KDC research agenda 2026 - 2030

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Content overview

The Knowledge and Development Centre (KDC) is a foundation which objective is to support the innovation of Mainport Schiphol, to ensure a sustainable future for aviation in the Netherlands. Within KDC, the sector partners KLM, RSG and LVNL co-operate coordinate their development activities and cooperate with knowledge institutes such as the Netherlands Aerospace Centre, the NLR, consultancy firms and universities.

The research and development activities in KDC are managed on the basis of a KDC research agenda. The research agenda contains a description of studies that are currently active as well as proposed research topics. Furthermore, this document is used to set priorities between projects whilst maintaining a clear overview of proposed research questions. Research projects become active when the KDC board has given a formal ‘go ahead’, based on a study plan (or proposal) and the financial proposal by the KDC management team.

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1 Introduction

The Knowledge and Development Centre (KDC) is a foundation which objective is to support the development and innovation of Schiphol as a mainport. Within KDC, the sector partners KLM, RSG and LVNL co-operate with knowledge institutes such as the Netherlands Aerospace Centre - NLR, consultancy firms, Delft University of Technology, Amsterdam University of Applied Sciences and the Dutch meteorology institute KNMI. Industry partnerships are also part of the KDC framework.

The KDC research agenda contains a work program for the innovation of Mainport Schiphol operations, in particular the airside part of the Schiphol operation. Studies which require the involvement of multiple sector partners or knowledge institutes are candidate subjects for the KDC research agenda. KDC can initiate research projects if requested by e.g. the government (i.e. the Department of Infrastructure and Water Management, and its programs) or by one of the sector partners. The objective of the research agenda is to provide guidance to the work program 2026 and beyond. The KDC research agenda is a multi-annual agenda with a time horizon of five years.

The research agenda 2026 – 2030 will be executed within the context of the post-corona era which is characterized by a gradual recovery of global aviation. With the recovery, reduction of the environmental footprint of aviation will become increasingly important. Other contextual developments for the KDC research agenda are:

- The national airspace re-design program has identified a large number of technological and logistical innovations which need to be developed in support of the future airspace concept. The required developments include new capacity management techniques, in support of stable and predictable traffic handling.
- With the implementation of iCAS as the next generation ATM system by LVNL, the transition to Trajectory Based Operations (TBO) will become an important theme. TBO is the enabler for the “next-level performance” of the ATM system, in the area of safety, flight efficiency and environmental sustainability.
- The advent of artificial intelligence solutions (AI) is a key area of innovation in society, which also brings potential benefits to aviation. KDC intends to develop AI based solutions for Schiphol operations, with the aim to expand the level of automation in ATM.

An important national policy link for the KDC research agenda (beside the national airspace redesign program) is the program to reduce noise annoyance in the greater Schiphol area (minderhinderschiphol.nl). Within the KDC feasibility of new potential solutions is researched, which may find their way into the *minderhinderschiphol* program.

1.1 Structure of the Agenda

The agenda is structured as follows: chapter 2 presents the scope and strategic objectives of the program for the duration of the program. Chapter 3 presents the focus for the next year, as part of the multi-year program. Chapter 4 presents the descriptions of the development subjects. The development subjects are clustered around the strategic objectives for the ATM system in terms of performance.

The five research agenda clusters are:

1. Safe Airspace and Airport Navigation
2. Environmental sustainability
3. Operational Efficiency
4. Flow- and Capacity Management
5. Meteo innovation

2 KDC research agenda

The KDC sets itself the task of offering valuable and useful solutions for the sustainable development of the Mainport Schiphol. This task is executed by defining and realizing target orientated projects with close consultation of both the air transport sector and the government (Dept. of Infrastructure & Water Management).

2.1 Scope

The scope of KDC-projects varies from applied research to the development of executable system concepts. Examples are: technology explorations, ATM-process analysis and simulations, concept development, feasibility studies, performance analysis (e.g. economical security aspects and/or environmental aspects).

Fundamental/basic research is considered outside the scope of the KDC. This is considered to be a task of the universities and knowledge institutes. Engineering and realisation (implementation) is a responsibility of the individual sector partner and are normally also considered outside the scope of the KDC.

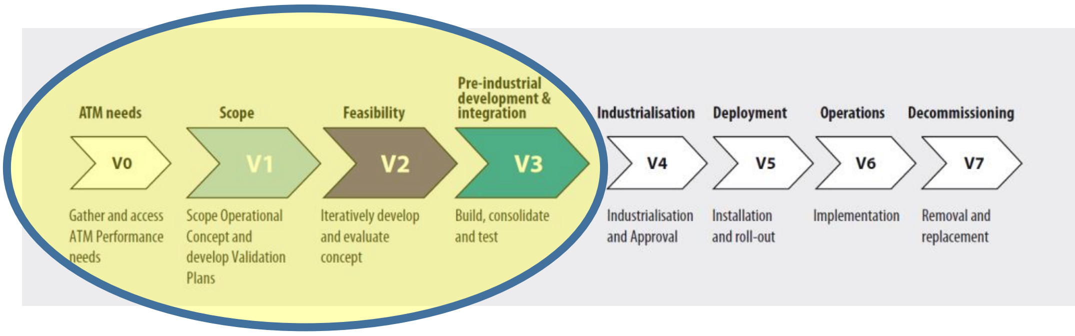


Figure 1: Scope of KDC-projects
(concept life cycle model, European Operational Concept Validation Methodology, E-OCVM)

For each KDC subject a Technology Readiness Level (TRL) and a E-OCVM CLM phase has been determined. The TRLs are a systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology. The TRL scale varies from TRL 1 to TRL 9. A more detailed description of the TRLs may be retrieved in Appendix A.

The E-OVM methodology is described by EUROCONTROL as a framework to provide structure and transparency to the validation of operational ATM-concepts, from early phases of development towards implementation. The complete lifecycle is subdivided into eight ‘V’ phases. The principal relation between the TRLs and Concept Lifecycle Model (CLM) phases is shown in the figure 2.

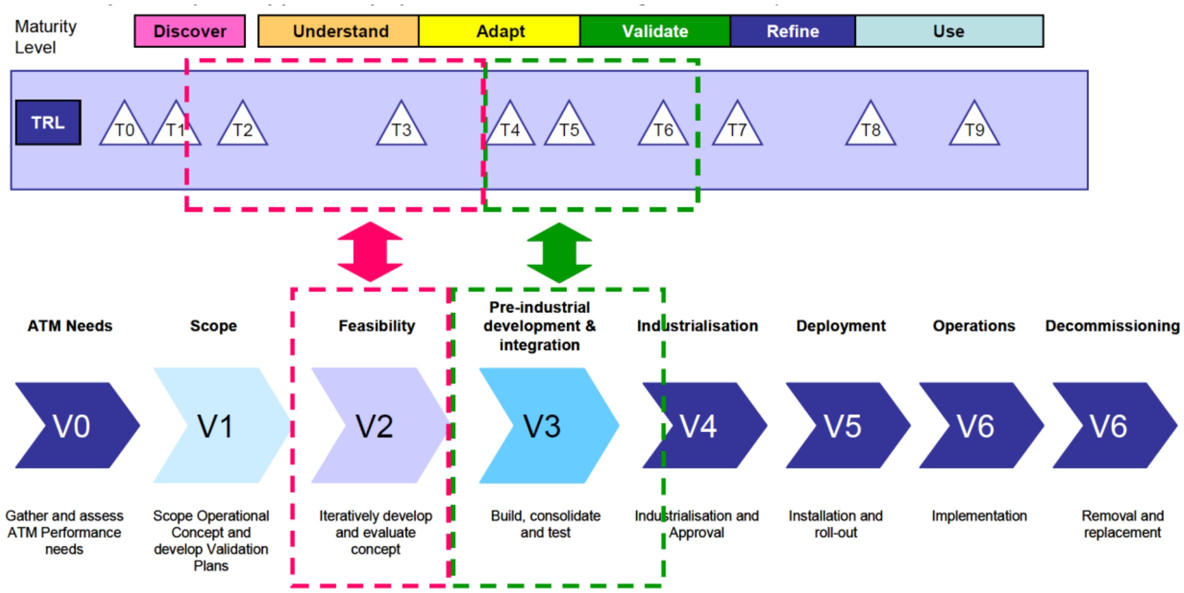


Figure 2: Principal relationship between the NASA TRLs and the E-OCVM CLM phases (source: EUROCONTROL, 2018)

In summary it can be stated that KDC research topics typically have a TRL level in the range of 3 to 6.

2.2 Management of the research agenda

The initial version of the research agenda was released in 2006, when KDC was established as a foundation. Since then the KDC research agenda is maintained by means of annual updates (or in some cases two releases per year).

The KDC program is a multi-annual program, managed on an the basis of an annual budget. Priorities are set by the KDC-Board on the basis of proposals made by the MT-KDC, and in consultation with the Dept. of Infrastructure and Water Management. These priorities indicate the sequence of execution for the studies. The sequence depends on a number of factors. One aspect is the time required to mature the assignment, i.e. the time lapse between the initial description of the development subject, and the approved assignment for the call for proposals. Depending on the subject and the parties involved this process may take several months. Underlying this process of course are the main driving factors in the priority setting: the urgency of the stated problem and/or the assumed benefit of the development in the near term.

Characteristics of KDC studies are:

- The assignment must have a direct relationship with the innovation of Mainport Schiphol.
- Multiple stakeholders share the requirement(s).
- Collaboration between different (knowledge/expertise) parties is needed to achieve a good/applicable solution (multidisciplinary solutions).

KDC studies focus on the development of so-called “building blocks[1]” that can be developed in a period of one to two years. Beside these “building block studies” KDC also performs, in some cases, strategy-structuring studies. These type of studies are intended to structure a new development area as input to the research agenda itself. An example is the “Transition to Trajectory Based Operations” which constitutes a large and complex operational change that affects a wide variety of operational components.

For each subject, a short description is given as well as the expected results and involved parties.

2.3 Strategic Objectives

The multi-annual research agenda addresses five development themes, each for which strategic objectives have been defined. The five development areas are:

1. Safe Airspace and Airport Navigation
2. Environmental Sustainability
3. Operational Efficiency
4. Flow- and Capacity Management
5. Meteo Innovation

In the following chapters each development area addresses its strategic objective for the 2026 – 2030 timeframe.

2.3.1 Safe Airspace and Airport Navigation

Within the theme of safety, not much research has been conducted in the context of KDC in recent years. This is partly due to the fact that the ISMS was set up in 2018, with its own research budget and activities. In addition, NLR has a substantial research budget for safety-related research that supports technological innovation themes (such as drones, autonomous flight / unmanned aviation, automation and digitalization).
However, safety-related research is of strategic importance for the development future ATM concept as well. The focus in the KDC is on the development of new applications that do not necessarily result from operational trends or incidents (as in the case of ISMS) or the advent of new technology. The transition to trajectory based operations, or plan-based ATM, and the implementation of data link changes the role of the human in the ATM system and offers new possibilities to develop safety-enhancing applications. This includes increasing the integrity of communication and conformance monitoring applications.

The KDC objective for the development of Safe Airspace and Airport Navigation in the 2026 – 2030 timeframe is:

Support safety validation aspects of the future ATM concept.

This objective will be achieved through the Air-Ground datalink evaluation studies, which commenced in 2024. In this study datalink solutions which provide both efficiency and safety benefits will be developed and operationally evaluated. In particular safety benefits are expected from the use of ADS-C data, which contribute to check the integrity of airborne and ground processes.

[1] In this document a “building block” is defined as an air traffic management solution that consists of a combination of changes in the area of systems, procedures, and training.

2.3.2 Environmental Sustainability

The development of innovative solutions to limit noise annoyance[2] and to reduce emissions are important for the future of Schiphol. For the period up to 2030, solutions in this area are expected on the basis of three technological developments:

a) The increased use of the navigation capabilities of modern aircraft
b) Developing advanced planning systems and including environmental aspects in planning and flight execution
c) Chain optimization (improved collaboration between stakeholders) and early influencing of traffic

These developments are intended to ensure that traffic is handled as much as possible from environmentally-preferred runways and that, as much as possible, noise-optimized routes and profiles are flown.

The reduction of emissions has become increasingly important for the future of aviation. For the KDC, this subject is embedded in almost every other subject, as it is very much in line with improving operational efficiency and reducing fuel burn. Examples are:

1. The new TMA concept with increased levels of continuous descent operations
2. Extended arrival management development with the aim to reduce delay absorption at low altitudes
3. Traffic segregation solutions to improve environmental performance and to facilitate a new generation of (electrically propelled) aircraft

The KDC objective for the development of Environmental Sustainability in the 2026-2030 timeframe is:

Support the development of building blocks that generate environmental benefits on the basis of advanced aircraft capabilities, technology and collaboration between stakeholders.

2.3.3 Operational Efficiency

It is important for Schiphol's hub function that a high degree of reliability of the transfer process can be guaranteed under all circumstances. This requires that the airport's capacity is made insensitive to weather conditions as much as possible. In addition, it is important that capacity-limiting weather conditions can be “forecasted” as reliably and as early as possible as well.

It should be expected, as Schiphol airport operates close to the limits of its capacity, that the hub function will become more sensitive to disruptions. For the hub function it is important that “connecting flights” can be safeguarded from delays that are the result of disruptions and non-nominal conditions. The priority sequencing concept can support the hub function, even when the airport is close to being saturated (with increasing network delay as a result).

The KDC objective for the development of Airline & Airport Operational Efficiency in the 2026-2030 timeframe is:

Support the further increase of the operational reliability of the hub function of Schiphol airport and support the increase of the operational efficiency for the airlines.

[2] Note: The overall program to reduce noise annoyance is published on minderhinderschiphol.nl (in Dutch).

2.3.4 Flow- and Capacity Management

The development of flow- and capacity management involves improved insight in available capacity (given weather conditions and other variables) and tailoring demand to the capacity as closely as possible, based on common agreed performance indicators. The development of capacity management is a complex matter, as it affects all parts of the Dutch ATM system, and is strongly influenced by decisions made within the European network.

For the future of Schiphol, it is important that the capacity management functions are state-of-the-art, so that local capacity decisions can be made in appropriate planning stages as part of the European planning processes. The development of capacity management also has strong interfaces with Schiphol's environmental objectives, because it affects the predictability of traffic handling and the planned use of runways (within the agreed framework).

The KDC objective for the development of Capacity Management the 2026-2030 timeframe is:

> *Support the development of multi-stakeholder capacity management processes with the aim to support the transition to the future ATM concept and to support the hub function of Schiphol airport.*

2.3.5 Meteo Innovation

Weather has a major influence on aviation in general and airport operations in particular. Meteorological forecasts for Schiphol have a very significant influence on the planning and realization of the airport's capacity.

It is therefore important that the national appointed service provider for meteorological services in the Netherlands, the KNMI, demonstrates a continuous development in the field of weather forecasting for aviation. Due to its big impact, even small improvements in the accuracy of meteorological forecasts have large returns.

The KDC partners expect KNMI to continuously make analyses of its performance. Knowing that weather forecasting is often based on statistical models, performance must be measured over longer periods to get an idea about the validity of these models.

The KDC partners expect KNMI to take its own initiatives to improve performance and expect performance improvements to be monitored and actively reported.

In general, the trend is that sector parties are planning their operational processes with greater time horizons and intend to take operational decisions earlier in the process. This requires decision information, including meteorological forecasts, to be available at a greater time horizon, and with greater accuracy/certainty.

The KDC objective for the development of meteorological services in the 2026-2030 timeframe is:

> *Support the development of more accurate planning processes at greater time horizons through the provision of improved weather forecasting.*

2.4 Airspace user perspective

A literature study, conducted in the analysis phase of the first version of the research agenda, revealed what research is relevant for each sector partner. KLM's top priority as a hub carrier is to guarantee a reliable flow of inbound and outbound traffic at Schiphol. Capacity and reliability of the capacity (also called “sustainability”) ensure passenger connections can be realised. An important part of the research agenda is aimed at improving the sustainability of the capacity whilst increasing the capacity for various meteorological conditions.

Generally, for airspace users, such as KLM, it is important to continuously improve their efficiency. Part of the research agenda aims at efficiency improvements at Schiphol and in the Dutch FIR in strong cooperation with LVNL and RSG.

The figure below (figure 3) shows that certain runway combinations (indicated by roman numbers) deliver less hourly capacity compared to other runway combinations. Furthermore, the visibility conditions (good, marginal and poor) also have significant influence on the available capacity. Not all runway combinations are always available. Use of less favourable runway combinations can result in reduced capacity.
The KDC research aims to increase airport capacity and reliability of the capacity as indicated by the arrows in figure 3.

It should be noted that within the framework of the KDC that *capacity* is not equivalent to *traffic volume*. Capacity of the airport, or rather throughput is very much synonymous with quality of the airline network and is synonymous with reduction of secondary runway use. As throughput increases for a given traffic volume, the duration of runway use decreases, which greatly helps to alleviate noise annoyance.

