Multi-Airport Concept: Improved management of air traffic flows in The Netherlands

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Final report

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List of acronyms

AAS	Amsterdam Airport Schiphol
AC	Area Control
ACC	Area Control Centre
A-CDM	Airport Collaborative Decision-Making
ACI	Airports Council International
ACM	Airspace Capacity Management
ACNL	Airport Coordination Netherlands
AF	ATM Functionalities
AMAN	Arrival Manager
ANS	Air Navigation Service
ANSPs	Air Navigation Service Providers
AO	Aircraft Operator
AOP	Airport Operations Plan
APOC	Airport Operations Centre
APP	Approach
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information System
ATM	Air Traffic Management
ATS	Air Traffic Service
BARIN	Board of Airline Representatives in the Netherlands
B-RNAV	Basic Area Navigation
CAA	Civil Aviation Authority
CACD	Central Airspace and Capacity Database System
CANSO	Civil Air Navigation Services Organization
CAP	Collaborative Advanced Planning
CDA	Continuous Descent Approaches
CDG	Charles de Gaulle
CFMU	Central Flow Management Unit
CHMI	Collaborative Human-Machine Interface
CLSK	Commando Luchtstrijdkrachten
CMAN	Centre Manager
CTA	Control Area, Controlled Time of Arrival
CTOT	Calculated Take-Off Time
CTR	Control Zone
DCB/dDCB	Dynamic Demand Capacity Balancing
DMAN	Departure Manager
DMET	Departure Metering
DOP	Daily Operations Plan
DSNA	Direction des Services de la Navigation Aérienne

DSP	Departure Spacing Program
E-AMAN	Extended-AMAN
ECAC	European Civil Aviation Conference
ETFMS	Enhanced Tactical Flow Management System
E-TMA	Extended TMA
EU	European Union
FAB	Functional Airspace Block
FDPS	Flight Data Processing System
FIR	Flight Information Region
FMA	Flow Manager Aircraft
FMP	Flow Management Position (ATC); Flow Manager Passengers (AAS)
FMPC	Flow Management Position Controller
FUA	Flexible Use of Airspace
GA	General Aviation
IAF	Initial Approach Fix
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IDAC	Integrated Departure Arrival Capacity
IDRP	Integrated Departure Route Planning
iFMP	Integrated Flow Management Position
IFPS	Integrated Flight Planning System
ILT	Human Environment and Transport Inspectorate
IM	Interval Management
INP	Initial Network Plan
KDC	Knowledge Development Centre
KNMI	The Royal Netherlands Meteorological Institute
LACC	London Area Control Centre
LARA	Local and Sub-Regional Airspace Management Support System
LT	Local Time
LTCC	London Terminal Control Centre
LVNL	Luchtverkeersleiding Nederland
MAC	Multi-Airport Concept
MCP	Mandatory Cherry Picking
MDI	Minimum Departure Interval
MilATCC	Military Air Traffic Control Centre
MINIT	Minutes-In-Trail
MIT	Miles-In-Trail
MUAC	Maastricht Upper Area Control
MV	Monitoring Value
NEST	Network Strategic Modelling Tool
NM	Network Manager, Nautical Miles
NMOC	Network Management Operations Centre
NOTAMs	Notices to Airmen
OCB	Operational Capacity Briefings
OSO	Operationeel Schiphol Overleg

PBN	Performance Based Navigation
PBO	Performance Based Operations
PCP	Pilot Common Project
P-RNAV	Precision-Area Navigation
RAD	Route Availability Document
RECAT-EU	European Wake Separation Recategorization
RLNM	Royal Netherlands Marechaussee
RNAV1	Precision Area Navigation (P-RNAV)
RNAV5	Basic Area Navigation
SES	Single European Sky
SESAR	Single European Sky ATM Research
SOT	Sector Opening Times
STAM	Short-Term ATFCM Measures
STAR	Standard Arrival Route
STW	Slot Tolerance Window
SWIM	System-Wide Information Management
TBFM	Time-Based Flow Management
TC	Terminal Control
TFV	Traffic Volume
TLPD	Traffic Load Prediction Device
TMA	Terminal Control Area
TRA	Temporary Reserved Areas
TSA	Temporary Segregated Areas
TSAT	Target Start-up Approval Time
TTA	Target Time of Arrival
TTL	Time-To-Lose
TTO	Target-Time Over
TTOT	Target Take-Off Time
TWR	Tower
UAC	Upper Area Control
UDPP	User-Driven Prioritisation Process
UK	United Kingdom
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
XMAN	Extended-AMAN

1 Introduction

1.1 Background

Dutch airports have grown considerably over time. This growth takes place almost autonomously. No mechanisms are established to balance this growth among airports, routes or airspace strategically. It is assumed that, without profound reformation, the maximum airspace capacity will soon be reached.

The Ministry of Infrastructure and Water Management has initiated the Dutch Airspace Redesign Programme'(DARP) or *Programma Luchtruimherziening* to reform the Dutch airspace. In this programme there are various ongoing policy activities. The Knowledge Development Centre (KDC) performs research in support of some of these activities.

In the policy development, the relationship between Schiphol Airport and regional airports is examined closely. Presumably further independent growth of these airports will lead to bottlenecks in the Dutch airspace. Although the DARP aims to address these bottlenecks, the Ministry and KDC also want to carefully consider the ways air traffic can be better handled by jointly managing air traffic. Managing air traffic into multiple, nearby airports is regarded as a multi-airport environment.

1.2 Objective

The objective of this assignment is to study options of flight scheduling and integral Air Traffic Flow and Capacity Management (ATFCM) for the Dutch airports of Schiphol, Rotterdam, Lelystad and Eindhoven. Options in the strategic, pre-tactical and tactical domain are all to be explored. The most feasible options should be turned into a high-level concept, referred to as the Multi-Airport Concept (MAC), which would improve the management of traffic flows in the Dutch airspace after 2023.

1.3 Scope

The principle adhered to in this assignment is that airspace redesign in lower airspace should start with the identification and analysis of the main relevant traffic flows. As a next step arrival and departure routes and could be designed according to the most appropriate navigation standard and meeting the desired capacity level. Only then the airspace boundaries could be established effectively. This project is focused on traffic flows; the development of route and establishment of airspace boundaries is part of the DARP.

1.4 Project approach

Although ATFCM across multiple airports may be missing in Dutch airspace, Air Navigation Service Providers (ANSPs) in Dutch airspace have several measures to control flows and manage available airspace capacity. To obtain an understanding of these initiatives, site visits with interviews were held to identify gaps in the current system. In parallel, data analysis was performed to study actual traffic flows based on flight plans and radar tracks which helped to quantify the gaps in today's ATFCM and flight scheduling, but also estimate the gaps in future scenarios considering autonomous growth of air traffic.

Internationally, several cases exist in which groups of two or more airports exist in a metropolitan area with highly interdependent arrival and departure operations. These groups of airports are more commonly referred to as a 'metroplex', and research towards optimisation and Air Traffic Management

(ATM) in these areas has been conducted before. Hence, a literature study has been performed towards the international research on the Multi-Airport Concept and international best-practises.

Using the literature study and an understanding of the current practices, including the current and future gaps, options for a Multi-Airport Concept can subsequently be explored. Using workshop session with important stakeholders, promising flight scheduling or flow management options shall be selected which will be used to describe a feasible operational concept of a Multi-Airport Concept between 2023 and 2035.

1.5 Reading guide

Chapter 2 described the current situation for airports, airspace and ATFCM. Chapter 3 gives an overview of research on concepts enabling or support a multi-airport concept, while Chapter 4 shows the best-practises in other, relevant metropole regions. The results of data analysis into the gaps in the air traffic today and in future are provided in Chapter 5. Chapter 6 shows the potential measures for improvement, where Chapter 7 assesses these measures on their benefits. Finally, Chapter 8 integrates the most promising measures into a high-level concept of a multi-airport environment in the timeframe between 2023 and 2035. Conclusions and recommendations wrap-up the study in Chapter 9.

2 Current situation

In this chapter an overview is provided of the airports concerned in the study, along with the Air Traffic Control (ATC) sectors and ATFCM toolset of the three service providers: ATC the Netherlands (Luchtverkeersleiding Nederland, LVNL), Dutch Air Force (Commando Luchtstrijdkrachten, CLSK) and Maastricht Upper Area Control (MUAC).

2.1 Characterising the airports

This study focuses on four airports in the Netherlands closely located to each other. Their locations and layouts are displayed in Figure 1 and listed in Table 1. The three regional airports have a single runway with a southwest-northeast orientation. Schiphol has six runways in three different orientations. Schiphol typically uses three of its runways during an inbound or outbound peak and four runways while switching between these peaks. Off-peak two runways are normally used. The complexity of route design is to a great extend caused by many runway configurations that can be applied at Schiphol.

Figure 1: The four airports that are in the direct scope of this project.

Lelystad Airport differs from the other airports in this study as it currently only handles general aviation (GA) traffic. The Dutch government has decided Lelystad will be opened for commercial flights; it is not yet known when the first commercial flights will be scheduled. In the future concept, commercial flights will be assumed to take place.

Eindhoven Airport differs from the other airports in this study as it accommodates military traffic. For this reason, Eindhoven Airport has military tower (TWR) and approach (APP) control that handles both the civil and military traffic. In the future concept, civil ATC only is assumed. This will standardise operational procedures and information sharing among units.

Table 1: Characteristics of the airports that are in the direct scope of this study

	Main runways	Distance from Schiphol	Types of ATC
Amsterdam Airport Schiphol	18L/36R, 18C/36C, 18R/36L, 06/24, 09/27, 04/22	-	Civil TWR and APP
Rotterdam (The Hague) Airport	06/24	25 NM	Civil TWR and APP
Eindhoven Airport	03/21	55 NM	Military TWR and APP
Lelystad Airport	05/23	30 NM	Civil TWR and military APP

Table 2 shows the traffic numbers for the four airports concerned. Schiphol is currently the largest airport in terms of aircraft movements in The Netherlands. To put Rotterdam and Eindhoven Airport in perspective: they both have around 10% of that number of movements. Schiphol has reached its capacity of 500.000 commercial flights. This is an environmental ceiling, not an operational ceiling. From 2021 there is potential for growth up to 540.000 commercial flights, this growth has yet to be earned with noise reduction measures. Both Rotterdam and Eindhoven are reaching their environmental capacity limits, there is currently no plan for further growth. Lelystad has no commercial flights at the moment of writing. A cap of 45,000 commercial flights [1] is currently set for the period until the airspace redesign has been accomplished.

Table 2: Traffic figures in 2017 for the airports within the scope of this study [2]

	Commercial flights	General aviation	Future traffic
Amsterdam Airport Schiphol	496,739	12,178	From 2021 potential gradual increase to 540.000 flights
Rotterdam-The Hague Airport	16,270	9,979	Max. noise capacity reached
Eindhoven Airport	38,642	1,558	Max. 43.000 flights
Lelystad Airport	0	84,218	From opening max. 10.000 commercial flights, max. 45.000 flights with DARP.
Total	551,651	107,933	

2.2 ATC sectors

In the Amsterdam Flight Information Region (FIR), ATC is provided by three service providers: LVNL, CLSK and MUAC. Each service provider manages their designated parts of airspace. Provision of ATC is divided into different sectors, so the resulting tasks have a manageable workload for Air Traffic Controllers (ATCO). ATC sectors usually have a declared capacity. The declared capacity is expressed as the maximum number of aircraft entering a specified portion of airspace per hour, taking due account of weather, ATC unit configuration, staff and equipment available, and any other factors that may affect the workload of the controller responsible for the airspace.

Generally, an increased demand is met by the provision of more sectors so that the traffic (and workload) is divided over more controllers. Usually this demand is calculated as short-term operational predictions based on planned flights. Opening/closing of sectors should closely monitor the demand to achieve efficient use of all available resources. The opening of new sector does not guarantee the sum of the capacities of the elementary sectors – the combined capacity is a combination of factors such as traffic flow direction, coordination procedures, in-sector flight times, etc. Therefore, a specific capacity figure is calculated for every sector configuration.

The four airports concerned in the study are each enclosed by their specific Control Zone (CTR) and Terminal Control Area (TMA). The concept of ATC sectors generally applies to en-route airspace specifically, in Dutch lower airspace serviced by the ATC units of Amsterdam Area Control Centre (ACC) at LVNL and Military Air Traffic Control Centre (MilATCC) Area (CLSK) and in upper airspace by MUAC. For each unit, the area of responsibility and sector configurations is described in more detail in Annex B.

2.3 Strategic capacity management

2.3.1 Slot coordination at ACNL

Airport slots are the permission to schedule a landing or departure at a coordinated airport during a specific time period. They are issued by an independent slot coordinator. Note that they are not to be confused with Air Traffic Flow Management (ATFM) slots (also referred to as Calculated Take-Off Time (CTOT) combined with the associated Slot Tolerance Window (STW)) provided by the Eurocontrol Network Manager.

The main reason to apply slot coordination at an airport is that capacity limitations at the airport are reached and this is limiting free market-driven growth of operations. Examples of capacity limitations are the number of gates, terminal capacity and runway capacities. In these situations, conform European Union (EU) regulation, an independent party should be designated to allocate the scarcely available slots to create a level playing field between operators.

Airport Coordination Netherlands (ACNL) is the independent non-profit organisation that coordinates the slot allocation for coordinated airports in the Netherlands. The three coordinated airports in the Netherlands currently are Schiphol, Rotterdam and Eindhoven Airport. At the moment of writing, it is uncertain whether Lelystad Airport will be a coordinated airport in the near future.

All three coordinated airports send a capacity declaration to ACNL to indicate their capacity for the upcoming summer or winter season. In this capacity declaration they describe their slot constraints, which mainly comprehends the number of slots per 20 minutes that can be used throughout a day. Airports usually set inbound and outbound peaks in which arrival and departure slots dominate, respectively. Conditions for the four airports are indicated in Table 3. Moreover, the capacity declaration may set other restrictions, such as minimum turnaround times and aircraft type restrictions which are beyond the scope of this study.

During the season there are slot trading mechanisms. Primary trading is when an airline would give its slots back to ACNL and ACNL would then make the slot available to other airlines. However, secondary trading is common, in which airlines trade their slots bilaterally.

Table 3: Main slot coordination parameters

	Inbound slot peaks	Outbound slot peaks
Schiphol Airport [3]	0700 – 0820 LT 1000 – 1040 LT 1200 – 1300 LT 1420 – 1520 LT 1720 – 1900 LT	0820 – 0940 LT 1040 – 1140 LT 1300 – 1400 LT 1520 – 1700 LT 1900 – 2040 LT
Eindhoven Airport [4]	2100 – 2330 LT	0700 – 0800 LT
Rotterdam Airport [5]	2200 – 2300 LT	0655 - 0900 LT
Lelystad Airport	Not applicable	Not applicable

Slot coordination and monitoring

Airport slot coordination could be considered the first ATFCM measure in the strategic phase. It limits the planned traffic flows in an early stage to a certain capacity rate. To understand the situation in the Netherlands, we need to look at the local slot coordination process.

Operationeel Schiphol Overleg (OSO) is the consultative body that discusses Schiphol's capacity declarations on a seasonal basis. Participating parties during these seasonal meetings are: Amsterdam Airport Schiphol (AAS), LVNL, aircraft operators (KLM, Transavia, Martinair, TUI, Corendon, easyJet), Schiphol Airline Operators Committee (SAOC) and the Board of Airline Representatives in the Netherlands (BARIN). The Ministry of Infrastructure and Water Management (IenW) acts as an observing party during these meetings.

Capacity declarations from OSO are captured in a seasonal letter to ACNL. It describes slot availability constraints. This has changed as the old slot allocation decree (Besluit slotallocatie) got updated in September 2019. AAS has become the main responsible for establishing the capacity declarations. There are also two extra precautions in effect: the Minister of Transport has the right to intervene and set constraints and there needs to be a 3-yearly independent evaluation of the capacity declaration process. The reason for the decree is that the OSO is facing a difficulty reaching consensus due to the scarceness of slots and the strong economical and/or strategical interests of the parties. Currently, 500,000 commercial flights are the maximum number of flights Schiphol can accommodate each year. So far, the OSO was able to collectively make the capacity declarations to stay within this number of flights, but as this limit has been reached consensus is no longer found.

To ensure the realisation is in accordance with the initial planning, slot monitoring is used. Slot monitoring in the Netherlands is currently limited to check the historic rights and unplanned night movements.

Slot monitoring for the historic right is done because of the local rule. When an aircraft operator uses 80% or more of its slots, it will keep the rights to all its slots for the next year. Otherwise, it will lose all slots. A slot is utilized when a matching flight occurs on the schedule day of the slot. In order to apply this rule, ACNL monitors daily operations for so-called "no-ops", a cleared airport slot without a flight movement. Virtually all operators tend to keep their historic rights. The only exception are the cargo carriers; their operations are less predictable and they sometimes risk losing their slots. To overcome this, a new *local* *rule* is introduced starting winter season 2019/2020, in which 25% of the slots that become available will be open to cargo carriers again.

Stricter monitoring of slots by ACNL is focused on the *unplanned night movements* at Schiphol Airport. Day time slots consist of departure slots between 07:00 – 22:39 Local Time (LT) and arrival slots between 07:20 – 22:59 LT. When unplanned night movements occur, they are reported to the Human Environment and Transport Inspectorate (ILT). ILT decides whether a fine is issued. Rotterdam and Eindhoven are not part of this regime; ACNL does not monitor unplanned night movements at those airports.

As the slot monitoring is currently limited to historic rights and unplanned night movements, there is no strong link between airport slots and actual flights. This gives airlines the opportunity to use the flexibility at Schiphol to strategically compensate for strict slot monitoring at other airports – potentially resulting in "bunches" at Schiphol which could lead to sector overloads. When the link between airport slots and actual flights would be strengthened, (pre-)tactical ATFCM measures may be of lesser need.

