KDC research agenda 2024 - 2028

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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 Dutch Aerospace Laboratory, 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 Dutch aerospace laboratory 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 programme 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 2024 and beyond. The KDC research agenda is a multi-annual agenda with a time horizon of five years.

The research agenda 2024 – 2028 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 programme 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 support the transition to TBO.

An important national policy link for the KDC research agenda (beside the national airspace redesign programme) is the programme 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 programme for the duration of the programme. Chapter 3 presents the focus for the next year, as part of the multi-year programme. 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. Airline and Airport Operational Efficiency
4. Capacity Management
5. Airspace Redesign & Innovation

In figure 1 below, these clusters have been projected on a horizontal plane, indicating for which parts of the Airport/Airspace system the clusters are applicable.

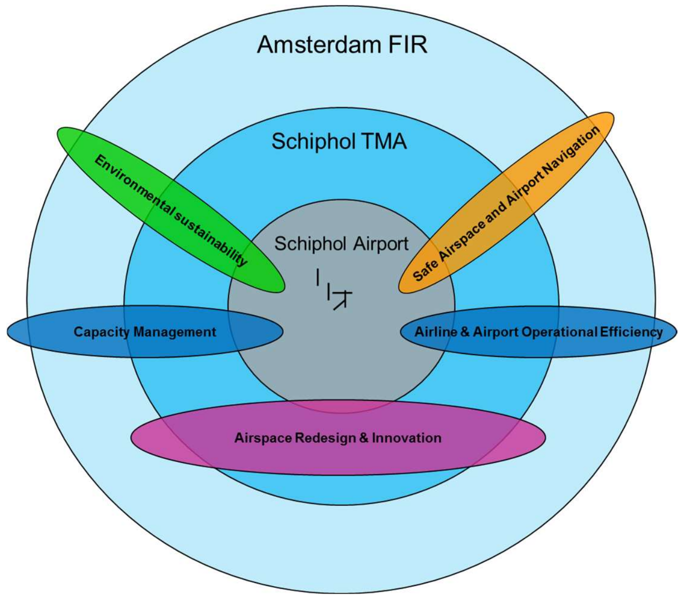

Figure 1: Research subjects projected on airport – airspace structure

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.

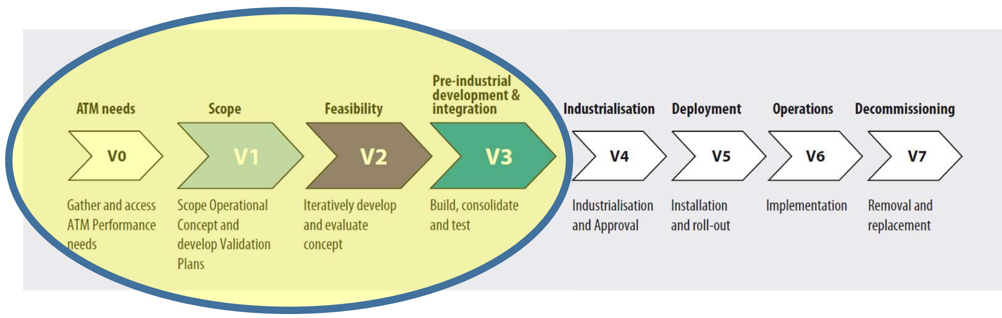

Figure 2: Scope of KDC-projects
(concept life cycle model, European Operational Concept Validation Methodology, E-OCVM)

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 3.