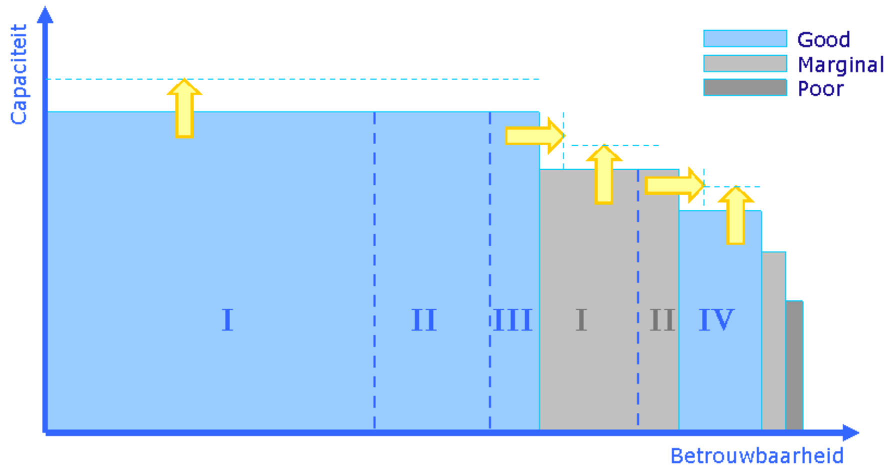


Figure 3: Sustainability (reliability of the capacity) vs. Capacity

3 Planned activities for 2026

The activities which will take place in 2026 are the result of the priority setting by the KDC board within the 2026-2030 program. Two types of activities can be distinguished in 2026:
a) Development of solutions in support of the Dutch Airspace Redesign Program
b) Development of air-ground datalink applications
Studies which address a specific application or function are considered to be part of the "building block development".

In 2026 the focus will be on the further development and validation of building blocks as most of the needed strategies have been developed in the 2021-2023 period. An area that will come into focus in the period 2026 – 2030 is the increased application of artificial intelligence techniques in aviation as described in the current EASA roadmap and the related roadmap of automation in ATC in Eurocontrol's ATM masterplan.

3.1 Summary of main activities

Below a summary is given of the subjects which are put forward for development in 2026 on the basis of priorities that have been proposed by the KDC management team.

A. Safe Airspace and Airport Navigation

1. **Air-Ground datalink operational validations (section 4.1.1)**
   This study will consist continuation of a study that was performed in 2022 – 2023 by the NLR. In this study two aspects will be addressed:
   1) A further detailing of CPDLC applications that are beneficial within the context of Schiphol
   2) An operational evaluation of ADS-C applications with the aim to improve operational efficiency and safety.
   It is expected that datalink application development will continue into 2027 and 2028.

B. Environmental sustainability

1. **Maintenance works impact model (section 4.2.3)**
   Planning of airport maintenance has been a subject that has been studied and developed in the KDC in the past. The focus so far was to determine the optimum time period to plan runway/taxiway maintenance, and to look into maintenance strategies, combining several maintenance activities in one larger activity, thus minimizing overall impact. In 2024 a new study was lauched looking into a broader set of performance indicators that are of interest to maintenance planning. Environmental impact being the prime performance area of interest. In 2025 the full potential of the model had not been achieved yet. Therefore in 2026 the development of this domain will continue.

2. **The development of RNP procedures, design and evaluation (section 4.2.4)**
   Making use of the advanced navigation capabilities of aircraft is important to support the new TMA concept based on fixed arrival routes and CDO. Furthermore RNP can be used to optimize arrival routes. In 2026 the KDC continues the study into feasibility and benefit aspects of advanced navigation capabilities of aircraft.

3. **NOMOS data research (section 4.2.11)**
   A two year study will be launched in collaboration with the Delft University of Technology to gain more insight in the measurement that have been made by the Schiphol Noise Monitoring system. This study will correlate operational improvements to actual noise measurements rather than noise models.

C. Operational Efficiency
   No studies are conducted in 2026 that focus solely on operational efficiency.

D. Flow and Capacity Management
   No studies are conducted in 2026, under the umbrella of the KDC, however, several activities in this domain have been initiated in the KDC Centre of Excellence.

E. Meteo Innovation
   No studies are conducted in 2026, under the umbrella of the KDC, in the area of meteo innovation.

3.2 Priority setting

As the KDC has a limited budget, compared to the scope and content of the program, priorities need to be set (factors playing a role in the setting of priorities are described in section 2.2). Within the currently known subjects, in the 2026 -2030 timeframe, a prioritisation has been made which led to a scope for 2025 (as described in section 3.1) which has been continued into 2026.

The following topics have been proposed by the KDC management team as development subjects for 2026:

Studies which started in 2025, which will be continued in 2026:
1. Air-Ground datalink operational validations, including prototype development for evaluation of ADS-C data
2. Established on RNP procedures, design and evaluation
3. Maintenance Works Impact Model
4. NOMOS research engineer

A number of subjects are still under development. For these subjects its too early to state with certainty what the context and scope of the assignment will be. These subjects are related to the following domains:
a. The further development and implementation of Arrival Management Concepts (4.2.1)
b. The further development of TBO. For this subject a PhD has been assigned to further develop this domain. It is expected that the development of the work program of the PhD will also lead to research subjects as part of the KDC research agenda.
c. The further development of artificial intelligence (AI) applications. This domain has been taken on in the KDC Centre of Excellence and its expected that it will also become an integral part of the KDC Research agenda.
d. Research into meteorological subjects such as climate change and the possible impact on Amsterdam Airport Schiphol.

4 Description of research subjects

4.1 Safe Airspace and Airport Navigation

4.1.1 Air-Ground datalink operational validations

Ref. Ext. Program	-	**TRL**	7			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval	30-11-2023	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	-
Financial Partner	DGLM					

Introduction:
The EUROCONTROL Link 2000+ program provides en-route Controller-Pilot Data Link Communication (CPDLC) services, which allow for the direct exchange of text-based messages between a controller and a pilot. The CPDLC messages automates routine tasks that can take up to 50% of a controller's time.

In 2023, KDC completed an implementation strategy for both CPDLC services as ADS-C based operational improvements. The study made a number of recommendation for the progression of this area of innovation. The most important recommendation is to further evaluate/validate suitable CPDLC services.

Goal / Expected benefit:
The goal of implementing air-ground datalink is to increase capacity and safety in the airspace below FL245 and in ground movements. This is done by replacing routine RT contact (e.g. transfer of control -, weather (QNH, wind data) -, or direct-to incentives) by text-based messages. The expected benefit is a reduced ATCo workload, and increased reliability as a result of redundant communication channels.
Furthermore ADS-C services are expected to enable more advanced trajectory management concepts, and are expected to enable conformance monitoring applications, thus enhancing safety.
The scope of the application of datalink services comprises the Amsterdam Flight Information Region, including area control (ACC), approach control (APP) and tower control (TWR).

Assignment:
Validate ADS-C data, both of arriving and departing aircraft, to quantify the potential features using this new data source in operation for efficiency- and safety purposes. Validate candidate CPDLC services in a simulated or prototype environment. Develop an implementation roadmap based on potential of features in several categories.

Short term objectives:
Selection and validation of suitable CPDLC services, in collaboration with airlines. Development of ADS-C based applications that enhance efficiency and/or safety. Pre-operational trials of both CPDLC and ADS-C.

Mid-term/Long-term objective:
Integration of ADS-C and CPDLC services in the TBO concept application in the Netherlands.

Involved parties:
KLM, RSG, LVNL, Dept. of I&W, KNMI

Source:
Implementation Strategy for Air-Ground Data Communication, NLR-CR-2022-363, July 2023

4.1.2 Conformance Monitoring Applications						
Ref. Ext. Program	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	-
Financial Partner	DGLM					

Introduction:
With the advent of a new generation of flight data processing systems and improved system interoperability, new levels of automation in ATM come within reach. System interoperability is an enabler for a new operational concept which can be described as “plan based” which will eventually evolve to a trajectory based concept. In the end situation the user preferred trajectory is the basis of the air traffic management optimisation process. Any change to the trajectory takes place in a collaborative manner, involving all relevant stakeholders.

Plan based ATM, and ultimately trajectory based ATM also is an enabler for a next level of safety performance, through new system support for planners and controllers. Conformance monitoring of flight execution with flight planning is expected to be more widely applied. But also clearance conformance checking will see a wider application with the increased use of datalink, and air-ground integration.

Goal / Expected benefit:
Investigate the potential of conformance monitoring applications that become available with the transition to plan based ATM and trajectory based ATM. The area of application is ground and tower operations, approach and area control.

Assignment:
Make an inventory of future conformance monitoring applications. Take into account the developments within the iTEC partnership program, and developments with the framework of SESAR.

Short term objective:
Identification of safety enhancements which can be deployed within three years.

Mid-term/Long-term objective:
Taking full advantage of iTEC and SESAR innovations.

Involved parties:
KLM, RSG, LVNL, Dept. of I&W

Source:
-

4.2 Environmental Sustainability

4.2.1 Arrival Management Concepts

The development of arrival management concepts and solutions has been an important part of the KDC research program since 2011, collected in a series of studies labelled as “The AMAN cluster”. The KDC AMAN cluster supported the development and pre-implementation work of the new AMAN which was commissioned in 2018 (AMAN version 1.0).

After the implementation of AMAN 1.0 the continued development was incorporated in a new project called AMAN 2.0. The content of this project was in part developed within the KDC, and it was felt that there was not much development to do in the field of AMAN, pretty much every aspect had already been studied and made ready for implementation. There was however one subject that still lacked development: Extended AMAN, also called XMAN in the FABEC program. However, the planned 2019 trial with MUAC (XMAN for the ACC south sector 3) fell flat due to lack of resources within the LVNL systems department, after which AMAN was taken out of the KDC program as a subject.

The above does not mean that AMAN development is finished. The DARP project, in particular, is very interested in a continued AMAN / XMAN development in support of the new TMA concept. Thus, as of 2024, AMAN has been included once again in the KDC program, but with a broader scope than previously established. All subjects that are arrival management related, which affect the Approach – Area Control – En route interfaces are incorporated in the agenda. This includes merge support and holding support for ACC, subjects which are both still not well defined.

As part of the KDC program three subjects have been expanded as part of the arrival management concepts:

1) Increased accuracy of traffic delivery to TMA
2) Holding support for area control
3) Schiphol night-time arrivals

However, there are many more research questions related to the arrival management process. These questions have been structured in a research roadmap, and have been included in attachment C.

4.2.2 Increased accuracy of traffic delivery to TMA

Ref. Ext. Program		**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
The arrrival management system supports LVNL operations in handling arriving flights in a collaborative way, distributing delay absorption between APP, ACC and en-route sectors. The arrival management system is the primary enabler of a new TMA concept with fixed arrival routes and low altitude CDO. This concept, which is developed by the DARP program) serves multiple goals with respect to flight profile optimisation, i.e. emission reduction, noise reduction and fuel savings. The most important feature of the arrival management function is the ability to shift delay absorption (the location where aircraft are delayed by means of speed reduction and/or path stretching) from the TMA to the ACC sectors, to en-route.

Since 2023 AMAN has come into focus as a means to reduce workload of APP controllers. This reduction of workload was already identified as a benefit of the new TMA concept with fixed arrival routes. Fixed arrival routes in themselves have the potential to reduce APP controller workload, because controllers can simply clear an aircraft onto an approach to the runway, rather than vector the aircraft to the runway with multiple heading and speed instructions. However, the longer the fixed arrival route, the smaller the available airspace in the TMA to delay aircraft. Therefore it has been a goal from the beginning of the fixed arrival route development to increase the accuracy of traffic delivery to the TMA. The assumption has been (since 2007) that a 30 second accuracy delivery (95% of the arrivals) is needed to support (long) fixed arrival routes.

In the meantime the DARP program has lowered its ambition to implement fixed arrival routes and CDO. Currently a CDO starting from 4000ft or from max 6000 ft is foreseen. The necessity to deliver aircraft within 30 seconds accuracy is not urgent from the DARP perspective. However the need to push delay absorption out of the TMA into ACC and en-route sectors remains. The expectation is that a structural lowering of delay absorption in the TMA will help to structurally lower workload, which will benefit the success rate of training new air traffic controllers. To achieve this goal a first target of 60 second accuracy delivery (95% of aircraft) has been set.

Goal / Expected benefit:
Workload reduction of APP controllers, and increased succes rate of training new air traffic controllers.

Assignment:
Support incremental and iterative activities (trials, evaluations) to gradually increase the delivery accuracy by ACC.

Short term objective:
Achieve a target of 60 second accuracy delivery (95% of aircraft) by ACC.

Mid-term/Long-term objective:
Achieve a target of 30 second accuracy delivery (95% of aircraft) by ACC.

Involved parties:
LVNL

Source:
Taskforce TWR/APP controller, initial inventory of solutions.

4.2.3 Holding support for area control

Ref. Ext. Program	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC			✓	✓	✓	✓
Financial Partner	DGLM					

Goal / Expected benefit
Holding patterns are mainly flown in non-nominal situations in order to deal with adverse weather, wind, emergencies or delays. Flying holding patterns have significant environmental, cost impact and plan stability. Optimizing the holding operation could lead to a better flow of traffic, less fuel use and improves accurate delivery for approach Schiphol.

Introduction:
Holding procedures keep aircraft within a specified airspace by prescribing speed, hold entry procedures, timing and rate of turn. AMAN tools for area control do not offer any decision support for flying a holding pattern. Area controllers use only their expertise for an efficient holding execution while complying with the required delivery accuracy for the TMA. Awaiting further clearance from ATC, aircraft can safely and orderly be sequenced to the runway.

Assignment:
- Research possibilities to provide area controllers with decision support tools while holding (speed, timing and rate of turn while holding, taking in account separation minima). Also, take in account the available vertical view tool.
- Assess the performance of relevant options

Short term objective:
Creating an overview of the available options to provide ATCOs with decision support during holdings.

Mid-term/Long-term objective:
Provide ATCOs with more convenient procedures or decision support tooling in flying holding patterns

Involved parties:
KLM, AAS, LVNL, Dept. of I&W, KNMI

Source:
Design and Evaluation of a Support Tool for Planning Adherence While Holding Inbound Air Traffic S.M.G. Wiechers

4.2.4 Schiphol night-time arrivals

Ref. Ext. Program	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC			-	-	✓	✓
Financial Partner	DGLM					

Introduction:
LVNL has taken many steps over the years to optimize the night-time operation, and more options are being considered to exploit the advent of new technology. New technologies under consideration include RNP (enabling new route designs), AMAN and Extended AMAN, datalink and merge support tools. These technologies will eventually enable a fully optimized night-time operation where aircraft can fly a direct route towards Schiphol airport (in Free Route Airspace) followed by a CDA from top of descent. Conflict free planning of inbound- and outbound traffic streams, and early planning and sequencing of arrivals are the main enablers of this concept. The future concept also includes the cockpit side of the operation, taking full advantage of the capabilities of Flight Management Systems.

To progress the development towards the future night-time concept, it is important to structure current and future improvements in a single coherent strategy. This strategy must not only address the step-wise development of the night-time operation, it must also link the night-time operational concept with day-time operations. Even though different regulatory frameworks apply, it is important to address the relation to day-time operations as well. The main reason being the fact that for the day-time operation a new TMA concept is being considered as part of the national airspace re-design program. In this program a 3D separated route structure is considered for low altitudes. Some of the same tools are needed to support both day-time and night-time operations, and this is to be taken into account when developing a strategy for the night-time period. Other aspects that need to be considered are related to route design: to what extent can night-time routes and day-time routes be identical?

Goal / Expected benefit
A strategy for the development of night-time operations was developed in 2022. The next steps will be to develop and test building blocks to deploy operational improvements.

Assignment:
Develop and test the building blocks of the developed nighttime strategy for the development of the Schiphol night-time operational concept for the period 2026 – 2035, addressing: conceptual aspects, airspace and route structure aspects (not including the airspace or route design itself) system support aspects, air-ground integration aspects, noise and emission benefits

Short term objective:
Implement and demonstrate improvements in support of the night-time operation with the aim to reduce fuel burn/emissions and noise annoyance.

Mid-term/Long-term objective:
On the basis of the strategy, carry out validation activities to initiate the strategy execution, maturing the building blocks in support of implementation planning

Involved parties:
KLM, AAS, LVNL, Min. I&W

Source:
KDC report: Development of a Strategy for Schiphol Night-time Operations, September 29, 2022

4.2.5 FUA above and below FL245

Ref. Ext. Program	-	**TRL**	5			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Christiaan Evertse		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
The introduction of the FUA Concept is based on the fundamental principle that airspace is one continuum to be allocated for use on a day-to-day basis to accommodate user requirements, and thus FUA does not allocate airspace any more as purely "civil" or "military". Any necessary airspace segregation is temporary, based on real-time usage within a specific time period.

For civil airspace users, military usage of the airspace is detrimental to fuel usage, emissions, flight time and track miles. Airlines wish to file their flight plans in the most unconstrained way, so the obstructions of restricted areas are undesired.

