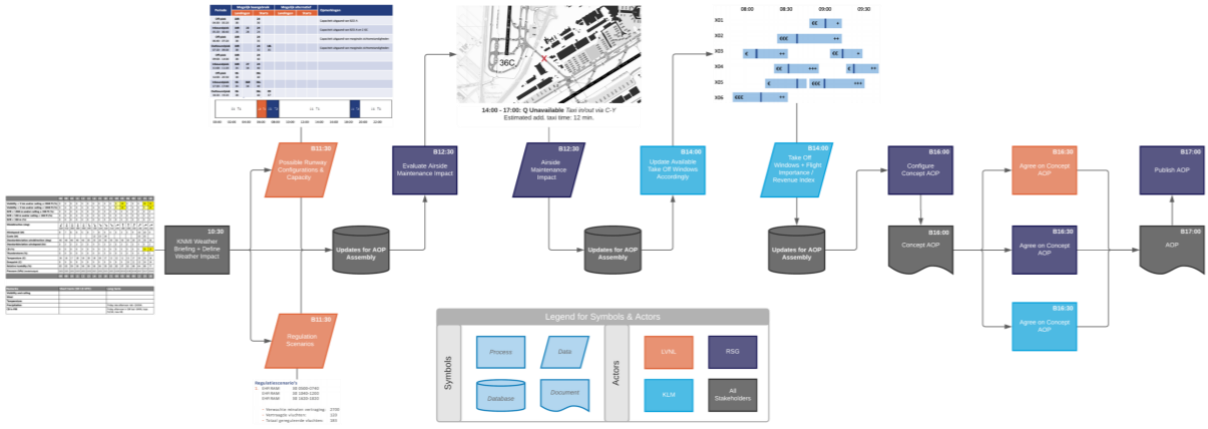


Figure 11: Proposed process for collective preparation

Timeline for Exchanging Information

With the configured process maps for both LVNL and RSG it is possible to gain insight in the availability of information and certain data elements over time. Using this information, it was possible to construct an outline for proposed data sharing during D-1 as seen in Figure 11. Alongside this process map is a tabular overview of proposed data-exchanges and required actions as seen in Table 3 and 4. Although there are numerous uncertainties on the day prior to operation, the involved stakeholders should try their best to come to a collective planning with the information available. Here, one of the most important influential yet uncertain aspect of operation is the weather. As feedback from the plan exchange has pointed out, the stakeholders would like to have a joint briefing on the weather by the KNMI in which they collectively assess capacity impact from foreseen meteorological conditions. Since this variable is thought to be most influential to airport operation, it is best to have it form the foundation of further decision-making in the proposed collective operation. Therefore, it is recommended to start with a joint weather briefing with all stakeholders and a KNMI representative at 10:30LT.

Since the ANSP already prepares its foreseen runway configurations & capacity and regulation scenarios before the daily OPS Plan meeting at 10:30LT, these data should be available as of that time. While the meeting does allow for minor updates to these elements, one can expect finalised information before 11:30LT (end of meeting).

When submitted to the database, the APOC experts can start assessing the impact of scheduled maintenance activities with the runways foreseen to be used. With the information already available in the AOP regarding airside maintenance, what rests is a geographical impact analysis of these workings for the flow of aircraft on aprons and run- and taxiways. Next to providing an estimation of the additional delay, it might be wise to include an alternative route/option for the sake of completeness. As the number of airside maintenance works is mostly spread out over time, it is unlikely to have multiple influential activities per day. Therefore, it can be assumed that the operation centre will not need more than one hour to submit these data into the shared database, doing so best before 12:30LT.

Once both the ANSP and APOC have brought in details regarding tomorrow's operation, the airline can start anticipating on the foreseen runway usage & capacity and maintenance works. Since KLM currently still uses the AFOS-tool to predict runway configurations, directly receiving this information from the actor is likely to resemble operation on D-0 more closely and with better accuracy. With this insight at hand and impact analysis of airside maintenance, the airline could issue desired take off windows for each flight as well as a revenue index, providing the airport and air traffic control with slightly increased flexibility regarding the scheduling of departures. Using these two variables the APOC and ANSP have some room to schedule flights, hereby striving to achieve a better planning with no worse – but ideally better – average take off time and revenue index than previously scheduled by the airline. In order to grant the APOC some time for the AOP finalisation, it is proposed to have KLM input their preferences window data before 14:00LT.

Now that all overlapping aspects have been submitted, it is up to the APOC to finalise the daily AOP. As it could take up some time to tailor the plan accordingly, the preferred time to distribute the concept plan is before 16:00LT. Since the team does not have to wait to configure most of the elements in the AOP it is likely to already have a decent foundation when receiving the update from the airline. In order for all stakeholders to agree on the collectively configured plan for tomorrow's operation, they must agree to its contents and submit potential feedback or desired changes before 16:30LT to the airport's operation centre. The final step in the process of jointly preparing for operation is the publication of the plan in the pre-existent Power BI dashboard from RSG, ideally before 17:00LT.

Although the APOC is currently aimed at setting up a rolling AOP, certain deadlines must be met by the involved partners as this provides a framework of when to have data ready. Choosing for a rolling plan requires the set-up of a continuous data stream from both LVNL and KLM directly into the AOP,

something that might should be awaited for implementation when periodic, timed updates have proven to functional well. This would see more frequent updating of the data elements below in Table 3, requiring all stakeholders to more frequently run and submit their foreseen runway usage + capacity, airside maintenance impact and take off windows.

Deadline (LT)	Stakeholder	Data Elements
11:30	LVNL	- regulation scenarios + delay - runway configuration + capacity
12:30	RSG	- airside maintenance activities - impact assessment + delay & reroute
14:00	KLM	- flight schedule take off windows - revenue index + pax. importance index

Table 3: Proposed data update deadlines for collective preparation on D-1

Deadline (LT)	Stakeholder	Proposed Tasks
10:30	All	- briefing on weather by KNMI - assess meteorological impact
16:00	RSG	- configure concept version of AOP
16:30	All	- assess + accept concept version of AOP - submit potential changes/updates
17:00	RSG	- publish final version of AOP

Table 4: Proposed tasks for collective preparation on D-1

Requirements for Exchanging Information

In the case of the ANSP, the data elements currently present in the OPS Plan (as indicated in Appendix I) should be brought into a centralized database which is likely to be managed by the APOC development team. Transferring the data directly into one's database might seem like a big step to take but given the exchange has already taken place via e-mail, there has always since been a possibility to extract wanted information from the provided PDF-file. Particularly of interest from LVNL is the foreseen runway configuration & capacity for the upcoming 24 hours, since this is currently predicted by KLM using the AFOS-tool. In addition to the possible runway usage and capacity, the air navigation service provider should submit regulation scenarios with their associated delay.

In the case of the airline, a new framework for information sharing will have to be set up. Since they have not been actively engaged in sharing information with the APOC it is best to make an inventory of available data. KLM makes use of multiple decision-support tools which means that data used for operational preparation is mostly nested inside these systems and could therefore prove difficult to transfer out. As information regarding target take off times and flight scheduling is already available in the A-CDM system, new sources of ready-to-share insights should be provided. One of these elements could be the timeframe per flight in which the airline wishes it to take off or arrive. Ideally these also include a flight revenue and importance index based on the on-board flyers' status.

The number of updates being brought into the plan is likely to start off low. In order to direct the KLM and LVNL data into the AOP via a structured manner, the current process of exchanging updates via e-mail will have to be altered. Setting up a collective database in which all actors can update their data whenever they have new information available allows for greater flexibility for the exchange. In order to fully synch up the preparatory planning, it is best to collectively agree upon daily deadlines at which each stakeholder should have submitted their data elements. After having submitted the necessary

elements the APOC experts can commence evaluating the received input and start configuring the AOP accordingly.

Starting off with sharing information as mentioned in Table 3 yields a functional system via which the involved stakeholders can commence the desired data-exchange. Dependent on the level of integration they want to pursue, it could be possible for either of the partners to submit more elements of their individual planning into the shared database. In the case of the ANSP it is relatively easy to transfer additional elements of the OPS Plan into the shared database as the information it uses is already digitized. For KLM this is likely to be more time consuming since preparation is not done via a daily holistic plan and operational data might not be easily extractable from in-use systems. This would likely require another examination in the available data at the airline, together with evaluation on its importance for other stakeholders' preparation.