2.3.2 Pan-European RAD restrictions

Route Availability Document (RAD) restrictions are a measure to confine flight plans for certain city pairs. These restrictions typically include flight level capping and sometimes restrictions on routes.

RAD restrictions have been a strategical tool for many years. In 2018 the Network Manager (NM) published several major updates to harmonize and extend the RAD format [6] . They are coordinated on a European level.

A Dutch example of such a RAD restriction is that flights from Amsterdam and Rotterdam Airport that fly to the Canary Islands must fly through sector 4 instead of sector 3 during peak periods. This RAD restriction relieves sector 3, and makes these flights go via London ACC instead of MUAC and Brussels ACC.

2.3.3 Post-operational analysis at MUAC

The strategical capacity management at MUAC starts one year in advance, when post-operational analysis is performed in which the previous day of operations is evaluated. During the analysis, the sector throughputs, controller productivity and sector productivity are evaluated. Additionally, it is evaluated what in hindsight would have been the best sector configurations throughout the day.

Sector configurations are specific predefined combinations of opened sectors that are handled by a single ATCO at the radar position. MUAC sector configurations are defined per sector group (one for DECO, one for Brussels and one for Hannover). This results in three sector configurations at any time that are determined independently. In Figure 2, the sector configurations for the Hannover sector group are displayed. A sector configuration may combine horizontally or vertically adjacent sectors, or both.

Determining the sector configuration and thus the number of ATCOs at any time is key. With the expected traffic growth for the next year and the trends for similar days (same day of the week and the same time of the year) the analysis results in a first strategical planning of ATCOs. This is governed in the Master Sector Opening Times (Master SOT) which is determined 9 months in advance. It most importantly should ensure that the holiday leave of ATCOs does not lead to an understaffing of ATCOs at a certain day.

The Master SOT is only the first rough draft for the sector configuration timeline and is refined pre-tactically and tactically, as described in the following sections.

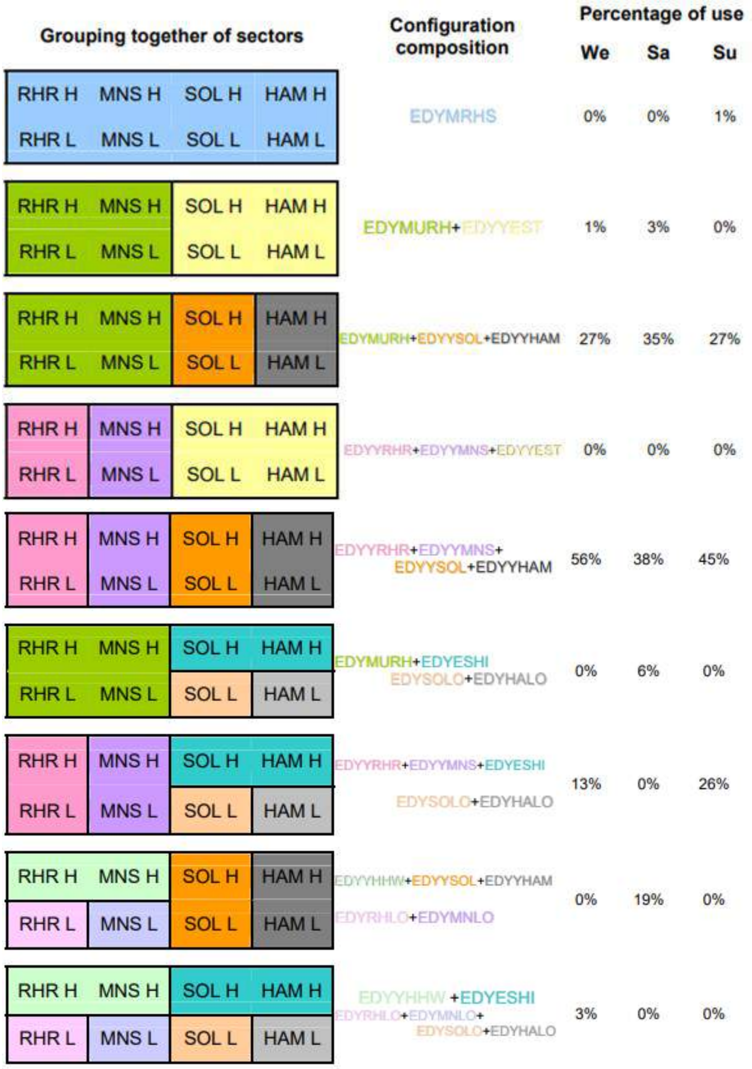

Figure 2 Sector configurations for the Hannover section group. Note the distinction between the low (L) and high (H) sectors, the boundary between the two is at FL335 [7].

2.4 Pre-tactical capacity management

2.4.1 Schiphol Capacity Briefings

Operational Capacity Briefings (OCB) are held four times a day at 03:30 LT, 09:15LT, 14:00 LT and 20:30 LT. and are chaired by the Schiphol Flow Manager Aircraft (FMA) from AAS. During these meetings forecasts are presented by the Dutch national weather service The Royal Netherlands Meteorological Institute (KNMI) and the Schiphol APP supervisor (capacities resulting from amongst others weather and planned runway configurations) to the Amsterdam ACC supervisor, the Amsterdam Flow Management Position (FMP), the Technical Supervisor LVNL (maintenance planning) and a KLM Flow and Hub Controller. Optional attendees include Unit Management by LVNL, the Flow Manager Passengers (FMP) by AAS, the fire brigade and the gendarmerie force Royal Netherlands Marechaussee (RLNM).

After each briefing the Schiphol APP supervisor distributes the presented capacity forecast Schiphol to a wider range of stakeholders from which they can decide on required action at their own playing field. The Amsterdam ACC Supervisor for instance uses this information as a starting point to decide on possible sector overloads and required ATFCM measures.

Next to this, Schiphol APP presents the expected runway combinations for the next peak hour (inbound or outbound) on a closed circuit information system that is available to Aircraft Operators (AO). the goal of sharing is to inform pilots with the latest update on runways to expect and also to cope with deviations from runway planning in between capacity briefings. This information is also transmitted on an open radio frequency; the so called "Schiphol Channel 9 broadcast" which operates beside the standard Automatic Terminal Information Service (ATIS) transmissions.

2.4.2 D-1 project at LVNL

LVNL only communicates severe meteorological conditions, such as when low visibility procedures are anticipated, at the day before operations to Eurocontrol NM. This can be referred to as 'D-1'. Contrarily, LVNL takes note of the Initial Network Plan (INP) as established by NM at D-1. A well-designed preparatory process at D-1 can be a valuable input for its stakeholders and the network, LVNL declared.

In 2018 LVNL initiated a project to implement a 'D-1 process' that should result into a plan for the actual day of operation [8]. Preparations for this plan start at a maximum of a few months ahead and are completed at D-1. LVNL Operations will use the plan as a baseline for the actual operations but will adapt the plan only when the conditions that day require to. Another part of this project is embedding the governance of the process into the organisation structure, which will not be considered here.

In the first step of the D-1 project, all currently already available information, notwithstanding fragmented, is being gathered into a single plan that can be published at D-1. This 'light' plan will contain amongst others:

- Current Daily Operations Plan (DOP)
- Weather forecast
- OPS agenda: military exercises (like Frisian Flag) or civil events (like Sail)
- Airspace availability
- Use of special areas
- Sector capacity information (nominal or reduced)
- Requests from adjacent centres
- Requests for special flights (like para jumping, survey or test flights)
- Relevant Notices to Airmen (NOTAMs)
- ATCO announcements
- Maintenance programmes (airport infrastructure, navigation aids, software releases)

In the second step of the project, traffic predictions and duty roster information will be incorporated into the plan. Lastly, guidelines for pre-tactical ATFCM measures, such as timely regulation of the critical morning peak will be developed.

In the first semester of 2019, trials have been performed. A small group of representatives from the Operations department participated in the preparations of a D-1 plan and evaluated the plan thereupon on quality and completeness. Figure 3 provides an illustration of the first two pages of a dummy D-1 plan:

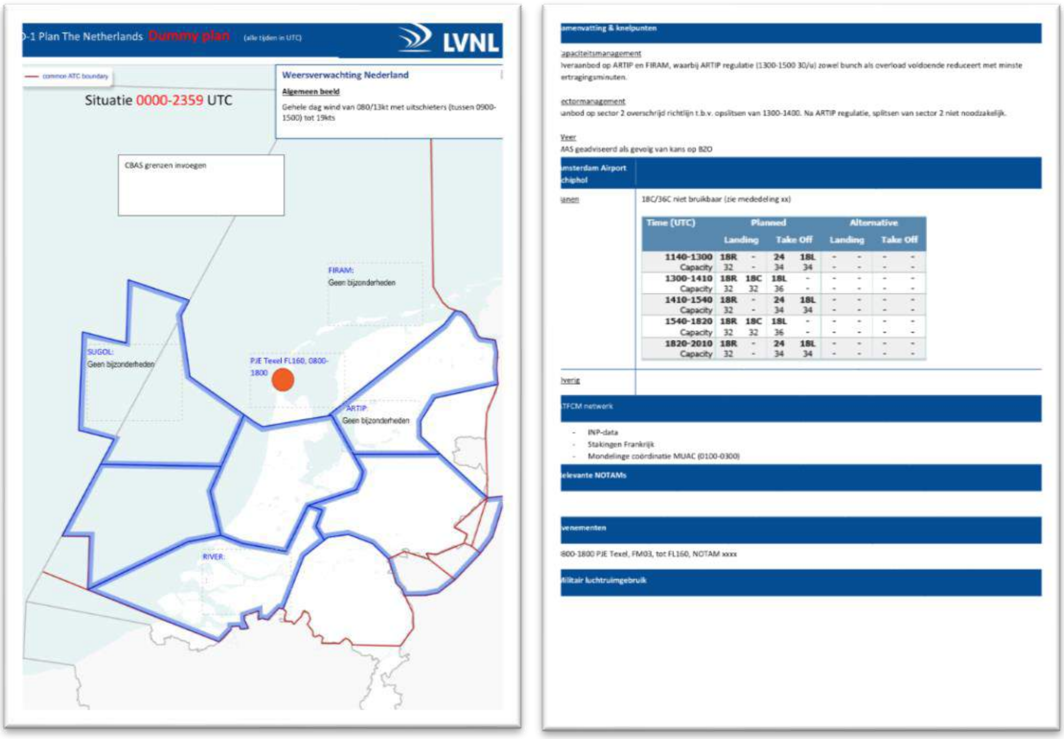

Figure 3: Extract of a LVNL D-1 dummy plan.

2.4.3 Sector opening times at MUAC

Strategically, the Master SOT is determined as a first draft for the sector opening times at the day of operations. The Master SOT is monitored up to 2 weeks prior to execution, to ensure that no major discrepancies exist between SOT and ATCO staffing. Three months in advance, the pre-publication of the roster is published and two weeks in advance, the roster is published.

After publication of the roster, the SOT is still being refined. For example, by adopting information from the same weekdays in the two weeks before execution. Note that the roster still allows for optimisation of the SOT, as the roster makes use of flexible duties. For example, an assigned “morning duty” is refined for each ATCO to one of the six morning shifts. This means the exact start and end time of an ATCO’s shift can be optimized to the latest insights.

At D-1 the SOT incorporates the last short-term information from one day before execution. Strikes and weather are typical types of short-term information that are incorporated.

2.5 Tactical capacity management

2.5.1 Enhanced Tactical Flow Management System

The Enhanced Tactical Flow Management System (ETFMS) is the function applied by the Eurocontrol Network Management Operations Centre (NMOC) to determine traffic demand for individual ATC sectors in the network and compare it with the respective monitoring values. When demand exceeds capacity, measures can be taken and implemented to reroute or regulate demand. This is carried out by means of consultation between the ANSPs and NM.

The ETFMS processes information from:

- Flight plan data from the Integrated Flight Planning System (IFPS)
- Traffic volumes and capacities from the Central Airspace and Capacity Database System (CACD)
- Live position reports from ANSPs
- Live position reports from AOs
- Meteorological information

2.5.2 Flow Management Position

The NMOC (formerly known as the Central Flow Management Unit or CFMU) was founded in 1988. It provides ATFCM services to airspace users operating in the airspace of European Civil Aviation Conference (ECAC) member states. In founding the NMOC, a central unit for flow management and supporting, local FMPs were planned.

In each ACC unit in the NMOC area of responsibility, an FMP is positioned. The FMP is the liaison between the NM on one side and the ANSP and airports on the other side. The FMP provides the NM with information about the local situation which the NM will use to improve their network plan to most effectively use the available capacity within the network. All FMPs in the NM area of responsibility have an equal status. However, their area of responsibility differs, it generally corresponds to the area of responsibility of the respective ACC unit. In some cases, for instance the United Kingdom (UK), the FMP area of responsibility is the combined area of responsibility of multiple ACC units.

NM, in cooperation with Amsterdam FMP at Amsterdam ACC, is responsible for the execution of ATFCM measures within the Amsterdam FIR. The responsibility of Amsterdam FMP is primarily tactical flow management. The Amsterdam FMP integrates information from the previous flow management stages into the decision making about for instance traffic regulations. The Flow Management Position Controller (FMPC) is the duty officer of Amsterdam FMP. His hours of operation are from 06:20 to 23:00 LT. Outside these hours of operation, the ACC supervisor represents Amsterdam FMP.

2.5.3 Traffic volumes

The Traffic Volume (TFV) is a mechanism being used to monitor traffic demand in a customized airspace volume. A TFV can also be used to apply traffic regulations to flights crossing the volume. A TFV is always linked to a reference location. This can be a geographic location like an airport, airspace or navigation point. A common method of visualising TFVs is to use 20-minute time block summing the traffic counts. Another method is to use 20-minute time block summing the traffic counts for the upcoming hour, called a rolling hour. In the traffic counts, there is usually a distinction between planned flights and already activated flights.

Most TFVs come with a Monitoring Value (MV). For Amsterdam FMP the MV equals the nominal hourly capacity of the TFV. So, if the traffic demand exceeds the MV, the TFV requires the attention of the FMP. Each TFV has its unique identifier consisting of a maximum of eight characters. The most commonly used TFVs for the Amsterdam FMP are:

- EHFIRAM
- EHARTIP
- EHSUGOL
- EHRIVER
- EHSECT3

EHFIRAM is the most used TFV for traffic regulations by Amsterdam FMP. It is a volume slightly exceeding the boundaries of the Amsterdam FIR. It is only focused on traffic arriving at Schiphol. It excludes domestic flights from De Kooy, Lelystad and Rotterdam to Schiphol. EHARTIP, EHSUGOL and EHRIVER concern the same volume, however they target arrivals over the respective individual initial approach fixes. Lastly, EHSECT3 is a TFV exactly matching the Amsterdam ACC sector 3 and concerns all traffic crossing it, meaning also potential traffic heading to Eindhoven, Lelystad and Rotterdam.

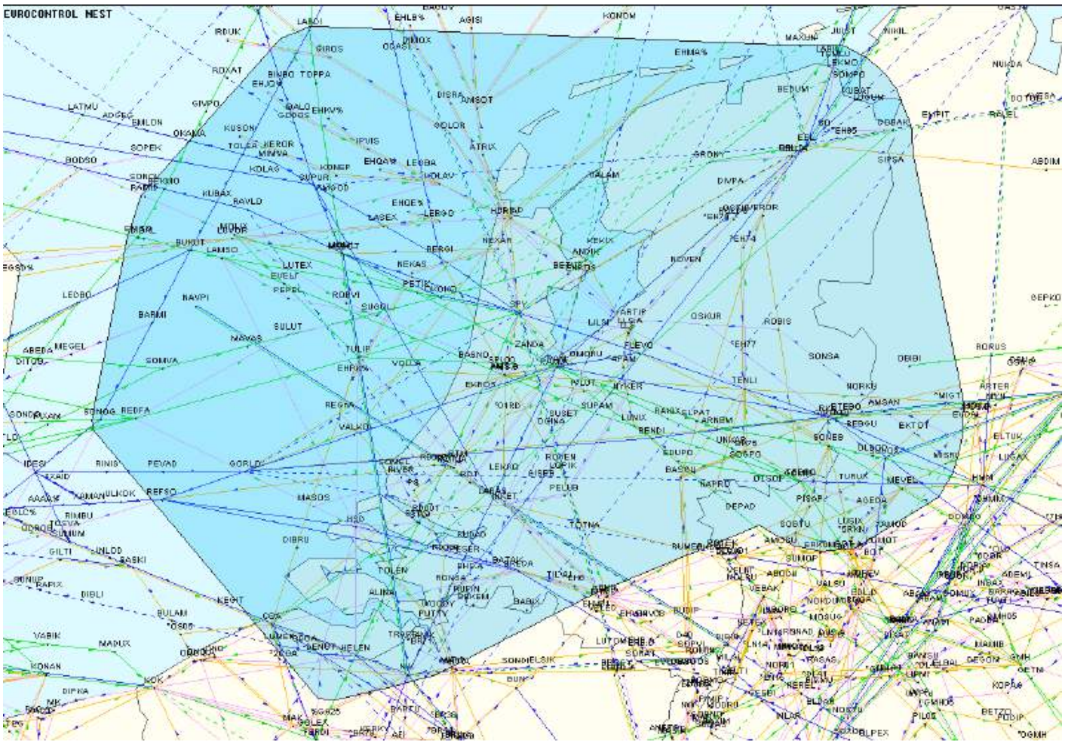

Figure 4: The traffic volume that is used for EHFIRAM regulations. Note that EHFIRAM regulations only regulate the FIR entry rate of inbound flights to Schiphol [9]

2.5.4 ATFCM measures

Tactical assignment of ATCOs

The ACC supervisor is in charge of setting the sector configuration at Amsterdam ACC. Based on the sector configuration, he assigns ATCOs. The supervisor has the authority to split combined and individual sectors, to deploy stack controllers and to eventually implement additional measures to affect or regulate the demand.