Although MUAC and the Royal Netherlands Air Force created the FUA cell in 2020 above FL245, there are many remaining inefficiencies below FL245. It is known for a fact that there are many flights that have flight plans routed around temporary restricted airspaces (TRA's), but that are flying through the TRA's daily through tactical rerouting. This is causing a lot of unnecessary fuel burn due to cost of weight for carrying the unnecessary fuel. In another example, it can be seen that conditional routes (CDR's) were closed for flight plan filing while the TRA's were open.

The following points should be researched in order to find the current 'state of the art' of FUA in The Netherlands:

- It is unknown at this stage what is exactly the implementation status
- The benefits of the current implementation are unclear
- It is unknown whether the military have tooling that indicates the total emissions due to closing TRAs for civil usage
- The implementation is much different above FL245, compared to below FL245

Next to finding the current state of FUA and analyzing the effectivity of the Dutch FUA implementation in its current form, it should be researched how the effectivity can be increased. The effectivity should be increased in terms of:

- Minimization of 'filing detours' around TRA's
- Aligning CDR opening times with TRA opening times
- Better alignment of TRA opening times with actual military needs

Since there is a big difference between the implementation above and below FL245, a clear distinction between the two variants should be made.

The research should include a quantification of the benefits in terms of fuel used and emissions.

Goal / Expected benefit:
Much better use of FUA in The Netherlands, which should improve fuel and emissions for civil airspace users while the military needs should be fulfilled.

Assignment:
Analyse the current implementation status (e.g. stakeholders involved, processes, systems, procedures, agreements), and the effectivity of FUA in The Netherlands above and below FL245. Perform a gap analysis on the current implementation state, that assesses whether the maximum potential is being met and, if not, what steps should be taken to maximize the benefits. Then design an end state in which

airlines can make maximum use of airspace that is not needed by military, which will maximize the effectivity of FUA in terms of track miles, fuel/emissions and flight time.

The study should make a distinction between the reservation/release of airspace one day in advance, versus ‘short term FUA’ which makes adjustments on day of operation. Furthermore, the study should include a quantification of the additional benefit that can be reached in terms of reduced CO_2 on an annual basis.

Short term objective:
Creating a better understanding of FUA in its current state. Making a road map that maximizes the potential.

Mid-term/Long-term objective:
Full implementation of FUA in The Netherlands in which all systems and stakeholders are fully aligned (military, civil flight planning systems, ANSPs).

Involved parties:
KLM, LVNL, DARP, DutchMil, MUAC, Min I&W

Sources:
Thesis report: IAF Assignment Optimization for Amsterdam Airport Schiphol Thesis, Max Aalberse
NLR-CR-2023-395: FUA onder betrekking van luchtruimgebruikers.

4.2.6 Maintenance works impact model

Ref. Ext. Program	-	**TRL**	6			
Customer	KDC Board	**Lifecycle phase**				
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Maarten Zorgdrager		✓	✓	✓	✓
Financial Partner	DGLM					

Goal / Expected benefit:
The goal of this research is to create a broad quantitative maintenance works impact model. This impact model has two goals:

1) Indicate the impact on the following performance indicators: environment, capacity, safety, cost and feasibility of maintenance work scenarios, by updating and broadening the maintenance strategy that should not only incorporate runway maintenance but also maintenance on taxiways, stands, gates etc.
2) Estimate the impact on the performance indicators earlier in time.

Introduction:
In 2017-2018, Schiphol, LVNL and KLM jointly developed a new runway maintenance strategy. For this purpose, a more enhanced Runway Forecasting tool (RFT) was developed. With this tool several quantitative analyses of delays, costs and hinderance were executed. The results from these analyses are the foundation of the developed runway maintenance strategy. Since 2018 runway maintenance has been executed according to the new strategy. In 2023 and 2024 the runway maintenance strategy has been evaluated based on the maintenance works between 2018 and 2023. Evaluation from this period showed that figures, starting points and assumptions applied in the quantitative analyses in 2017-2018 differ from the current situation (i.e. construction time, runway usage, costs, etc.). To get insights in the effects of these differences on the earlier results of the analysis and to further develop a broader maintenance strategy, RSG proposes to base the impact model based on the latest available prognoses and figures. Furthermore the scope of the strategy is to be extended from runways only to also include maintenance on taxiways, aprons, gates etc. in a quantitative manner.

Assignment:
Develop an impact model for a quantitative maintenance works impact model with a broad scope of airside maintenance works. This model should answer the question which maintenance scenario is most optimal scoring on the mentioned performance indicators. The maintenance cycle itself is not up for debate.

Simulations with the Runway Forecasting Tool (RFT) developed for the Runway Maintenance Strategy in 2017 can be used as a basis, to be updated with 2024 figures. In the current runway maintenance strategy the environmental impact indicators are calculated using Daisy tool at the end of the process. KDC asks the supplier to think about alternative methods in order to quickly determine the approximate impact on environmental indicators early in the process without the need of setting up complete Daisy studies. Furthermore KDC asks the supplier to propose how this impact model should be positioned in the current COBRA and TICAR planning processes.

An inventory of the currently available (simulation) ground models (at e.g. Schiphol, LVNL, KLM etc.) is part of the assignment.

The impact models shall take into account:

- A holistic approach with scenarios encompassing works at all key operational airside-related assets to include runways, taxiways, aprons and gates.
- Mid- and Long-term time horizon (2 up to 10 years)
- To be expected meteorological conditions per day/week/month
- Impact assessment on performance indicators

As Key Performance Indicators the following indicators <u>can</u> be used among others:

- Environment
    - Number of affected severely disturbed people within 48dB(A) Lden contour
    - Number of affected severely sleep deprived people within 40dB(A) Lnight contour
    - Number of affected houses within the 58dB(A) Lden contour
    - Number of affected houses within the 48dB(A) Lnight contour
    - Total annual effect of all runway maintenance works on the different areas around Schiphol
    - Total duration of maintenance works
    - Total number of flights handled from an alternative runway due to maintenance works
    - It is requested to contact the MRS and BRS regarding the set of environmental KPIs

- Capacity
  - Total delay minutes, including a distribution of the number of flights impacted vs delay minutes (split into SPL departure and arrival)
  - Taxi-in and taxi-out minutes
  - Hourly capacity (inbound & outbound)
  - Total flight cancellations
  - Total number of impacted flights
  - Total duration of the disruptions
- Costs
  - Cost of maintenance scenarios
  - Cost of airport charges
  - Total delay costs
- Feasibility
  - Feasibility of maintenance scenarios
- Safety
  - Impact of maintenance scenarios on safety
  - Number of groundside sectors where the most complexity for LVNL arises as a result of closures due to maintenance

If the present RFT cannot be modified to satisfy the aims, the assignment will be to investigate if such a tool can be developed, what would be the maturity/confidence level, and what are the limitations. In both cases the final impact model should be easy to use.

Short term objectives:

- Get quantitative insights in the effects of maintenance on performance indicators
- Effects on the maintenance strategy due to differences between initial boundary conditions and current practice.
- Possibly subsequently identify first elements to change/adapt the maintenance strategy

Mid-term and Long-term objective (> two years):

- Modify the existing RFT or develop a new tool capable of providing impact assessments on performance indicators with different scenarios
- Monitoring, optimisation and adjustment of the model and integrated maintenance strategy based on regular evaluation of maintenance planning vs actual maintenance (not-)performed

Involved parties:
RSG, LVNL, KLM, MRS/BRS for input of environmental KPIs

Sources:

i. RSG Baan Beschikbaarheid Strategie 2015
ii. Baanonderhoudsstrategie 2017 Vervolgonderzoek fase 1 - Resultaten kwantitatieve analyse
iii. RSG Baanonderhoudsstrategie 2019 Vervolgonderzoek fase 2 - Implementatiestrategie -
iv. RSG Publieksvriendelijke Samenvatting Baanonderhoudsstrategie (BOS) – augustus 2023
v. Evaluatie baanonderhoudsstrategie [2024]

4.2.7 RNP-AR approach procedures for EoR on rwy 18R + 18C

Ref. Ext. Program	DARP	**TRL**	7				
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration				
KDC Board Approval	13 March 2024	**Performance Targets**	S	Ec	Es	Env	
KDC PoC	Christiaan Evertse		✓	✓	✓	✓	
Financial Partner	DGLM						

Introduction:
The main goal of this study is to complete the first step towards fully functional Established on RNP (EoR) procedures on AMS by designing RNP AR APCH procedures for runway 18R+18C with both a straight-in ILS approach and a curved RNP-AR approach from 6.000 ft. For the 18R RNP AR APCH, a design over Noordzeekanaal shall be considered. These RNP AR APCH procedures shall allow the EoR concept during parallel operations, supporting an RNP AR as well as an ILS approach on the other runway. The study should include all stakeholders within the scope: DARP, LVNL, the airlines and ILT.

The combination of Fixed Arrival Routes (FAR) with Continuous Descent Operations (CDO) in the form of Established on RNP (EoR) procedures brings significant potential benefits in terms of noise abatement, track mile reduction, fuel consumption and environmental impact without compromising peak capacity. The Dutch Airspace Redesign Program (DARP) is working towards an operational concept for the EHAM TMA which relies on the implementation of FAR with CDO while maintaining independent parallel operations. For this, RNP AR APCH procedures designs are required, as examples to be used in simulations. The core objective is to start validation of mixed equipage operations at Schiphol airport.

With regard to airline capabilities, the RNP AR equipage at AMS is expected to rise rapidly to close to 50% in 2026 and close to 80% in 2027/2028, whereas an equipment rate of only 30 to 40% should be enough to start implementation of EoR operations at a given airport with benefits to all users. In this study, the design should allow for mixed equipage operations on both runways individually.

In 2024 a ConOps and road map have been created that elaborate on the implementation of EoR procedures at EHAM. It was determined that "*If RNP AR APCH procedures are already in place, it is possible to upgrade the operation to an EoR operation within less than a year. If, however, there are no procedures in place and the design needs to start from scratch, the FAA estimates that the entire implementation might take up to three years*".

Since RNP AR APCH procedures are not yet in place on AMS, the most important step at this moment towards fully function EoR is to establish RNP AR APCH procedures on AMS, while keeping in mind full EoR implementation later on.

Goal / Expected benefit:
The new procedures are an essential enabler for EoR operations on AMS, which unlocks benefits in terms of noise abatement, track miles, fuel consumption and environmental impact.

Assignment:
Describe a feasible operational deployment (CONOPS) of RNP AR APCH procedures for runway 18R+18C with both a straight-in ILS approach and a curved RNP-AR approach from 6.000 ft, with mixed equipage traffic on both runways. For the 18R RNP AR APCH, a design over Noordzeekanaal shall be considered as one of more options.

The following aspects should be included in the project:
- Two aspects are part of the new procedures:
  1. An ILS straight-in procedure that corresponds as much as possible to the current ILS procedures, for non-capable aircraft and in order to minimize the impact of change
  2. A curved ANRP AR EoR procedure, which will serve as a demonstration of the potential possibilities of RNP AR APCH procedures. This may include the previously tested route that overflies the 'Noordzeekanaal' to 18R
- A detailed proposal and feasibility assessment on how to operate the new procedures on AMS with different mixed equipage scenarios of 30%, 40%, 50% and >60% during southerly runway conditions
- Preparing a demonstrator ATC environment in iLabs with a form of merge support based on known concepts and systems (such as AMAN, Intelligent Approach, Interval Mgt etc.), is a must, in order to involve LVNL ops personnel in the research
- The research should take into account that *implementation* of RNP AR will start on a single rwy ops in order to minimize the impact of change on the air traffic controllers, while this research project must use RNP-AR

approach procedures that allow use for 18R+18C EoR operations (which is the Long-term end goal). For now, 18R is the candidate first runway.

The following previous and planned work should be taken as a starting point for this research:
- The report 'Implementation of Established on RNP AR APCH Procedures at EHAM - Roadmap' (2024)
- Planned and performed KLM trials (e.g. flight simulator trials of Established on RNP)
- The report 'EoR for EHAM', written by NLR in 2020
- The report 'PBN roadmap for the Netherlands 2020-2030'
- The report 'Vaste naderingsroutes met hoge capaciteit' (2020)
- The report 'Continuous Descent Operations from low altitudes to parallel runways 18R and 18C' (2013)

Short term objective:
Paving the way towards EoR implementation on EHAM by designing RNP AR APCH procedures for runway 18R and 18C.

Mid-term/Long-term objective:
Full deployment of EoR on AMS.

Involved parties:
KLM, RSG, LVNL, Dept. of I&W, DARP

Sources:
KDC reports:
1) Implementation of Established on RNP AR APCH Procedures at EHAM - Roadmap (2024)
2) Established on RNP for EHAM, March 2022
3) PBN roadmap for The Netherlands 2020-2030
4) Vaste naderingsroutes met hoge capaciteit, oktober 2020
5) Continuous Descent Operations (CDO) from low altitudes to parallel runways 18R and 18C, May 2013

4.2.8 Sustainable Ground Movements

Ref. Ext. Program		TRL	6			
Customer		Lifecycle phase	Pre-industrial development & integration			
KDC Board Approval		Performance Targets	S	Ec	Es	Env
KDC PoC			✓	✓	✓	✓
Financial Partner						

Introduction:
In 2023 a new program was initiatied to collect and develop requirements for Schiphol's ground operations and ground movements. The main aim of this program is to make the operation more sustainable, i.e. reduce emissions and increase fuel efficiency. The trigger for initiating the program has been the civil court ruling that air quality at the Schiphol platforms must be improved by 2030.

The program has identified the following research questions:

Heads-down working
What is the influence of increased head down working on the working methods of air traffic controllers?

Resectorisation
Develop an integral and integrated planning of the entire operation at EHAM. From inbound to outbound, incl. tug release point, deicing, CTOT etc.

Datalink
Develop more advanced forms of datalink to reduce radiotelephony (including for instance routing clearance, pushback clearance, engine startup clearance). Take into account A-SMGCS develepments in the US.

Contingency and back-up procedures
Develop contingency and back-up procedures taking into account all changes that are implemented in the Visual Control Room (VCR) (such as: towing control, remote tower west, resectorisation). Identify consequences for the backup procedures and systems of the ground operation (not only LVNL).

Remote tower technology
What role can remote tower technology play for the challenges associated with making the ground operation more sustainable?

Goal / Expected benefit:
Reduction of emissions on the ground, improvement of air quality in the work environment of ground handling staff, i.e. on the platforms of Schiphol airport.

Assignment:

Short term objective:

Mid-term/Long-term objective:

Involved parties:

Source:
-

4.2.9 Traffic segregation concepts

Ref. Ext. Program	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		-	✓	-	✓
Financial Partner	DGLM					

Introduction:
Outbound traffic segregation is the concept of segregating traffic on the basis of aircraft noise, aircraft performance or runway load balancing. In case of noise segregation, the noisy or heavy aircraft can be assigned to the noise preferred runway, whereas the less noise producing aircraft are assigned to the secondary runway. A similar strategy can be applied for segregation on the basis of aircraft performance, which can optimize runway throughput through optimal traffic mix sequences. A third option is traffic segregation based on runway load balancing. As there is almost never a perfect 50/50 division between east/west departing traffic, currently departure capacity is lost due to the coupling between runway and destination. If e.g. eastbound departures could also depart from the western departure runway in a start peak, the traffic load of the primary and secondary runway can be spread more equally increasing departure capacity.

However, there are many limitations, especially with regards to maintaining capacity, that need to be explored and addressed. One of the prerequisites is that the noise preferred departure runway during a start peak has active SIDs to all TMA sectors, where currently there is an east/west split active when operating two departure runways. This is known as a dual SID concept, in this concept outbound traffic can be fed to one sector from two different runways.

This study comprises of a feasibility study to the traffic segregation concept for Schiphol airport.

Goal / Expected benefit:
Study the feasibility of the traffic segregation concept for Schiphol airport.

Assignment:
Develop a concept of outbound traffic segregation on the basis of noise load distribution, runway load balancing, and/or performance. Capacity enhancing concepts, i.e. concepts which optimize the runway load balancing should be included. After the concept development, assess whether or not the principal is operationally feasible, and what measures (tools, practices, etc.) are needed for traffic segregation to be implemented.

Short term objective:
Produce a feasibility study, looking into a broad range of potential concept elements, both conventional (airspace and route design) and innovative trajectory management) solutions.

Mid-term/Long-term objective:
Improve the spreading of aircraft noise over the noise preferred runways by means of traffic segregation.

Involved parties:
KLM, RSG, LVNL, Dept. of I&W

Source:
KDC report Outbound Traffic Segregation Concepts, November 2021

4.2.10 Schiphol Outbound Trajectory Management

Ref. Ext. Program		**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
Air Traffic Management in the Netherlands is largely characterized as *"managing traffic streams in and out of mainport Schiphol"* as LVNL is basically operating an extended TMA in a fragmented part of the European airspace. The focus of LVNL has been, and still is, on arrival management, rather than departure management. This is due to the fact that managing arriving traffic plays a dominant role in the workload of the controllers. This in turn has to do with the fact that LVNL has limited influence in the manner in which traffic arrives at the FIR boundary. Arriving traffic streams are characterized by irregular sequences with frequent traffic "bunches". The traffic bunches consist of converging traffic which have to be forged into structured arrival streams to the runways, with high capacity. The focus on improving the management of arriving traffic has taken away some attention from improving the management of departing traffic.