6.2 Information Exchange Assessment

In order to evaluate the performance of the collectively prepared AOP, post-operation analysis can be performed. This, however, is a 'lagging indicator' of the plan's functioning as it only yields results after day-operation is fully completed. In order to get near real-time insight in the performance of both APOC's planning and handling, several processes should be actively measured and evaluated – also known as setting up KPIs. For this it is best to make a clear distinction between measuring the performance of operation on the one hand, plus measuring information exchange in its preparation process on the other hand. The first element is of importance for evaluating how well operation coincided with the foreseen in the AOP on D-0, whereas the second element is of relevance for assessing the information exchange during the preparatory phase on D-1.

Operational Performance Indicators (D-0)

Schiphol's APOC does not yet measure or evaluate the effectiveness of operation and accuracy of the daily plan, meaning they could benefit from enacting several relevant indicators. An overview of proven KPIs provided by DLR features 27 KPIs over 7 KPAs for TAM with an APOC, mostly based on the already-in-place A-CDM infrastructure and its associated data loggings (DLR, 2012). As derived from Appendix VI, these combined indicators provide quite a holistic view of the ongoing airport operation. When extending the range of the airport's control centre to D+1, thereby including the evaluation of operation, most of these indicators could be implemented with relative ease as most of the data is sourced from A-CDM systems.

Information Exchange Indicators (D-1)

Since this research mostly focusses on the information exchange between involved stakeholders, the following proposed performance indicators are aimed at measuring this data-interchange instead of evaluating the functioning of the actual plan. Monitoring the flow of data provides good insight in which information is already being made available between the three stakeholders and where areas of improvement might lie. When setting up the process of a collective planning in line with the contents of Figure 11, all parties must act in line with the previously configured deadlines.

The following KPIs are best to be set up for each stakeholder individually as this could bring in insight in their own performance and adherence to the set agreements. This could therefore yield an oversight per stakeholder or split by indicator, whichever is preferred. It is proposed to have the indicators update once every day during the late evening as this yields a brief performance overview for the following morning. Storing the values for each day f allows for evaluating The following KPIs are sorted in order of importance where time is the main factor.

1. average time of data updates (rolling 7-day average)

One of the most important indicators has to do with the time at which updates are issued into the shared database. Collectively agreeing to a collective process – built on the usage of each other's information

– requires a timely submission of one's own data via adherence to the set deadlines. Getting insight into how well set agreements are being adhered to is of great value since it highlights stakeholder commitment into providing the right information in the right time. Since multiple updates might be submitted during the day, only the time of the latter data upload is used for this KPI. This indicator is useful for each of the involved stakeholder as they are all required to submit a daily data update and has a target value of lower than or equal to the partner-specific deadline as seen in Table 3.

2. average time of AOP delivery (rolling 7-day average)
As the goal is to publish a collective and stakeholder inclusive AOP in an orderly and timely manner, the moment of its delivery should not be delayed. It is therefore important for the involved experts to stick to the proposed times to be able to publish the airport plan at 17:00LT latest. Monitoring the average time at which the daily plan is delivered can make it easier to see what actions positively or negatively influence the process of plan configuration one prior day of operation. Since the publication of the AOP is done by RSG after joint agreement, there is only one time to track for this indicator. This KPI has a target value of lower than or equal to 17:00LT.

3. number of data updates per day
This KPI focusses on the frequency of updates regarding submissions in the shared database. In this process, each stakeholder has been provided with a deadline by which they should have submitted their daily updates. This means that they could update their inputted values of the course of the day, enabling other partners to already start anticipating hereupon earlier. Keeping track of the number of updates that are done throughout the day could give insight in the actuality of the data that are being provided and might motivate colleagues to send out updates as early as possible. This indicator is useful for each of the involved stakeholder as they are all required to submit at least one daily data update. The target value for this indicator is currently unknown as real-world implementation should set its optimal value (too little updating leaves stakeholders unknowing, too many updating leaves an information overload).

4. percentage of preparatory plan exchanged
The final meter evaluates the extent to which the stakeholders are sharing their individual preparation on D-1. Sharing more information into the shared database allows for enhanced accessibility by the airline, the airport and the ANSP without having to fully search other's preparatory plan. As the aim is to include all aspects of airport operation into the future AOP, merging the different plans into one is likely to be done via one shared system. Keeping track of the number of elements already being shared in respect to total contents of the plans is a good way to measure if progress is being made on information exchange. Since only LVNL and RSG work with a daily clustered deliverable for preparing operation (Appendix I & II), this KPI cannot yet be implemented for all stakeholders. The target value for this indicator should come close to 100% since a holistic airport operational plan should eventually include all relevant air- and landside processes.

6.3 Common Data Sources

Both RSG and LVNL have previously expressed preference for utilizing common data sources as this rules out possible discrepancies in preparing for operation. One of the elements for which the partners have different places of retrieval is for the predicted in- and outbound traffic at Schiphol Airport. Currently, both the airport and ANSP include a forecasted number of inbound and outbound aircraft in their preparatory plans. For the airport this number results from summing up flight schedule submissions done by airlines, while LVNL forecasts this number based on the NM's flight data from EUROCONTROL. To be able to get a decent number of predictions to compare, data has been gathered from the 1st of April 2020 up to the 1st of April 2021 – meaning 365 days of operation. Since the OPS Plan originated in the first half of 2020, extending the timeframe would not yield more data entries for LVNL.

In order to evaluate the accuracy of the traffic numbers that RSG and LVNL provide on D-1 in their AOP and OPS Plan, respectively, these numbers have to be compared to the actual realisation at the day of

operation. Since both stakeholders store data on inbound and outbound movements, the first step of this analysis is to compare whether these numbers form a matching pair. If this were to be the case, a graphical view of both stakeholders' measured realisation would yield a coincident line.