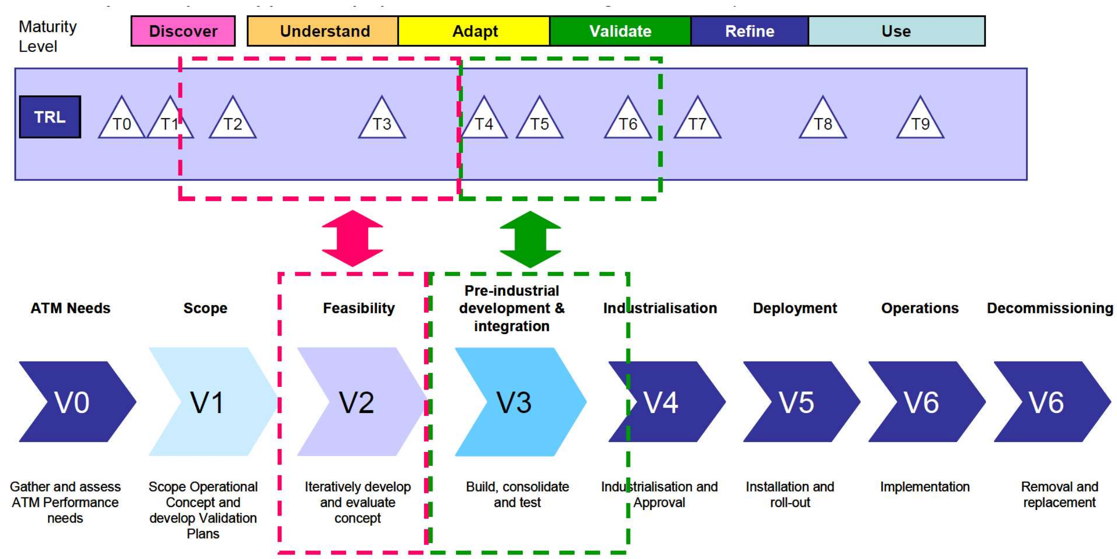

Figure 3: Principal relationship between the NASA TRLs and the E-OCVM CLM phases (source: EUROCONTROL, 2018)

In summary it can be stated that KDC research topics typically have a TRL level in the range of 2 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 programme is a multi-annual programme, 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. Airline & Airport Operational Efficiency
4. Capacity Management
5. Airspace Redesign & Innovation

In the following chapters each development area addresses its strategic objective for the 2024 – 2028 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. The cause 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 is supports technological innovation themes (such as drones, autonomous flight / unmanned aviation).
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 2024 – 2028 timeframe is:

Support safety validation aspects of the future ATM concept.

This objective will be achieved through the Air-Ground datalink evaluation study which will be commenced in 2024. In this study datalink solutions which provide both efficiency and safety benefits will be developed and operationally evaluated.

[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 subject, as it is very much in line with improving flight efficiency and reducing fuel burn. Examples are:
1) The new TMA concept with continuous climb and 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 2024 – 2028 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 Airline & Airport 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 being saturated (with increasing network delay as a result).

The KDC objective for the development of Airline & Airport Operational Efficiency in the 2024 – 2028 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 Capacity Management

The development of 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 2024 – 2028 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 Airspace Redesign & Innovation

Airspace re-design supports multiple strategic goals, both civil and military. With regard to the civil objectives, it is not only about improving the environment, capacity and safety performance of Schiphol, but also about the development of the regional airports of Rotterdam, Eindhoven, Maastricht, Groningen and Lelystad. The airspace re-design program not only creates a new design for the airspace, it also identifies the technological innovations needed to achieve the performance targets.

A number of the innovations identified within the airspace re-design program concern technological innovations that have been worked on for some time in the context of KDC. This creates a direct relationship between the strategic goals of the KDC (with Schiphol as focus) and the airspace re-design program.

One of the key developments in the airspace re-design program is the transition to a new TMA concept, which is based on fixed approach routes with continuous descent profiles, and SIDs with continuous climb profiles. It is foreseen that the transition to the new TMA concept requires a new operational concept, and several technological innovations.

The KDC objective for the development of Airspace Redesign & Innovation the 2024 – 2028 timeframe is:

> *Support the development of, and the transition towards, the new TMA concept, which is based on fixed approach routes with continuous descent profiles, and SIDs with continuous climb profiles.*

2.4 Airspace user perspective

A literature study, conducted in the analysis phase of the first version of the research agenda, revealed which of the research is relevant for each sector partner. Top priority for KLM as a hub carrier is to guarantee reliable capacity of the traffic stream in- and outbound 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.

For airspace users, including KLM, in general it is important to continuously improve its 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 4) 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 4.

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.