The initial planning scheme for ATCOs at ACC takes into account that all stacks could be manned by a stack controller. Normally this would not be necessary, which means they can be assigned to a different task tactically. Although MUAC does not use stack controllers, a similar approach applies to the rostering.

Minimum Departure Interval

Sometimes, a Minimum Departure Interval (MDI) is applied to restrict the number of departures per time interval at airports within the Amsterdam FIR. MDIs on request of the Amsterdam FMP supervisor are uncommon. Also, MUAC confirms the MDIs are rarely applied.

Cherry picking

Cherry picking is a measure where the FMP precisely controls a single flight plan to optimise for the greater good. For LVNL examples of cherry picking are repositioning flights from Groningen to Schiphol. In that case, they would control the exact departure time of that flight to relieve the sectors involved as much as possible. MUAC makes great use of cherry picking in consultation with AOs and NM. More on their use cases under ATM portal at MUAC.

Separating air traffic flows

The radar controllers at Amsterdam ACC solve ATFCM issues by horizontally and vertically separating traffic flows. During fog conditions for instance, a tactical measure could be to purposely add more flights to a holding, such that when the conditions change for a moment, the (temporary) capacity increase is fully utilized.

Rerouting

One of the tactical measures that can be taken, is to reroute arrivals or departures via a different ATC sectors. A common measure for instance is to have KLM aircraft from Norway enter via SUGOL in sector 5 instead of ARTIP in sector 1, to relieve ARTIP as busy entry stack.

Sector briefings

At the initiative of one of the sector parties, a sector briefing can be requested if an ATC exceeding capacity disruption is expected, such as in winter conditions, a strike, a grounding ban or a severe storm. The sector briefing decides jointly on the expected circumstances what the maximum take-off and landing capacity will be.

Air traffic regulations

As a last resort, air traffic numbers can be regulated. A regulation can be set for a specific TFV to prevent congestion in that volume. It aims to limit the amount of entries into that TFV both laterally and vertically. To accomplish this, the Network Manager (NM) issues CTOTs at outbound stations to restrict the departure to the STW (CTOT-5 to CTOT+10 minutes). If necessary, NM delays (certain) flights before going airborne by setting a CTOT later than the Target Take-Off Time (TTOT). This ensures the TFV with the regulation is relieved sufficiently.

The FMPC requests regulations to NM to prevent congestion of air traffic within the Amsterdam FIR. Regulations are often set for all inbound flights to Schiphol (EHFIRAM), but it is also possible to regulate a stack (e.g. ARTIP, i.e. all inbound flights to Schiphol via ARTIP).

In general, regulations are not fully effective, as there still tends to be an overshoot during peak hours with respect to the set capacity rate. Firstly, this is due to the STW at the outbound stations, that still allow for some variation in traffic. Secondly, pilots may fly faster or take a shorter route than anticipated and therefore create some overshoot. Thirdly, the inbound regulation for the Amsterdam FIR is not always the most penalizing, especially when there are capacity issues elsewhere in Europe.

2.5.5 Workload model at LVNL

LVNL has developed a so-called workload model in-house. Its purpose is to estimate the nominal workload of the controllers on duty. With the developed workload model the traffic demand can be analyzed based on traffic numbers as well as complexity. These workload estimations can, in turn, be compared to the traffic counts provided by the NM. The NM data is still dominant in the decision making; nonetheless the workload model strongly helps to interpret and differentiate the traffic counts.

The workload model is under constant development by LVNL. Currently the model is focused on the ACC controllers. It can represent the workload with 5-minute time bins with workload estimations for the next 20 minutes (rolling 20 minutes). Flights are classified based on their sector entry time. Furthermore, computations are based on nominal conditions with no (extreme) meteorological conditions, no holdings active and no direct routings. In the model each pair of flights on their specific routes corresponds to a pre-determined workload, based on a computation of three different factors: task load, complexity and interaction. For example, the workload increases when there is interaction between a pair of flights on the same route and flights on different, conflicting routes. The total workload estimation is computed based on an extensive matrix of parameters. The numbers in this matrix are pre-determined by expert judgement of experienced ACC controllers.

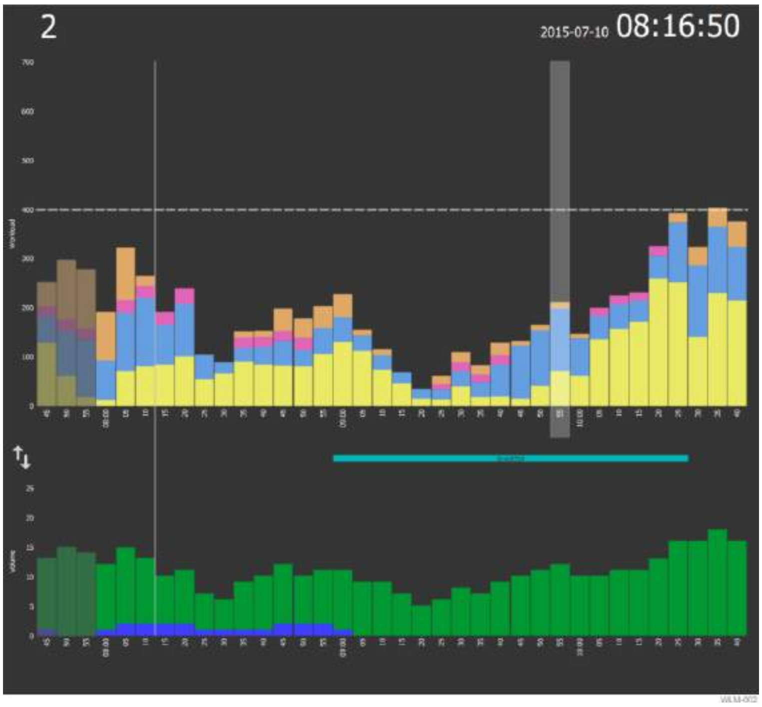

Figure 5: Impression of workload model at LVNL [9]

2.5.6 Integrated FMP and ATM Portal at MUAC

In the operational room at MUAC various tools are in use to maintain a controlled and stable operation. The integrated Flow Management Position (iFMP) and ATM Portal are examples of such tools, significantly extending the toolset provided by NM.

iFMP

The primary ATFCM decision making tool at MUAC is the iFMP. It was developed to address the growing demand, structural airspace limitations and demand fluctuations, while meeting targets set by the Single European Sky (SES). One of the main drivers of the iFMP for MUAC is to make the most of valuable finite ATM resources such as airspace and ATCOs. The iFMP provides operational staff with an integrated air situation picture. It visualises expected sector complexity and includes a sector optimiser and an overview of planned airspace use by military users. Besides its application in the tactical phase, iFMP generates a substantial amount of data used for the purpose of its post-operational analysis.

The iFMP capabilities are derived from multiple sources of data sourced externally and from within MUAC. External data sources include:

- NM – airspace entry predictions and imposed take-off times (ETFMS Flight Data)
- ANSPs – planning of Temporary Segregated Areas (TSAs), Temporary Reserved Areas (TRAs) by military users
- Meteorological information for relevant airports

Within MUAC, data is sourced from the Flight Data Processing System (FDPS) and manpower planning tool TimeZone. The FDPS consists of local trajectory predictions including controller inputs and operational constraints while TimeZone allows for local sector opening time planning. Better traffic predictions are expected to allow for more improved decision making. Through traffic dispersion advisories, sector load could be distributed better. Short-Term ATFCM Measures (STAM) such as level-capping, reroutings or speed-constraints could be tested real-time and communicated electronically with the NM and adjacent centres [10].

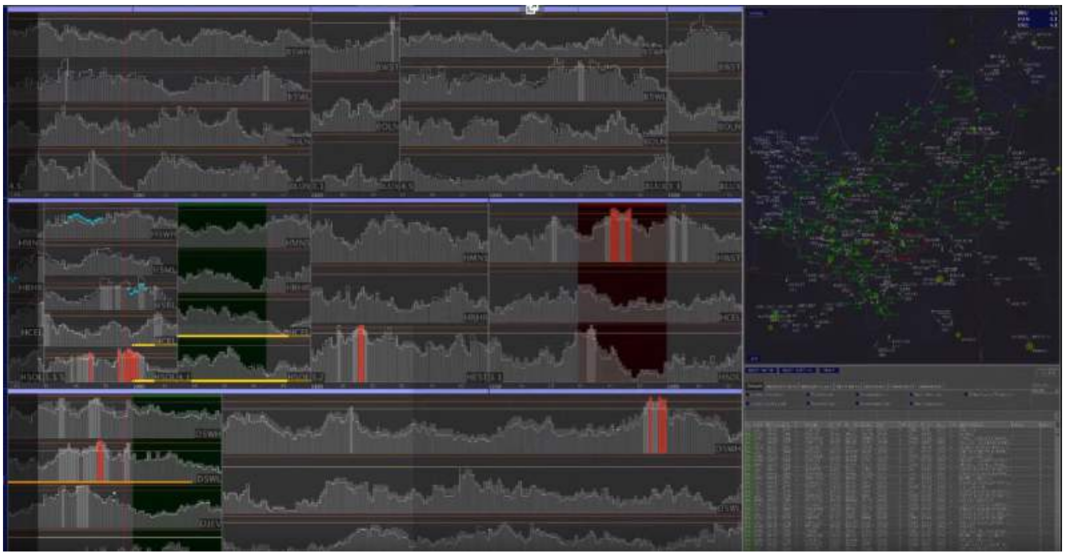

Figure 6: Impression of the integrated Flow Management Position (iFMP) [10].

ATM Portal

Next to the iFMP, MUAC has the capability to view aircraft-specific schedules at least a day ahead. This information is collected from the NM and accessed by operational staff at MUAC through the so-called ATM Portal. In general, only critical flights to an AO's network or flights nearing the curfew at an airport are considered. These flights are ranked based on factors such as delay and transfer capabilities. This allows for making careful decisions on whether these critical flights should be subject to a STAM such as rerouting or even be excluded from any measure that would work out to cause additional delay, previously described as cherry picking.

3 Research

In this Chapter the most relevant concepts under research which could enable and assist in the implementation of a Multi-Airport Concept are summarised.

3.1 SESAR 1

In Europe, under the Single European Sky ATM Research (SESAR) 1 programme several solutions were addressed such as AMAN (Arrival Manager), DMAN (Departure Manager), CMAN (Centre Manager) and point-merge. These solutions could be enablers for the Multi-Airport Concept in The Netherlands, as outlined in Chapter 8. Next a summary of the relevant solutions and their degree of maturity. Multiple SESAR sources were used [11], [12], [13], [14], [15].

3.1.1 Extended Arrival Management (AMAN) horizon (solution 05)

Extended-AMAN (E-AMAN or XMAN) allows for the sequencing of arrival traffic much earlier than is currently the case. By extending the sequencing of the arrival traffic further upstream (up to 200NM from the airport) a more stable, predictable and smooth arrival sequence can be obtained. ATCOs in the upstream sectors, which may be in a different control centre, obtain system advisories to support an earlier pre-sequencing of aircraft. ATCOs implement those advisories by, for example, instructing pilots to adjust the aircraft speed along the descent or even before top-of-descent, thus reducing the need for holding and decreasing fuel consumption. The result of this implementation is that need for holding is and traffic congestion are reduced, which furthermore translates into less noise and emissions.

This solution is available for industrialization. Currently there are ongoing trials for London Heathrow (section 4.1) and it is part of synchronized deployment plans across Europe in accordance with the Pilot Common Project (PCP).

3.1.2 Arrival Management into Multiple Airports (solution 08)

Although AMAN solutions are available for the purpose of a foresighted, cross-sectorial arrival planning, the current capabilities of these AMAN systems are not sufficient for the special case of a multi-airport environment where numerous arrival and departure streams are handled to the various airports in close vicinity. The main issue is the absence of a coordinated planning. Another issue of a multi-airport environment is the limited dimension of the TMA(s) and their adjacent en-route sectors which does not allow the controllers to implement sufficient Time-To-Lose (TTL) without both a drastic increase in workload and decrease of flight efficiency.

Therefore, an additional arrival planning component "CMAN" which accompanies the AMANs of the airports was developed [16]. schematically shows the interaction between AMAN and CMAN. It aims to support coordination of traffic flows into multiple airports in the same vicinity to enable smooth delivery to the runways and enable the controller to manage the interaction of flows in an efficient way without overload situations. The system generates a combined planning for several arrival streams into different airports by calculating the sequence of aircraft flying towards an area in an Extended TMA (E-TMA) en-route sector where their routes intersect. By imposing an adequate spacing of the aircraft in that area ("sector flow"), a TTL for the appropriate upstream ACC sector is calculated to meet this constraint. The ATCO in the upstream sector will be presented with the superimposed TTL from the AMAN and the CMAN, i.e. the highest amount of required TTL of either AMAN or CMAN will be shown. CMAN aims to increase Air

Navigation Service (ANS) efficiency, enhance predictability, and timely avoidance of traffic bunching in the E-TMA sectors.

This solution has been implemented in Zurich and is planned for implementation in Germany and Portugal. XMAN (solution 05) is considered a pre-requisite for this solution.

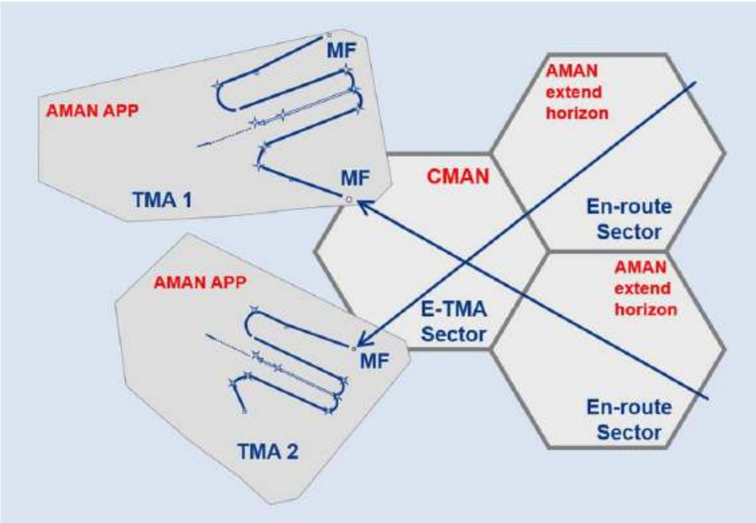

Figure 7 Extended TMA with multiple airports and AMAN extended horizon [16]

3.1.3 Departure Management baseline for integrated AMAN-DMAN (solution 106)

The basic DMAN was designed to support current Departure Management procedures which are established for controlling target times at start-up approval. The main function of the Basic DMAN is to produce an optimized pre-departure sequence by taking into account all the information available for each departure aircraft (scheduled times, slot constrains, target times for off-block and take-off, taxi times, runway capacity, airport constrains, aircraft readiness to leave the stand, etc). The information exchange is supported by A-CDM (Airport Collaborative Decision Making) platform.

The basic operational concept also supports DMAN integration with arrival manager (AMAN) and Advanced Surface Movement Guidance and Control System (A-SMGCS). DMAN and A-SMCGS need to be integrated in order to compute and provide the most accurate information: Target Start-up Approval Time (TSAT) and TTOT are calculated and provided by the pre-departure sequencing function of the DMAN, using accurate taxi times provided by the A-SMGCS routing and planning function. The obtained optimized pre-departure sequence enables more predictable traffic, reduces queues at the runway, contributes to on time performance, and reduces fuel burn and carbon emissions.

The solution has been implemented at Paris Charles de Gaulle Airport (CDG). This solution is available for industrialization. DMAN synchronized with pre-departure sequencing is part of synchronized deployment plans across Europe in accordance with the EU PCP.

3.1.4 Flow-based Integration of Arrival and Departure Management (solution 54)

The solution enhances the coordination method currently in use between the approach and the tower by introducing a new operational method where both controllers pro-actively agree on a defined “sequence pattern" of arrivals and departures, i.e. the number of departures that will be placed in between successive landings, based on an integrated arrival / departure picture built for the runway.

Departure flow to the runway is currently managed by the pre-departure sequencing planning tool, while arrival flow to the runway is managed by arrival metering. The solution is defined as "flow-based integration" since it aims to optimize traffic flows, i.e. coupled pre-departure sequencing and arrival metering. Controllers are requested to follow the pattern, but they are not expected to exactly follow the planned sequence of aircraft. This solution allows increasing predictability and to reduce or at least better manage delays in a busy single runway environment. Also, the solution contributes to a small increase in runway throughput and reduction of fuel consumption.

This solution is planned for implementation at the following airports: Vienna, Paris Charles de Gaulle, Milan Malpensa, Rome Fiumicino, Riga, Warsaw Chopin.

3.1.5 Point Merge in complex TMA (solution 107)

Point Merge is a method developed by the EUROCONTROL Experimental Centre; it enables the merging of traffic flows, whilst incorporating the predictability of precision navigation, but affording ATCOs a degree of flexibility in the way they manage aircraft associated with traditional ATM. By using standard sequencing legs ahead of the Initial Approach Fix (IAF), replacing or next to conventional holdings, aircraft can be guided along shorter or longer distances in order to reach a single-entry point. For a busy terminal area ATCOs can start to sequence arrivals at an earlier stage. It also results in pilots receiving fewer interventions and being able to fly a more efficient approach path down to the runway. Point merge procedures builds upon Precision-Area Navigation technology (P-RNAV) for merging traffic into a single-entry point, which allows efficient integration and sequencing of inbound traffic together with Continuous Descent Approaches (CDA). The previously developed concept is further developed to cater for airspace constraints or multi-airport TMAs.