There are important reasons for to pay due attention to the departure process as well:
1) The outbound traffic streams are characterized by a "converging" part as well: the planning and ground handling phase from gate to runway. This phase of flight has its own challenges due to the uncertainty of the Target Off-Block Times (TOBT). Managing these uncertainties is essential for achieving high outbound capacity at the runways.
2) Outbound predictability is very important to the European Network, in essence the capacity of en-route airspace. LVNL has to make a contribution to the European Network development by making outbound Schiphol traffic more predictable.
3) Environmental gains are to be achieved by means of joining Free Routes at lower altitudes. LVNL already makes a contribution to this goal by clearing outbound aircraft on a "Direct To" route as much as possible. The challenge is to expand this practice and to do it in a planned manner as to maintain predictability of outbound traffic.
4) Multi-airport operations pose challenges for Amsterdam radar, in particular high workload due to conflicts arising from departures from regional airports, with Schiphol traffic. For example departures from Eindhoven airport have been a workload issue in ACC sector 3 since 2016 and these concerns have played a role in the route design of Lelystad airport. It turned out that 3D separation of Lelystad and Schiphol traffic streams raised noise annoyance concerns. If Lelystad were to open for commercial passenger traffic these concerns will come into play again. Therefore trajectory management solutions should be developed as an alternative to 3D separation of traffic streams.

The above stated reasons justify giving due attention to the management of outbound trajectories.

Goal / Expected benefit:
The goal is to improve the management of the time component (and ultimately all 4D components) of outbound trajectories with the aim to:
a) Improve runway capacity
b) Lower controller workload
c) Improve the European Network, i.e. reduce tactical delays
d) Reduce noise annoyance

Some of the goals are already addressed in the form of an implementation project. For instance: the DMAN (the Schiphol Departure manager) intends to make the outbound planning more stable and to increase runway capacity. Beside the DMAN project multiple initiatives intend to make the TOBT planning more reliable, this in return will benefit DMAN.

Assignment:
Develop a concept, and develop a demonstration, for a multi-airport outbound trajectory manager, deconflicting departures from regional airports from Schiphol arrivals and departures.

Short term objective:
Perform a proof-of-concept.

Mid-term/Long-term objective:
Full predictability of (outbound) traffic streams with strategical- and tactical deconfliction. Improved European network Management, reduction of controller workload, and reduction of delays.

Involved parties:
LVNL, KLM, DGLM

Source:
European ATM Master Plan 2024

4.2.11 Research engineer for NOMOS aircraft noise measurements

Ref. Ext. Programme		**TRL**	Not applicable			
Customer	KDC Board	**Lifecycle phase**	Not applicable			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC Point of Contact	Maarten Zorgdrager					x
Financial Partner	DGLM					

Introduction:
Air traffic causes noise hindrance. By default noise levels are calculated using noise models. However, common criticism is that aircraft noise should (also) be measured instead of just calculated. The NOise MOnitoring System (NOMOS) is the noise measurement system of Amsterdam Airport Schiphol. NOMOS has been active since 1993 and measures sound levels caused by air traffic at 41 locations around the airport. NOMOS data is currently not being properly evaluated. This research proposal aims to fix this.

Goal / Expected benefit:
The goal is primarily to improve the sound level measurement quality from NOMOS measurement sensors and perform relevant research using this data.

Assignment:
Fulltime position for a research engineer at the Aircraft Noise and Climate Effects (ANCE) section in the Control & Operations Department of the TU Delft under supervision of KDC. Location is also at ANCE in Delft. Contract for two years, with possible extension of one year. Assignments for this position can include:

1. Assess and map the data quality of current measurements of sound levels caused by air traffic and of quantities derived from these measurements.
2. Fix data issues for specific noise measuring posts (also called Noise Monitoring Terminals) and suggest improvements.
3. Gather wishes/requirements on data quality from all parties involved (researchers/government/ Bewoners Aanspreekpunt Schiphol (BAS)/KDC).
4. Implement NOMOS updates based on input.
5. Serve as a Point of Contact for questions regarding NOMOS performance.
6. Feeding raw noise measurements onto TU Delft servers. Having these raw measurements is essential to validate the detected aircraft events and assess the probability for missed and false detection.
7. Research installing ADS-B receiver(s) to obtain real-time flight data to match with the acoustic measurements and allow for a better matching between aircraft performance parameters and noise signature.
8. Analyse requests for additional NOMOS measuring posts thereby linking to the national measuring strategy written by the RIVM in the context of "Programmatische Aanpak Meten van Vliegtuiggeluid" (PAMV).
9. Explaining the cause of certain high LAmax values in NOMOS measurement points.
10. Setting up a server at TU Delft to store incoming data for the long term to test developed methodologies on sufficiently large data volumes.
11. Serve as a point of contact for the (Dutch) aviation sector for data inquiries regarding aircraft sound levels on the ground caused by air traffic. These questions can come from inside the sector or outside (e.g. from local communities) through BAS/LVNL/Schiphol.

Deliverables

1. Based on data analysis pinpoint logical locations for additional NOMOS measurement stations, thereby taking into account the national measuring strategy.
2. Using NOMOS measurement data, investigate the difference in measured noise levels of the NADP2 start procedure vs. NADP1.
3. Using NOMOS measurement data provide an insight in the effect of fleet renewal on noise levels.

Relationship with other projects/research:
This project links closely with the research from PhD Rebekka van der Grift on sound level measurements. This assignment is also linked to the now completed governmental program PAMV. One of the results of PAMV is that the method or model used for noise calculations could be improved based on NOMOS measurements. Therefore, it is vital that data quality of these measurements is fit-for-this purpose.

Involved parties:
TU Delft, Schiphol, BAS, LVNL.

Background information:
https://www.rivm.nl/nieuws/landelijke-kaders-voor-meten-vliegtuiggeluid
https://noiselab.casper.aero/ams/

4.3 Operational Efficiency

4.3.1 Automation in Operations

Ref. Ext. Program		**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
The human operator plays a key role in the management of air traffic. The human operator has always had this role, and it is foreseen that the human operator will maintain this role in the future. This is due to the fact that rare circumstances are best solved by humans, rather than machines which rely on pattern recognition. However, it is foreseen that automation and digitalization will increasingly play a more important role in ATM. Large benefits are expected from the automation of ATM, in particular relieving the human operator of workload, but also safety and performance benefits.

The 2024 edition of the ATM Masterplan lays out a vision and a roadmap for automation in ATM:

> *Higher levels of automation will be introduced in the air and on the ground in the form of advanced digital tools (in some cases using artificial intelligence) to deal safely with complex decision-making while increasing capacity and environmental performance. This increased automation will require the teaming up of human operators and systems (i.e. human-machine teaming) to make best use of the large volumes of data to optimise trajectories.*

The Masterplan distinguishes five different levels of automation from level 0 tot level 4. For 2030 and 2035 the following milestones for automation have been set:

- By 2030: ATM in Europe will operate at automation level 0, and AI will be only marginally used in machine learning applications for supporting ATFM or airport landside processes. Significant progress will have been achieved on the development of the future platforms for en-route, TMA and airports designed for automation level 4.
- By 2035: ATM in Europe will operate at automation level 2 thanks to the implementation of increased automation support tools and the transition to trajectory-based operations phase 2. This will have been achieved with the implementation of sector team configurations, automatic speech recognition, user profile management, attention guidance and trajectory prediction tools supporting the earlier detection and resolution of potential conflicts.

Goal / Expected benefit:
Automate ATM functions with the aim to reduce controller workload, and with the aim to provide a more uniform high output performance.

Assignment:
Workout a detailed automation roadmap for ATM in the Netherlands with 2035 as the time horizon. Capacity planning processes must be included in the roadmap. The iTEC system roadmap must be taken into account as part of the automation roadmap.

Short term objective:
Workload reduction for controllers. Improved decision making processes.

Mid-term/Long-term objective:
Introduction of autonomous processes in ATM.

Involved parties:
KLM, RSG, LVNL, DGLM

Source: European ATM Master Plan 2024
EASA Roadmap for AI (https://www.easa.europa.eu/en/document-library/general-publications/easa-artificial-intelligence-roadmap-20)

4.3.2 Inbound priority sequencing

Ref. Ext. Program	-	TRL	3			
Customer	KDC Board	Lifecycle phase	Feasibility assessment			
KDC Board Approval	3-12-2019	Performance Targets	S	Ec	Es	Env
KDC PoC	Evert Westerveld		-	✓	✓	-
Financial Partner	DGLM					

Goal / Expected benefit:
Expected benefits are in the area of efficiency.

Introduction:
Traffic flows inbound Schiphol are currently planned on a first-come-first-serve basis. Traffic is planned in such way to optimize runway capacity. No airline priorities are taken into account. 80% of the passengers onboard KLM aircraft are transfer passengers. Realizing passenger connections is therefore very important for KLM. KLM attributes different values to its inbound aircraft depending on the number of connecting passengers and level of passenger loyalty (alliance membership).

In the future ATM system, inbound traffic flows will be handled based on the value of individual flights (ref. AAA replacement business case). The Arrival Management function will take airline priorities into account and traffic flows will be built upon these priorities. This process is dynamic, prioritization of individual flights shall be possible from preflight to the latest moment LVNL can accommodate prioritization. Prioritization of traffic flows inbound Schiphol shall be done as early as possible, the planning based on this prioritization shall be maintained in the NL-FIR.

Assignment:
Define, develop and test an experimental arrival management function which takes airline priorities into account. The study shall be done sequentially in the following defined steps:
1. Case study to identify the possibilities & benefits when LVNL prioritizes KLM flights based on airline priorities. In this initial step the studies performed in 2004/2005 (Inbound Priority Sequencing) should be taken into account as background material.
2. Identify which value information is needed to support the planning process based on airline priorities.
3. Define a concept of operations to handle KLM traffic based on airline priorities.
4. Small scale trial to test concept with KLM flights
5. Full scale trial to handle traffic based on KLM priorities
6. Define a plan including concept to enable trading of priorities between airlines.

For step 1 to 5 it is assumed that prioritization between inbound flights can only be done intra-airline.

Short term objective (first year):
Steps 1, 2 and 3 are expected in the short term objective.

Mid-term objective (two – three years): Steps 4 is expected in the Mid-term objective.

Long-term objective (> three years): Steps 5 and 6 are expected in the Long-term objective.

Involved parties: KLM, LVNL, TU-Delft

Source:
1) AAA Replacement Business Case Report S&I \ ATMS \ DOC-427
2) Concept of Operation (CONOPS) for “Inbound Priority Sequencing” Document D/R&D 03/089 Release 3.0

4.3.3 RECAT-EU Pair-Wise Separation (PWS)

Ref. Ext. Program		**TRL**	6			
Customer		**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC			✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
RECAT-PWS [1], or Recategorization of Pair-Wise aircraft Separation is the next step in the evolution of increasing the granularity of aircraft wake separations since the introduction of RECAT-EU [2]. RECAT-EU was the first modification step in which the existing ICAO-based four aircraft wake categories (Low, Medium, Heavy, and Super heavy (for the A380-800)) that were solely based on aircraft mass, were expanded to six categories. The two new categories were added by splitting the Heavy and Medium categories both into an Upper and a Lower part. Aircraft were newly placed inside one of these six categories (and renamed CAT-A to CAT-F), based on aircraft wingspan (b) and aircraft mass (m), as well as wake risk assessment studies performed. The new RECAT-EU categorisation tables provided new a/c wake separation limits, both distance based and time based. These new separation tables were set up for both departing and landing aircraft.
LVNL operationally introduced the RECAT-EU and Time Based Separations (TBS) in 2023 for all runways.
RECAT-PWS is the second modification step. It no longer places aircraft types in dedicated wake separation categories, but it consist of a matrix where each aircraft type has a unique wake separation value with another aircraft type. As a result, the current matrix is about 102x102 a/c types large and is expanded annually in case new aircraft types enter into operation. The classification of aircraft types under RECAT-EU is officially approved by EASA. Likewise this will be the case for the PWS matrix updates.
The operational introduction of RECAT-EU by LVNL at Schiphol was a relatively simple step for the ATCOs, as it did not modify their existing working procedures for aircraft wake separation too much and was effectively supported by CCIS presented aircraft wake category and wake separation (table) information, both distance based and time based. However ATCOs will not be capable of remembering the full 102x102 a/c wake separation matrix anymore. Hence the second step, the introduction of RECAT-PWS, will require more automation support to ATCOs. Also the interaction of the RECAT-PWS defined a/c separation values with the Minimum Radar Separations (MRS) and with the allowed maximum Runway Occupancy Times (ROTs) for a single runway needs to be carefully analysed and needs to meet the EASA (and ICAO) rules on these matters.

Goal / Expected benefit:
Introduction of RECAT-PWS will increase the Schiphol arrival and departure runway capacity under peak hours operations with the aim to improve the capacity on the primary runways as to reduce the secondary runway usage. Previous (KDC) research performed on this aspect, see [3,4], as well as under SESAR proved that consistently. Both arrivals and departures are within the scope of the subject.

Assignment:
The project should establish, for Schiphol, with the most recent traffic mix available and a near future (5 years ahead) traffic mix, what the actual amount of additional peak hour capacity will be compared to RECAT-EU/TBS operations in use today.
Furthermore, the project should investigate what the impact of the introduction of RECAT-PWS would have on the existing ATCO (LVNL) system setup and ATCO operations. This implies investigating the following:
- What kind of automation support would be necessary, hence needed?
- How would the currently existing Intelligent Approach (IA) system of LVNL, on which RECAT-EU is implemented, have to be adapted for introduction of RECAT-PWS?

- Which ATCO procedure, training and HMI implications will follow the introduction of RECAT-PWS? Implications for both TWR , APP and ARR.(when appropriate) should be checked.
- What ATCO automation support systems and potential backup/fall back options are needed for the actual introduction of RECAT-PWS?
- What are the operational implications for the airspace users?
- Can an (initial) insight be provided on the risk assessment and certification implications of the introduction of RECAT-PWS at Schiphol?

Finally, the impact on the environment (noise, emissions, etc.) of the RECAT-PWS operations should be investigated.

Short term objective:
Establish via a new, limited, data analysis the potential peak capacity impact of the introduction of RECAT-PWS. Limit this data analysis study to the most important runway combination of interest for peak capacity (under heavy wind conditions) only. Check capacity effects for primary and secondary runways. Perform a numerical (data-analysis) study on the ROT/MRS/PWS implications for introducing RECAT-PWS. Assume an MRS update from 3.0 (current system) to 2.5 and even 2.0 NM (with a new system). Do the actual average runway ROTs fulfil the ICAO requirement?
Perform a first qualitative overview and insight of the impact of the RECAT-PWS operations on all the previously listed research topics (defined under the assignment).

Mid-term/Long-term objective:
Based on the outcome and reporting of the short term objectives, follow on and deepen out the research questions posed above under 'assignment'.

Involved parties:
LVNL, KLM, IenW, Schiphol

Source:
[1] – EUROCONTROL, "Approach and Departure Optimised Wake Turbulence Re-Categorisation and Pair-Wise Separation Minima", Edition 2.0, 29 June 2023.See also: Approach and Departure Optimised Wake Turbulence Re-Categorisation and Pair-Wise Separation minima | EUROCONTROL
[2] – EUROCONTROL, "RECAT-EU-European Wake Turbulence Categorisation and Separation Minima on Approach and Departure", Edition 1.2, 14/02/2018. See also https://www.eurocontrol.int%2Farchive_download%2Fall%2Fnode%2F9681&usg=AOvVaw2IaBh33oGhJ-ZbY7uHtunu&opi=89978449
[3] – KDC, "Benefits analysis of RECAT-EU for Schiphol Airport", August 2016. Also published as NLR-CR-20216-131 by G.B van Baren (NLR).
[4] KDC, "RECAT-EU for Departures at Schiphol", Version v1.0, 30 Oct 2020. Also published as Report FWY-2020-01 by Ferdinand Dijkstra (Ferway).

4.3.4 Increased capacity during low visibility procedures

Ref. Ext. Program	-	**TRL**	6				
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration				
KDC Board Approval	9-12-2020	**Performance Targets**	S	Ec	Es	Env	
KDC PoC	Evert Westerveld		✓	✓	-	✓	
Financial Partner	DGLM						

Introduction:
In 2008 a KDC study has been performed to research increasing capacity during marginal and low visibility conditions. The study requires a follow-up based on the current situation, to see if potential solutions can be identified in increasing capacity during these conditions. Given the time elapsed since 2008, new technologies have become available, new systems have been implemented, and new developments have taken place. These developments warrant a new look into opportunities to increase capacity under low visibility conditions.

Goal / Expected benefit: Increase the resilience of the Schiphol operation by increasing capacity during marginal/low visibility conditions. As a side-benefit this also allows for an increased use of preferential runways when two landing/departure runways are in use.