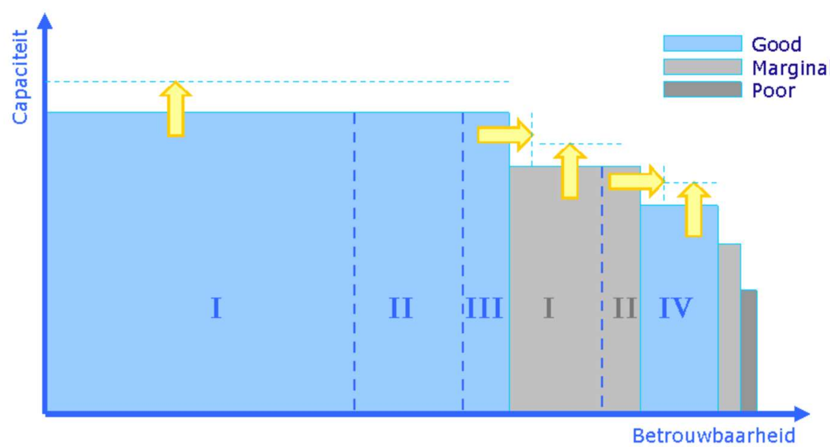

Figure 4: Sustainability (reliability of the capacity) vs. Capacity

3 Planned activities for 2024

The activities which will take place in 2024 are the result of the priority setting by the KDC board within the 2024 – 2028 programme. Two types of activities can be distinguished in 2024:

a) Conceptual structuring of a new area or a new development
   This type of study is applicable to subjects (or rather development areas) that potentially include a large number of building blocks (or rather functional changes). Conceptual structuring can also be labelled as an “inventory” type of study, making an inventory of potential solutions, and classification on the basis of performance indicators.
b) Development of a building blocks
   Studies which address a specific application or function are considered to be development of “building block development”. The development of a merge support function for approach is an example of a building block study.

In 2024 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 2024 – 2028 is the increased application of artificial intelligence techniques.

3.1 Summary of main activities

Below a summary is given of the subjects which are put forward for development in 2024 on the basis of priorities that have been proposed by the KDC management team.

A. Safe Airspace and Airport Navigation

1. **Air-Ground datalink evaluation (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.

B. Environmental sustainability

2. **Schiphol night-time arrivals (section 4.2.2)**
   In 2024 a follow up will be made on the strategy for night-time arrivals, that was completed in 2022. In collaboration with KLM options will be explored to synchronize long haul traffic in an early stage, through OCC measures. Furthermore Target Time of Arrival concepts will be explored which could be environmentally beneficial in case a (partial) nighttime curfew would be implemented at Schiphol airport.

3. **The development of RNP procedures**
   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 2024 the KDC continue the study into feasibility and benefit aspects of advanced navigation capabilities of aircraft.

C. Airline and Airport Operational Efficiency

4. **Future Ground Movement Concepts (section 4.3.4)**
The development of future ground movement concepts is aimed at both workload reduction for the ground controllers, as well as solutions for reduced emissions and improved air quality at Schiphol airport. In 2024 a conceptual study will be completed, which looks at various concepts (and levels of degree) of emission free ground movements.

D. Capacity Management

5. **Schiphol Airport Operations Centre (APOC) (section 4.4.2)**
The development of APOC is aimed at alignment and integration of airport planning processes and management of disruptions. The 2024 development builds on the studies performed in the 2021 – 2023 timeframe.

E. Airspace Redesign & Innovation

6. **Transition to Trajectory Based Operations (section 4.5.1)**
In 2023 the second study to support the transition to TBO has been completed. This study builds the framework needed to take innovative ideas from the level of conceptual demonstration to the pre-operational trial phase. Further studies in support to the transition to TBO are foreseen in 2024.

3.2 Priority setting

As the KDC has a limited budget, compared to the scope and content of the programme, 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 2024 - 2028 timeframe, a prioritisation has been made which led to a scope for 2024 (as described in section 3.1). The scope for 2024 has been generously set, which means that more subjects have been proposed than likely can be executed within the 2024 budget.