The concept is expected to deliver significantly reduced controller workload, improved situational awareness for pilots and reduced radio telephony. This enables safety improvements and also enables effective delivery of traffic to meet airport capacity requirements, i.e. making best use of available airport capacity. Aircraft are expected to spend less time holding but there is likely to be a slight increase in the distance flown, and therefore fuel burnt, for arrivals. However, departing aircraft are expected to have far more efficient climb profiles (lateral and vertical), which reduces fuel burnt and noise pollution.

This solution is available for industrialization. Point Merge has been already implemented in many airports in several countries all over the world. The first airport was Oslo in 2011 and the first multi-airport environment was Paris in 2013. Solution 108 addresses the coupling of AMAN and Point Merge, yet implemented in Germany, France and Ireland and planned in Italy and Portugal.

3.2 SESAR 2020

In its new wave of solutions, SESAR 2020 is investigating new ideas and expanding on already delivered solutions from SESAR 1. The solutions briefly described below are candidates for the second wave of research and development, which means that they are not yet ready to be delivered and further testing is still being performed.

3.2.1 Extended Arrival Management with overlapping AMAN operations and interaction with DCB and CTA (solution PJ.01-01)

This solution researches the further extension of the arrival planning distance and incorporating more complex and high-density environments where the en-route sector serves more than one airport or TMA. This solution takes into account constraints applied for dynamic Demand and Capacity Balancing (DCB/dDCB) purposes and integrates information from multiple AMAN systems, enabled by SWIM, operating out to extended ranges into en-route sectors using local traffic/sector information and balancing the needs of each AMAN. The interaction between Traffic Synchronization and DCB, including the identification of integration needs, and Controlled Time of Arrival (CTA) in high density/complexity TMAs is also addressed.

3.2.2 Use of arrival and departure management information for traffic optimization within the TMA (solution PJ.01-02)

In this solution TMA traffic is managed in near real-time, taking advantage of predicted demand information provided by local AMAN and DMAN systems to identify sector overload or spare capacity, and to resolve complex interacting traffic flows in and around the airport. Sector load can be balanced by controlling sector entry times or waypoint times using instructions such as speed advisories, CTA, ground delay or alternate routing. Where multiple airports are included, this solution addresses departure synchronization from more than one airport, through data sharing of specific events such as TTOT or the flow of aircraft through specific waypoints. Data sharing can be also used to optimize traffic flow when arrival and departure routes cross at similar altitudes.

3.2.3 Enhanced collaborative airport performance planning and monitoring (solution PJ.04-01)

This solution builds upon the integration of the airport into the network, particularly Airport Operations Centre (APOC) and the information in the Airport Operations Plan (AOP) and relies on A-CDM. That integration was part of SESAR 1 and is ready for implementation. Now, the goal of this solutions is to also extend that integration to items such as landside processes (baggage and passenger flows), status updates generated by Target Off-Block Times (TOBTs), infrastructure inefficiencies, or other airport ground related issues and failures. This information sharing is supported by SWIM.

3.2.4 Enhanced collaborative airport performance management (solution PJ.04-02)

This solution aims at increased situational awareness and, thus, a more pro-active management of the airport, by means of a dashboard which contains key performance indicators from both landside and airside processes of the airport. This not only includes the evaluation of current data but historical data as well. Forecast and what-if scenarios are also supported contemplated for this solution. The goal is to support airport stakeholders in their decision-making.

3.3 Departure Metering

Eurocontrol in cooperation with NATS has undertaken to study the feasibility of benefits of Departure Metering [17], which is a procedure for alleviating traffic bunching in busy airspaces where several departures flows from different airports merge and when this problem cannot be solved within the NM granularity limits.

Departure Metering (DMET) will constrain particular aircraft by means of either advancing or delaying them, on top of departure slot that may have been assigned by the NM. Advancing aircraft implies to speed up aircraft during the initial climb, however this is hard to realise. Also delaying aircraft during the initial climb is hard, aircraft are mainly delayed while still on the ground. The aim of these measures is to spread out the bunch and flatten traffic peaks at particular merge points, normally the TMA exit points or at other points where the ATCO workload can drastically increase.

Research conducted by Eurocontrol has shown that Departure Metering is a feasible solution for avoiding bunching in a busy TMA with multiple departure flows from different airports. Like AMAN and Point Merge this solution delivers enhanced efficiency of airspace, especially in the (extended) TMA. This improvement has its limitations and it will not be the solution for long-term traffic growth. There is a point from which an airspace redesign and/or runway reconfiguration are needed in order to accommodate higher levels of departure demand.

This particular case studied was the London TMA including five major airports. In this considered case the traffic rate over TMA exit points is limited to a certain number of aircraft per certain time period, e.g. 5 aircraft in 10 minutes. Aircraft levels exceeding that limit rate will lead to aircraft obtaining a departure delay in order to satisfy the assigned limit rate and thereby to smoothen the merging departure traffic peak. It is conceivable to apply different measures with the same objective. One possible measure would be to apply spacing constraints such as Miles-In-Trail (MIT) limits or Minutes-In-Trail (MINIT) limits.

For optimal results, Departure Metering should be integrated with the DMAN of the respective airports, so the time constraints imposed can be integrated and optimized.

3.4 Metroplex programme

In the United States, one of the key goals within the NextGen modernization program of the Federal Aviation Administration, is the improvement of metroplexes (metropolitan areas with several airports and complex air traffic flows, usually one major city with more than one commercial airport in a shared airspace) in terms of efficiency, capacity and environmental impact, 21 metroplexes were identified and the initial effort have been allocated to those which are expected to yield near-term benefits, they are all listed in Table 4.

Table 4 Summary Metroplexes analysed by FAA [18].

Metroplex	Daily Average by Fiscal Year		Projected Annual Benefits			Metroplex Phase
	2017 Total Operations	2017 Scheduled Flights	Fuel Savings (Gallons of fuel in millions)	Value of Fuel Savings (Fuel costs in millions)	Carbon Savings (Metric tons of carbon in thousands)	
Atlanta	3,165	2,335	2.2**	$6.3	18.8	Complete
Charlotte	2,735	1,884	4.2****	$12.1	36.0	Complete
Cleveland-Detroit	2,200	1,309	3.4*	$9.7	28.9	Implementation
D.C.	2,785	1,998	2.0***	$5.6	16.5	Complete
Denver	2,904	1,503	0.6*	$1.8	5.4	Design
Florida	7,316	3,050	5.4*	$15.5	46.1	Design
Houston	2,275	1,475	1.8****	$5.3	15.7	Complete
Las Vegas	2,189	954	2.6*	$7.5	24.8	Design
North Texas	4,368	2,062	2.6**	$7.5	22.4	Complete
Northern California	3,349	2,020	0.7**	$2.0	5.6	Complete
Phoenix	----	----	----	----	----	Cancelled
Southern California	6,106	2,889	3.1***	$8.8	26.0	Complete

The metroplex program is performed in collaboration with aviation stakeholders by means of the optimization of the airspace and procedures, in particular new Performance Based Navigation (PBN) procedures are designed and Time-Based Flow Management (TBFM) is used. For instance, currently in New York metroplex the Departure Spacing Program (DSP) is being deployed to manage departure fix constraints. DSP is expected to be replaced by the Integrated Departure Route Planning (IDRP, a decision support tool to support proactive Traffic Flow Management decision-making) and Integrated Departure Arrival Capacity (IDAC, a tool that coordinates departure times between several airports, provides situational awareness to ATC and identifies possible departure slots).

4 Best-practices

In this Chapter two relevant metropole regions with multiple airports are discussed. These metropole regions are London and Paris. For each region, the airport and airspace characteristics as well as specific ATFCM measures are described. In general, the information is obtained from publicly available sources, some detailed information is extracted from an international benchmark on capacity management by LVNL [19].

4.1 London region

4.1.1 Airports

The London region consists of six main international airports: Heathrow, City, Gatwick, Luton, Stansted and Southend. Heathrow and Gatwick can be regarded as the main hubs. Combined they account for more than half of the total 1,213,033 movements carried out by the six main airports in the London area in 2018. To put these movements into perspective, the smallest airport in the London area: Southend, has a comparable number of movements as the second largest airport in The Netherlands: Eindhoven Airport.

Under the Traffic Distribution Rules 1991 whole plane cargo services or general or business aviation cannot be operated at Heathrow or Gatwick airports during periods of peak congestion declared for each scheduling season, without permission from the airport operator [20].

Table 5: Traffic figures for the main airports in the London area in 2018 [21]

Airport	Air Traffic Movements*
London Heathrow	477,604
London City	80,854
London Gatwick	283,919
London Luton	136,511
London Stansted	201,614
London Southend	32,531
Total	1,213,033

**Commercial movements only (air transport, positioning flights and local movements, excludes test and training, aero club, private, official, military, business aviation and other flights).*

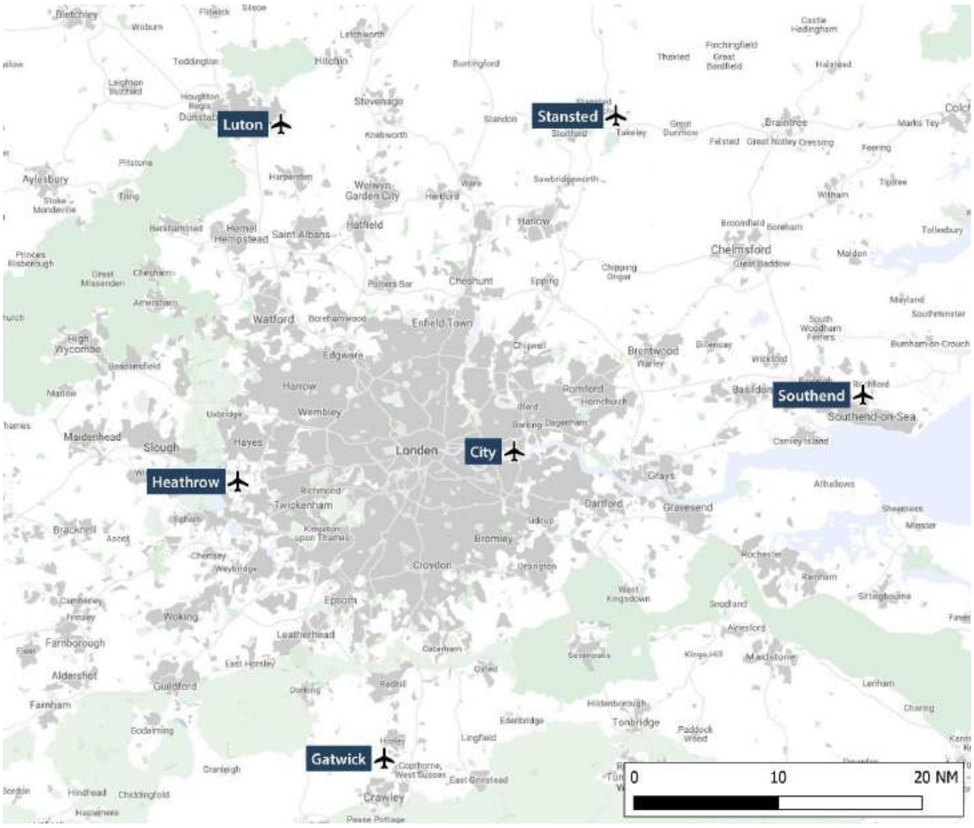

Figure 8: Main airports in the London area

Table 6: Characteristics

Airport	Main runways	Distance from Heathrow
London Heathrow	09L/27R 09R/27L	-
London City	09/27	19NM
London Gatwick	08L/26R 08R/26L	22NM
London Luton	08/26	24NM
London Stansted	04/22	36NM
London Southend	05/23	43NM

4.1.2 Airspace structure

NATS controls the airspace above the London area. This airspace is divided into London Terminal Control (TC, surface to FL245) and London Area Control (AC, FL245 to FL660). Both are controlled from the London Terminal Control Centre (LTCC) and London Area Control Centre (LACC) in Swanwick. Contrary to The Netherlands, tower control in the Aerodrome Control Zone (CTR) is a commercial service not reserved for NATS. After take-off the flight leaves the CTR is handed over to NATS before entering the TMA (Figure 9)..

Figure 9: London TMAs

London Heathrow, City and Gatwick are co-located within LTMA 1 (2500ft – FL195), with Luton, Stansted and Southend co-located in the adjacent LTMA 3 (3500ft – FL195).

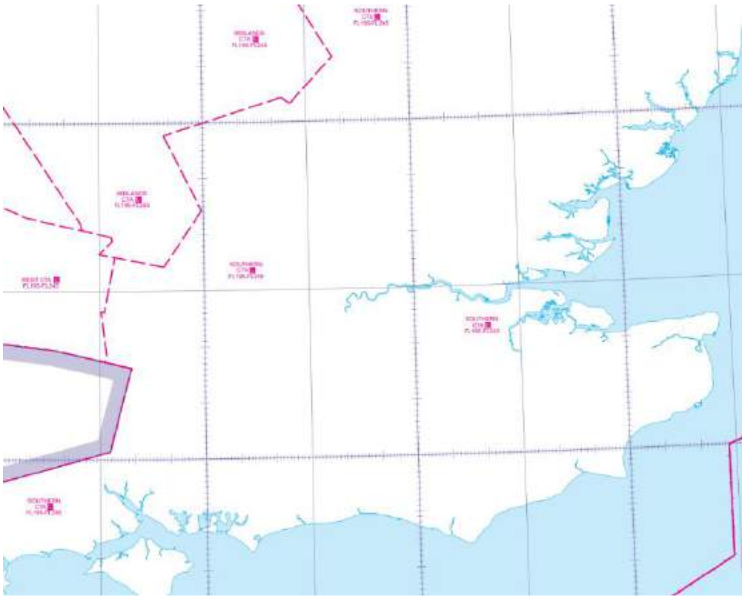
Figure 10: Southern CTA (FL195 - FL245)

The LTMAs go up to FL195, above which the Southern Control Area (CTA) is located (Figure 10). This airspace goes up to the lower limit of LACC airspace (FL245).

4.1.3 ATC sectors

The London Terminal Control Area (TMA) is split into two groups or banks, TC North and TC South, which not only relates to the position of the airspace sector relative to London Heathrow, but also the direction in the Terminal Control Room in which that sector's controllers face when at their radar consoles. TC North is further split into North East, North West. TC South is further split into South East and South West. There can be a total of 10 subsectors configured. At its busiest, each sector will have an individual radar controller. When it is quieter sectors are "band boxed" with one controller operating multiple sectors, until at night there may only be one controller operating the whole bank.

Aircraft departing Heathrow, Gatwick, Luton (to the north or west only), and Stansted mostly depart on a free-flow principle: the radar controllers do not release each individual flight for departure, they just receive an indication on their radar screen that a flight is pending. In this case the tower controller can decide on the most efficient departure order. In many cases the departure route does not conflict with the approach sequence of aircraft arriving at the airport, so the airport's approach control does not need to handle the aircraft and it is transferred straight to the TMA controller on departure. The TMA controllers then climb the departures through the arrivals to the airports that they are also working.

Arrivals to the London airports usually follow standard arrival routes and are descended against the departing traffic, sorted out into different levels, and routed to various holds (generally at the end of STARs), where they will hold until the approach control units are ready to position them into an approach sequence to land. Dedicated approach control units for the five major London airports are also controlled from TC, plus the radar approach services for Biggin Hill. Each approach unit has more than one sector. Most of the work for the approach units is controlling the sequence of aircraft making an approach at an airport from the holds until established on final approach about four miles away from the airport. The approach units also handle some aircraft departing from the airport, when that aircraft's departure conflicts with the approach sequence.

Slightly unusual to the approach sectors at TC is that some of them can be staffed by two controllers at a time, making transmissions on the same frequency.

4.1.4 Route design and procedures

In the UK, Basic Area Navigation (B-RNAV or RNAV5)[1] is mandated to the base of the airway structure on all existing routes. Current CAA guidance requires all new ATS routes to be designed in line with RNAV1[2]. specification which requires a higher degree of navigation accuracy resulting in concentration of aircraft on route centrelines with the potential to increase airspace capacity (NATS, 2015).

The route design into the five major London airports is largely laterally and vertically separated which allows the airports to operate independently to a certain degree. There is no clear policy set in case routes do overlap, radar controllers solve this tactically.

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[1] B-RNAV or RNAV5 is an equipment specification which permits aircraft to navigate without the use of point source navigation aids. To meet the specification, aircraft track keeping accuracy must be within +/- 5 nautical miles of the route for at least 95% of the time.

[2] RNAV1 is a performance requirement of +/- 1 nautical mile for at least 95% of the time

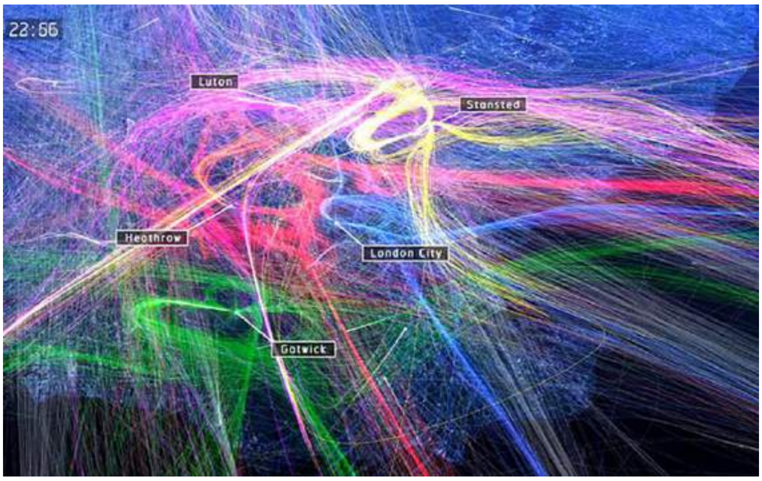

Figure 11: Route structure London area

4.1.5 Airspace Capacity Management

Airspace Capacity Management (ACM) activities at NATS are organised in four planning phases; of strategic, pre-tactical, tactical and post-operations. Fundamental to these activities are partnership agreements between NATS and various stakeholders which enable a transparent collaboration while maintaining confidentiality.