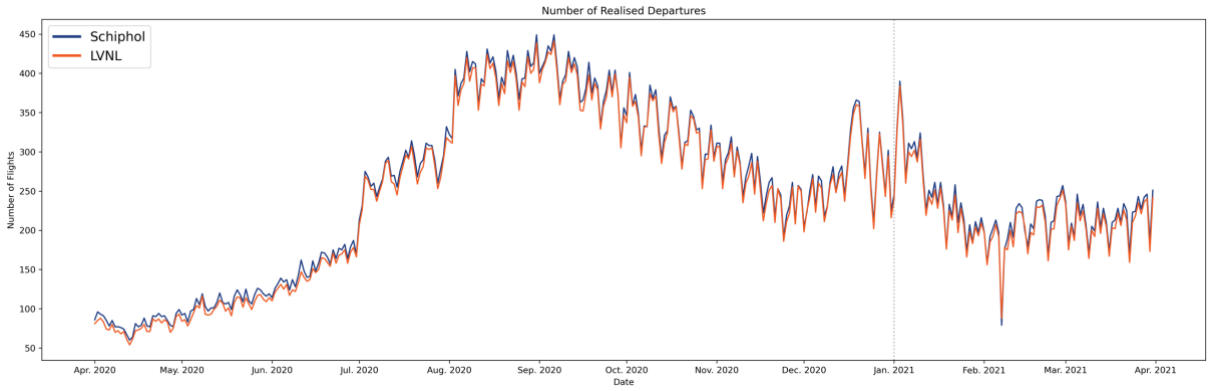


Figure 12: Schiphol and LVNL departure realisation

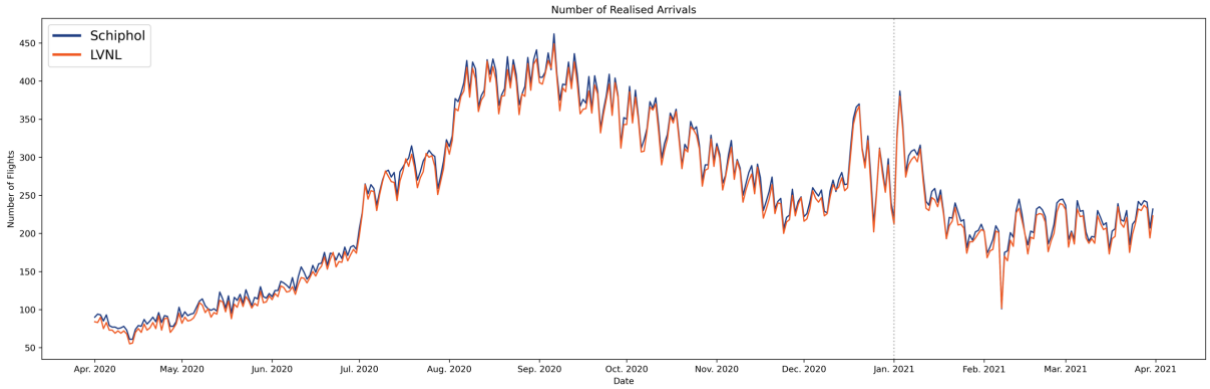


Figure 13: Schiphol and LVNL arrival realisation

As visible in Figures 12 and 13 above, the realisation numbers do not match up for both partners, neither for arrivals nor for departures. Schiphol (as indicated by the blue line) seems to have logged more departing flights per day than ATC, thereby no agreement can be found in the data. Finding out how traffic numbers are measured could explain the observed difference since both parties are likely to use other methods for recording aircraft movements. To get an idea of how large the difference actually is between both observations, daily percentual deviations are computed for the one-year period.

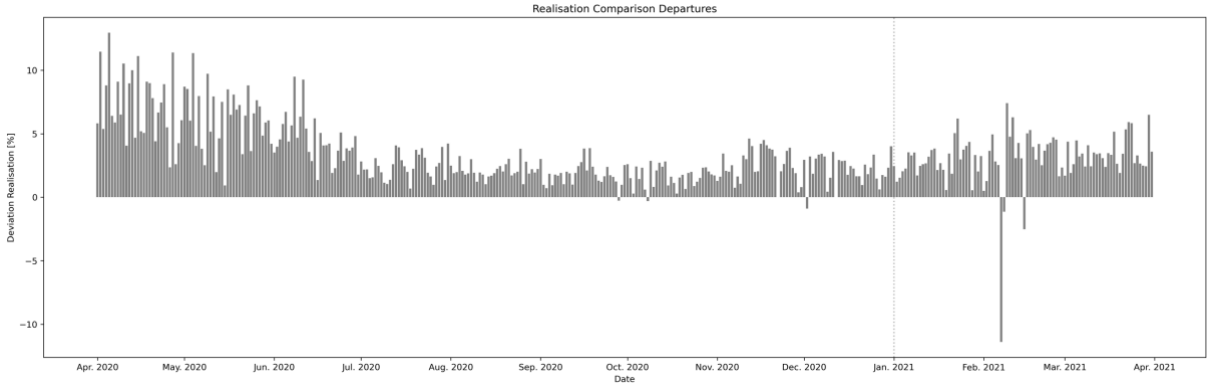


Figure 14: Deviation from LVNL's departure realisation

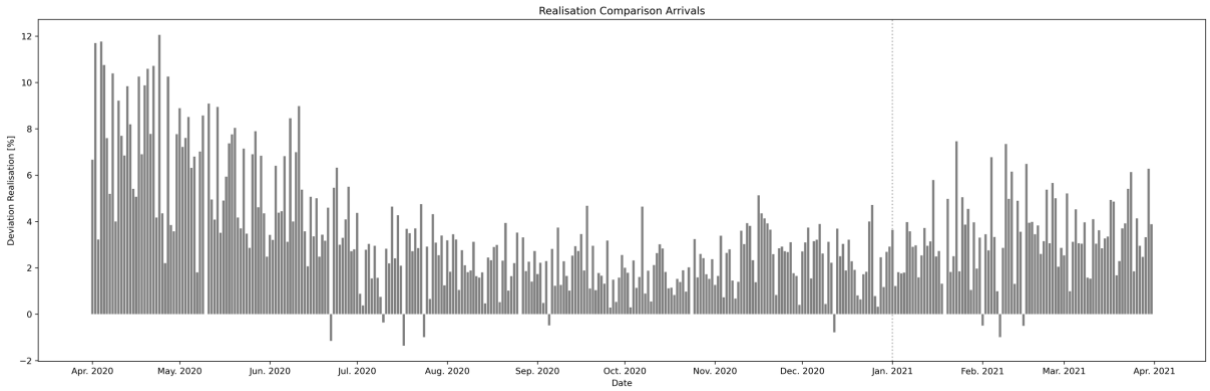


Figure 15: Deviation from LVNL's arrival realisation

Figures 14 and 15 have been retrieved through dividing the daily delta between Schiphol and LVNL by CISS' data points, yielding a percentual deviation in realisation. Reading from both graphs it becomes evident that the airport mostly holds records with both more departures and arrivals. Judging by the figures it seems as if there is a lower deviance for departures, but since the y-axis has shifted slightly this is not the case. When comparing the deviation for the one-year period it is found that Amsterdam Airport has logged an average of 3.31% more departures and 3.40% more arrivals.
Comparing the predictions of the ANSP and airport requires having a set of common reference values for realised arrivals and departures per day, but as is seen in Figure 14 and 15 this is not the case. After discussing the discrepancy with experts from both organisations it was concluded that such a substantial deviation could not be explained by differences in definitions of measurement while these sometimes differ by more than 10%. It could have been the case that either one of the measurements included or omitted general aviation, but it was found that both loggings include these movements. Schiphol however does not count flights that are performed in secrecy, like hidden flights by governmental aircraft.

In order to find out why these discrepancies could be so significant, it was posed to do a comparison for two days where the deltas (percentual difference, negative and positive) were largest. It was chosen to look into departures here only as these movements are best predictable for both Schiphol and the ANSP since they originate in Amsterdam. When searching through these values for departures (Figure 14) it is found that Sunday the 5th of April saw the largest surplus (+12.94%) on Schiphol's administration, whereas Sunday the 7th of February saw the largest surplus (+11.39%) on LVNL's loggings. After having received the data, it became clear that comparing which departures were logged and which ones were not would prove complex using the provided flight-specific data.

Although the logging occurs at both stakeholders, they do not store the same data – neither is it structured in a similar format. The ANSP stores more data on the route and type of the aircraft, while the airport stores more information on relevant times, as can be seen in Table 5 and 6. The easiest method for linking the movements would likely be using the flight numbers or IDs, but a quick analysis saw no similarities among these columns. Although some of the flight numbers/callsigns did show some similarity, it did not make for a clear rule of thumb e.g., removing the third letter or inserting a zero prior to a numerical sequence. Another method to make a connection between two flights could be by using a combination of the date and time at which they were logged, but this also proved insufficient. The time logged by LVNL is in the actual take-off or landing time, a value also seemingly logged by the airport. However, after analysing several flights which could be directly matched on their flight number, it was found that the times logged by both partners does not coincide. Since there could be a set difference between the times used (UTC to LT or other time zone), it was tried to shift one of the times forward or backward in time by a fixed number of minutes. This, however, did not yield a set of corresponding times, meaning that the times logged by LVNL and RSG proved very difficult to align.

Since the time and flight number are the only commonalities within the two data sets, there were limited options for linking individual flights. To evaluate the accuracy of the flight predictions done by the two parties it is required to have a baseline value to compare to, but as there was no possibility of verifying the true realisation this evaluation proved too difficult. If more time was taken for the analysis of the two days, it might have been possible to come up with a method for linking the flights on an individual basis.