The following topics have been proposed by the KDC management team as development subjects for 2024:

Studies which started in 2023, which will continue in 2024:
1. Established on RNP procedures
2. Future Ground Movement Concepts

New subject:
3. Air-Ground datalink evaluation

Note:
At the annual release date of the updated KDC program, 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:
1. Assignments that are under development by the airspace re-design program (PLRH).
    a. So far PLRH has stated that their interest is in three areas.
        i. The further development and implementation of AMAN
        ii. The further development and implementation FUA (Flexible Use of Airspace)
        iii. Air-Ground datalink implementation
2. The further development of TBO. For this subject a PhD will be 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.
3. 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.
4. Additional research into maintenance strategies for Schiphol airport. This subject is related to maintenance of runways and/or taxiways. In the past studies into this area have been conducted by KDC, with a limited scope. Currently an evaluation of the Schiphol’s maintenance strategy is being performed, which may lead to addional KDC studies.
5. Research into meteorological subjects such as climate change and the possible impact on Amsterdam Airport Schiphol. In 2024 also meetings will be held between KDC and KNMI in preparation of the RP4 programme. During RP4, which starts on Jan 1, 2025, new meteo innovations will be developed, which have yet to be defined.

To further develop the KDC research agenda, a “knowledge-team” will be put together by the MT-KDC, in which the KDC management team participates as well. The goal of this team is to develop new assignments, to develop the KDC research agenda, and to disseminate results from KDC studies.

4 Description of research subjects

4.1 Safe Airspace and Airport Navigation

4.1.1 Air-Ground datalink implementation strategy

Ref. Ext. Programme	-	**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		✓	✓	✓	-
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 2014, KDC completed a business case study that explored which datalink services are beneficial to the Schiphol operation below FL245, and implemented in the 2013-2016 timeframe.

Since the publication of the business case, the technology availability has changed, and the industry has advanced. According to the SESAR Concept of Operations, routine voice communications shall be replaced by 2020 for en-route traffic above FL285. As almost all traffic at Schiphol is affected by this Data Link Services Implementing Rule (DLS IR) EC29/2009, technology equipage levels are expected to be very high, if not 100%. Therefore, implementation in lower airspace is possible. The business case for implementation of the Air-Ground datalink on the current AAA system used by LVNL was negative, however in iCAS, this is expected to be different. In 2024 iCAS will be operational, opening up new possibilities for the implementation of air-ground datalink.

Goal / Expected benefit:
The goal of implementing air-ground datalink is to increase capacity and safety in the airspace below FL245. 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.

Assignment:
With the (upcoming) full equipage of airline datalink technology in accordance with DLS IR, investigate which Datalink services are beneficial to the Schiphol operation below FL245. Special focus should be applied on routine messages, such as: The transfer of control at the IAF, weather information such as wind data, and direct-to incentives. An implementation strategy should be created, outlining how the technology will be implemented into iCAS, and at what moment in time.

Short term objective:
An implementation strategy that outlines the transition from RT communication to (partially) sending commands over the air-ground datalink in the lower airspace.

Midterm/Long term objective:
Operational trial which demonstrates the technical feasibility of routine instructions via datalink instead of voice communications.

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

Source:
Applications of ADS-C, 23 December 2014 / Datalink Business Case study, December 2013

4.1.2 Conformance Monitoring Applications

Ref. Ext. Programme	-	**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 programme, and developments with the framework of SESAR.

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

Midterm/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 Schiphol night-time arrivals

Ref. Ext. Programme	-	**TRL**	3			
Customer	KDC Board	**Lifecycle phase**	Feasibility assessment			
KDC Board Approval	29-07-2021	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Madelyn Bentvelzen		-	-	✓	✓
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 programme. In this programme 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 2024 – 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.

Midterm/Long term objective:
On the basis of the strategy validation activities which will be deployed, 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

4.2.2 Established on RNP procedures

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

Introduction:
The development of navigation technology with a high level of integrity has culminated in NAV CANADA publishing RNP-AR arrival routes for parallel runway combinations.

https://airtrafficmanagement.keypublishing.com/2018/11/23/nav-canada-implements-world-first-established-on-rnp-ar-icao-separation-standard/

These type of routes could be of interest to the Schiphol situation, as RNP arrival routes provide more flexibility in the placement of the base-leg segment of the route. Without navigation integrity safety requirement dictate a 3NM/1000ft separation between aircraft at the point of localizer intercept. With RNP separation is ensured by means of the navigation accuracy and integrity of the aircraft, and crew, that have been certified for the procedure.