4.1.6 Strategic: Strategic team

Strategic ACM is carried out by the strategic team which comprises of office staff with an operational background. Its main activity is carrying out operational evaluations on a seasonal and monthly basis. These evaluations commence a year to a week before actual day of operation. The work mainly consists of collecting data on flight schedules and special events. In collaboration with an ACC supervisor, ATCO or other relevant experts the Strategic ACM team carries out impact analyses to create an estimation of the impact of future events and the consequences for the operation. These analyses provide a forecast of the available airspace and required ATCO staff related to a future actual day of operation.

Analyses carried out by the Strategic ACM team are supported by NATS analytics. This department is responsible for data collection, warehousing and development of performance metrics used for dashboarding purposes. Examples of data used in the dashboard are:

- Regulations
- Available capacity
- Deployed ATCO

Three months to a week before the actual day of operation the forecast is more fine-tuned and serves as the basis for ACM activities in the pre-tactical phase (D-7 to D-1).

4.1.7 Pre-tactical phase: D-1 planning

Based on the D-7 forecast carried out by the Strategic ACM team, the FMP team works towards creating a D-1 planning. Terminal airspace planning becomes quite stable from approximately D-5 days. An ACC Supervisor is involved in the D-1 process which reduces the amounts of adjustments on the actual day of operation.

A tool used by the team is NEST (Network Strategic Modelling Tool) from Eurocontrol which can load traffic predictions from PREDICT data directly from the NM. With this tool the team simulates 'scenarios' which are based on bilateral agreements with adjacent ANSPs before being shared with the Network Manager. It serves as an instrument to reduce regulations in the tactical phase.

Alignment between civil and military users is enabled through an airspace booking process using the airspace booking tool LARA (Local and Sub-Regional Airspace Management Support System) from Eurocontrol. Based on the bookings, in which military missions are leading, NATS analyses the effects on airline efficiency. To ensure optimal functioning of Flexible Use of Airspace (FUA), NATS actively monitors Key Performance Indicators (KPIs) such as the availability and use of Conditional Routes.

The final D-1 planning is published at 16:00LT before the day before operations. Where relevant, it contains agreements with customers of NATS related to the actual day of operation. These agreements are made in consultation with the ACC supervisor. The D-1 planning is also incorporated in a UK/Irish Functional Airspace Block (FAB) D-1 report in a reduced form.

4.1.8 Tactical: Extended Arrival Management

The priority for airlines flying into London Heathrow is to maximise the runway capacity. In support of this priority, holding stacks are applied to ensure a continuous demand. An average 'holding delay' of six minutes was deemed acceptable between NATS and the airlines. However, reality showed this average to be nine minutes. The three minutes of delay attributed by NATS had to be addressed somehow.

As part of a broader strategy to reduce holding times for London Heathrow, the UK/Ireland FAB, MUAC and Direction des Services de la Navigation Aérienne (DSNA) collaborate in extending the arrival management systems to better absorb delay in the en-route phase of flights, reducing the need for excessive holding. In a running trial, NATS can request MUAC or DSNA to have flights under their control to reduce their speed (e.g. 'reduce speed by 0.02 Mach'). It is still regarded as a delicate process to both avoid overstacking as well as understacking.

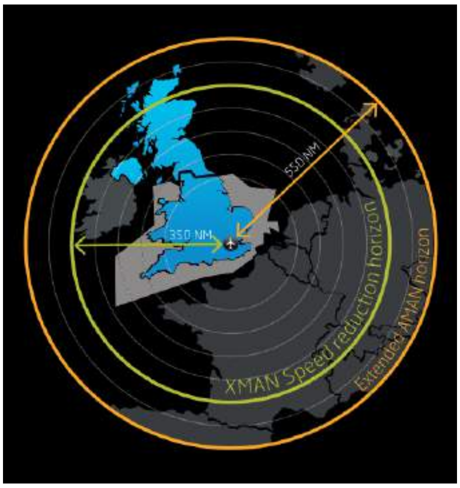

Figure 12: Extended AMAN and speed reduction horizons

4.1.9 Tactical phase: Flow Management Position

The UK has established a single FMP to act as liaison between NATS and the Network Manager. The position is manned in shifts by a team of eight persons located in the Swanwick Centre. The FMP is responsible for utilising the ACC capacity within the London, Scottish and Swanwick Oceanic FIRs to the maximum possible extent.

The FMP and ACC supervisor both monitor workload using the Traffic Load Prediction Device (TLPD). In the addition to the TLPD, the FMP also uses the Collaborative Human-Machine Interface (CHMI) provided by the NM and the local meteorological conditions at the various airports potentially affecting capacity.

In case of a predicted over-demand, the FMP approaches Aircraft Operators and provides them with the opportunity to avoid a tactical regulation by adjusting their flight plans accordingly.

In case flow and capacity interventions cannot be avoided, NATS has a set of STAMs applicable which includes Mandatory Cherry Picking (MCP), MIT and MDI for the purpose of peak spreading and de-bunching of outbound traffic.

Responsibilities in tactical air traffic regulations are strongly divided between NATS and the airports in the London area. In case an airport is not able to handle the declared capacity, such as in case of runway or taxiway maintenance or severe weather, the airport will communicate this constraint to the FMP. NATS only takes the initiative to regulate ATC sectors, which by design may contain traffic destined for more than a single airport. There is no mechanism to prioritise traffic flows with NATS. In this structure, they aim to maintain a level playing field and allows the NM to regulate in an indiscriminatory way.

4.2 Paris region

4.2.1 Airports

The Paris region consists of two major airports: Paris CDG and Paris Orly. Orly airport accommodates the domestic flights by Air France and is also the main hub for Transavia France, whereas CDG airport is the main hub for international Air France flights and is served by members from the alliances Star Alliance, OneWorld and SkyTeam. Almost all traffic at Orly is point-to-point traffic. Additionally, Le Bourget serves general aviation traffic. As seen in Figure 13, it is located close to Paris CDG.

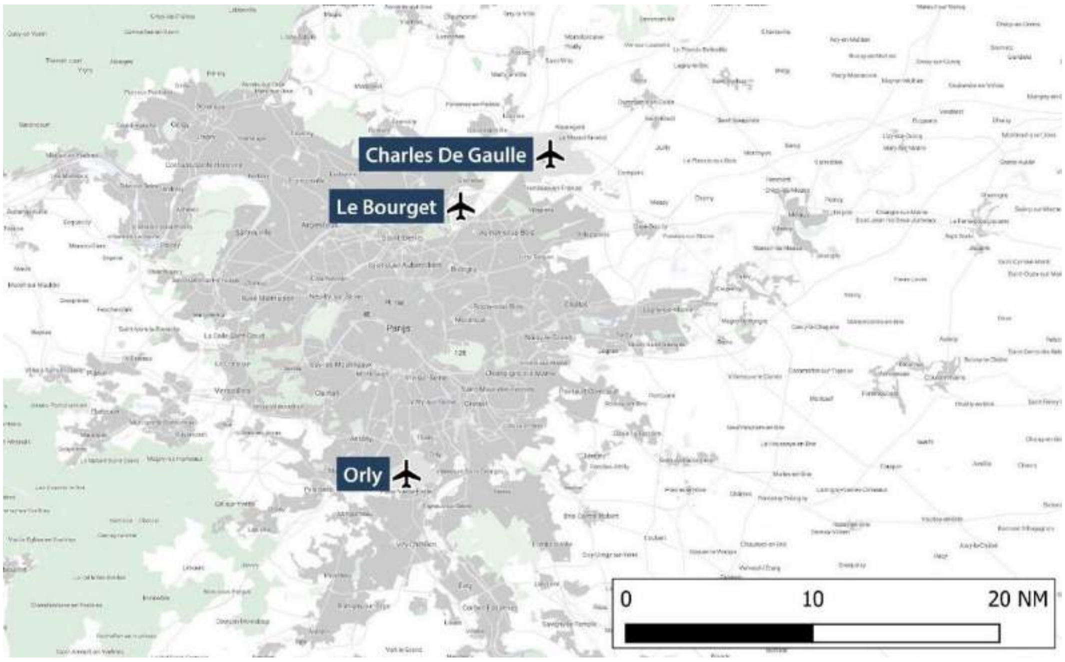

Figure 13: Main airports in the Paris area

CDG has two pairs of parallel runways. Of each runway pair, one runway is designed for departures and the other one for arrivals. This efficient design lead to a programming capacity in 2017 of 120 movements per hour. Orly and Le Bourget have converging and crossing runways. Details can be found in Table 7.

Table 7: Characteristics of main airports of Paris

	Main runways	Distance from CDG
Paris - CDG	08L/26R, 08R/26L, 09L/27R, 09R/27L	-
Paris - Orly	06/24, 08/26, 02/20	20 NM
Paris - Le Bourget	03/21, 07/25, 09/27	5 NM

In terms of air traffic movements, CDG is the biggest airport and Orly comes in second. Together they serve around 700,000 flights. Details are listed in Table 8. Air traffic at Orly airport is subject to two regulatory constraints: 250,000 slots for takeoff and landing per year and a daily curfew from 23:30 to 6:00. Traffic at Le Bourget is subject to a specific night curfew between 22:15 and 6:00, in which takeoffs of jet aircraft and the use of the second runway by planes of more than 5.7 tons is prohibited.

Table 8: Current traffic figures for Paris [22].

Airport	Air Traffic Movements (2018)
Paris - CDG	480,945
Paris - Orly	229,052
Paris - le Bourget	60,325
Total	770,322

4.2.2 Airspace structure

The entire Paris area is covered by the Paris TMA. The TMA structure is indicated in Figure 14. A schematic of the vertical profile can be seen in Figure 15. The vertical structure of the TMA is sometimes referred to as an upside-down wedding cake. This TMA shows nine different levels on top of the airport's control zone that ends at 2.000 ft. The airspace classification is exclusively A; therefore, no traffic operating under Visual Flight Rules (VFR) is allowed.

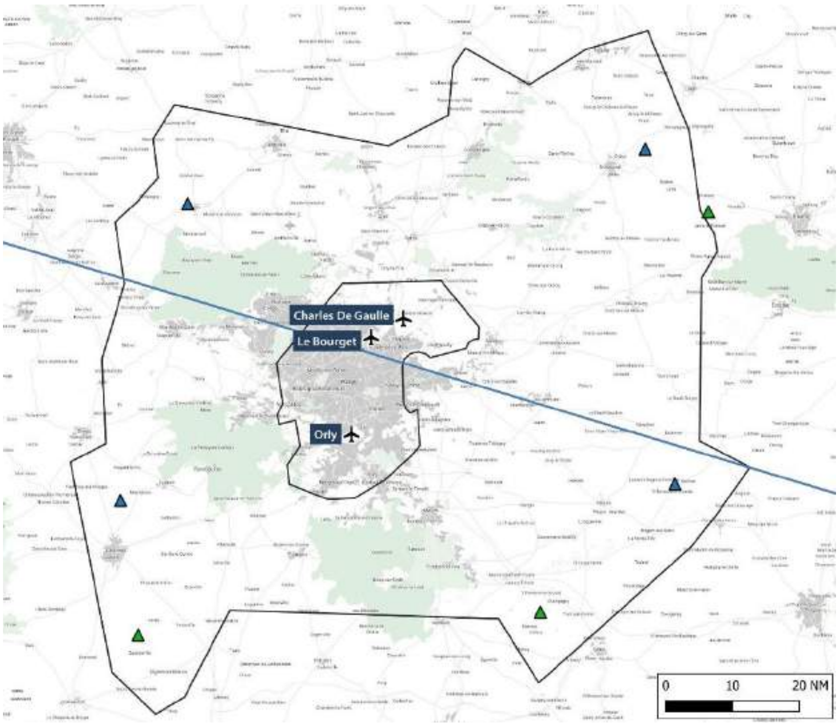

Figure 14: Paris CTR, TMA 7 and IAFs for Paris CDG, Le Bourget and Orly airports

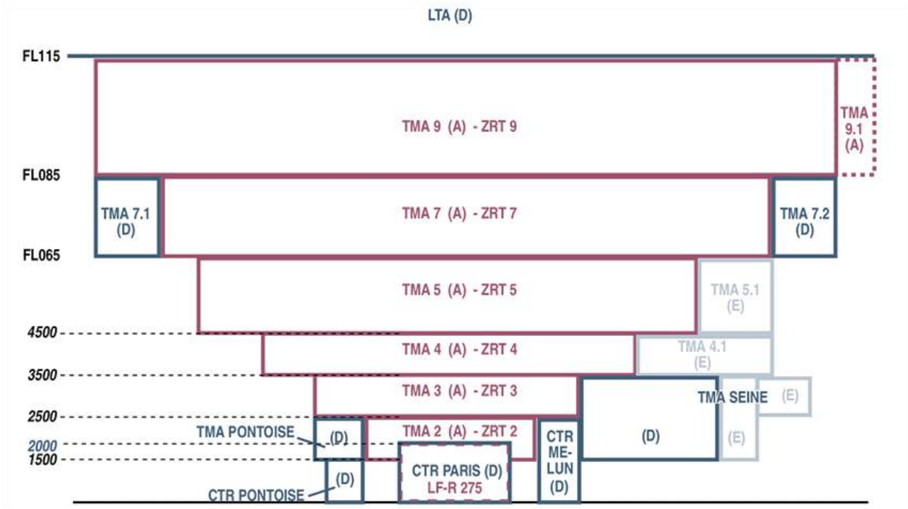

Figure 15: Schematic of airspace structure of Paris [23].

4.2.3 ATC sectors

Paris ACC provides air traffic services within certain parts of the TMA at flight level 115 and above. Paris CDG APP and Paris Orly APP provide air traffic services within the other parts of the TMA. The northeast sector of the TMA is controlled by De Gaulle APP, the southwest sector by Orly APP. The diagonal line between Paris CDG and Orly in Figure 14 indicates the boundary of the respective sectors. There is permanent radar service for all sectors. Paris CDG, Le Bourget, Paris Orly and Villacoublay (military airbase) are all located in the Paris CTR which is class D airspace. Pontoise and Melun have a dedicated CTR with a TMA with class D airspace, where also flights operating under VFR are allowed.

4.2.4 Route design and procedures

The route design for Paris CDG and Orly is separated by design to reduce dependencies and optimise capacity. Both airports use a similar four corner posts methodology. Paris CDG has four entry TMA entry points and Orly has three for their arrivals as indicated in Figure 14. These points are located in the corners of the TMA, departure route will use exit points in between. At each entry point there is a dedicated holding pattern for Paris CDG /Le Bourget and Orly. Route design is based on RNAV1 principles.

Paris CDG and Le Bourget use two main runway configurations: west and east. Normally, if Paris CDG changes the runway configuration, Le Bourget will adapt theirs, due to operational dependencies. It only rarely happens that the two airports operate oppositely, because this will have operational constraints. Figure 16 and Figure 17 show the main runway configurations and the indicators of the associated standard instrument departure routes.

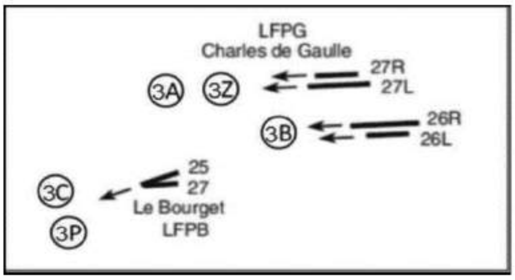

Figure 16: Runway configuration west [23].

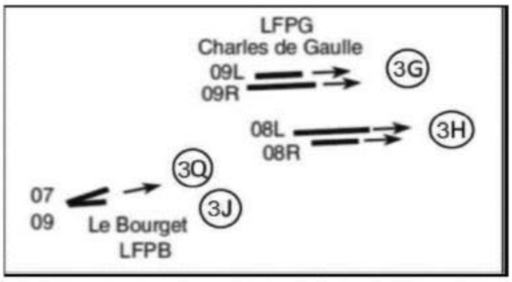

Figure 17: Runway configuration east [23].

4.2.5 Point-merge concept

In 2013, the point-merge concept was introduced in Paris ACC. It is used to sequence arrivals at the four IAFs of Paris ACC. Figure 18 shows a specific route design for Paris CDG arrivals using point merge and Figure 19 depicts the resulting tracks during an inbound peak.

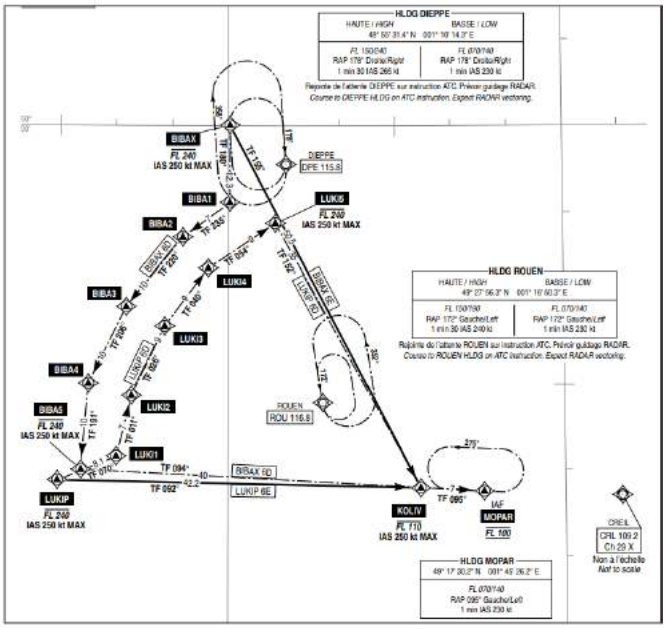

Figure 18: Point merge route for Paris CDG [23].