Flight ID	Date	Direction	Callsign	Flight Type	Aircraft Type	Origin	Destination
11678578	2019-01-01 00:08:19	TAKEOFF	PGT69B	OUTBOUND	A20N	EHAM	LTFJ

Table 5: Used fields for logging realisation at LVNL

A/D	FltNR	Fltnr_Sarp	datetime_SCH	datetime_ACT	datetime_BLK	SERVICE_type
D	MP7121	MPH7121	01-04-2020 01:00	01-04-2020 01:15	01-04-2020 01:04	F

Table 6: Used fields for logging realisation at RSG

As seen from the analysis, it proved impossible to form a daily number of common arrivals and departures due to different methods of logging at the airport partners. Therefore, no useful conclusion can be given on the accuracy of the forecasts in both the OPS Plan and AOP. Although it does not allow for a meaningful statement on which of the predictions would give the best insight in tomorrow's operation, it makes for a recommendation regarding the data storage process. Working towards an inclusive APOC eventually means the stakeholders will have to start using common data sources to base decisions on. For this analysis to be carried out in the future, it is required to have either LVNL store the flight number like RSG or have RSG store the callsign like LVNL. Finding out why the dates and times have shifted can also prove useful in the case that no direct link can be made between the same flight stored in two systems. Once it is found that the stored realisation coincides for both partners or small deviations can be explained by easy analysis, one can start comparing the forecasts for the OPS Plan and AOP. Based on this breakdown it might come to the usage of one, best-performing predictive method for anticipating foreseen traffic within the airport operation centre.

7 Discussion

For forming recommendations on collective operational preparation for the KDC stakeholders operating at Amsterdam Airport Schiphol it has been analysed how individual preparation is done. With the consultation of several experts and the attendance of virtual meetings it has been attempted to map all steps in preparing for tomorrow's works as detailed as possible. Since covid-19 has forced almost all employees to work from home, it has been impossible to schedule a visit to either one of the stakeholders. When physically attending their daily meetings and following the steps taken during the day, one would have been likely to more precisely draw out all steps in their preparatory process – resulting in a better overview of the available data and decisions taken. Although physical visits and meetings did not prove possible, maximum effort has been put into researching partner preparation.

Added to this is the limited extent to which KLM has bundled information regarding their daily operation, not being in the form of daily operational plan as is the case with LVNL and RSG. This brought additional difficulty in the procedure of mapping which information is available and how this is accessed, resulting in omission of their process map for this research. If it were to be provided it might have been possible to better optimize the collective timeline and further specify the information needed from the airline.

Although the theoretical benefits of data-sharing within the preparatory phase are numerous, it should be noted that several quantified improvements mentioned in chapter 5.3 might not be fully realised at Schiphol. Like for many other theories brought into practice, it is mostly found to be slightly less optimal than previously anticipated on paper. The benefits found during this research can only (partly) arise if stakeholders prove willing, now and in the future, to cooperate in data-exchange and allocate time & resources within their own company for further collaboration.

Further case-studies of intensified information among airport stakeholders have sadly not been found since the TAM concept of collating partners into one collective preparatory process is so new. This means that very limited quantifiable benefits have been established, as well as real-world insight into successful implementation. Even after contacting numerous airport representatives that have been actively using intensified information sharing, none of them proved willing to elaborate on implementation or performance of the enhanced process. As EUROCONTROL is currently still conducting investigation into the benefits and implications of intensifying stakeholder collaboration, it is expected that additional real-world examples and applicable advantages will be delivered at the end of 2022.

This research has primarily focused on the information exchange one day prior to operation, whereas EURONCONTROL's AOP outline extends up to D-180. Clearly, due to uncertainty and an abundance of anticipation time it might not be useful to set up a framework for collective preparation alongside its entire timeline. Herein, it could be practical to follow the timeframe in which Schiphol's APOC currently operates, currently not exceeding D-30 to D+1 (D-0 not included). After the airport's operation centre has gained sufficient experience in preparing and evaluating operation, stakeholders could tune in to this pre-existent process and share their available information accordingly. In doing so, partners should periodically evaluate what data they deem relevant for exchange to avoid partner-information overload.

A suggestion for further research is aimed at the set-up of operational evaluation using the KPIs provided in chapter 6.2 in order to assess the performance prior to stakeholder participation and after some time of APOC-inclusion. Another interesting area of further research is as previously mentioned in chapter 6.3 and focusses on evaluating traffic predictability for both LVNL and RSG, given that both stakeholders have standardized their storage of flight movement data for some time. After the ANSP and main carrier have joined the airport's operation centre, additional investigation can be done into data availability for other influential stakeholders for the realisation of total airport management.

8 Conclusion

These conclusions aim to answer the seven main research question as mentioned in chapter 2.1, supported by answers to the seven listed sub-questions provided in the like-numbered chapter.

This research used high-level process analysis of stakeholder preparation on D-1 together with low-level analysis of preparatory works from D-7 up to D-1 to investigate how KDC's main stakeholders could continuously match their planning cycles using relevant and up-to-date partner information. It was found that a collective timeline with set deadlines provides a framework for issuing data updates to a shared database in an orderly and timely manner. Together with assessment of the data elements present in current planning documents and requirements for individual preparation, a new method of organizing operational planning has been provided which enables prior partner anticipation.

The current collaborative decision-making concepts currently in place are primarily focussed on managing ongoing airport processes as the A-CDM implementation at Schiphol Airport demonstrates. Shifting away from actively managing to pro-actively preparing operation, one finds the APOC at the heart of the more advanced TAM concept.

Roles within the preparatory process are very different per stakeholder, as is the planning (document) that they configure. For LVNL, the Pre-tact Unit prepares the OPS Plan in which information is included regarding – but not limited to – traffic volumes, runway configuration and sector configuration. For RSG, the APOC prepares the AOP in which information is included regarding – but not limited to – aircraft, passenger and baggage processes. For KLM, the dispatch department prepares the individual flights in which information is included regarding – but not limited to – flight plans, NOTAMs and passenger lists.

Preparatory processes prove quite similar for both LVNL and RSG as they both configure a (work)daily plan in which a holistic image is rendered for expected D-0 operation. Several experts collaborate on constructing a complete operational forecast using information from various internal and external sources. The preparation for KLM is slightly different as the airline is mostly aimed at individually preparing flights and reviewing foreseen network functioning. Several decision support tools are used for anticipating expected capacity-reducing influences, either as a result of internal or external factors.

Current deficiencies in the process of stakeholder exchange have been researched through feedback analysis and several consultations with various experts from stakeholders. When looking at the current information interchange it is found that not all partners actively share their data, possibly causing individual reticence for own participation to a more collective planning. The ongoing meetings and plan-exchange between the Pre-tact Unit, the APOC and KLM are a good step-up to a more integrated form of operational preparation and prove that willingness to cooperate can come a long way. Here though, cross-distribution of preparatory information occurs mostly via e-mail or online interfaces. Working towards a more collective and inclusive planning process would require other, more standardized manners of transferring data in an organised and secure manner.

The effects that the inclusion of additional information brings to stakeholder's decision-making process are numerous and mostly prove beneficial for operational performance. Although challenging to quantify, benefits at least include enhanced insight in on-going processes, improved predictability of airside operation, refined mechanisms to establish performance baselines with better air- and landside performance management. Translating these theoretical advantages into measurable improvements requires not only active stakeholder participation but also collective evaluation of airport performance. Next to the theoretical benefits that apply to all involved stakeholders, there are also various partner-specific advantages that arise when intensifying information sharing, both on the short and long-term. For the ANSP these add up to better insight in asset availability and condition, de-icing updates for better clearance allocation, more efficient aircraft throughput with less noise pollution. For the airport

these boil down to a holistic view of stakeholders' intentions, enhanced passenger experience with a higher level of service and a reduction in both noise and air pollution. For the airline these sum up to receiving information straight from the authority in charge, better insight in asset availability and condition, earlier indication of regulation scenarios, improved traveller experience and a decrease in fuel consumption.

Planning cycles of involved stakeholders can be combined into a collective process by sharing data elements and can be synched up by various prearranged deadlines on D-1. This proposed method does not completely unite all preparatory processes, as this would require an enormous shift in both time and resource allocation for the participants involved. Instead, it provides partners with a conceptual guideline on what information to share in which moment in time. When eventually working towards the stakeholder-inclusive APOC at Amsterdam Airport Schiphol alongside the TAM-concept, one will likely see gradual amalgamation of partner specific planning.