Mandate scenarios
In parallel to the research into RNP design solutions research is required into the possibility for an RNP mandate for air traffic arriving at Schiphol. A decade ago Schiphol was the first European airport to issue an RNAV1 mandate. The RNAV1 equipage rate quickly rose to 100%, which helped increase efficiency and throughput while reducing ATC workload. It also enabled the withdrawal of conventional navigation infrastructure.
Nowadays a further modernization has taken place with the full implementation of PBN at the airport, including RNP SIDs and approaches. The operation is more complicated than necessary however, as there are still some aircraft which are not certified for RNP flight procedures. Handling those airplanes with different routes and clearances reduces efficiency and causes unnecessary noise nuisance in the surroundings.
This research should focus on identifying the conditions for different mandate scenarios and their implications. One key question is whether the compulsory use of RNP with fixed radius (RF) legs would be possible for night time arrivals.

Goal / Expected benefit:
Environmental benefits in terms of less noise annoyance (more route design flexibility). Workload reduction for controllers.

Assignment:
On the basis of the NAV CANADA implementation: investigate the feasibility of the RNP-AR concept development and implementation for Schiphol airport. In parallel develop mandate scenarios in support of RNP deployment at Schiphol.

Short term objective:
Assessment of feasibility of the concept application. Assessment of environmental benefits potential. Develop mandate scenarios.

Midterm/Long term objective:
Full deployment of the concept.

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

Source:
KDC report: EoR for EHAM, March 2022

4.3 Airline and Airport Operational Efficiency

4.3.1 Inbound priority sequencing

Ref. Ext. Programme	-	**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. Inbound KLM traffic has different values based on passenger flows and individual value of passengers.

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.

Midterm objective (two – three years): Steps 4 is expected in the midterm 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

4.3.2 FF-ICE

Ref. Ext. Programme	-	**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 also opens up possibilities to plan trajectories 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. 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)

Goal / Expected benefit:
FF-ICE is expected to enable shorter and safer route planning, and an increased data exchange between ATM partners. As a result, FF-ICE has many expected benefits. First off all, flight plan reliability will be increased by reducing the time difference between the flight plan and the actual flight time. Furthermore, it is expected to reduce on board fuel reserves, which reduces emissions. Lastly, it is expected that the planned arrival time of aircraft at the FIR boundary is more reliable.

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.

Short term objective:
An implementation strategy for the ATM actors in the Dutch FIR.

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.

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

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].

4.3.3 Increased capacity during low visibility procedures

Ref. Ext. Programme	-	**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.

Midterm/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

4.3.4 Future Ground Movement Concepts

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

Introduction:
Ground operations at Schiphol airport became capacity constrained when working with only two ground controllers. LVNL therefore expanded the operational floor in the Schiphol control tower, replaced the paper strip system with an electronic flight strip system, and expanded the ground controller working positions from two to three positions. Schiphol ground operations is a complex environment with dynamically changing workload distributions over the three ground controller positions. At the moment, GC-North and GC-South in particular are heavily loaded and GC-Center (3rd ground controller) is only used to a limited extent to relieve the others. Making a smart cut between the work areas turns out to be difficult.

Research is needed to explore possible options for distributing work areas and/or traffic among the ground controllers, thereby improving the workload distribution and thus increasing safety and possibly capacity. Feasibility of new ground control concepts, i.e. improved workload distribution, must be validated in a areal-time simulation environment.

In parallel to improving the workload distribution of ground control, as an enabler for increased safety and capacity of the operation, research is needed to integrate new operational procedures and concepts in the operation with the aim to reduce environmental impact and to improve sustainability. Zero emission operations, and solutions to improve air quality must be developed and integrated into the overall Schiphol ground operations concept. This part of the study needs to be aligned with the developments in the “sectorteam duurzaam taxiën”.