Due to its systematic character, point merge allows for maximization of inbound capacity at an IAF while allowing the merge of multiple arrival flows. Point merge increases predictability while preserving track miles and flight time [15]. When considering point merge, or any other path stretching technique, in a multi-airport concept within Dutch airspace, it is important that it will be used in a planned way or working and not in a tactical way. The background is that with 3D separated trajectories in the TMA, delay absorption in the TMA will not be possible any longer. Consequently, arriving flights will have to be delivered accurately at the TMA entry point, and a planned way of working that combines speed adjustments and path stretching/shortening is deemed necessary to achieve a high precision at the TMA entry point in accordance with the AMAN planning.

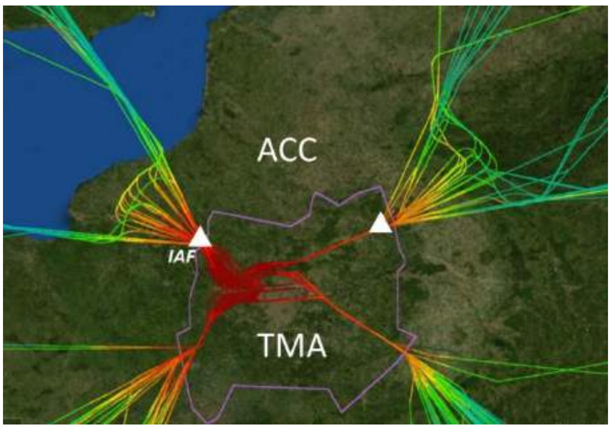

Figure 19: Point merge in Paris ACC to Paris CDG [12].

To show the airspace dimensions of the Paris TMA and point merge concept relative to the entire Dutch airspace, Figure 20 was drawn. The map shows the Dutch airspace contours and the four airports involved in the study. The contour surrounding the airports is a projection of the Paris TMA and the two green pie tips are the point merge procedures in place for Paris' airports. What stands out are the relatively large dimension of the Paris TMA. Combined with point merge procedures, the procedures should immediately be initiated when entering Dutch airspace. This means that merging should actually be instructed already outside Dutch airspace by adjacent centres. The point merge procedures in Paris start at a relatively high flight level, lower flight levels could be more appropriate in Dutch airspace.

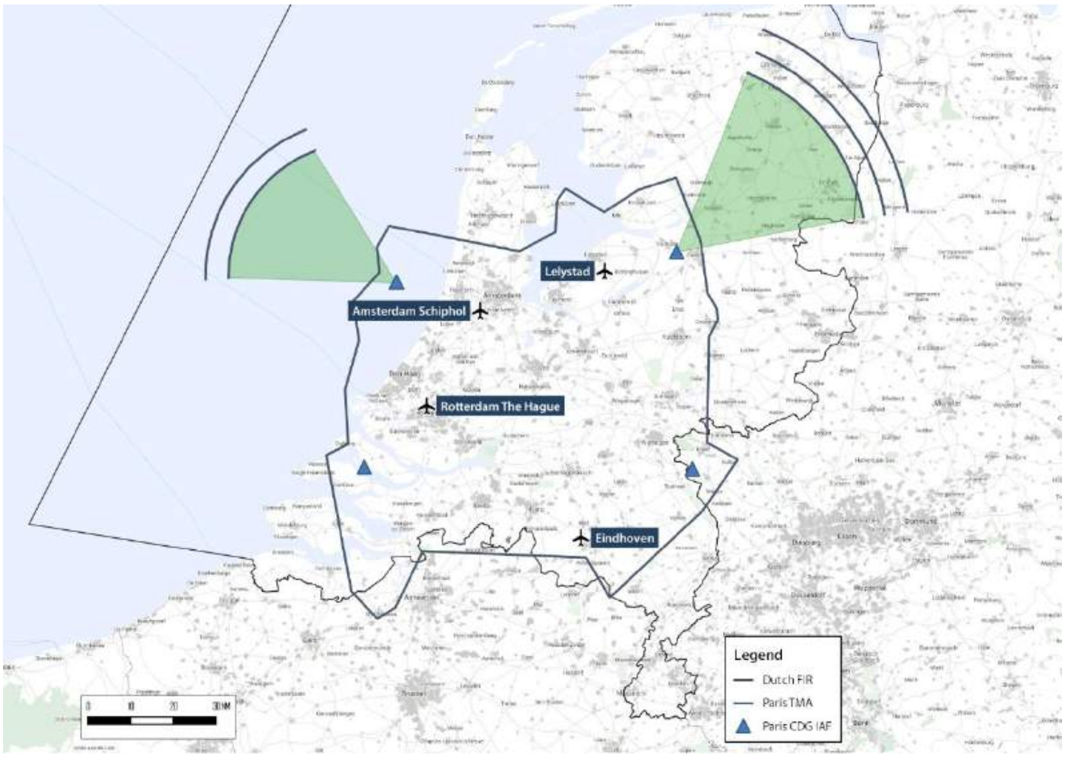

Figure 20 Paris TMA and point merge projected on Dutch airspace

4.2.6 European Wake Separation Recategorization (RECAT-EU)

The RECAT-EU system, distinguishing six categories of aircraft according to wake turbulence, is used in the airspace controlled by De Gaulle APP for the aerodromes of Paris CDG and Le Bourget. With this new classification, new separation minima based on distances are used for arriving and departing aircraft in flight.

4.2.7 ATFCM Collaborative Measures

DSNA has taken several ATFCM collaborative measures (which they refer to as "the MAC project") for Paris ACC and adjacent Upper Area Control (UAC). The various levels of measures are described in the following paragraphs.

4.2.8 Pre-tactical: Target Time of Arrival trials (2017 - present)

During the summer of 2017, Target Time of Arrival (TTA) trials were performed in Paris ACC to optimize arrival times at Paris-Orly airport. From May to October 2018 this was repeated for Paris CDG. DSNA developed their own experimental tool and interface for XMAN within the Paris region called iAMAN. Using MCP, the FMP can assign a TTA to a flight. This is then fed to the NM, which calculates the corresponding CTOT.

From January until June 2019, a new Orly trial phase was initiated. During this trial phase, 81% of the 102 flights with a priority request were adjusted. The trial was during many days not active due to lack of

ATFCM regulations (which is a prerequisite), and technical or meteorological issues. Furthermore, not all requests could be granted due to too late or incorrect requests or other technical reasons. From August until September 2019, the Orly trial was expanded with an interface called AFLEX, allowing airlines to set priorities of their flights via a web portal. AFLEX is basically an improved slot-swap procedure, but with a lot of added value in terms of directly involving both NM and local ATC. During this trial, only one swap with another flight and four arrival time improvements were requested. 60% of those requests were fully or partially accepted.

4.2.9 (Pre-)tactical: Collaborative Advanced Planning (CAP)

Collaborative Advanced Planning (CAP) by DSNA aims to have aircraft operators refile their flight plans when hotspots are predicted. The CAP web portal is currently used by KLM, Easyjet, British Airways, Ryanair, Air France, Air Lingus, Vueling, Transavia and others. Besides the AO, German ANSP DFS and Spanish ANSP ENAIRE are also involved.

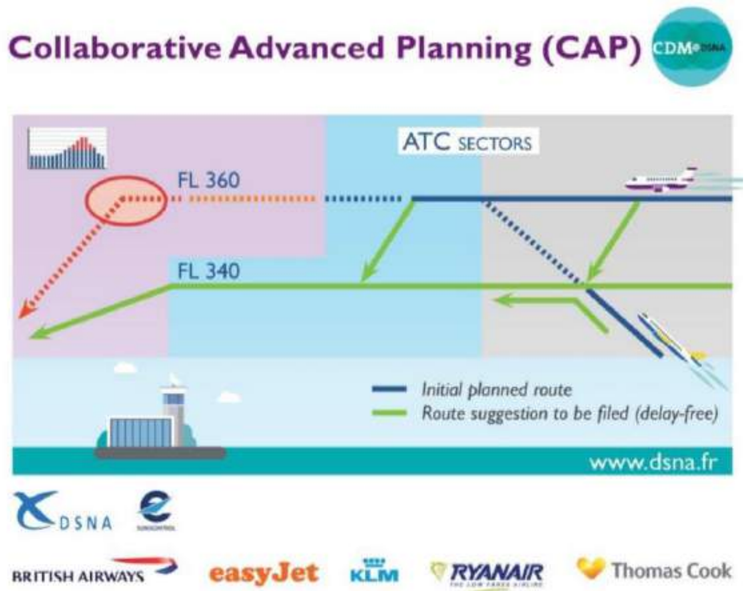

Figure 21 Collaborative Advanced Planning by DSNA [33]

In the case of a predicted overload, the flight is listed and highlighted to the FMP. The FMP can provide route suggestions to the AO directly or via chat functionality. An example suggestion is shown in Figure 21. When the system detects a flight plan is refiled and the foreseen conflict is resolved, the flight will move to the green table. By encouraging the aircraft operators to proactively refile their flight plans, regulations by the ANSP may be prevented.

4.3 Main observations

The two large metropole regions of London and Paris have been studied. Both regions show multiple large airports in close proximity, similar to The Netherlands. On the contrary, airspace structure and route design are largely different. It has become clear that in the London region, air traffic flows into various airports are separated from each other in the route design and dedicated altitude window. No particular coordinated planning among the airport exists. Notwithstanding, the region has mature airspace capacity management compared to The Netherlands. In the Paris region, both the airspace and route design allow the larger airports of Paris CDG and Orly to operate almost separately. Also in this region, mechanisms are in place to better utilise congested airports and airspace. On top of that they use reduced separation standards.

Most outstanding is that in both regions the complexity of interfering traffic flows in the multi-airport environment has been avoided by separating route structures, not the focus of this study. By any means, interesting mechanisms are applied, both metropole regions use cross-border arrival management concepts including TTA to better plan air traffic flows to and from the airports, which could also be considered for the future multi-airport environment in the Netherlands.

5 Traffic flow analysis

5.1 Introduction

A data analysis has been performed to identify so-called hotspots when looking at traffic flows to and from four Dutch airports (Schiphol, Eindhoven, Rotterdam and Lelystad). The rationale for the analysis is the anticipation that the traffic flows from these four airports and its interaction may become problematic in the future and may necessitate the need for multi-airport measures to mitigate potential traffic flow issues.

The analysis has looked at three different aspects of the planning and executions of air traffic. Firstly, at a tactical level based on actual flight data. Secondly, at a pre-tactical level based on flight plan data. Thirdly, at a strategic level based on schedule data. Access to this data was provided by LVNL.

As baseline the year 2018 was analysed. Thereafter, the analysis was repeated based on traffic growth estimates for the years 2023 and 2035 were made. Note that the analyses of growth scenarios have a high level of uncertainty; they strongly depend amongst others on economic growth, political and other strategic decisions.

5.2 Description of the method to identify hotspots

The method to identify so-called hotspots is based on an analysis of a theoretical remaining capacity based on gaps in the traffic flows to/from Schiphol in a certain ACC sector and the demand of Eindhoven, Rotterdam and Lelystad regarding that same sector. If demand exceeds capacity, then we consider it a hotspot.

Firstly, the traffic flows of Schiphol airport are analysed for each ACC sector, inbounds and outbounds independently. The traffic flows are based on the actual/planned/scheduled flight data, typically the take-off and landing times, and information about the sectors that each flight will cross (for schedule and flight plan data) or has crossed (for actual data). Then for each traffic flow, so per sector and per inbound or outbound flow, gaps of 4 minutes or more will be identified between consecutive flights in the traffic flow. If a gap is found then the number of flights that theoretically could be inserted into that traffic flow is determined, a minimum of 2 minutes[3] between flights is used. For example, if a gap of 7 minutes is found, then 2 flights could be inserted (at +2 and +4 minutes; +6 is not possible anymore because only 1 minute remains to the aircraft that forms the gap). The number of aircraft that theoretically could be inserted in the Schiphol traffic flows is called the “remaining capacity”. This is determined for each hour of the day.

Secondly, the traffic “demand” of the three regional airports (Eindhoven, Rotterdam and Lelystad) is computed for each hour of the day. This demand is the number of flights, either the actual numbers of 2018 or the estimated ones for 2023 and 2035, that constitutes a traffic flow in a specific sector. For

[3] The absolute minimum is 60 seconds, which equals a minimum separation distance of 5 NM (in ACC sectors) divided by 300 knots groundspeed. The 300 knots is based on an average altitude and wind in the ACC sectors. On top of the minimum value a margin of 60 seconds is added. The 120 seconds result in a maximum flow capacity of 30 aircraft per hour, which seems reasonable for today’s situation. One could argue to reduce the margin, for example to half a minute.

example, all flights departing from the three airports and flying through sector 2 on the second of July between 9:00-10:00 Universal Time Coordinated (UTC). Note that crossing traffic is not accounted for, e.g. inbounds to Eindhoven from the UK crossing inbounds to Schiphol from the south, as the scope of the study is related capacity surplus of traffic flows and not the capacity surplus of sectors. The latter needs much more detailed analysis, including controller workload, traffic complexity and so on.

Subsequently, the so-called “capacity surplus” is calculated for each hour and each traffic flow. This is the difference between the “remaining capacity” (or gaps) and “demand”. Again, this capacity surplus is related to traffic flows.

Statistics for the capacity surplus are calculated per traffic flow (inbound and outbound flow through sectors 1 to 5) and per season (summer and winter). The next section presents the results and conclusions of this analysis based on these statistics, i.e. the 5^{th} percentile, median and 95^{th} percentile of capacity surplus. The area between the 5^{th} and 95^{th} percentile lines represents capacity surplus in 90% of the time. And everything below this area represents the capacity surplus in 5% of the time. And everything above this area also represents the capacity surplus the remaining 5% of the time. In this study, we define that there is no absence hotspot when a positive capacity surplus exists at least 95% of the time. This means that hotspot occurs when a part (of the whole) of afore-mentioned area lies below zero, meaning a traffic flow capacity shortage more than 5% of the time during that time period and season.

Note that the absence of flow issues (i.e. hotspots) does not mean that there is no issue at all in a sector. There could be issues or hotspots in a sector due to other reasons, for example a very complex traffic situation may result in controller workload related hotspots and subsequent measures. This study only considers traffic flow aspects, since going from flows, to routes, to sectors and eventually to controller workload predictions requires much more analysis including detailed route and sector definitions and a detailed definition of the controller working methods, which is beyond the scope of this initial study.

The next section presents the results of the analysis of actual flight data. Schedule and flight plan data has also been looked at in order to see whether traffic flow issues at (certain) ACC sector are already present at strategic or pre-tactical level. However, due to the nature of the schedule and flight plan data it was not possible to derive a credible distribution of traffic flows in the ACC sectors. The issue is that multiple departures from Schiphol are scheduled/planned at the same time. This makes it impossible to easily allocate realistic take-off times and take-off runways to the departures. The same is true for arrivals at Schiphol. Consequently, no proper analysis of the schedule and flight plan data could be performed.

5.3 Traffic flow analysis based on actual flight data

5.3.1 Actual demand or number of movements - 2018

The actual amount of traffic to the four airports is presented in the figures below. A distinction is made between inbound and outbound traffic flows. Ten main flows have been analysed, these correspond to the inbound and outbound flows in the five Dutch ACC sectors (see Figure 45 in Appendix A 1).

The figures present the average number of aircraft flying to or from Amsterdam Airport Schiphol (EHAM), Eindhoven Airport (EHEH) and Rotterdam-The Hague Airport (EHRD). Lelystad Airport (EHLE) is not considered as in 2018 the number of commercial air transport movements were still negligible, at least compared to the other three airports.

For the summer period of 2018 (March 25, 2018 through October 27, 2018; 31 weeks) the data is presented between 04:00-21:00 UTC, i.e. 06:00-23:00 LT.