Assignment: This project aims at updating the status of the solutions in the report based on the current situation, complemented by possible new procedures or concepts to increase capacity during LVP.
As example, the following topics can be researched

- Decreasing ILS sensitive area
- Increased visual guidance during low visibility conditions
- Ground-Based Augmentation System (GBAS) for Cat. II and Cat. III operations
- Using full landing capacity during 2 + 1 runway use during BZO category C.
- Shape of ILS sensitive area
- Introduction of ILS in combination with Super Wide Aperture Antenna
- Taxi behaviour and use of runway 27

The scope of research is increasing capacity during low visibility conditions (from marginal up to BZO category D).

Short term objective: Highlight potential solutions which can increase capacity during marginal and low visibility conditions without compromising safety.

Mid-term/Long-term objective: Implement these solutions in order to increase resilience of Schiphol operation.

Involved parties:
KLM, RSG, LVNL, Min. I&W

Source:
Verhoging landingscapaciteit, tijdens marginaal en slecht zicht condities, KDC/2008/032, versie 1.0, 17-11-2008
Increased Sustainability Schiphol (ISS), Final Report, KDC/2010/0111

4.4 Flow- and Capacity Management

4.4.1 Collaborative Demand – Capacity Balancing: Decision Support Tool (DST) sector wide collaboration

Ref. Ext. Program	-	**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval		**Performance Targets**	S	Ec	Es	Env
KDC PoC	Christiaan Evertse		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
To keep the volume of flights to Schiphol in balance with the capacity of the airspace, LVNL must frequently delay inbound flights by regulating them. Regulating involves delaying flights at their departure airport by holding at the gate, causing the flights to arrive at Schiphol later. These delays are costly for airlines and annoying for travellers. In order to improve this process, LVNL has put the Decision Support Tool (DST) into operational trial in 2023. This meant that the tool was enabled for use by the Flow Managers (FMP) at LVNL, but the decision-making was still based on the incumbent flow management interface CIFLO (NM) and workload model WLM (werklastmodel). The goal of DST is to provide better information to the FMP position such that better decisions can be made regarding the setting of regulations. DST uses new prediction and simulation techniques and machine learning to achieve an optimal balance between capacity and sustainability, well before flights enter the Dutch airspace.

In more detail, DST provides extensive, predictive information (t-4 hours) about the expected traffic demand in the FIR and all relevant different subsections of the FIR. It also predicts capacity in terms of runway use, airspace availability and overall availability of capacity in all subsections of the ATM system. Combining the predicted traffic demand and enhanced airspace/airport capacity, DST is ultimately able to make a detailed prediction of the in-FIR delay, ATC workload and overall (un)balance between traffic demand and airport/airspace capacity.

This is already valuable information, considering the fact that DST is able to predict this (un)balance to a high degree of certainty. What makes it even better, is that the FMP can simulate various scenarios by making adjustments to the input weather, runway use and regulation settings, thus enabling the FMP to 'try out' certain regulations in advance before definitive implementation.

DST is a great tool, however it is running 'isolated' currently within LVNL. This has two main disadvantages:
1) There are more controlling parameters for maintaining a good traffic demand/capacity balance than only regulations: one can think of airline delays, in-flight adjustments or even cancellations. The airlines and airport (including APOC) currently do not have access to the valuable predictions of DST, due to which all the stakeholders do not have a single source of truth.
2) The inputs of DST could be enriched by airline and airport data, which could increase the reliability of the predictions of DST even further. This can be beneficial, since the predictions can still be off.

Goal / Expected benefit:
By collaborating DST with the sector partners (airports, airlines, APOC), it gives the sector the best and single source of truth on which all important operational decisions can be made. This will improve the decision-making. By feeding data back from the sector partners to DST, the reliability of its predictions can be improved even further.

Assignment:
Develop a concept on which DST can be used in a collaborative way. The study should focus on two different aspects:
- New data inputs to increase the reliability of the predictions. The study should investigate which data can be fed from the sector partners (airports, APOC, airlines, possibly ground handlers, FUA Cell) to the DST in order to increase the reliability of its predictions.
- Which outputs from DST could be used in the sector, which could improve the decision-making. Think of APOC, operational meetings, airline flow control. The study should include an elaboration or qualitative analysis on how the decisions of the sector partners are improved, if DST output were to be used in a collaborative way.

The study should take the two different time scopes of DST into account: t-4hr and t-24hr .

Short term objective:
The primary objective is to have a single source of truth for all sector partners. Given the high quality of DST output, it is expected that DST provides the best available data about traffic demand and airspace/airport capacity.
The secondary objective is to increase the reliability of the DST predictions by incorporating more inputs from the sector partners.

Mid-term/Long-term objective:
Collaborative decision-making across all sector partners by having a single source of truth.

Involved parties:
KLM, RSG, LVNL

Sources:

4.4.2 Collaborative Demand – Capacity Balancing: Schiphol Airport Operations Centre (APOC) Development

Ref. Ext. Program	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval	3-12-2019	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Eugene Leeman		-	✓	✓	-
Financial Partner	DGLM					

Introduction:
As of January 2020 Schiphol launched the Airport Operations Centre (APOC). Its main purpose is to plan and monitor the complete airport operations process together with stakeholders. By taking a D-7 approach, it will look constantly 7 days ahead of the day of operations. APOC will therefore forecast events and proactively identify capacity constraints that might influence performance. The outcomes of these forecasts will be discussed in the APOC among all parties in order to reach solutions or modify the plans that have been made. APOC wants to start with these integral decision making from D-3 onwards, in order to reach a final AOP at D-1, that will be issued for the day of operation

Goal / Expected benefit:
The goal is to define a methodology describing the decision making model needed to decide upon bottlenecks, capacity and demand measures from D-3 up to D0 onwards in the APOC.

Assignment:
Help with creating a methodology for scenario based planning in the APOC
- What kind of decision model is needed?
- How can demand and capacity estimates of the different stakeholders be harmonized?
- What procedures to use?
- What is the role of different parties in the model?
- How to deal with conflicting stakeholder goals?

Mid-term objective (two – three years) :
- Decision making in APOC will facilitate a common ground in the sector on how performance and capacity is used most efficiently
- An improvement of the on time performance as a significant negative influencer of the performance by anticipating collectively instead of reacting to it in daily operations.

Long-term objective:
SESAR AOP/APOC implementation

Involved parties:
KLM, RSG, LVNL, KDC partners

Source:
KDC report: Airport Operations Centre Amsterdam Airport Schiphol, April 2021
KDC report: D-1 Demand Prediction, January 2022
KDC report: Airport Operations Centre Ontwikkeling - Besluitvormingsproces in D-Min Cyclus, October 2023

4.4.3 Multi-airport concept

Ref. Ext. Program	Airspace re-design program	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval	3-12-2019	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
Schiphol as well as regional airports grow. Traffic flows from different airports use the same airspace. Therefore it is needed that, parallel to a new airspace design, airports are jointly managed, to efficiently use the available airspace. This concerns strategic, pre-tactical as well as tactical planning. In the strategic domain for example, schedules of slot regulated airports currently do not take other airport schedules into account. In the pre-tactical domain, the Schiphol D-1 planning, Schiphol sector briefings, LVNL workload model, and management of disruptions can be studied.

Goal / Expected benefit:
The goal of this study is to propose measures for an efficient use of airspace with multiple airports. This concerns strategic, pre-tactical as well as tactical planning measures.

Assignment:
- Investigate how the management of traffic flows in Dutch airspace can be improved, taking into account the location and function of Dutch airports. Options under consideration are: alignment of flight schedules, coordination of peak hours, refinement of flow measures, tactical complexity management measures.
- Develop a concept for the planning and management of traffic flows.

Short term objective:
Produce measures that streamline the multi-airport operation with regard to the Dutch airspace redesign programme (DARP).

Mid-term/Long-term objective:
-

Involved parties:
KLM, RSG, LVNL, Dept. of I&W, PLRH

Source:
KDC report Multi Airport Concept, March 2020

4.4.4 Traffic buffering concept

Ref. Ext. Program	-	**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval	3-12-2019	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld en Christiaan Evertse		-	✓	✓	-
Financial Partner	DGLM					

Introduction:
Traffic buffering means: planning and absorbing delay during the executive phase of flight. Traffic buffering can apply both for inbound and outbound traffic. Traffic buffering means that more aircraft are allowed to "enter the system" than the available capacity. The justification for absorbing delay in the executive phase of flight must come from KPI improvement, for instance in the area of environment or capacity or in terms of the delay itself.

In the case of arrival traffic buffering aircraft have to fly orbits at the TMA boundary to wait their turn to land, to absorb delay. Currently LVNL does not operate a buffering concept in the sense that structural holding occurs. However, some traffic buffering takes place during arrival peaks to cope with traffic bunches. In that case traffic buffering is used to smooth the flow of traffic into the TMA. The stack holdings are used incidentally, not structurally. The stack holdings must be available at all times to cater for loss of capacity unbalance in case of unforeseen circumstances.

Besides buffering for inbound traffic, the concept is also relevant for outbound traffic. For outbound traffic, holding is a ground based measure where departing traffic is taken from the gate to absorb delay "in the field" before being cleared to the departure runway. Potential benefits of outbound holding can be freeing up gates for inbound flights as well as a more constant feed of traffic for efficient departure sequencing. Both benefits are expected to positively influence capacity

Goal / Expected benefit:
Investigate whether benefits can be obtained by means of buffering aircraft in the AMS FIR and at Schiphol Airport.

Assignment:
Perform a benefit analysis of a buffering concept. What are the benefits of implementing the traffic buffering concept at Schiphol, and what are the implications.

Analyse the traffic buffering concept on:

- What benefits can be expected in terms of ATFM delay reduction, or peak-hour capacity.
- What are the design implications for the ATM concept: how many stack holdings would be required to support the concept?
- What are the strategic implications in terms of:
  - Compliance with PCP regulation 716/2014 to expand the planning horizon of the AMAN system to 180 NM to optimize descent profiles
  - Compliance with PCP regulation 716/2014 to implement fixed arrival routes in the TMA.
  - and low altitude CDA's.
- What drawbacks should be expected in terms of:
  - Environmental impact in terms of gaseous emissions (Cox and NOx)
  - Negative cost impact on the airlines (fuel burn)
  - Negative cost impact on the ANSPs (staffing costs)
  - Increased workload for TWR-GC and ACC

Short term objective: -

Mid-term/Long-term objective: -

Involved parties:
KLM, RSG, LVNL, Dept. of I&W

Source: -

4.4.5 FF-ICE - Dynamic Flow Management

Ref. Ext. Program	-	**TRL**	7			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval	3-12-2019	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld & Christiaan Evertse		✓	✓	-	✓
Financial Partner	DGLM					

Introduction:
Flight & Flow Information for a Collaborative Environment (FF-ICE) is a real time data exchange system in which actual airspace and aircraft parameters are shared to support ATM operations. It is an ICAO proposal that should replace the current ICAO flight plan standard. FF-ICE is a 4D trajectory planning tool that can increase flight planning reliability and 4D optimization. FF-ICE becomes an enabler for Dynamic Flow Management where trajectories can be planned through restricted areas that are available at the planned crossing moment. This reduces the amount of fuel that needs to be reserved for the detour, thereby decreasing emissions and making better use of airspace which positively affects airspace capacity and ATC workload. Lastly, FF-ICE is a far more collaborative format that makes it easier for the ATM community to exchange information. All parties involved in the ATM process will have a great level of awareness to where an aircraft is at what point in time. (ICAO.int, 2011)

Dynamic Flow Management is a concept which was introduced as a building block in the national airspace re-design programme (DARP). The idea behind dynamic flow management is to manage workload in airspace sectors dynamically by redirecting traffic flows. Using the FF-ICE flightplanning capabilities, the concept can be applied to optimise a variety of performance indicators. Besides workload the concept can also be applied to manage delay or to redirect flows to meet environmental performance indicators.

The concept of dynamic flow management differs from the traditional network management principles that are based on setting airspace capacity limitations and restricting flows on the basis of these limitations. Introducing FF-ICE opens possibilities by adding more predictability and accuracy. Dynamic flow management is intended to avoid network delay altogether through a collaborative decision making process, matching capacity and demand in a cooperative manner.

Goal / Expected benefit:
FF-ICE and Dynamic Flow Management are expected to enable shorter and safer route planning, and an increased data exchange between ATM partners. As a result, these concepts have many expected benefits. First off all, flight plan reliability and intent detail will be increased by reducing the time difference between the flight plan and the actual flight time. Furthermore, it is expected that onboard fuel reserves can be reduced, which again reduces emissions. Lastly, it is expected that the planned arrival time of aircraft at the FIR boundary is more reliable. The Dynamic Flow Management setting provides air traffic control organizations with the opportunity to dynamically optimize a wide range of performance indicators, i.e. workload, capacity, delay and environmental performance indicators.

Assignment:
Construct an implementation strategy, based on the expected benefits of the FF-ICE implementation phases, detailing what measures need to be taken to implement FF-ICE in the Dutch FIR.

Develop the concept of dynamic flow management in collaboration with the Network Manager, adjacent centres, and KDC partners within the framework of the future airspace concept and by aligning the development with the implementation strategy for FF-ICE. The concept application in the Netherlands must take into account existing capacity management developments, and define a path forward to full application.
Expected results:

- Description of the concept
- Initial assessment of feasibility also in view of the FF-ICE implementation strategy amongst others.
- Identification of performance potential (in particular reduction of network delay and improvement of environmental performance).

Short term objective:
An implementation strategy for the ATM actors in the Dutch FIR.
Identification of initial implementation step of FF-ICE in an initial Dynamic Flow Management setting with the aim to reduce delay.

Midterm/Long term objective:
Dynamic 4D flight planning; enabling shorter and safer routings, reduction of emissions, and increased punctuality with respect to the flight plan.
Full application of the Dynamic Flow Management concept in support of the future DARP concept with fixed arrival routes and Dynamic Flexible User Of Airspace (FUA).

Involved parties:
KLM, RSG, LVNL, MUAC, NATS, EUROCONTROL, Dept of I&W, PLRH

Source:
ICAO.int. (2011). *FF-ICE Leaflet*. [online] Available at: https://www.icao.int/airnavigation/FFICE/Documents/FF-ICE%20Leaflet%20final.pdf [Accessed 27 Nov. 2019].
Report “Voorkeursalternatief 2020-2035”, Version 0.9, Programma Luchtruimherziening

4.4.6 Schiphol Target Time of Arrival (TTA) Concept						
Ref. Ext. Program	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval	7-12-2018	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld & Christiaan Evertse		-	✓	✓	-
Financial Partner	DGLM					

Introduction:
In 2017 traffic numbers for LVNL peaked at their highest on record. More than 600,000 flights were handled by Amsterdam ACC and almost 500,000 commercial flights (without general aviation) arrived and departed at Schiphol Airport. These record traffic numbers resulted in a significant increase in delay as well.

In current operations LVNL is facing traffic demand well above the declared capacity on daily basis. Regulations are put into place to counter these Schiphol inbound traffic peaks. As such safety and orderly handling of traffic are ensured. With the increase in traffic, the delay caused by these regulations has increased as well. In 2017 Amsterdam Airport generated 13.8% of all European airport arrival ATFM delay (ATFM stands for Air Traffic Flow Management). According to the Network Manager, Schiphol Airport is one of the most congested airports in Europe and its generated delay has the largest impact on the network.1 ATFM delays are a problem for the aviation business mainly for the airline operators. Delays increase airline operating costs (cost of ATFM delay is around €80-€100 per minute) and it disrupts airline operations (including reactionary delay). Furthermore delays can disrupt airport operations (need for use of less environmentally preferable runways, gate planning, planning of ground handling, etc.). Finally the use of ATFCM-measures (regulations) decreases the planning flexibility of the European Network (due to the increased issuing of CTOT's).

To counter these delays, LVNL is seeking to increase capacity and to balance capacity & traffic demand in more efficient ways. One of the potential improvements is the use of "less stringent" regulations (potentially using higher rates and/or smaller regulation periods) by increasing the effectiveness of these regulations. In current operations, LVNLs experience is that regulations, used to reduce traffic peaks / bunches, do not always results in a sufficient safeguard for traffic overloads Often traffic peaks reoccurs before or after the planned peak moments. Different root cause generate the deviations, for example deviations in flight plan filed versus actual flown, different offset in the regulation model developed and in use by the Network Manager. Furthermore ATC in en-route sectors can issue directs to aircraft, resulting in further deviations. In addition airlines sometimes try to recover endured delays by flying more efficient (routes, heights and speeds). All mentioned root causes result in regulations (and capacity) that are managed with some conservatism to overcome these effects.

KDCs is interested in the concept of improving the regulation concept and target times solutions (TTO/TTA) as measures to increase effectiveness of regulations by preventions of bunching. TTO stands for Target Time Over (TTA Target Time Arrival) and represents the target time for a flight to enter an (regulated) airspace according to the flight profiling done by Network Manager. When pilots are able to operate more according to these times, risk of traffic bunches occurring may decrease.

In 2018 and 2019 the aviation sector partners conducted a study through KDC to develop a TTA concept for Schiphol, and tested it to a limited extend during a trial period. The tests were inconclusive. The reports are listed under reference 3 and 4.