The objective of this KDC study is to identify the issues and problem areas and propose (sector wide supported) solutions with respect to the development of an aircraft ground movement concept that allows the deployment of sustainable taxiing within the safety criteria and the expectations on environmental and capacity improvements. Develop a clear and commonly agreed concept of operations and propose a roadmap / time-line for actions to be taken by the stakeholders resulting in a feasible aircraft ground movement operational concept.

Goal / Expected benefit:
Reduction of workload, and increased capacity. Improved air quality and reduction of emissions of ground operations.

Assignment:

a) Develop solutions (static and dynamic) to improve workload distribution of Schiphol ground control
b) Develop solutions for zero emissions, and improved air quality, operations that can be integrated in the ground operations concept of Schiphol airport.

Short term objective: Improved capacity and reduced workload.

Midterm/Long term objective: Zero emissions operations, improved air quality.

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

Source: -

4.4 Capacity Management

4.4.1 Collaborative demand-capacity balancing, AMAN – DMAN coupling

Ref. Ext. Programme	-	**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:
Schiphol airport, with its five main runways, has traditionally been an airport where arrival and departure capacity could be planned relatively independently from each other. The connection between arrival and departure capacity was dictated by the 2+1 runway use concept, but there was only limited interference between arrival and departure capacity: except for the runway use limitations, there was not much effect of the one on the other.

In the 2015 – 2019 period Schiphol started to approach it's capacity limits, not only in terms of volume but also in terms of hourly capacity. As arrival and departure peaks increasingly overlapped, hourly rates in excess of 110 movements per hour were seen, and workload started to become an issue for Schiphol Ground and Schiphol approach. The 2015 – 2019 saw an increase in tactical regulations on inbound traffic in order to manage arrival traffic bunches and related workload. This development in turn put strain on the airport's turn around process as delayed arrivals led to delayed departures of connecting flights. This cascade of delays due to overlap of peaks has a self-enforcing effect on this same phenomenon: it adds to the further overlap of peaks.

The negative spiral of peak-overlap and delays, which started to show when Schiphol was operating close to its capacity, needs to be addressed by means of a more collaborative approach to demand-capacity balancing, supported by a more integrated picture of arrival and departure capacity and demand. The airport, the hub carrier, the ANSP, and the network manager should all work towards the same goal: airspace and airport capacity is planned in an integrated manner which support the hub-function: the managed connection of flights.

Goal / Expected benefit:
Reduction of delay, increased predictability, increased connectivity, improved airport utilisation, environmental regulation compliance

Assignment:
Describe the future collaborative arrival – departure capacity planning process, involving the airport, the hub carrier, the ANSP, and the network manager.

Short term objective:
Development of a masterplan for Schiphol airport capacity management.

Midterm/Long term objective:
Fully collaborative capacity planning and management.

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

Source:
-

4.4.2 Schiphol Airport Operations Centre (APOC) Development

Ref. Ext. Programme	-	**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?

Midterm 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

4.4.3 Multi-airport concept

Ref. Ext. Programme	Airspace re-design programme	**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 streams 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, currently schedules of slot regulated airports do not take other airports' schedule 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:
- Research how the management of traffic flows in Dutch airspace can be improved, taking in 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 project of airspace redesign.

Midterm/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. Programme	-	**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)

Short term objective:
-

Midterm/Long term objective:
-

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

Source:
-

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

Introduction:
Dynamic Flow Management is a concept which was introduced as a building block in the national airspace re-design programme. The idea behind dynamic flow management is to manage workload in airspace sectors dynamically by redirecting traffic flows. The concept can be applied to a optimise a variety of performance indicators, beside workload the concept can also 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 which is based on setting airspace capacity limitations and restricting flows on the basis of these limitations. The traditional network management principles in a way also lead to a form of flow management, as airspace users probe alternate routes to avoid delays. 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:
The operational concept of dynamic flow management gives the air traffic control organization the opportunity to dynamically optimize a wide range of performance indicators, i.e. workload, capacity, delay and environmental performance indicators.