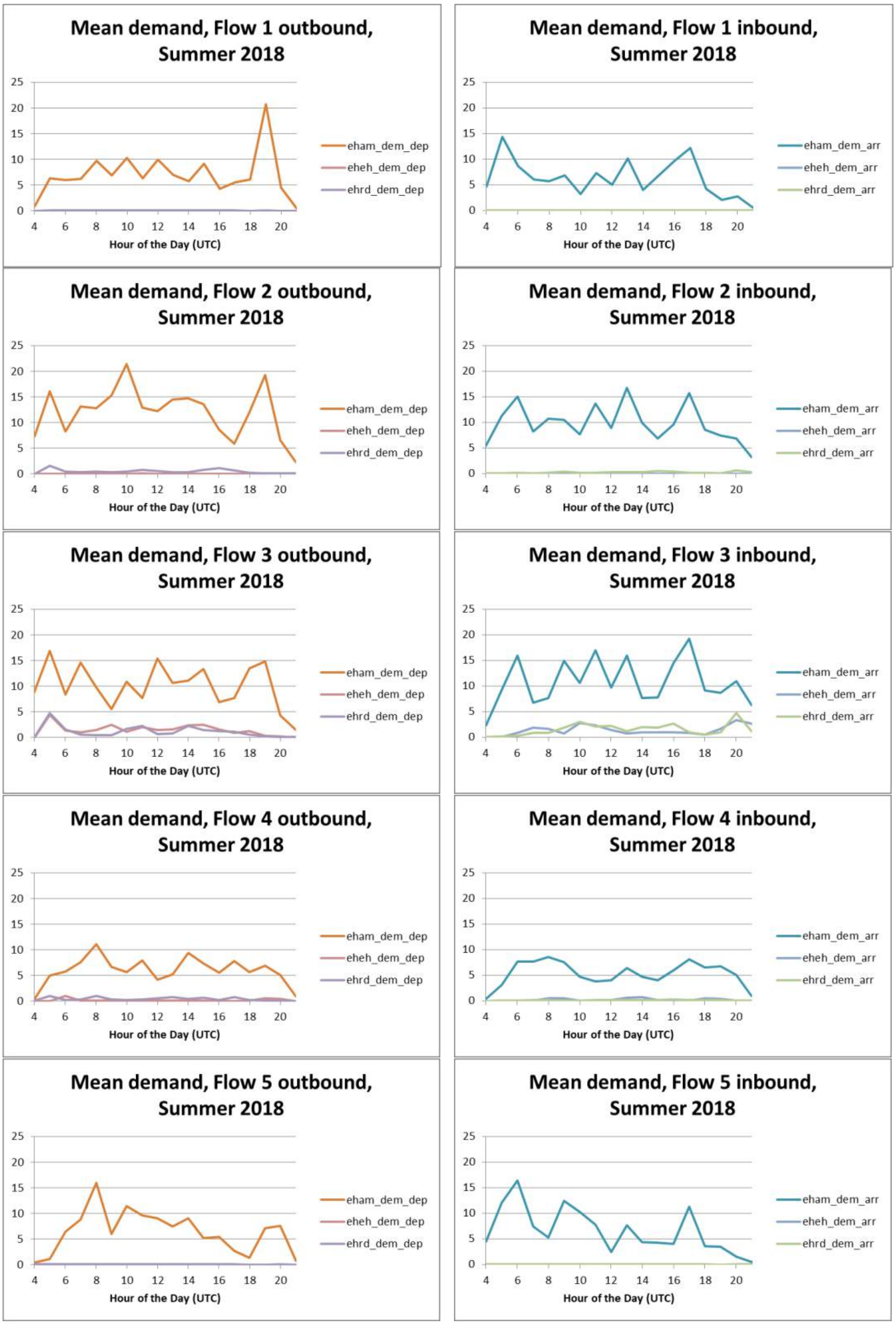

Figure 22: Mean number of actual movements (called demand) in the Dutch ACC sectors, to and from EHAM, EHEH and EHRD, during the summer of 2018.

As can be seen from the (hourly) average number of movements, the contribution of EHEH and EHRD is very limited to absent in ACC sectors 1 and 5. There is some traffic to/from EHEH and EHRD in sectors 2 and 4. But most traffic to/from EHEH and EHRD is passing sector 3, the South sector, with some peaks after opening and prior to the night closure.

Figure 22 also shows that sectors 2 and 3, the East and South sectors, are on average the busiest sectors regarding traffic flows to/from EHAM. Noteworthy is the single peak in sector 1, at 21:00 UTC, caused by departing traffic of Schiphol.

For the winter periods of 2018 (January 1, 2018 through March 24, 2018; and October 28, 2018 through December 31, 2018), the data is presented between 05:00-22:00 UTC, that is 06:00-23:00 LT, see Appendix B . The winter of 2018 gives a similar trend as the summer. As the summer is the busier season and therefore the more critical, the summer season is described in detail in the remainder of the document. The graphs of winter 2018 are included in Appendix B , both figures with the mean demand (as presented above) and the figures with capacity surplus (as presented in the next paragraph). However, the conclusions will address both seasons.

5.3.2 Hotspot identification based on actual traffic data

As explained in section 5.2 the method to identify so-called hotspots is based on an analysis of the a theoretical remaining capacity based on gaps in the traffic flows to/from Schiphol in a certain ACC sector and the (non-zero) demand of Eindhoven and Rotterdam-The Hague regarding that same sector. The metric that will be used is the capacity surplus.

The figures below show this capacity surplus during the summer of 2018. As mentioned before, the area between the 5th and 95th lines represents the capacity surplus in 90 percent of the time during the season for the given time and traffic flow. And a hotspot is defined when a part (or the whole) of this area is below zero.

The data is presented for 2018 and two growth scenarios. The number of movements and growth percentages for the four airports is given in Table 9, the values used in the growth scenarios are based on input from the DARP (*Programma Luchtruimherziening)*.

It is assumed that the growth at Eindhoven and Rotterdam will follow the current pattern of peaks and troughs, however this may develop differently. Airline market considerations and/or limitations imposed by the terminal building or the number of aircraft stands (*vliegtuigopstelplaatsen* in Dutch) may influence the growth over the day. And it is assumed that, for now, the traffic flow to/from Lelystad airport is uniformly distributed over the day. Again, airline market considerations will likely result in a pattern with peaks and troughs. But for the moment no substantiated assumption on this distribution can be made, therefore a uniform distribution is assumed. A third assumption is that the traffic flows to/from Lelystad is distributed over the ACC sectors as follows: 40% flies via sector 2, 40% via sector 3 and the remaining 20% is distributed over the sectors 1, 4 and 5, this is verified with *Programma Luchtruimherziening*.

Table 9: Number of movements in the reference and two growth scenarios (x1,000)

MAC study	Reference (2018 actuals)	Step 1 ("2023")	Step 2 ("2035")
EHAM	500	523 (+4.6%)	625 (+25.0%)
EHEH	37	43 (+16.2%)	51 (+37.8%)
EHRD	18	19 (+5.6%)	23 (+27.8%)
EHLE	0	10	45

5.3.3 ACC sector 1

The inbound and outbound flows in sector 1 were analysed based on actual movements in 2018 and the two growth scenarios. The gaps in the EHAM flows are compared with the demands of the three other airports (EHEH, EHLE, and EHRD). Figure 23 shows the results for the summer of 2018, Figure 24 shows the results of growth scenario 1 and Figure 25 shows the results of growth scenario 2. In general, the lower the line in the graph, the lower the capacity surplus and (when below zero) the bigger traffic flow issue.

It can be concluded that no hotspots are currently present in sector 1 and will also not develop in growth scenario 1 (2023). However, in growth scenario 2 (2035) a single hotspot is predicted to occur at 19:00 UTC for the outbound flow. The main cause of the hotspot is due to the large outbound peak, through sector 1, of departing traffic from Schiphol at that time of the day.

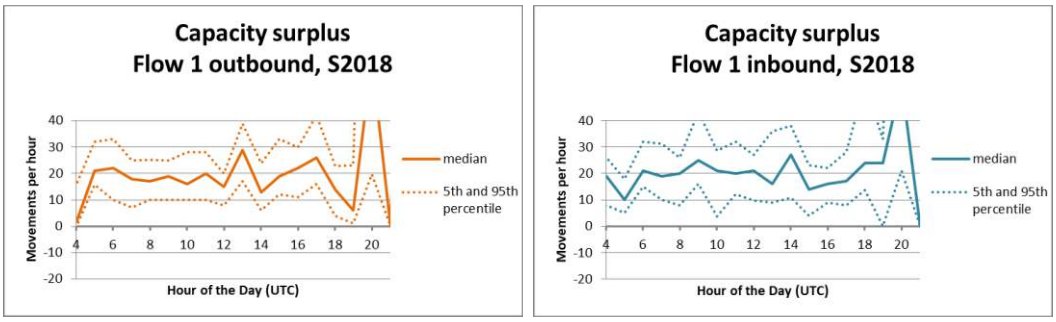

Figure 23: Capacity surplus of traffic flows in sector 1 based on actual 2018 data.

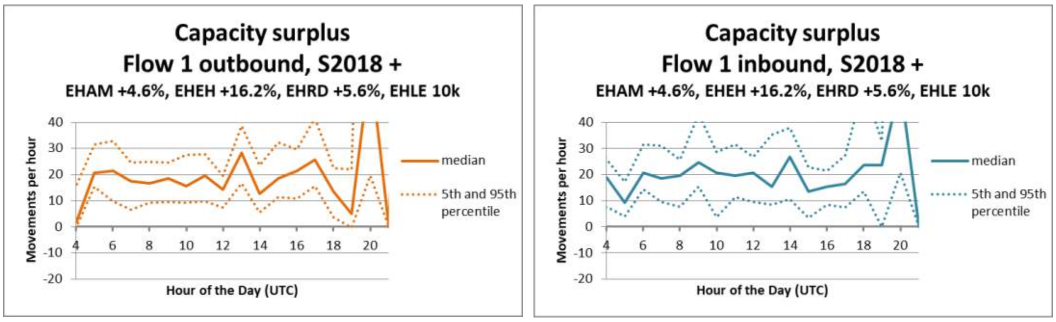

Figure 24: Capacity surplus of traffic flows in sector 1 based on growth scenario 1.

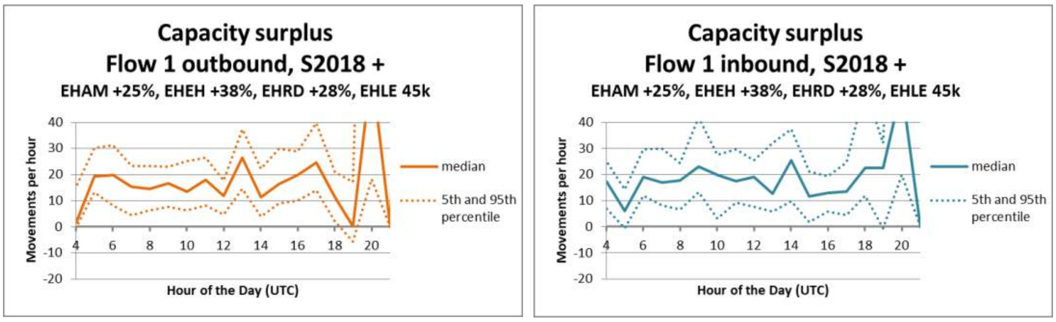

Figure 25: Capacity surplus of traffic flows in sector 1 based on growth scenario 2.

5.3.4 ACC sector 2

The inbound and outbound flows in sector 2 have been analysed based on actual movements in 2018 and the two growth scenarios. The gaps in the EHAM flows are compared with the demands of the three other airports (EHEH, EHLE, and EHRD). Figure 26 shows the results for the summer of 2018, Figure 27 shows the results of growth scenario 1 and Figure 28 shows the results of growth scenario 2.

For the outbound flows through sector 2, it can be seen that at 10:00 UTC, 12:00 LT, a hotspot is beginning to develop. The gaps in the EHAM outbound flow is about equal to the demands of the combined outbound flows of EHEH and EHRD. For the inbound traffic flows through sector 2, the actual data of 2018 does not show a hotspot.

For growth scenario 1, hotspots are becoming a reality for the outbound traffic flows. And at more periods of the day the capacity surplus is becoming almost zero, this can be seen in both the inbound and outbound flow.

For growth scenario 2, the hotspots for the outbound traffic flows are increasing, both in size and in duration. Hotspots are present during large parts of the day. For growth scenario 2, three hotspots are predicted for the inbound traffic flow through sector 2.

In summary, there are currently not yet any hotspots in sector 2, but hotspots will develop and become a reality with the autonomous growth of the airports and without mitigating measures. In particular for the outbound traffic flows, hotspots may develop during large parts of the day. Similar results are derived for the winter of 2018, see Appendix B .

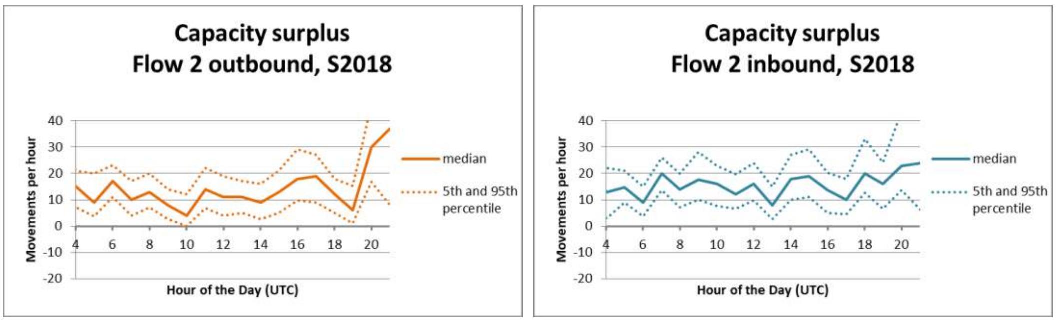

Figure 26: Capacity surplus of traffic flows in sector 2 based on actual 2018 data.

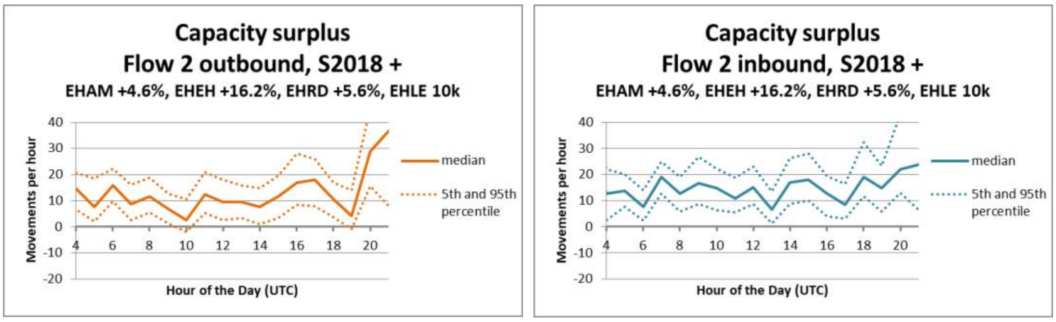

Figure 27: Capacity surplus of traffic flows in sector 2 based on growth scenario 1.

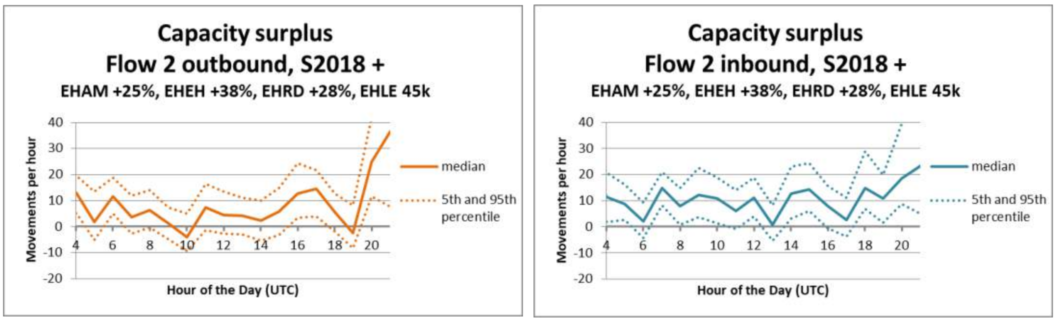

Figure 28: Capacity surplus of traffic flows in sector 2 based on growth scenario 2.

5.3.5 ACC sector 3

The inbound and outbound flows in sector 3 were analysed based on actual movements in 2018 and the two growth scenarios. The gaps in the EHAM flows are compared with the demands of the three other airports (EHEH, EHLE, and EHRD). Figure 29 shows the results for the summer of 2018, Figure 30 shows the results of growth scenario 1 and Figure 31 shows the results of growth scenario 2.

For the outbound flow through sector 3, it can be seen that at 05:00 UTC, 07:00 LT, a hotspot is present. The first hour after the daily opening of both EHRD and EHEH the outbound traffic flow, departing via sector 3, shows a relatively large peak. For the inbound traffic flow through sector 3, the actual data of 2018 indicates that multiple hotspots are present: at 10:00 and11:00 UTC (12:00 and13:00 LT), at 16:00 and17:00 UTC (18:00 and 19:00 LT), and at 20:00 UTC (22:00 LT).

For growth scenario 1, the hotspots are similar to the 2018 situation. It should be noted that in particular the hotspot in the outbound flow at 5:00 UTC (7:00 LT) increases in magnitude.

For growth scenarios 2, the hotspot in the outbound traffic flow further increases in magnitude and many new hotspots are estimated to become to develop. Hotspots are now present during large parts of the day. A similar development is visible for the inbound traffic flows.

In summary, there are currently a couple of isolated hotspots in sector 3. These hotspots are estimated to grow in magnitude and many new hotspots are estimated to develop, again all under the assumption of autonomously growth of the airports and the absence of mitigating measures. Inbound and outbound traffic flows show in a similar development of hotspots, in particular in growth scenario 2 (2035) hotspots are estimated to be present during large parts of the day.

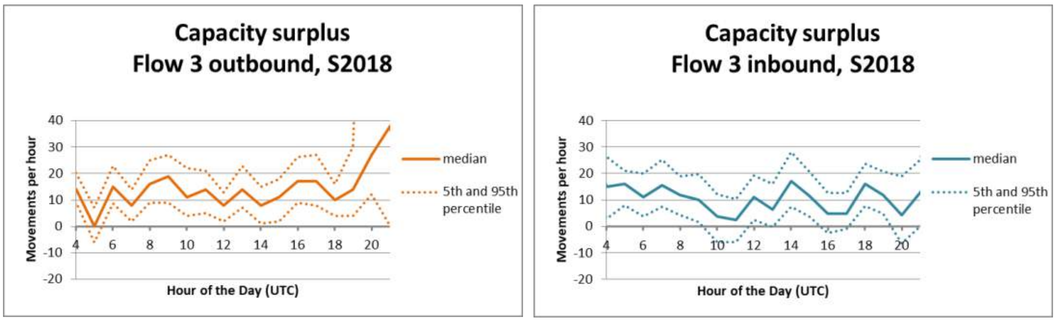

Figure 29: Capacity surplus of traffic flows in sector 3 based on actual 2018 data.