Goal / Expected benefit:
More effective EHFIRAM regulations, less Airport ATFM delay and (in longer term) increased capacity

Assignment:
KDC requires a sort study addressing the following topics:

What is the TTO/TTA concept, how does it work?
- SESAR Network Manager regulation concept
- Trials at ANSP's
- Collaboration between Network Manager, ANSP's and Airlines

Which performance benefits can TTO/TTA deliver

- Effectiveness of ATFCM measures (regulations)
- Improvement of the regulation model (decreasing offset/ flight plan deviations)
- Performance effects on capacity and ATFM-delay

Feasibility of TTO/TTA use at Amsterdam Airport Schiphol / Amsterdam ACC

- Improvement of the regulation model (decreasing offset/flight plan deviations)
- Incorporation of TTO/TTA in current and/or future operations
- Possibilities to conduct trials in current operations
- Effectiveness for non-regulated flights (e.g. intercontinental traffic)
- Relations with current and future developments (like AMAN 2.0 and XMAN-trials)

Short term objective:
Delivery of a report addressing the benefits and feasibility of the regulation model and TTO/TTA concepts at Amsterdam Airport Schiphol and Amsterdam ACC

Mid-term/Long-term objective:
Depending on the feasibility study:
Mid-term objective is the conducting of one or multiple trials at Amsterdam Airport Schiphol and Amsterdam ACC

Depending on trial results:
Long-term objective is to introduce TTO/TTA at Amsterdam Airport Schiphol and Amsterdam ACC

Involved parties:
KLM, RSG, LVNL, Dept. of I&W

Source:

1) PPR2017, Performance Review Report 2017, https://www.eurocontrol.int/sites/default/files/publication/files/prr-2017.pdf
2) European airline delay cost reference values Final Report (Version 3.2), https://www.eurocontrol.int/sites/default/files/publication/files/european-airline-delay-cost-reference-values-final-report-v3.2.pdf
3) KDC report Initial Target Time Over/Arrival Concept for Amsterdam Airport Schiphol, March 27, 2019
4) KDC report Schiphol TTO trial, December 16, 2019

4.5 Meteo Innovation

4.5.1 RP4 focus areas for meteo innovation

Meteorological forecasts for Schiphol have a major impact on the planning and realization of the airport's capacity and related decision-making processes. It is therefore important that KNMI shows continuous development in the field of airport weather forecasting. Even small improvements generate large benefits. The KDC partners expect KNMI to continuously perform statistical analyses of performance. Knowing that weather forecasting is a statistical discipline, performance must be measured over longer periods. The KDC partners expect KNMI to take its own initiatives to improve performance and expect that the performance improvements are made demonstrable and actively reported. In general, the trend is that sector parties are planning further ahead and want to make decisions earlier. This requires that information needed for decision-making, including meteorological forecasts, must be available on a longer time horizon and with greater accuracy/certainty.

4.5.1.1 Airport related meteo development

Examples of airport related developments that the sector parties would like to see:

a) Cloud base forecast and monitoring
The cloud base is important for the use of convergent runway combinations. Uncertainty about the cloud base, especially forecasts around 2000 feet, have capacity- and environmental impact.

c) Visibility forecast and runway visual range forecast
The aviation sector expects KNMI to work on low frequency phenomena with a high impact on capacity, such as low visibility (BZO) conditions. In 2008, KNMI implemented an improvement on the visibility forecast in the Schiphol probabilistic forecast (SKV). It is important that this development will continue, by developing local Schiphol weather models and providing these models with local sensor measurements.

c) Wind forecast
The wind forecast has a dominant influence on runway use and on capacity. Schiphol desires to offer a greater degree of transparency to the environment and community, for example by making predictive apps available, so that the environment knows what to expect in terms of runway use. This noise/noise nuisance forecast is not only about the question of which runway combination will be used, but also about how long this combination will be used. The quality of runway planning is not only important because of the aspect of nuisance perception. A stable runway planning is important for reliable capacity planning, but is also important for the transition to Trajectory Based Operations. Being able to influence approaching traffic earlier, preferably before entering Dutch airspace, depends on being able to estimate the landing time. This requires that the flight path is known, and the runway in use influences the length of the flight path. Cross-border arrival management and trajectory based operations depend on stable and predictable runway use. A reliable wind forecast is therefore an important enabler for the future operational concept.

d) TMA wind forecast
The wind at the field and the wind at cruising altitude are important meteorological factors that influence flight planning and flight handling. The wind forecast at intermediate altitudes (below approximately 10,000 feet) plays a less important role, for the simple reason that aircraft are only at these altitudes for a short time (in the Netherlands, almost all traffic is climbing from or descending to Schiphol). Nevertheless, the TMA wind forecast does play a role in the handling of traffic and decision-making about runway use. Strong upper winds (for example from the west) can warrant path extensions to allow traffic to descend and slow

down, and can be a reason that transfer of traffic to adjacent centres cannot take place at the agreed altitude. In the future, the TMA wind forecast will play a greater role in the decision-making about the way in which traffic is handled. For example, it partly determines whether fixed approach routes can be used, and whether 3D separation of approaching and departing traffic is feasible. For this reason, it is also necessary to further develop and evaluate the TMA wind forecast.

e) Rain (shower) forecast in Dutch airspace
The forecast of rain showers determines the planning of sector capacity, both for ACC and APP. In addition, the presence of showers (where it does not matter whether they are in- or outside the TMA) determines whether or not fixed approach routes can be flown. For operations, the way in which pilots deal with showers is an additional complicating factor. In this area, research is needed to inventory whether innovations are possible that make the operation more stable and predictable when there are showers in Dutch airspace.

f) Increased chance of lightning strike forecast
For airlines, lightning strikes are a flight-disrupting event with possible logistical consequences and possible physical damage to the aircraft. For passengers, a lightning strike is primarily a frightening event. If areas can be identified where there is a temporary increased risk of lightning strikes, and the traffic situation allows these areas to be avoided, this possibility should be used. The sector desires to develop an operational concept, supported by meteorological decision information, in which the risk of lightning strikes is minimized. The KNMI is the designated party to develop the decision information for this concept.

g) Significant weather recovery
When there is a reduced capacity due to meteorological conditions, it is of great importance that restrictions are lifted as quickly as possible when conditions improve. It is important for the sector that KNMI improves the so-called ‘recovery performance’ by evaluating and analyzing the events in which this occurs.

4.5.1.2 Meteo development for Trajectory Prediction

A key development area for the aviation sector is to provide accurate meteo information to the trajectory predictor processes used by LVNL. This involves information with a sufficiently fine grid and update rate that supports accurate estimates of arrival times and times over waypoints. The trend in trajectory prediction is that increasingly accurate information is needed, within an ever-larger geographical horizon.

KNMI is expected to actively participate in European developments in this area, and to collaborate with neighbouring meteo providers in order to provide LVNL with accurate information, within a large geographical horizon. In addition, KNMI is expected to investigate what additional sensors/data sources can mean for the further development of trajectory prediction accuracy and horizon.

4.5.1.3 Meteo development for planning processes

Transition from the numerical weather prediction (NWP) model HIRLAM to HARMONY: It must be demonstrated that a possible transition from HIRLAM to HARMONY will result in a performance improvement in the meteo service provision. This research is necessary before a decision can be made about HARMONY application.

In the Decision Support Tool that LVNL is developing, the probability forecast Schiphol Kans Verwachting (SKV) information is used to control the runway forecasting. In addition, hi-res meteo information is used to determine the landing capacity. Sometimes the SKV information is not consistent with the hi-res. These discrepancies must be investigated.

There is a desire to expand the SKV information for the DST application, to calculate landing capacity in the future. Hi-res meteo would then no longer be necessary for DST. It should be researched which additions are desired/possible for this.

There is a desire to evaluate the quality of the SKV on the different time horizons. In addition, there is the desire to evaluate the SKV quality in different sub-areas: wind, visibility, precipitation (APT), CBs, …

For hi-res meteo: for further DST development, one of the areas is dealing with probabilities. Therefore, it is desirable to add probabilities to hi-res data. A study could focus on what exactly is possible, what needs to happen at KNMI and what is the impact on LVNL.

4.5.2 Meteo assignments for 2026

4.5.2.a Climate adaptation transition risks						
Ref. Ext. Programme		**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval	29-08-2024	**Performance Targets**	S	Ec	Es	Env
KDC Point of Contract	Maarten Zorgdrager		✓	✓	✓	-
Financial Partner	DGLM					

Introduction:
Governments, authorities and inhabitants address climate change and the impact on society as an urgent risk. Royal Schiphol Group (RSG) states in their vision that they aim to be climate resilient by 2050, which is in line with the ambitions of the Dutch government and local authorities. In the vision "Sustain your World strategy, and the Strategic Investment Plan for Water" the risks of climate change and the need to include climate adaptation in RSG's policy becomes clear. This Climate Adaptation Strategy is the start of an integral Climate Adaptation policy for RSG. The 2022 climate adaptation strategy resulted in a:

- weighted list of climate related risks for Schiphol;
- Climate Adaptation Roadmap, and
- short term action plan to get things started.

These actions will be adopted into the Sustainability Roadmap, securing the climate adaptation roadmap in the current governance structure.
Future research however is still required into the field of:

1. **transition risks** and
2. the **impact of climate change on the network** (e.g. disappearance of wintersport destinations, impact of hurricanes on the network, etc.)

Goal / Expected benefit
The goal of this research is to obtain thorough knowledge of the **transition risks** for Amsterdam Airport Schiphol related to climate adaptation and develop mitigating policies which can be implemented in line with the Corporate Sustainability Reporting Directive (CSRD) requirements.

Assignment:
[Short description of assignment made by the customer. What does the customer expect to be achieved by which date. What are the deliverables?]
Identify the transition and physical risks of climate change for Amsterdam Airport Schiphol and structure it in a CSRD framework which can be used to implement it in new policy (CSRD framework will be provided). As starting point the Climate Adaptation Strategy shall be used.

Transition risks can be defined by:

- climate-related transition risks and opportunities in own operations and along the value chain, in particular:
  - i. the identification of climate-related transition events, considering at least a climate scenario in line with limiting global warming to 1.5°C with no or limited overshoot; and
  - ii. the assessment of how its assets and business activities may be exposed to these climate-related transition events, creating gross transition risks or opportunities for the undertaking.

Physical risks:

- climate-related physical risks in own operations and along the value chain, in particular:
  - i. the identification of climate-related hazards, considering at least high emission climate scenarios; and
  - ii. the assessment of how its assets and business activities may be exposed and are sensitive to these climate-related hazards, creating gross physical risks for the undertaking.
  - iii. And create policies that will help mitigating the defined transition and physical risks.

Measurable factors of the climate adaptation transition risks could include:

- Impact of warm weather on operations (number of delayed/canceled flights).
- Impact of weather on staff (too hot to work, storm) and therefore on the operation.
- Impact of overflowing sewers due to high rainfall and not enough drainage to groundwater (liters that go into the sewer compared to the maximum and how long would it last if there is more flow to groundwater).

The duration of the project is expected to be 9 months.

Short term objective:
[what is the objective within 0 - 3 years?]
To gain insight of the climate transition and physical risks and to have a mitigating policy in place.

Midterm objective:
[what is the objective when this project is implemented, after 3 - 5 years?]
Once this project is completed the policies will be implemented and the climate adaptation risks will be reduced.

Long term objective:
[What is the objective/what goals must be achieved within 5 - 10 years? (if applicable)]
The provided policy should decrease the transition and physical risks to a minimum.

Relationship with other projects/research:
Previous research into the subject of meteo:

- *2022: Climate resilient airports – Schiphol Climate Adaptation Strategy 2022*
- *2021: EUROCONTROL study on climate shange risks for European aviation.*
- *2013: Klimaatbestendig Schiphol Syntheserapport HSMS02*
- *2012: Wind climatology of Schiphol*
- *2012: The impact of climate change on the critical weather conditions at Schiphol airport*
- *2012: Temperature climatology for Schiphol (the Netherlands), for present-day and climate scenarios in 2050*
- *2011: Upper air climatology of Amsterdam FIR, using ERA-Interim 1989-2008 part 1 & part 2*
- *2010: Climatology of low visibility for Amsterdam Airport Schiphol 2010: Extreme precipitation statistics for Amsterdam Airport Schiphol*
- *2010: Temperature and cloud distribution during day time for aircraft cooling capacity at Schiphol, climatology 1990-2009*
- *2009: Windchill equivalent temperature (WCET) : climatology and scenarios for Schiphol Airport*

Involved parties:
[which stakeholders, sector partners, customers actively participate in the research?]
Schiphol Group, KNMI

4.5.2.b Local wind prediction modelling for gate planning

Ref. Ext. Programme		**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval	29-08-2024	**Performance Targets**	S	Ec	Es	Env
KDC Point of Contract	Christiaan Evertse		✓	✓	✓	-
Financial Partner	DGLM					

Goal / Expected benefit:
Being able to take earlier and better decisions for gate allocation during foreseen strong wind conditions in different scenarios.

Introduction:
High wind conditions often pose Schiphol airport for various challenges, not only resulting in reduced runway capacity but also in limitations on aprons and open aircraft stands to be used. A project called Windflag was initiated but was halted prematurely in 2019 so no results could be published.
To date, the decisions are based on a table with available gates for strong winds coming from SW and NE directions and various wind speeds.

Assignment:
Develop a decision model for connected gates and open stands at Schiphol, based on different wind scenarios (direction, speed) in order to better and more precisely predict which gates can be used (without compromising safety), and what the capacity impact will be for the different scenarios.

Short term objective (first year):
- Get quantitative insights in the effects of different, most likely strong wind scenarios with regards to which gates and open aircraft stands can be used or not.
- Improve impact assessment (better quality, predictability) during strong wind scenarios with aim to use as many gates/open stands as feasible and to reduce the ground handling stops (‘afhandelingsverbod’) to the minimum possible.
- Improve gate allocation decision making process at D-1 due to improved predictability and better decision making insights.

Midterm objective (two – three years) :
- *Improve gate allocation process as we learn, reduce operational impact and increase predictability for D-3…D-1*

Long term objective (> three years) :
- *Improve gate allocation process as we learn, reduce operational impact and increase predictability for D-7…D3 to the extent possible*

Involved parties:
LVNL, KLM, AAS, KDC partners

Source:
- Present strong wind scenario description + strong wind gate availability table
- Windflag project info (2019)

5 List of Acronyms

AAA	Amsterdam Advanced Air traffic control system
AAS	Amsterdam Airport Schiphol – see also RSG
ACC	Area Control Center
ADSB	Automatic Dependent Surveillance-Broadcast
AMAN	Arrival Management
AMS	Amsterdam
ANSP	Air Navigation Service Provider
AOP	Airport Operations Plan
APOC	Airport Operations Centre
APP	Approach
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATFCM	Air Traffic Flow & Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
B-KDC	Board – Knowledge & Development Centre
CCO	Continuous Climb Optimisation
CDA	Continuous Descent Approaches
CDM	Collaborative Decision Making
CLM	Concept Lifecycle Model
Cox	Carbon Oxides
CPDLC	Controller-Pilot Data Link Communication
CPDSP	Collaborative Pre-Departure Sequence Planning system
CTOT	Calculated Take-Off Time
CTR	Controlled Traffic Region
DGLM	Directoraat-Generaal Luchtvaart en Maritieme Zaken
DLS IR	Data Link Services Implementing Rule
E_C	Efficiency related to capacity
EHAM	ICAO: Amsterdam Airport Schiphol
Env	Environment
E-OCVM	European – Operation Concept Validation Methodology
E_S	Efficiency related to sustainability
ETA	Estimated Time of Arrival
FF-ICE	Flight & Flow Information for a Collaborative Environment
FL	Flight Level
FMS	Flight Management System
FIR	Flight Information Region
ft	Feet
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
iCAS	iTEC-based Centre Automation System
ILS	Instrument Landing System
IM	Interval Management
IPS	Inbound Priority Sequencing

KDC	Knowledge and Development Centre
KLM	Koninklijke Nederlandse Luchtvaartmaatschappij
KPI	Key Performance Indicator
LVNL	Luchtverkeersleiding Nederland
Dept. of I&W	Ministerie Infrastructuur en Waterstaat
MT-KDC	Management Team – Knowledge & Development Centre
NLR	Nederlands Lucht- en Ruimtevaart Centrum
NM	Nautical Miles
NOx	Nitrogen Oxides
OCC	Operations Control Center
OTP	On-Time Performance
PCP	Pilot Common Project
PBN	Performance Based Navigation
PoC	Point of Contact
QNH	Query: Nautical Height
RECAT-EU	Re-categorisation for Europe
RNAV	Area Navigation
RSG	Royal Schiphol Group
RT	Radiotelephony
S	Safety
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure
SIRA	Systematic Risk Analysis
TMA	Terminal Control Area
TRL	Technology Readiness Level
TTA	Target Time of Arrival
TTO	Target Time Over
TWR	Tower
TU	Technische Universiteit/ University of Technology
WTC	Wake Turbulence Category
XMAN	Extended Arrival Management

Appendix A: Project Template

Template for describing research subjects within KDC. This template differs over the years, as the format is optimized.