To eventually measure the exchange of information and the potential performance boost brought alongside it, the process should be actively monitored and assessed using pre-defined KPIs. Analysing adherence to the collective planning framework can be done via monitoring the average times of data updates & AOP publication and the number of data updates during the day. Keeping track of additional informative elements issued to the shared database allows for quantifying improvements over time. Next to assessing the information exchange before operation, it is of importance to evaluate operation after its execution. Using a holistic combination of key performance areas with associated indicators provided by DLR makes for a trusted and proven framework of performance management.

9 Recommendation

From the talks and interviews with experts at the three stakeholders, it was found relatively often that views regarding the APOC did not coincide with the roles and responsibilities as posed by EUROCONTROL, nor in line with the concept's view provided by RSG. Deduced from these interviews it might be good to have several experts from Schiphol's airport operation centre sketch out what is expected of stakeholders that are featured for future APOC-inclusion. This could be in the form of e.g., an explanatory document, an interactive workshop or educative visit to the operation centre. It is key to have the three involved stakeholders line up their expectations for preparing operation more collectively since they form the basis on which new partners will eventually synch in with the airport's control centre.

Working towards an inclusive APOC at Schiphol Airport requires a shared airport operational plan in which relevant stakeholders issue important information in a timely and orderly manner. In order to set up a collective preparatory phase it is best to adhere to the EUROCONTROL concept and ensure the information ends up in the already existent AOP, instead of setting up a new shared preparatory document. In order to collate all relevant updates and informative messaging from involved stakeholders, it is recommended to set up a shared database via which the partner experts can access and submit data via a secured connection. Stakeholders partaking in the airport operation centre might feel like their participation is only to complement the contents of the AOP but should also see the benefits of a having a collective body providing a continuous holistic insight during all phases of airfield functioning (pre-tactical, ad-hoc and post-operation). This does, however, not mean that stakeholders should just yet give up preparing their individual actions on an internal level since there will always be elements that are less relevant to partner stakeholders (e.g., personnel, resource allocation, workload assessments).

If useful conclusions are desired on the achieved improvement throughout the process of preparing for operation in a more collaborative manner, one should have a performance benchmark of current airport functionality. Since present preparatory works are mostly done without many stakeholder interactions it is possible to compare the more individualistic with the joint approach. It is therefore required to start post-operation analysis at the APOC as soon as possible (D+1) to measure potential improvements from gradually intensified information sharing. Assessing what and by how much information improves predictability can prove of great value and might concretize the case for further stakeholder involvement.

Once LVNL and KLM have eventually been physically installed in the operation centre it might be tempting to cross-check every single decision taken due to the real-time response possibilities that working together in person brings. There should however be refrained from discussing every possible judgement made during the day as not all decisions made by representatives in the APOC play out influencing operation of all stakeholders. It is best to use the available time in the shared workspace to collectively examine and discuss situations that impact operation on a multi-stakeholder level.

Setting up a well-functioning operation control centre at Schiphol Airport requires full commitment from involved stakeholders and experts working within these organisations. Both individuals and management teams have to overcome initial reticence to share their data with multiple parties to benefit the operation of their own. Especially since it proves incredibly difficult to translate theoretical benefits into measurable practical improvements, it might seem that active involvement in information sharing may not bring real benefits to operation. The crux here is that in order to translate the abstract paybacks into quantified statements, measurements have to be conducted both prior to and after the set-up of joint preparation to evaluate improvement – still requiring active, collective involvement.

In addition, suggested by one of KLM's flow managers (Rob Arnhem, personal communication, May 24, 2021) was to better evaluate the collective operation, especially when large disruptions have taken place together with sector briefings. He finds that currently, after a period of significantly reduced capacity,

reporting is done on the event(s) after which these documented evaluations end up at the manager's desk. These submissions rarely see active evaluation with individuals who were working when disruptions took place, an easy action that can bring new insights and guidelines for when new capacity reductions occur. Lastly, proposed by one of LVNL's ACC SUPs (Rogier Hendriks, personal communication, June 9, 2021) was to evaluate how the runway predictions from AFOS and the ANSP's own (under construction) support tool hold up against realised runway configurations.

10 Bibliography

ACI Europe. (2017, 04 19). *ACI releases preliminary 2016 world airport traffic rankings*. Retrieved from ACI: https://aci.aero/news/2017/04/19/aci-releases-preliminary-2016-world-airport-traffic-rankings-robust-gains-in-passenger-traffic-at-hub-airports-serving-trans-pacific-and-east-asian-routes/

Alanne, J. (2017, 04 23). *Airport Situational Awareness: Processes and Development.* Retrieved from Theseus: https://www.theseus.fi/bitstream/handle/10024/126723/alanne_joonas.pdf?sequence=1

Alexopoulos, Y. (2021, 03 16). Explanatory: A-CDM / APOC / TAM. (G. Bekkers, Interviewer)

Aviation Strategies International. (2018). *Airport Enterprise Management Centre | A Step towards an Industry Standard.* Montreal: IAP CoP Administrator / Aviation Strategies International (ASI) Institute.

DLR. (2012). *Benefit Assessment in TAMS.* Retrieved from DLR: https://www.dlr.de/fl/en/Portaldata/14/Resources/dokumente/projekte/tams/TAMS_Dissemination_Event_09_Jipp_20120522.pdf

DLR. (2012, 07 30). *TAMS Operational Concept Document.* Retrieved from DLR: https://www.dlr.de/fl/en/Portaldata/14/Resources/dokumente/projekte/tams/TAMS_OCD_v-1-0-1_public.pdf

DLR. (2012). *TAMS Validation Report.* Berlin: DLR.

EUROCONTROL. (2016). *APOC Business Process Reengineering Big Data Study.* Retrieved from https://www.eurocontrol.int/sites/default/files/publication/files/apoc-bpr-big-data-final-report.pdf

EUROCONTROL. (2017). *Airport CDM | The Manual.* Retrieved from EUROCONTROL: https://www.eurocontrol.int/publication/airport-collaborative-decision-making-cdm-implementation-manual

EUROCONTROL. (2017, 09 12). *Ten European airports and the Network Manager implement SESAR concepts.* Retrieved from atcnetwrok: https://www.atc-network.com/atc-news/eurocontrol/ten-european-airports-and-the-network-manager-implement-sesar-concepts

EUROCONTROL. (2018). *Airport Network Integration | Concept for establishment of an Airport Operations Plan (AOP).* Eurocontrol.

EUROCONTROL. (2021, 03 03). *Airport Collaborative Decision Making*. Retrieved from EUROCONTROL: https://www.eurocontrol.int/concept/airport-collaborative-decision-making

Goldnadel, F. (2021, 02). The APOC: The ultra-booster of operational performance. *International Airport Review*, pp. 9-11.

IBG. (2020). *A-CDM & TAM / APOC / AOCC*. Retrieved from IBG Sweden: https://ibg-sweden.se/services/a-cdm-tam-apoc-aocc/

ICAO. (2017). *Seen Through an IATA Lens | A-CDM Globally.* Retrieved from ICAO: https://www.icao.int/SAM/Documents/2017-ACDM/2.0%20IATA_3o_Workshop_ACDM_Lima.pdf

Kelder, H. (2021, 03 10). Explanatory: A-CDM / APOC / TAM.

LVNL. (2021, 03 01). *Corporate Visie Strategie*. Retrieved from LVNL: https://www.lvnl.nl/over-lvnl/corporate-visie-strategie/onze-rol-in-de-keten-versterken

Malaysia Airports. (2019). Retrieved from Annual Report 2019: http://mahb.listedcompany.com/newsroom/MAHB_Annual_Report_2019_-_Part_1.pdf

Papagiannopoulos, N. (2021). The value of data analytics for airports: Use cases and novel methods. *International Airport Review*.

Poland, W., & Grosmann, R. (2021). *Airport Operations Centre Amsterdam Airport Schiphol.* NLR, Amsterdam.

Royal Schiphol Group. (2021). *Annual Report 2020.* Amsterdam: Royal Schiphol Group.

Schiphol. (2019). *Schiphol Airport CDM Operations Manual.* Amsterdam.