Assignment:
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. 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
- Identification of performance potential (in particular reduction of network delay and improvement of environmental performance).

Short term objective:
Identification of initial implementation steps within the current concept with the aim to reduce delay.

Midterm/Long term objective:
Full application of the concept in support of the future TMA concept with fixed arrival routes.

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

Source:
Report “Voorkeursalternatief 2020-2035”, Version 0.9, Programma Luchtruimherziening

4.4.6 Schiphol Target Time of Arrival (TTA) Concept

Ref. Ext. Programme	-	**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. To counter these delays and looking to improve its performance.

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 test 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

Midterm/Long term objective:
Depending on the feasibility study:
Midterm 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) Initial Target Time Over/Arrival Concept for Amsterdam Airport Schiphol, March 27, 2019
4) KDC report Schiphol TTO trial, December 16, 2019

4.5 Airspace Redesign & Innovation

4.5.1 Transition to Trajectory Based Operations

Ref. Ext. Programme	-	**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:
LVNL has decided to join the iTEC consortium as part of its AAA replacement strategy. This approach will ensure commonality and interoperability of the LVNL (technical) ATM system (iCAS) in the future and will ensure access to innovative system components developed by the SESAR program.

The replacement of AAA with iCAS will enable LVNL to migrate overtime towards TBO, trajectory based operations. TBO is a new operational concept which is founded on system interoperability, air-ground integration and collaborative decision making processes. The end-stage TBO concept is currently not very well defined, and subsequently the implementation date of a fully developed TBO is not yet known. The road towards the end-concept is not very clear either: there are many building blocks that fit the description as a step towards TBO, but choices about the usefulness of some of these building blocks are still to be made. One aspect that complicates matters is the perceived conceptual overlap between building blocks, this is especially true for arrival management related solutions.

Goal / Expected Benefit:
A structured and clear path towards trajectory based operations with respect to arrival management related building blocks.

Assignment:
Make an inventory of all conceptual building blocks that are related to arrival management process, describe the essential functions of these building blocks, and structure these building blocks in a roadmap towards TBO. Conceptual overlap must be identified and recommendations to reconcile these overlaps must be made. The following conceptual building blocks must be taken into account as a minimum:
AMAN, XMAN, Long-range XMAN (LHR concept), Traffic buffering concept, TTO/TTA concept, RTA, CTA, COP-sequencing, Traffic debunching, Priority Sequencing, Dynamic Flow Management

Short term objective:
An agreed path towards TBO with beneficial near term implementation steps that are part of the end-stage TBO concept.

Midterm / Long term objective:
Full scale deployment of TBO.

Involved parties:

Source:
KDC report: Transition to Trajectory Based Operations, February 2022

4.5.2 Transition to high capacity fixed arrival routes

Ref. Ext. Programme	-	**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:
In the national ATM strategy it is outlined that in 2024 traffic in the TMA is guided over fixed arrival routes with low altitude CDA's. This measure is meant to reduce noise annoyance and gaseous emissions, as the fixed arrival routes will be optimized to avoid overflying of habited areas.

Currently LVNL has published one fixed arrival route for daytime use in the Schiphol TMA: the ARTIP1X approach from ARTIP to runway 36R. In practise this fixed arrival route is not used because runway 36R is a secondary runway and can only be used during inbound peak periods: The demand during these periods is too high relative to the capacity of the ARTIP1X arrival route.

The capacity of ARTIP1X is estimated to be about 30 movements per hour. This figure however has not been validated and may also be lower. In order to be able to use fixed arrival routes in the daily operation, the capacity of fixed arrival routes needs to be increased. There are several measures to increase capacity of fixed arrival routes, for example:

1) Improved delivery accuracy at the IAF
2) Allowance of flexibility (e.g. tromboning)

For fixed arrival routes to the primary runways, merging support for approach will be required, as these routes merge traffic from two IAFs.

Goal / Expected benefit:
Calculate and validate the capacity of fixed arrival routes for Amsterdam airport and the benefit to capacity of the aforementioned optimizations.