<table>
<tr><th colspan="7">Chapter No. Project title</th></tr>
<tr><td>Ref. Ext. Program</td><td>Program reference</td><td>TRL</td><td colspan="4">Technology Readiness Level</td></tr>
<tr><td>Customer</td><td>Entity which accepts and uses the result</td><td>Lifecycle phase</td><td colspan="4">Phase in the E-OCVM methodology</td></tr>
<tr><td>KDC Board Approval</td><td>Date</td><td>Performance Targets</td><td>S</td><td>Ec</td><td>Es</td><td>Env</td></tr>
<tr><td>KDC PoC</td><td>Name</td><td></td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Financial Partner</td><td>Provider/Stakeholder which financially supports the project</td><td></td><td colspan="4"></td></tr>
</table>

Introduction:
Short description in common language of the research subject.

Assignment:
Short description of assignment made by the customer. What does the customer expect to be achieved by which date.

Short Term Goal (0 - 3 years):
Breakdown of goals in short term, Mid-term and Long-term. The short term goal must be achieved within 0 - 3 years.

Mid-term Goal (3 – 5 years):
This goal must be achieved within 3- 5 years.

Long-term Goal:
This goal must be achieved within 5 – 10 years.

Relationship with other projects/research:
When considered essential to understanding the place of this research subject in relation to other developments, this paragraph can be added to the description.

Involved Parties:
A list of parties which actively participate in the research.

Background information:
Any other relevant information which helps understanding the relevance of the research subject.

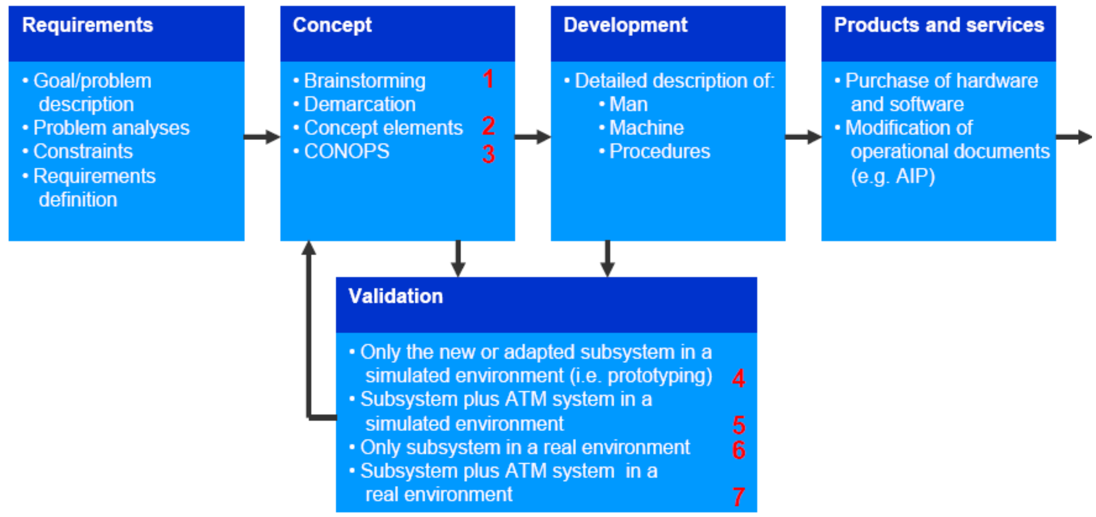
Source:
The source of the research.

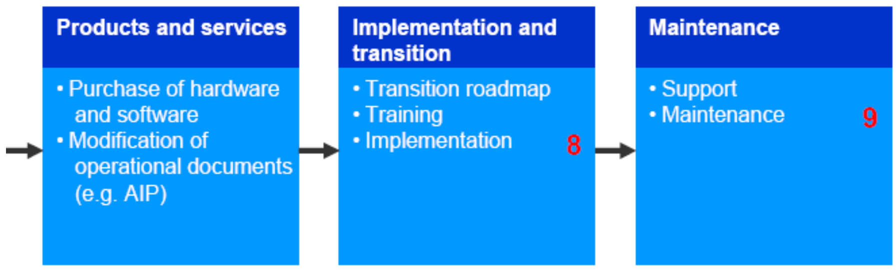
Result report:
Reference to the outcome of the project.

Technology Readiness Levels (TRL):
TRLs are a systematic metric/measurement system that supports assessment of the maturity of a particular technology and the consistent comparison of maturity between different types of concept. The definitions of the different TRL levels are given in the table below.

Technology Readiness Level	Description
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Example might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high fidelity' laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and 'flight qualified' through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system 'flight proven' through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.

Appendix B: Relationship between TRL levels and the ATM System Development Phases





Attachment C: Arrival Management Research Roadmap

C1: Introduction

This document aims to contribute to the development of the AMAN Roadmap from the KDC expert team. The document is structured along the same lines as the current AMAN Roadmap:

- Trajectory information (Accurate Traffic Picture)
- Planning information (Stable planning)
- Support information (Early actions)

Various cross-sections can be made. The above-mentioned is just one of them. Other cross-sections are for example: Horizon (AMAN, XMAN, ATFM) or Human-Machine-Procedures. These aspects will be included in the chosen cross-section. The chosen cross-section can also be formulated as: Prediction -> Planning -> Execution. This cross-section functions as a base for the rest of this document.

Where possible, recommendations will also be made for possible KDC studies. These recommendations are also depicted in a first draft planning in the Excel appendix.

C2: Trajectory information

The accuracy of the Trajectory information, provided by the Trajectory Predictor (TP) functionality, is fundamental to all automation concepts that are built on it. It is therefore important to have a good overview of factors that can contribute to this. These will be discussed below.

C2.1 Current position

A good TP accuracy starts with accurate information about the starting point of a trajectory. This can be the runway of departure, but usually it is the current position when the flight is airborne. Predictability of the ground process is not considered here. Sources for this can be:

- Radar surveillance

  This one is the most well-known. Previous KDC research has shown that a larger range makes a significant contribution to the Planning information quality in preventing pop-ups. By using the full radar range of MADAP, planning horizons of up to 18 minutes for IAF are realistic.

- Datalink

  By means of ADS-C, the current position of the aircraft can be obtained independently of the available radar range. The disadvantage of this source is that in the short term the coverage of this source will be low. Depending on the geographical situation, this can however be a relevant addition.

- NM B2B

  Although NM does not provide current position information, it can be derived approximately. The big advantage is that this concerns all traffic, the accuracy is expected to be less.

- Commercial providers

  There are several commercial companies that provide position information such as Aereon, FlightRadar 24, Flightaware, etc. These are already used by some ANSPs as an additional surveillance source for ATFM or Capacity Management applications in particular.

Recommendation 1: investigate the added value of additional sources for current position, in relation to existing and maximum expectations of radar-based Surveillance coverage. Also investigate the horizon on which this information becomes available, the possible data link protocols and their availability.

C2.2 3D and speed information

There are several sources for the 3D information that a TP needs to be able to make accurate predictions:

- IFPS (NM)

The flight plan (FPL) provided by the IFPS currently consists of the ICAO 2012 FPL and will be replaced by FF-ICE in the coming years. This will make more route detail available. This applies not only to the lateral plane but also to the vertical profile and speed profile.

Any updates on this can be received via B2B. However, this will only become available when iCAS is put into use.

- Datalink

With the arrival of ATS B2 ADS-C, it is possible to obtain very detailed route information for both lateral, vertical and speed. The same considerations apply here, as mentioned for the current position information. This information can be integrated into the ground TP to further improve the ground TP accuracy. It remains desirable to have the ground TP independently generate the 4D trajectory information for various reasons:

- The ground (ATC) must be able to determine trajectory management actions in order to be able to plan and control traffic with high capacity and efficiency at the same time.

- Not all aircraft will offer ADS-C; in addition to a long lead time, it will also remain necessary for the robustness of the system.

- The ground TP will be able to handle a much higher accuracy of the wind and temperature model for the foreseeable future, which means that calculation by the ground of the time dimension also remains desirable

Special attention is paid to the so-called “in-horizon” departures, also known as pop-up traffic for the AMAN. The current ASAP and Night-OWL TPs have proven themselves in terms of accuracy. However, this is limited to the cruise and descent phases of the flight. For climb-to-cruise, these TPs are inaccurate and this phase will play a role in expanding the planning horizon.
Here, an ADS-C trajectory can add accuracy, especially for the vertical profile. This can be a supplement to 3D information from FF-ICE.

Integration with the ASAP/NOWL-TP then consists of adding the time dimension to the 3D (climb) trajectory and speed profile of the aircraft from ADS-C. This form of trajectory integration is recommended because the ground-TP will use a more accurate wind field (hi-res meteo).

Recommendation 2: Investigate the differences in 3D accuracy between the various sources of 3D route information mentioned. Also include the 4th: the time dimension. Investigate the best place in the AMAN roadmap to integrate this application into the ATM System.

C2.3 Relationship between Operational Concept and Trajectory Information

Another part of the complexity of making accurate trajectory information available, is the relationship with the operational concept used. The various aspects of this will now be described.

The 3D route and speed information is not only used in the ground-TP, but also by the FMS for the trajectory information obtained from ADS-C. If the ground-TP is partly going to use ADS-C information, this will have to be carefully considered in relation to the operational concept. Further analysis is needed to select suitable elements for development and to place them in time with all mutual dependencies.

Ultimately, the operational concept will have to pay attention to providing the FMS with the correct 3D route and speed information (from AMAN/XMAN) to have accurate and integrated trajectory information determined by FMS and ground-TP. These aspects will be described in this section.

- TMA routing and Runway

This information forms an essential part of the 3D route for the TP on the ground and in the FMS. The AMAN/XMAN system must be able to provide this information predictably. This will be described further in the chapter on planning information in relation to horizon aspects.

- UTA/CTA lateral routing

The route from the current position of the aircraft to the TMA is divided into 2 large parts:

1. FIR part: this is normally the STAR from entry-COP to IAF. For the purpose of front loading (see next chapter) this route can also be directly to the IAF from entry-COP or current position. It is not expected that front-loading routes will be sent to the aircraft.

2. Climb/En-route part: this segment is largely determined by (XMAN) agreements with the upstream centers. The level at which a predictable concept can be developed with regard to 3D routing will contribute greatly to the TP accuracy, planning and execution in an XMAN setting. In principle, the filed route in the FPL/ADS-C downlink should be used (also see the next section), but clear agreements on the predictable application of this will increase the success factor of the XMAN concept.

- UTA vertical profile

There are various sources for the vertical planning information of a trajectory:

1. The airline's flight plan
2. The flight plan as calculated by NM
3. A possible ADS-C downlink
4. Published constraints in national AIPs
5. Letter of Agreement (LoA) between control centers
6. The Route Availability Document (RAD) of Eurocontrol

The above diversity of information describing and/or limiting the vertical profile of a flight makes that both FMS and ground-TP trajectories are not always representative of the actual trajectory. In order to achieve an accurate trajectory on which planning and execution can take place, this aspect will have to be addressed in the operational concept. This can best be illustrated with an example:

A constraint is applied for inbounds EHAM of FL300 on the French-Belgian border between Reims UAC and MUAC. This information can only be found in item 5 of the list above. These types of situations exist at various locations in MUAC airspace around the AMS-FIR.

The fact that these situations have existed for a long time indicates that conventional methods are not sufficient to solve this. A Trajectory Based solution is needed in which the trajectory is considered integrally, from current position to the runway with all intermediate vertical constraints.

Recommendation 3: Investigate which situations exist, as described above, in the airspace around the AMS-FIR and develop operational concept elements with involved upstream centers to address this problem. The KDC TBO report can be used for this. Also include the lateral component. These results contribute to the development of the XMAN concept for EHAM.

C3: Planning information

The AMAN function, performed in the LVNL system by the ASAP system, plays a pivotal role in the arrival process of EHAM. The extent to which the arrival process can move from tactical to planned operations is largely determined by the quality of the AMAN function. This in turn is also influenced by the accuracy of the trajectory information. However, most attention is often focused on the TP, while various other factors play a major role in the total process. These will be discussed in this chapter.

The next chapter will specifically look at the aspect of the accuracy of the execution of the planning. There is an interaction between the two, which will also be considered in each chapter.

C3.1 Front loading

One of the objectives of ATC, in addition to the safe handling of air traffic, is efficient handling with high capacity. This is an important aspect for the Schiphol model. The flow of inbound traffic is mainly determined by the block system of KLM and the runway usage at Schiphol, which results in inbound peaks several times a day.

If traffic can be handled ‘faster’ in the run-up to an inbound peak, this means a possible reduction of delays of following traffic, if the demand exceeds the landing capacity, which often happens during a peak. This acceleration is also called ‘front loading’. It primarily consists of two components:

- A more direct route to the runway from a tactically chosen point, to a point in the TMA where the final approach for the runway can be initiated.
- A higher speed during the descent towards the TMA.

The ability of the ASAP-TP to convert this adjusted route and speed profile information into a 4D trajectory provides front loading support in ASAP. It is essential to apply the tactically applied rules in the TP in such a way that a balance is created between accurate capacity planning and 'tactical reserves' (please also refer later in this chapter to "Stability advisory support").

It is also important to take into account the fact that these front loading situations do not only occur at the beginning of an inbound peak. This is also relevant in the middle of a peak or certainly also during outbound peaks where only one landing runway is used.

C3.2 Horizon aspects

Trajectory Based working means considering a trajectory integrally on a 'relevant' scale. For the AMS-FIR this means that Trajectory Management (TM) must take place integrally with upstream centers. It also means that this Trajectory Management becomes more effective because trajectory modifications can be effected earlier and therefore more efficiently.

In this chapter, two aspects that play a role in this will be further explored: the predictability of the landing runway and the handling of pop-up flights.

- Runway predictability

  The horizon on which TM acts requires an extension of the AMAN time horizon. It is well-known that this poses challenges for the TP accuracy, inherent in forecasting at longer distances, but also other TP factors as discussed in the previous chapter. In this paragraph another factor for extending the horizon is considered: runway predictability.

  As described in the previous chapter, it is important to know the TMA route and runway, also at a longer horizon. This brings two challenges with it, in addition to operational disruptions such as special weather conditions and unexpected situations:

1. The choice of the number of runways (called ‘runways mode switch’) and the exact runway(s). This is in principle determined and published in the Capacity Forecast Schiphol (CFS) after the so-called Supervisor-consultation in which the sector partners also participate. However, during the implementation, the APP Supervisor, in consultation with the TWR Supervisor, can still make adjustments and determine the exact moments of changes in landing and take-off runway use.
2. The runways load-balancing during inbound peaks. This activity is often decided late at a tactical moment, usually within the (current) planning horizon of ASAP.

The problems of both aspects can be considered at two levels:

- Macro level: during transitions/changes, ‘switchover losses’ will occur, this does not detract from the great advantage of efficiently handled traffic volume.
- Individual flight level: for one or more flights, the planned TM solution can turn out unfavorable, which must be viewed by all parties at the macro level, in order to prevent acceptance problems in the total operation. A negative view can be reinforced by the problem of pop-ups as described in the previous chapter.

In the DST system developed for LVNL, in pre-operational use at ACC Sup/FMP, a model has been created to address both runway predictability aspects. In addition to the challenge of modeling a strongly tactically driven process in a planning system, the fact that the load-balancing model was developed for use in Capacity Management and does not aim for the accuracy of the tactical process for individual flights plays a role, particularly for the load-balancing model.

Recommendation 4: Investigate the suitability of the current DST prediction on the intended AMAN horizon of 20 minutes for IAF, for improving the runway predictability in the inbound process.

- Pop-up flights

In addition to the problem of correctly predicting the trajectory to be flown, the effect of pop-up flights increasingly plays a role when the planning horizon is extended. This cannot always be prevented despite better surveillance information, for example because these are flights that depart from airports that are (or will be) located in the AMAN horizon. These flights appear, in contrast to previous predictions, earlier or later than the position at which they were planned in the AMAN horizon. This can have two types of consequences:

- The flight arrives later and must be planned later in time. An ‘free slot’ is left behind in the planning that, if not filled, leads to a loss of capacity.
- The flight arrives earlier and must actually be placed earlier in the planning, which, if the planning is not adjusted, can lead to (slight) TMA overload.

In the tactical operation this is solved in different ways:

- ACC performs an EAT-swap (EAS) on the involved flights to get the flight in the right place in the planning sequence. ACC can only do this for flights that fly via the same stack.
- The APLN sees the sequence error and adjusts it manually, possibly followed by a re-planning of times. Sometimes the APLN also sees it for flights via the same stack and, unnoticed, ACC and APP work against each other by undoing each other's solution.
- No planning adjustment is made with in theory the consequences as described above, but often this is solved tactically with speed control and/or vectoring. However, this is not conducive to Trajectory Based Operations and the use of fixed approach routes in the TMA, especially with high AMAN performance requirements.

The above solutions therefore lead to extra workload, irritations and irregularities in the planning. A mitigation for this could be to support the ACC and APP system in these types of situations. This could be done, for example, by giving ACC clear sequence error signals and by ACC addressing them and at the APLN the sequence error that involve two stacks with clear agreements about this division. Other solutions are also possible with a different division of tasks.