Schiphol, LVNL. (2021, 06 23). *Voorspelbaarheid vertrekkend vliegverkeer verbeteren*. Retrieved from Minder Hinder Schiphol: https://minderhinderschiphol.nl/maatregelen/in-behandeling/voorspelbaarheid-vertrekkend-vliegverkeer-verbeteren/

SESAR. (2019). Retrieved from PJ.04 Final Project Report: https://www.sesarju.eu/sites/default/files/documents/projects/FPR/PJ_04%20FPR_Final%20Project%20Report_Edition%2001_00_00.pdf

SILO, AIA, PACE, ISI, CELLOCK. (2019). *D5.2 – Demonstrators Execution Scenarios and Readiness Documentation.* ICARUS.

Zwaaf, D. (2021, 03 16). Explanatory: A-CDM / APOC / TAM. (G. Bekkers, Interviewer)

Appendix I: Contents | OPS Plan LVNL

Feature	Data Type	Responsible	Category
Points of Attention	str	OSD	General
Traffic Supply Remarks	str	OSD & CMA	Traffic Supply ACC
Regulation Scenarios (RS)	str	CMA	Traffic Supply ACC
EHFIRAM Inbound / hour	graph	OSD & CMA	Traffic Supply ACC
EHFIRAM Inbound / hour (20 min.)	graph	OSD & CMA	Traffic Supply ACC
Regulations Points of Attention	str	CMA	Analysis Regulations
RS Date & Time	datetime	CMA	Analysis Regulations
RS Delay Time	int	CMA	Analysis Regulations
RS Delay No. Flights	int	CMA	Analysis Regulations
RS Day-view	graph	CMA	Analysis Regulations
Stack Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
ARTIP Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
RIVER Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
SUGOL Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
Sector Configuration	graph	CMA	Analysis Regulations
S1+S2 Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
S3 Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
S4+S5 Traffic Supply (20 min.)	graph	CMA	Analysis Regulations
Weather Forecast Description	str	OSD & CMA	Weather Forecast
Runway & Capacity Inbound-peak	str / int	OSD	Runway & Capacity
Runway & Capacity Outbound-peak	str / int	OSD	Runway & Capacity
Runway & Capacity Off-peak	str / int	OSD	Runway & Capacity
Alternative Configurations Remarks	str / datetime	OSD	Runway & Capacity
Seasonal Inbound-peak Times	datetime	CMA	Runway & Capacity
Seasonal Outbound-peak Times	datetime	CMA	Runway & Capacity
Seasonal Off-peak Times	datetime	CMA	Runway & Capacity
Schiphol Traffic Remarks	str	OSD	Runway & Capacity
Runway Configuration Day-view	graph	CMA	Runway & Capacity
No. Departures & Arrivals Day-view	graph	CMA	Runway & Capacity

Appendix I(A): Manual output for OPS Plan of LVNL

Feature	Data Type	Source	Category
No. Departures + Arrivals	int	NM PREDICT	General
No. Flights ACC	int	NM PREDICT	General
Inbound Peak Hour	datetime	NM PREDICT	General
Inbound Peak No. Flights	int	NM PREDICT	General
Runway / Capacity Announcements	str	NOP / ISC plan.	Remarks / NOP
Network Operations Plan	str	NOP	Remarks / NOP
Technical Maintenance	str	ISC planning	Maintenance / OHD
OHD Special Events	str / datetime	DOP / OPS help.	Maintenance / OHD
Test & Survey Flights	str / datetime	DOP / OPS help.	Maintenance / OHD
Additional Information	str / datetime	DOP / OPS help.	Maintenance / OHD
Weather Forecast	int / datetime	KNMI	Weather Forecast
No. Departures & Arrivals	int	NM PREDICT	Runway & Capacity

Appendix I(B): Automatic output for OPS Plan of LVNL

Appendix II: Contents | AOP RSG

Feature	Data Type	Responsible	Category
Points of Attention	str	APOC	Integral Overview
Critical Path	graph	APOC	Integral Overview
Points of Attention Aircraft Process	str	APOC	Aircraft
Geographical Points of Attention	map	APOC	Aircraft
Critical Path Aircraft Process	graph	APOC	Aircraft
Particularities In- & Outbound	str	APOC	In- & Outbound
Geographical Points of Attention	map	APOC	APC
Additional Information	str	APOC & APC	APC
NOP Points of Attention	str	NOP & APOC	NOP
Maintenance Activities	str / datetime	Kermit & APOC	Aircraft Maintenance
Long-term Maintenance Activities	str / datetime	Kermit & APOC	Aircraft Maintenance
Important Memo's	str / datetime	APOC	Memo's
Passenger Points of Attention	str	APOC	Passenger
Scenarios & Measures	str / datetime	APOC	Passenger
Passenger Critical Path	graph	APOC	Passenger
Check-in Points of Attention	str	APOC	Departure Hall
Handlers	str / int	Handlers / APOC	Departure Hall
Operational Bottlenecks Departure	str	APOC	Departure Filters
Koninklijke Marechaussee (KMAR)	str	KMAR & APOC	Departure Filters
Security	str	Security & APOC	Departure Filters
Operational Bottlenecks Transfer	str	APOC	Transfer Filters
KMAR	str	KMAR & APOC	Transfer Filters
Security	str	Security & APOC	Transfer Filters
Additional Information	str	APOC	Transfer Filters
Operational Bottlenecks Arrivals	str	APOC	Arrival Filters
KMAR	str	KMAR & APOC	Arrival Filters
Customs	str	Douane & APOC	Arrival Filters
Reclaim	str	APOC	Arrival Filters
Maintenance Activities	str / datetime	Kermit & APOC	Pax. Maintenance
Geograph. Maintenance Activities	map	Kermit & APOC	Pax. Maintenance
Long-term Maintenance Activities	str / datetime	Kermit & APOC	Pax. Maintenance
Assets in Failure	str / datetime	Kermit	Pax. Maintenance
Important Memo's	str / datetime	APOC	Pax. Memo's
Landside Points of Attention	str	APOC	Landside
Possible Particularities Pax. Flow	str	APOC	Landside
Scenarios & Measures	str / datetime	APOC	Landside
Landside Points of Attention	str	APOC	Capacity & Supply
Forecast Ceintuurbaan + K&R	graph	APOC	Capacity & Supply
Parking	str	Schiphol Parking & APOC	Capacity & Supply
Public Transport	str	APOC	Capacity & Supply
Operational Permit Airside (OVA)	str	Kermit & APOC	Capacity & Supply
Maintenance Activities	str / datetime	Kermit & APOC	Land. Maintenance
Geograph. Maintenance Activities	map	Kermit & APOC	Land. Maintenance

Long-term Maintenance Activities	str / datetime	Kermit & APOC	Land. Maintenance
Memo's	str / datetime	APOC	Land. Memo's
Baggage Points of Attention	str / datetime	APOC	Baggage
Baggage Critical Path	graph	APOC	Baggage
Geograph. Baggage Points of Attention	map	APOC	Baggage
Operational Points of Attention	str	APOC	Forecast Baggage
Forecast Handlers	str	Handlers & APOC	Forecast Baggage
Security HBS	str	APOC	Forecast Baggage
Customs	str	Douane & APOC	Forecast Baggage
OVA	str / datetime	Kermit & APOC	T1
Reclaim 1	graph	APOC	T1
T1 Points of Attention	str	APOC	T1
OVA	str / datetime	Kermit & APOC	T2/E
T2 Points of Attention	str	APOC	T2/E
OVA	str / datetime	Kermit & APOC	D
TSD Points of Attention	str	APOC	D
OVA	str / datetime	Kermit & APOC	T3
T3 Points of Attention	str	APOC	T3
Maintenance Activities	str / datetime	Kermit & APOC	Bag. Maintenance
Long-term Maintenance Activities	str / datetime	Kermit & APOC	Bag. Maintenance
Memo's	str / datetime	APOC	Bag. Memo's
Snow / Slipperiness	str	APOC	Weather Forecast