Assignment:

- Design a rough concept of fixed arrival routes for EHAM that resemble 2024 implementation.
- Perform a real time simulation to validate the capacity of ARTIP1X and the proposed arrival routes.
- Optimize the capacity of the fixed arrival routes before Interval Management implementation, and validate the capacity benefit of the optimizations.

Short term objective:
Defining the expected capacity for fixed arrival routes at Amsterdam airport.

Midterm/Long term objective:
Capacity increase for fixed arrival routes.

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

Source:
KDC report: Vaste naderingsroutes met hoge capaciteit, October 2020
KDC report: Validation early split & late merge, October 2021
KDC report: FAR Implementation Strategy – Baseline Analysis, February 2022

4.5.3 TMA Merging and sequencing concept

Ref. Ext. Programme	-	**TRL**	6			
Customer	KDC Board	**Lifecycle phase**	Pre-industrial development & integration			
KDC Board Approval	9-12-2021	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Evert Westerveld		✓	✓	✓	✓
Financial Partner	DGLM					

Introduction:
The airspace redesign programme has adopted a concept for the Schiphol TMA, the area around Schiphol with a 50 km radius, which is based on fixed arrival routes and low altitude continuous descent approaches. It is foreseen that the new Schiphol TMA design will have four initial approach fixes (IAFs), entry points from where aircraft will follow the fixed arrival routes. From these four IAFs two landing runways will be fed, which means that for each runway a merging point will be part of the fixed arrival route design.

The merging of traffic is an important aspect of the fixed arrival route concept. For the approach controller, who is responsible for the safe handling of traffic in the TMA, information must be provided that separation minima are respected through-out the merging process. This information must be provided some time prior to the actual merge of aircraft pairs converging on the merge point, in order for the controller to take timely action to prevent loss of separation.

There are two main system/concept options available to support the controller with his/her merging task:

1. Flightdeck Interval Management (FIM). F-IM requires aircraft equipage which supports the time/distance keeping functions between aircraft pairs. This technology has been developed but airline equipage levels are currently zero. However, American Airlines decided in 2018 to equip some 200 A321 aircraft with ADSB-IN technology in order to fly IM procedures into Phoenix, Arizona, becoming the first early adopter of the IM concept
2. Ground Based Interval Management. GB-IM is a comparable concept as F-IM, but guidance information (i.e. radar target or ghost indicator) is given to the controller (not to the aircraft's avionics), and the concept lacks automation. Similar to F-IM sequencing support and merging support can be provided through GB-IM.

Goal / Expected benefit:
Stable, safe and environmental friendly TMA operations with high capacity.

Assignment:
Define a preferred path forward, conceptually, for merging and sequencing process that supports the future TMA concept. Information from previous KDC studies must be taken into account. Furthermore, the current RECAT-TBS development must be taken into account. Implementation risks and workload/capacity aspects must be taken into consideration as well.

Short term objective:
Establishing an agreed development and implementation strategy for merging and sequencing in the Schiphol TMA.

Midterm/Long term objective:
-

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

Source:
-

4.5.4 Holding support for area control

Ref. Ext. Programme	-	**TRL**	3			
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 en Christiaan Evertse		✓	✓	✓	✓
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 aircrafts within a specified airspace by proscribing 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. Awaiting further clearance from ATC, aircrafts can safely and orderly be sequenced to the runway.

Assignment:
- Research possibilities to provide area controllers decision support 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.

Midterm/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:
-

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
Ec	Efficiency related to capacity
EHAM	ICAO: Amsterdam Airport Schiphol
Env	Environment
E-OCVM	European – Operation Concept Validation Methodology
Es	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	Nationaal Lucht- en Ruimtevaart Laboratorium
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.

Chapter No.	**Project title**					
Ref. Ext. Programme	Programme reference	**TRL**	Technology Readiness Level			
Customer	Entity which accepts and uses the result	**Lifecycle phase**	Phase in the E-OCVM methodology			
KDC Board Approval	Date	**Performance Targets**	S	Ec	Es	Env
KDC PoC	Name		✓	✓	✓	✓
Financial Partner	*Provider/Stakeholder which financially supports the project*					

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, midterm and long term. The short term goal must be achieved within 0 - 3 years.

Midterm 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