Currently, an MSc assignment is running in the KDC CoE, regarding the consequences of increasing the planning horizon. It is possible that this assignment will yield new insights and solutions regarding this problem.

Recommendation 5: determine the relationship between the number of pop-up flights, the effects of this on the workload, capacity and on the AMAN Performance. Also investigate possible solutions for system support and methods to mitigate these effects. Also include the results of the CoE MSc thesis on this subject.

C3.3 Advanced support functions

A more accurate TP is not enough to make the AMAN planning more stable. In addition to better runway selection support, as described in the previous paragraph, more advanced planning functions are also required for this. These can be divided into two groups: functions for specific situations and functions that support the Approach planner (APLN) in managing planning stability. These will now be discussed in turn.

- Support for specific situations

In addition to the regular operation of AMAN based on the “First Come First Served” (FCFS) principle, operational situations occur where deviations from this principle are required. In such situations, there is no specific support for the APLN to process these situations in a planned manner and manual interventions are made with loss of planning accuracy and stability.

Perhaps the most common situation is when the delay, other than on an FCFS basis, must be assigned to one specific stack. This can have various causes, such as cooperation with ACC or weather conditions. Support for this will contribute to a higher degree in which stable and accurate planning can be maintained, with a related workload reduction for the APLN in particular and the usual advantages of stable and accurate planning.

Another planning function that is related to the assignment of delay to a specific stack is the possibility of shifting traffic in one stack. This often involves responding to a tactical problem in the operation, where ‘space’ needs to be created. Having such a relatively simple function at your disposal will contribute to maintaining correct planning for longer and/or returning to a planned operation sooner after a (serious) disruption.

Finally, with regard to stack-specific planning, there is a specific operational situation where, if it happens, (complete) loss of planning occurs and a way back to planned operations is found with cumbersome tactical handling. This is the situation where (out of necessity) a switch has to be made from 2 runways to 1 runway, while there is still a lot of demand for 2 runways. This can occur due to all kinds of circumstances, but in many cases due to weather influences, such as an unexpected amount of water on the runway. It is possible that this situation occurs more often than expected, namely with strict adherence to the rules for runway use and Capacity Management not aligned with them. Although less serious, it can be expected that the resulting planning will contain irregularities that can contribute to less stable and accurate planning. The problem in the planning in these situations is caused by the application of the delay rules when changing runways. If this is then followed by a re-planning for the remaining runway, a (completely) incomprehensible and unfair planning picture is created for the APLN. Additional rules for re-planning can prevent this situation and probably also improve the overall quality of the planning after a re-planning.

Recommendation 6: investigate to what extent and with what frequency the above-mentioned specific situations occur, which system support would be needed, the expected improvements for planning accuracy and an indication of implementation effort.

- Support for stability

Managing an AMAN planning means at an abstract level nothing more than maintaining a balance between the demand and the available capacity (Demand and Capacity Balancing, DCB). The balancing results in possible delays. In the specific situation of an active planning for the next 30 minutes, for example, the capacity is determined by a multitude of factors, first of all the current capacity of the landing runway, but also the total process of traffic handling in the TMA and the demand for the TMA.

The stability of the AMAN planning is ultimately determined by finding a balance between planning accuracy on the one hand and the necessary adjustments due to the dynamics of the arrival operation on the other.

At the moment, finding this balance is completely dependent on the tactics of the APLN. This is one of the factors that play an important role in the discussion about adherence to the planning: after all, if it is not stable, this results in a lot of workload for ACC and compliance becomes increasingly difficult. Conversely, if the planning is not accurate enough, either TMA overload or capacity loss will occur. This is the heart of the EAT adherence problem.

By providing support information to the APLN, he/she can be supported in this analogous to the DST system supporting the ACC Sup/FMP to make better informed decisions regarding their DCB role in ATFM decisions.

Support for the APLN to keep a planning stable, must therefore first provide insight into the expected demand, the capacity and the result of the current balance in terms of delay and/or capacity loss. Based on this, the APLN can assess whether adjustment is desirable. This functionality must then support the APLN in making decisions in adjusting that balance so that it can be assessed which adjustment will actually be implemented.

Recommendation 7: investigate the possibilities for providing support information to better inform the APLN for making AMAN planning adjustments for high accuracy and the effects thereof on planning stability.

- Support for probing

A wish expressed by APP since 2004, is the possibility to perform small simulations of interventions in the planning, comparable to the simulation possibilities that ACC Sup/FMP now have in DST. This may prove to be a good vehicle to carefully introduce instruments such as support for stability. Without these advanced functions, probing will at least be able to improve the tactical balancing of demand and capacity as it is done up to now. This is not a simple technical function, but it can lay a growth path for gradual improvement that is necessary for improving stability versus accuracy.

C3.4 Human aspects in the AMAN operation

The previous sections have already described how the APLN needs to manage many aspects in order to make and maintain a good and stable planning. In summary:

1. Enter the correct runway planning in ASAP in time, coordination with ACC + TWR.
2. Ensure good initial and ‘continuous’ front loading.
3. Load balancing between two runways during inbound peaks.
4. Specific circumstances with deviating ‘nominal’ patterns in the TMA/Stacks and holding use/not.
5. Balance runway use (Capacity) and TMA load (Safety/Environment).

All these tasks require a great diversity of skills to plan traffic and manage the planning system well. They are essential components in the transition from tactical operations to a more systematically controlled operation. This does not only concern APLN, it is a collaboration between APLN and ACC in particular, but also with TWR and ACC Sup/FMP.

Recommendation 8: Investigate the possible design of an AMAN training program in which all relevant aspects regarding accurate and stable planning and execution thereof are mapped out and the recommended frequency of refresher training. Special attention should be paid to mutual causes of misunderstanding and friction and how these can be reduced by proper use of systems and methods.

In the following two sections, these aspects are further elaborated, divided into horizon-related skills and stability and accuracy-related matters.

- Training of horizon aspects

One of the causes of misunderstanding about planning on a larger time horizon is the 'late' introduction of the current runway configuration. When training ACC, attention to the causes of the sometimes late introduction and/or deviation will deserve attention in order to increase understanding on the ACC side. For the APLN it is useful to pay attention to the implications of the workload of late runway changes and the consequences for flight efficiency and workload for the cockpit. Trainings with specific scenarios in the system and illustrations of analyses can be supportive. This could be supplemented with explanations by KLM and/or Airbus.

When increasing the freeze horizon of the planning, it is crucial to clearly map out the positive and negative effects (e.g. workload, individual loss for an involved flight, but gain for the entire flow) of a larger horizon with the APLN group. This can be done by presenting the results of analyses, by deepening certain traffic situations by, for example, training sessions in which these are replayed. Together, these activities should convey a clear message of a net positive balance. KLM may also be able to provide a supporting message that it is ultimately about the balance and realizing the goals of TBO in an environment that is now filled in by the PLRH.

If system support is provided to recognize the effects of pop-up traffic early and to solve them easily as described earlier in this chapter, then good training will also be needed for this. This will not so much be the use of supporting automation, but should mainly focus on awareness of the problem and the consequences.

Recommendation 9: Investigate the possibilities for using different platforms in LVNL to visualize and train these aspects. This could include iLabs, DST systems, ASAP test and NARSIM resources as previously used during the introduction of ASAP. Also consider the resource of probing in ASAP in this evaluation.

- Training op stability aspecten

Managing the balance between demand and capacity at the AMAN planning level is the most complex task of the APLN role in AMAN. Without any further tooling, training would still be required to give the ALPN more insight into the consequences of various considerations as described earlier. This also keeps tactical skills up to date.

With or without stability support, training should not focus exclusively on the APLN, after all, TM extends over a large part of the “AMAN managed” trajectory, so ACC and upstream centers are also involved.

ACC because of their understanding of the complexities of managing the balance and the need for their cooperation for “stable and accurate” execution of the planning. A good understanding of the mutual influence between the complexity of good planning and its execution is an essential building block for a good AMAN operation.

Attention should be given to clear communication about (possible) disruptions of that balance and recovery actions. This is all happening now, but it is purely dependent on the current crew and without further support. By providing support for this and training repeatedly by means of suitable scenarios, stable and accurate planning and execution can be achieved more often and better, with more mutual understanding. This not only benefits the process, but is also conditional.

In addition, the required training in the field of execution (see also next chapter) plays a role for ACC in relation to upstream centers. They are also involved in TM via the XMAN concept and this relationship plays a role in the execution of the planning and therefore also the stability.

Recommendation 10: Develop a roadmap for the introduction of a process of improving planning stability and accuracy with integral attention to the role of system development, for example the means of probing in ASAP, with special attention to the different roles of the people and units in this.

C4: Planning execution

The execution of the planning plays a major role in the planning stability and accuracy. The training aspects of this will be discussed in another chapter. In this chapter, the aspects that play a role in realizing the AMAN planning are discussed. First, ACC will be examined and then the role of upstream centers will be discussed.

C4.1 ACC planning execution

At this moment, ACC is supported in the execution of the planning by means of the delta-t. This indicates the difference between the planned TMA entry time (EAT) and the current prediction of the TP, at which the aircraft is expected at the stack. ASAP also provides a delta-t that adjusts to the speed entered by the air traffic controller, allowing him to try a suitable speed.

A number of aspects play a role in this, which will be discussed in this paragraph.

- Interpretation of the EAT adherence requirements

  Apart from the exact definition of the EAT adherence window itself, there is much discussion about the use of this window: is it aimed at the smallest possible difference in principle, or is every delta-t value ultimately a good goal to strive for in the implementation. In some cases, the window boundary (usually the “too early side”) is maintained. If deviations occur in the implementation for whatever reason (see next paragraph), exceeding the EAT window is an expected consequence.

  This effect creates more spread during the implementation, which may require additional adjustments in the TMA. This is particularly the case if these variations occur between two or three stacks and together can amplify the deviation from the planned TMA dosage, causing a temporary overload of the TMA or loss of capacity. It is expected that the adjustment options for partially or completely fixed approach routes in the TMA will become insufficient. It also contributes to an increase in the workload for the APP controllers.

Recommendation 11: Develop a research facility to gain insight into the consequences of this method on flight operations in the TMA. In addition to a possible bias in EAT adherence, this can also concern the distribution of EAT adherence itself. A facility to investigate this should also be suitable for training to draw attention to this aspect.

- Holding

  What also should be highlighted, is the situation in which holding plays a role. Firstly, the choice to use holding is a highly tactical process in which the decision to use holding is made by ACC in consultation with the APLN. The choices made in this regard in current operations will very likely require adjustment and training if a different EAT adherence is to be assumed.

  Experience also shows that in holding mode, EAT adherence decreases due to the nature of the holding process. Technical solutions have already been developed in concept for this in the CoE, but these are not expected to be applicable until sometime after iCAS has been put into use. Further research into the underlying problem could be considered as a mitigating measure.

  Finally, there is a complicating problem in the tactical transfer from ACC to APP during holding: ACC usually uses a holding speed of 220KIAS. The EAT is in principle determined at a speed after passing the stack of 250KIAS. Whether or not to accelerate from 220 to 250KIAS during transfer can cause substantial deviations from the planned TMA inflow, which can lead to friction between APP and ACC. There are individual differences and opinions about technical solutions in this.

Recommendation 12: Investigate which problems with regard to the EAT adherence in the holding operation can be solved in the short term with few or no system adjustments. Also assess which procedural solutions and training aspects can play a role, with or without system adjustments.

- Usability of the delta-t

The ASAP system now uses high-resolution meteorological data to make the ASAP-TP predictions more accurate. This improves the usability of the delta-t function: if a controller decides on a different speed based on the delta-t and enters that speed, ASAP will display the new delta-t based on that speed. The extent to which that prediction is correct determines the usability of the delta-t for supporting ACC.

However, complaints are regularly made about the usability of the delta-t, despite the use of good speed and meteorological information. It is suspected that one of these factors lies in the vertical navigation methods used by some pilots. This means that pilots regularly choose to perform the first part of the descent with a limited descent speed (usually 1000 feet/min), in order to increase this descent speed at a tactical moment in order to arrive at the desired height at the stack.

This practice results in the flight often being above the vertical profile expected by ASAP during the first part of the descent in ACC (and usually also in UTA), which leads to errors in the delta-t. This increases the workload for the ACC controller and does not contribute to EAT adherence. It also promotes distrust of system support and leads to more frequent use of tactical control.

A technical solution for this is in fact not possible, because this concerns human behaviour and not predictable operational factors.

Recommendation 13: Investigate the causes of deviating delta-t values that hinder ACC in meeting EAT adherence. If pilot working methods play a role in this, develop and conduct consultation sessions with relevant representatives to influence this working method.

- Additional information from the aircraft

With the arrival of ATS B2 ADS-C datalink, additional information can be obtained from the aircraft about the expected execution of the trajectory by the aircraft. If the pilot has chosen to let the descent take place under FMS control (VNAV), this information provides a detailed overview of what the air traffic controller can expect in terms of speed and altitude information. This data can also indicate whether VNAV is indeed active.

This information can also be used by the ASAP TP for a higher delta-t accuracy. By not using the time predictions from ADS-C for this, the air traffic controller can still try speed adjustments himself and also use the high-resolution weather information that is not available in the FMS (for now).

All this information can further support the ACC air traffic controller in the execution of the planning and in the primary task of ensuring the required separation. This can become extra relevant due to changes in FMS algorithms and/or airline operating practices or even ATC operational concepts, whereby, for example, speed changes are planned and executed differently by the FMS. Situations of this kind have already been observed on, for example, the A320Neo family. Ultimately, this type of trajectory information can also be fed into high-quality conflict detection functions that further support the air traffic controller.

C4.2 Implementation with XMAN centers

The upstream centers play an increasingly important role in the plans and regulations for supporting the execution of an AMAN planning. A large number of technical developments and possibilities play a role in this. Various aspects are also relevant in the field of the associated operational concept. In the chapter on Trajectory information, attention has already been paid to this from the TP perspective. In this chapter, a number of specific technical and operational concept elements are further elaborated in the light of the execution of the planning.

- Role of the ADS-C Common Server (ACS) as a coordination tool

The ACS is a central source of downlinked trajectory information, which allows each ANSP to easily receive this data at any desired range without having to communicate with the aircraft itself. The information is useful for TWR/APP and ACC for various operational applications. Some relevant ones for the TP, planning and execution have already been mentioned. It is therefore important to quickly connect to this development in order to be able to use it in time, not only operationally, but first and foremost in the preparation for operational use.

This becomes particularly relevant for the execution of the planning, where the use of ADS-C information can support the XMAN concept. In this, requests for adjusting speeds are passed on by the AMAN center to the upstream centers, which, in some cases such as south of the AMS-FIR, can extend over more than one upstream ANSP. There are two major operational issues:

1. The executing upstream center is not always prepared to confirm whether or not a speed request will be granted.
2. Intermediate upstream centers may require to be informed about speed adjustments.

If all centers involved have access to ADS-C information, the desired feedback from ADS-C can be obtained, since ATS B2 contains ADS-C speed schedule information. This information can also provide early insight into the execution of the agreed “XMAN routing” to the centers involved.

- Use of OLDI

Although the use of ADS-C has major advantages, the introduction of this technology is still in its early stages and alternatives are needed:

1. As an alternative to “coordination via ADS-C”, OLDI can be used. However, since OLDI is peer-to-peer and not all centers can make full use of the OLDI message set, there are some drawbacks to this. However, OLDI can fulfil this role to a certain extent.
2. In some cases, feedback on XMAN actions will not always be possible. Procedural solutions and/or agreements or application of XMAN requests must be sought for this.

Recommendation 14: Investigate the possibilities for XMAN feedback with the relevant upstream partners and how these can or cannot be realised. Also inventory the impact on the XMAN roadmap. Assess this in relation to the possibilities of using the ACS.

- Route aspects

As described in the Trajectory information section on CTA/UTA lateral routing, clarity about the route to be applied in the application of the XMAN concept is crucial. This “XMAN route” will be one of the most important points of attention in the definition of the XMAN concept and its implementation.

Experience shows that a very large number of flights receive direct routing from MUAC, this varies more to the west of the AMS-FIR due to different traffic types. During implementation it must be clear which XMAN routing agreements may be assumed. Proposed speed adjustments must therefore be based on this.

For example: the upstream center not following up a speed request could be caused by the requested adjustment and/or the impossibility to follow the XMAN routing for the flight in question. This must be clear in all cases.

- Vertical constraint aspects

As for lateral routing, the expected vertical profile is also essential for a successful application of XMAN techniques. The current tactically applied vertical constraints, as described earlier, make this impossible if this is not addressed.

An XMAN operational concept can contain various solutions for this. It should be noted that due to increasing automation and direct flying, air traffic controllers will increasingly be prepared not to apply tactical constraints. However, if this is done on a tactical and non-planned basis, no good

XMAN solution can be determined without a coordination tool because the AMAN system does not have the correct profile information.

Recommendation 15: Investigate which operational concept variants are possible to solve the problem of managing the lateral and vertical route profile in the XMAN context. These variants serve as input for consultation with the upstream partners in the development of well-executable XMAN requests.