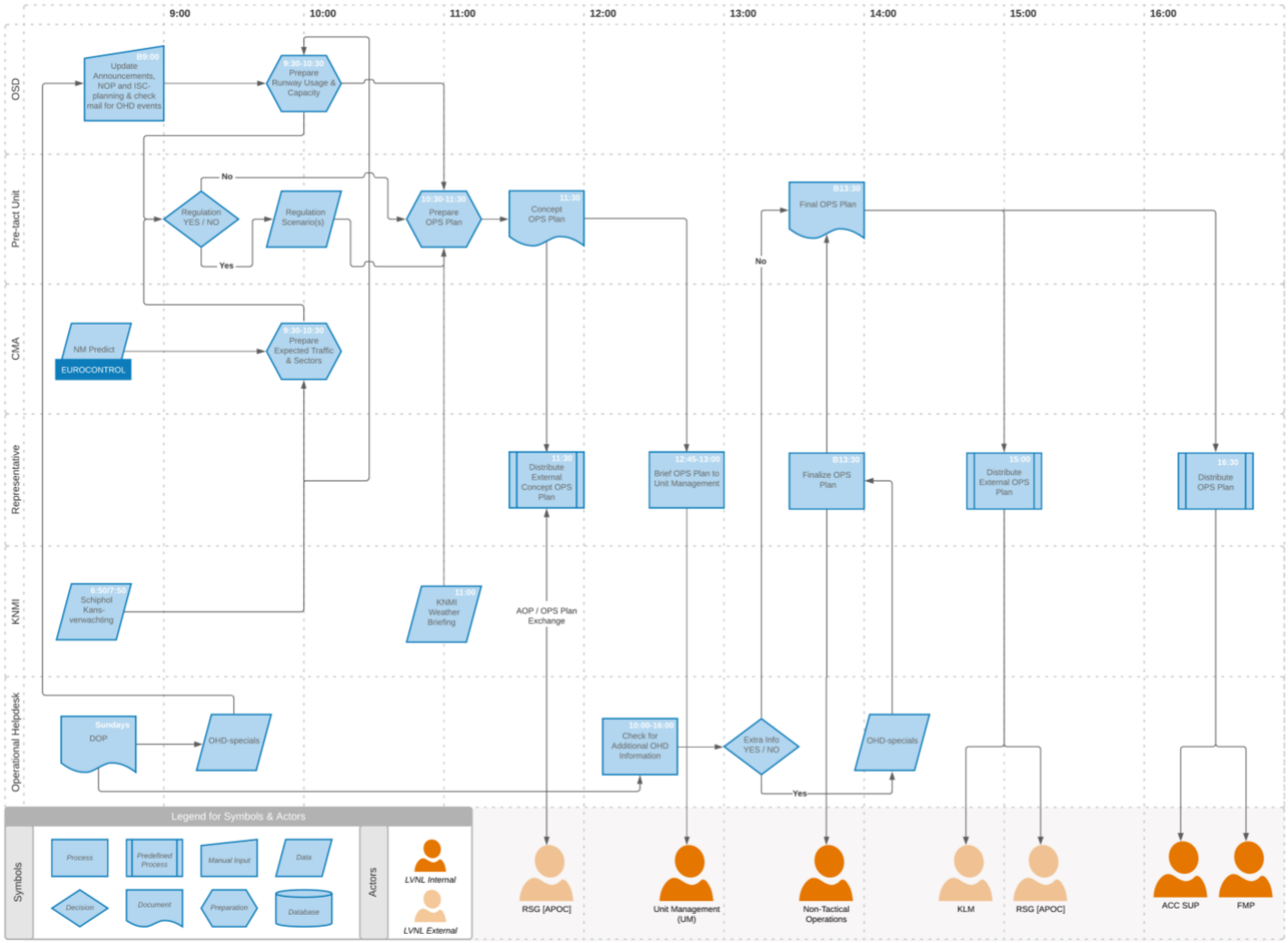
Appendix II(A): Manual output for AOP of RSG

Feature	Data Type	Source	Category
Weather Forecast	str	KNMI	Integral Overview
No. Aircraft	int	CISS & TAF	Integral Overview
No. Passengers	int	CISS & TAF	Integral Overview
No. Baggage Items	int	CISS & TAF	Integral Overview
Uniform Daylight Period (UDP)	datetime	AIP	Aircraft
No. Passenger Arrivals	int	CISS & TAF	In- & Outbound
No. Other Arrivals	int	CISS & TAF	In- & Outbound
No. Total Arrivals	int	CISS & TAF	In- & Outbound
No. Passenger Departures	int	CISS & TAF	In- & Outbound
No. Other Departures	int	CISS & TAF	In- & Outbound
No. Total Departures	int	CISS & TAF	In- & Outbound
No. Departures & Arrivals Dayview	graph	CISS & TAF	In- & Outbound
Gate / Apron Capacity	str	GMS & APC	APC
NOTAM	str	NOTAMinfo	NOP
Gate Maintenance	str / datetime	Kermit & APC	APC
No. Departing Passengers	int	CISS & TAF	Passenger
No. Transferring Passengers	int	CISS & TAF	Passenger
No. Arriving Passengers	int	CISS & TAF	Passenger
Forecast Departure Hall Day-view	graph	Flow4cast	Departure Hall
Forecast Transfer Day-view	graph	Flow4cast	Transfer Filters
Forecast Arrival Day-view	graph	Flow4cast	Arrival Filters
No. Baggage Check-ins	int	FACT department	Forecast Baggage
No. Baggage Transfers	int	FACT department	Forecast Baggage

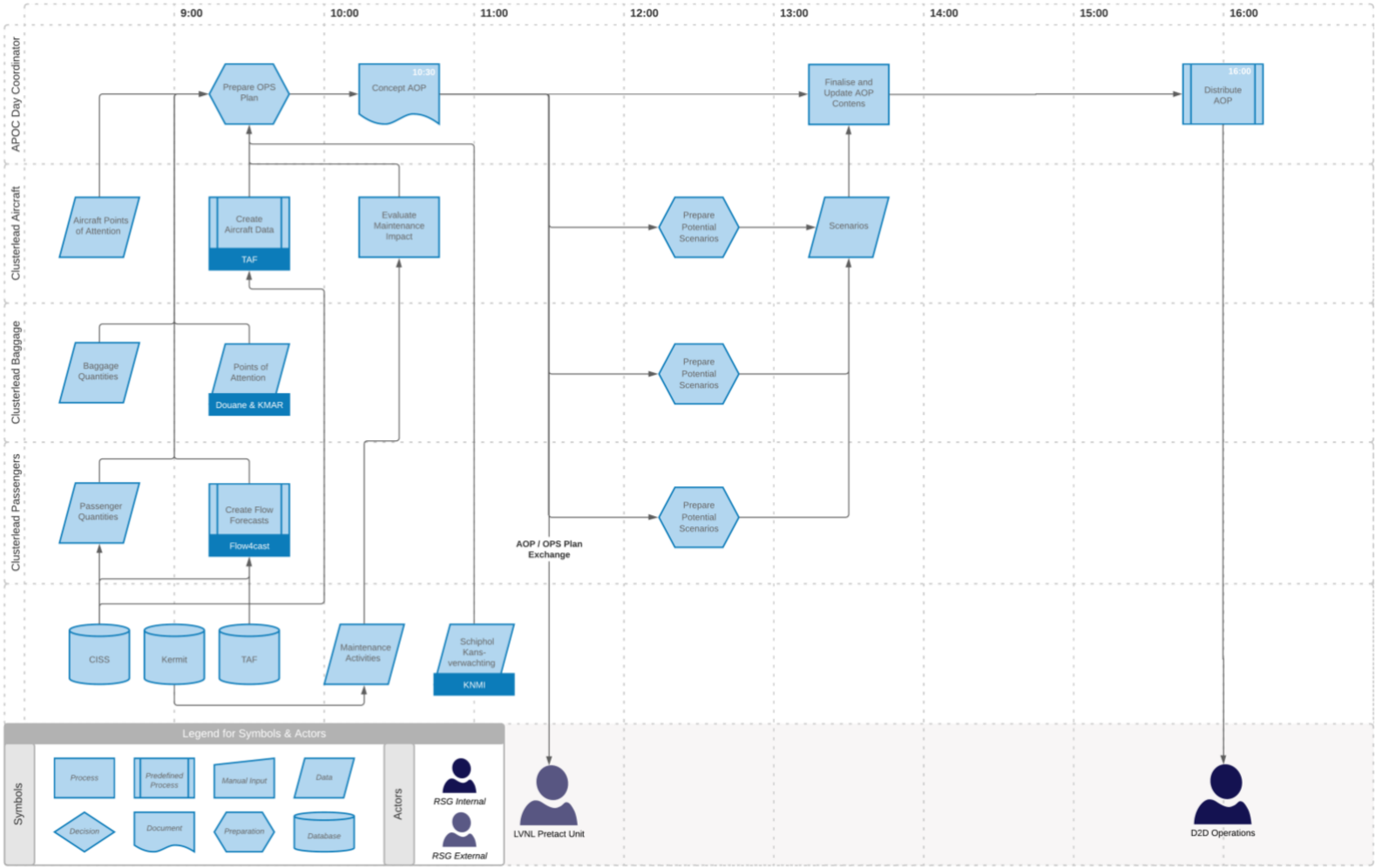
Forecast Baggage Day-view	graph	FACT department	Forecast Baggage
Layout Z Day-view	graph	Baggage department	T1
Planning Z Day-view	graph	Baggage department	T1
Planning Loskade Z	graph	Baggage department	T1
Layout E Day-view	graph	Baggage department	T2/E
Planning UQE Day-view	graph	Baggage department	T2/E
Layout D Day-view	graph	Baggage department	D
Planning TSD Day-view	graph	Baggage department	D
Layout W Day-view	graph	Baggage department	T3
Planning T3 Day-view	graph	Baggage department	T3
KNMI Briefing	str	KNMI	Weather Forecast
No. Early Passengers	int	FACT	Capacity Forecast
No. Late Passengers	int	FACT	Capacity Forecast
No. Night Passengers	int	FACT	Capacity Forecast
No. Passengers per Service	graph	FACT	Capacity Forecast
No. Passengers A+D Day-view	graph	FACT	Capacity Forecast
No. Transfer Pax. per Service	graph	FACT	Capacity Forecast

Appendix II(B): Automatic output for AOP of RSG

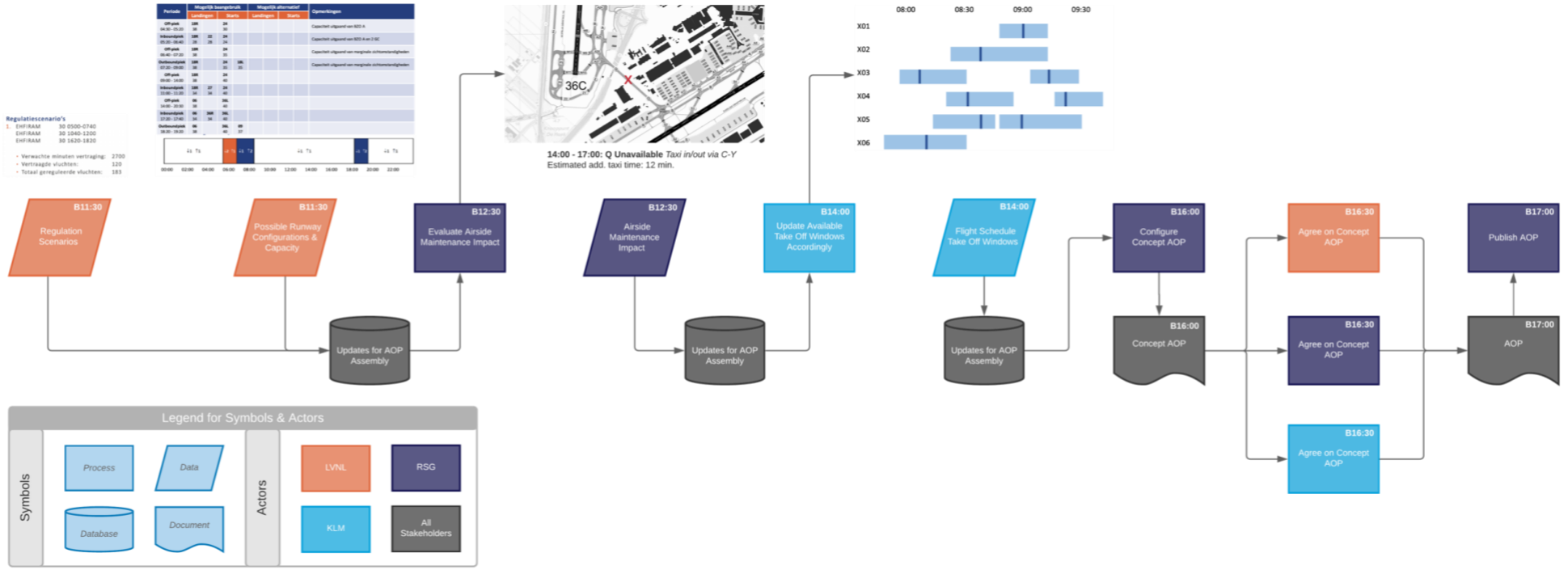
Appendix III: Process Map | OPS Plan LVNL



Appendix IV: Process Map | AOP RSG



Appendix V: Process Map | Collective Preparation



Appendix VI: Proposed KPIs/KPAs for TAM with APOC

KPA	KPI	Metric
Traffic Volume & Demand	Handled Traffic	Number of flights arrived and departed to and from an airport in a given period of time.
	Handled Passengers	Number of arriving and departing passengers processed in a given time period.
Capacity	Airport Declared Capacity	Average number of airport slots per hour.
	Slot Compliance	Number of TOBT not compliant with CTOT. / Number of flights departing outside assigned CTOT.
	Terminal Capacity	Average number of available process stations in a given time period.
Punctuality	Arrival Punctuality	Comparison AIBT to SIBT. / Percentage of flights arriving no more than 15 minutes late compared to scheduled arrival times.
	Departure Punctuality	Comparison AOBT to SOBT. / Percentage of flights departing no more than 15 minutes late compared to scheduled departure times.
	Early Arrivals	Percentage of flights arriving 15 minutes or more ahead of schedule.
	Departure Delay Causes	Percentage of contributory cause to departure delays (based on airline reported IATA delay codes).
	Waiting Time at Runway	Aggregated comparison ATOT to AOBT with taxi time.
	Boarding Punctuality	Aggregated comparison of ASBT to ESBT for different times of measurement.
	Passenger Connectivity	Percentage of passengers catching their connection flight (of all transfer passengers) in a given time.
Efficiency	READY Reaction Time	Aggregated comparison push-back/taxi given and AOBT push-back delay.
	Aircraft Stand & Passengers Gate Freezing Time	Number of short-term position changes in a given period of time.
	Level of Service (LoS)	Actual LoS compared to planned LoS over a given time.
Predictability	Stand Allocation Accuracy EIBT	Aggregated comparison EIBT to AIBT.
	Stand Allocation Accuracy EOBT	Aggregated comparison EOBT to AOBT.
	TOBT / TSAT Predictability	Precision of TOBT for different times of measurement, aggregated comparison TOBT to best estimate.
	TTOT Predictability	Aggregated comparison TTOT to ATOT for different times of measurement.
	ELDT Predictability	Aggregated comparison ALDT to ELDT for different times of measurement.

	EPGT Predictability	Aggregated comparison APGT to ETPG for different times of measurement.
Environment	Noise on Ground	Measure taxi-in and taxi-out times.
	Emission from Ground Vehicles	Measure driven kilometres per type of vehicle.
	Airport Infrastructure Energy Efficiency	Measure consumption of power, water, etc.
Safety	Number of Aircraft Queuing on Sequence	Measure the number of aircraft queuing on sequence.
	Number of Safety Incidents	Measure the number of safety incidents (airside and landside).
Security	Number of Security Incidents	Measure the number of security incidents (airside and landside).

Appendix VI: KPIs/KPAs for TAM with APOC as proposed by DLR (DLR, 2012)