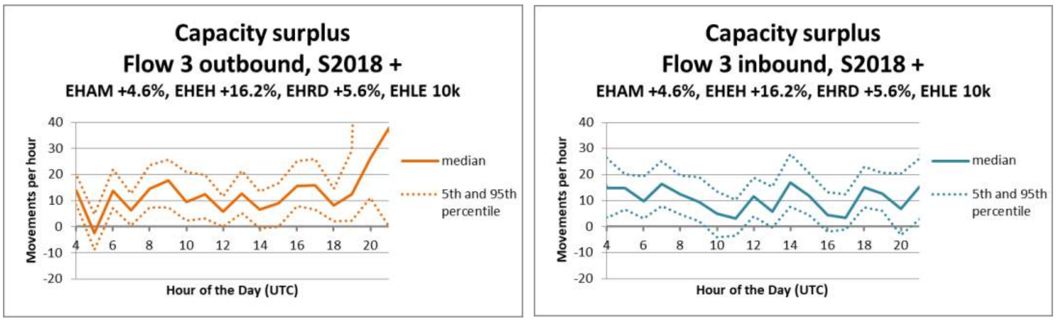

Figure 30: Capacity surplus of traffic flows in sector 3 based on growth scenario 1.

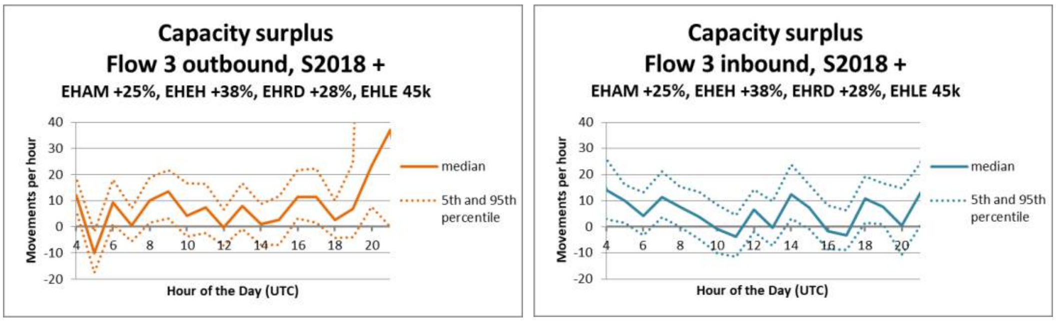

Figure 31: Capacity surplus of traffic flows in sector 3 based on growth scenario 2.

5.3.6 ACC sector 4

The inbound and outbound flows in sector 4 were analysed based on actual movements in 2018 and the two growth scenarios. The gaps in the EHAM flows are compared with the demands of the three other airports (EHEH, EHLE, and EHRD). Figure 32 shows the results for the summer of 2018, Figure 33 shows the results of growth scenario 1 and Figure 34 shows the results of growth scenario 2.

It can be concluded neither that hotspots are currently present in sector 4 nor that they will develop with the considered growth scenarios.

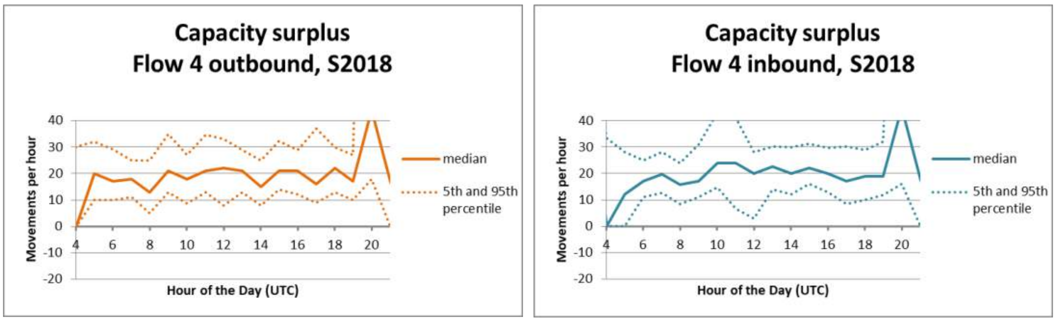

Figure 32: Capacity surplus of traffic flows in sector 4 based on actual 2018 data.

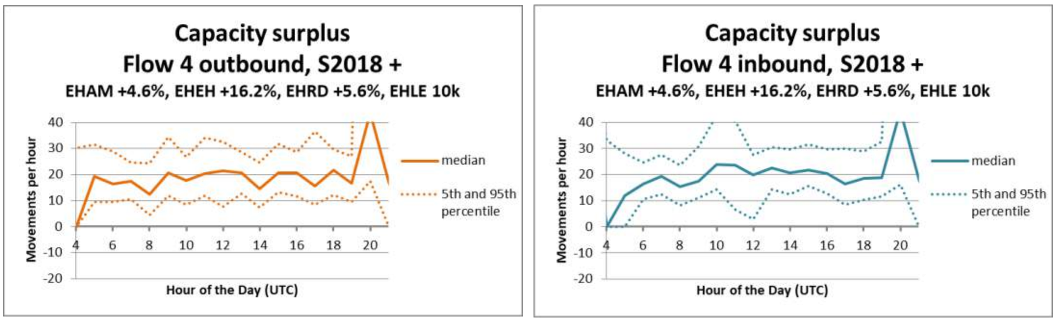

Figure 33: Capacity surplus of traffic flows in sector 4 based on growth scenario 1.

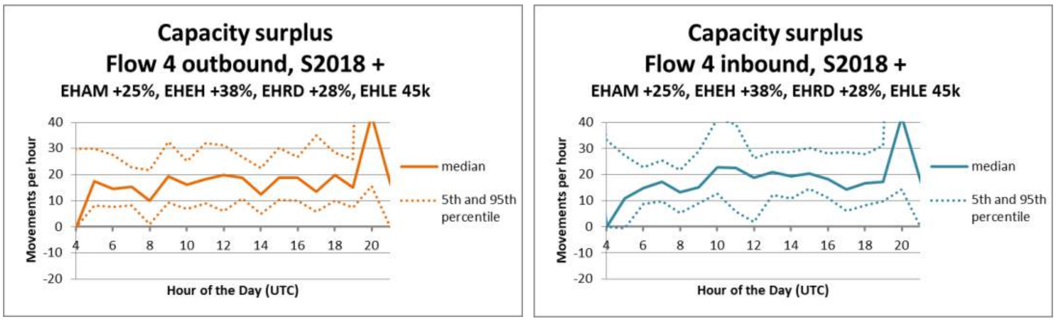

Figure 34: Capacity surplus of traffic flows in sector 4 based on growth scenario 2.

5.3.7 ACC sector 5

The inbound and outbound flows in sector 5 were analysed based on actual movements in 2018 and the two growth scenarios. The gaps in the EHAM flows are compared with the demands of the three other airports (EHEH, EHLE, and EHRD). Figure 35 shows the results for the summer of 2018, Figure 36 shows the results of growth scenario 1 and Figure 37 shows the results of growth scenario 2.

It can be concluded that no hotspots are currently present in sector 5 and it is estimated that they will also not develop with the considered growth scenarios. It should be noted that during certain times of the day, there are (almost) no gaps in the EHAM traffic flows. However, the traffic flows to/from the other airports via sector 5 is (almost) absent. Consequently, no hotspot is present in sector 5 or is estimated to develop with the growth scenarios.

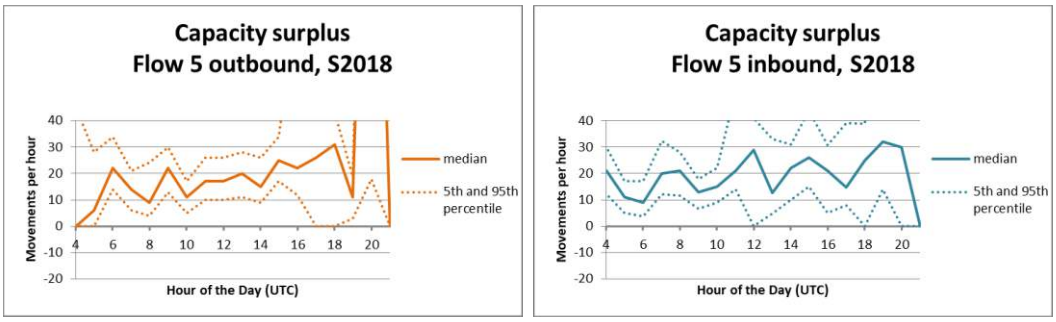

Figure 35: Capacity surplus of traffic flows in sector 5 based on actual 2018 data.

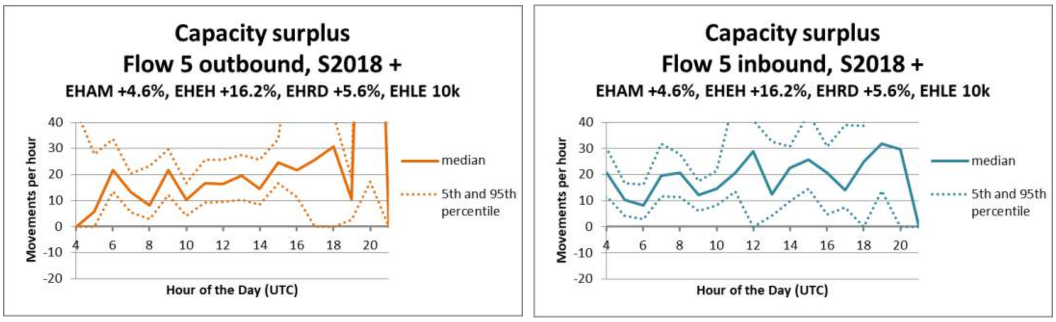

Figure 36: Capacity surplus of traffic flows in sector 5 based on growth scenario 1.

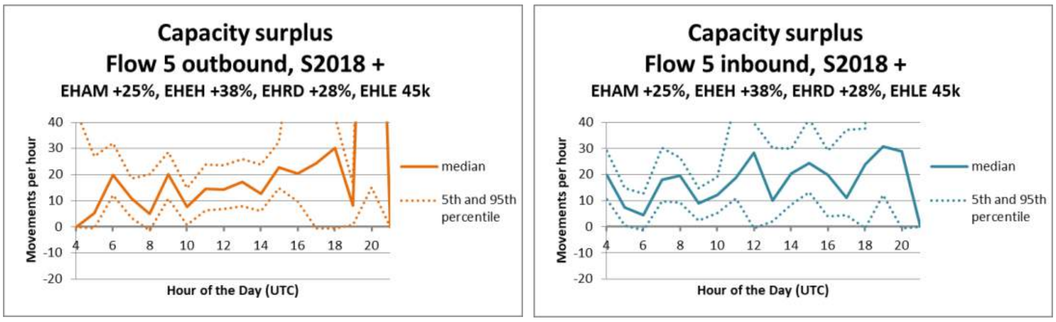

Figure 37: Capacity surplus of traffic flows in sector 5 based on growth scenario 2.

5.4 Summary of results

Table 10, Table 11 and Table 12 provide an overview of the location of hotspots and their development in future scenarios based on the analysis in the previous paragraphs.

The crosses in the tables mean that hotspots are present or estimated to develop in the traffic flow. The colour codes indicate whether the hotspot occurs or is predicted to occur during 1-2 hours of the day (yellow), 3-5 hours of the day (amber) or during large parts of the day (red), see the legend below the tables.

Clearly, sector 3 is of most concern. Hotspots already exist in sector 3 in the summer period and will develop during the winter season. Thereafter, in sector 2 hotspots will also develop based on the growth scenarios. In 2023 still limited, but in 2035 for both inbound and outbound flows and both seasons.

Finally, in sector 1 a specific hotspot is estimated to occur in the 2035 scenario. This is caused by the departures at Schiphol, which show in a large peak of outbound traffic in sector 1 at 19:00-20:00 UTC (see also Figure 22). In case of autonomous growth at the four airports and without mitigating measures, it will result in a localized hotspot in the 2035 scenario.

Table 10: Occurrences of hotspots in 2018 scenario

		Summer	Winter
Flow 1	Inbound	V	V
	Outbound	V	V
Flow 2	Inbound	V	V
	Outbound	V	V
Flow 3	Inbound	X	V
	Outbound	X	V
Flow 4	Inbound	V	V
	Outbound	V	V
Flow 5	Inbound	V	V
	Outbound	V	V

Table 11: Occurrences of hotspots in 2023 growth scenario

		Summer	Winter
Flow 1	Inbound	V	V
	Outbound	V	V
Flow 2	Inbound	V	V
	Outbound	X	V
Flow 3	Inbound	X	V
	Outbound	X	X
Flow 4	Inbound	V	V
	Outbound	V	V
Flow 5	Inbound	V	V
	Outbound	V	V

Table 12: Occurrences of hotspots in 2035 growth scenario

		Summer	Winter
Flow 1	Inbound	V	V
	Outbound	X	V
Flow 2	Inbound	X	X
	Outbound	X	X
Flow 3	Inbound	X	X
	Outbound	X	X
Flow 4	Inbound	V	V
	Outbound	V	V
Flow 5	Inbound	V	V
	Outbound	V	V

Legend
V = capacity surplus during the entire day
X = capacity shortage during 1-2 hours per day
X = capacity shortage during 3-5 hours per day
X = capacity shortage during large parts of the day

5.5 Main observations

In case of autonomous growth at the four airports (Schiphol, Lelystad, Rotterdam and Eindhoven) and no mitigating measures are being taken to alleviate traffic hotspots, the data analysis of traffic flows to and from the considered airports shows:

5.5.1 Historical 2018 actual data

There is currently a hotspot In ACC sector 3 in the period 7:00 to 8:00 LT. This coincides with the opening hour of both Rotterdam-The Hague airport and Eindhoven airport, these airports generate relatively large outbound peaks after opening at 7:00 LT. Currently there are no hotspots in ACC sectors 1, 2, 4 and 5.

5.5.2 Predicted situation in 2023 and 2035

Hotspots will (further) develop in ACC sectors 1, 2 and 3. With an autonomous growth of the four airports, traffic flow hotspots will appear during large parts of the day in sectors 2 and 3. No hotspots will develop in ACC sectors 4 and 5 based on the growth scenarios.

5.5.3 Mitigation measures

In case hotspots are only occurring during certain limited times of the day, multi-airport measures could be effective to better distribute the capacity surplus over the day. In case hotspots are occurring during (almost) the entire day (i.e. sector 2 outbounds and sector 3 inbounds and outbound in the 2035 scenario) then a general capacity issue will develop. Multi-airport measures alone will not be sufficient to address this issue. Other measures will be needed to generate additional capacity, possibly in combination with multi-airport measures that redistribute the peaks and troughs in traffic demand in or over the sectors.

The identified hotspots in this chapter together with the research and best practices regarding multi-airport aspects, as described in Chapters 3 and 4, are the basis of the candidate multi-airport measures in Chapter 6.

6 Potential measures

In this chapter potential measures for the introduction of a Dutch multi-airport concept are described in more detail. The measures are a result of the analyses performed in previous chapters. Each measure will be assessed on its potential in Chapter 7. The most promising measures or combination of measures will be integrated into a high-level concept in chapter 8.

6.1 Coordinated slot allocation

In The Netherlands airport slot allocation is currently a local process, this means there is no coordination of declared capacity (for example peak hours) between the slot-coordinated airports. By managing the capacity declarations between the airport involved in the multi-airport concept, as part of the slot coordination process, the root cause of congestion could be addressed. An example that could be better managed is the structural congestion of Amsterdam sector 3 between 7:00 and 8:00 LT due to the large number of departures from Rotterdam, Eindhoven and Schiphol Airport, see Figure 22 in section 5.3.

The slot coordination process could be further optimized by restricting the number of flights to specific airways at specific timeframes to strategically relieve certain ATC sectors. Local planning and operational restrictions are already part of the current capacity declarations to ACNL and could be expanded with restrictions that are derived on a national level.

All stakeholders have an interest into balanced air traffic demand and capacity, on the ground and in air traffic flows, in order to create stable traffic flows, resilient and robust against disruptions. Stable and predictable traffic flows eventually allow ANSPs to reduce their buffer capacity, leading to a small increase of capacity and accommodation for future growth.

Another reason of the traffic imbalance is that monitoring of airport slot utilisation is not actively performed by the slot coordinator. Whilst airlines will not consequently structurally deviate from their allocated airport slots, this lack of monitoring could result in increased traffic during peaks. Hence, to enlarge the effect of coordinated slot allocation, slot monitoring should be improved as well.

6.2 Strategic flight scheduling

Strategic flight scheduling is a technique that schedules flights in such a way that the interference of flights is reduced. In a far-fetched scenario, flights to the south may be scheduled from a southerly airport and flights to the north from a northerly airport. In this scenario it could mean that traffic to (from) the south will mostly depart from (arrive at) Eindhoven and Rotterdam-The Hague airports, whereas traffic to (from) the north or north-east will mostly depart from (arrive at) Lelystad airport. This scenario will result in conflicting interests. Airlines business strategies will most likely not support it.

A less far-fetched scenario, as proposed for this measure in this document, is to redistribute the traffic over the various sectors, therewith reducing the load on specific sectors. For example, flights to (from) South America or the Canary Islands could always be planned and executed via sector 4, thereby alleviating sector 3 to a certain extent.

The scheduling of flights via sectors with less or no hotspots could in principle be used in all phases (strategic, pre-tactical, tactical), though most impact could be anticipated when applied at a strategic level. This occurs already on European network level in the strategic phase.

6.3 National daily ATFCM entity and plan

The current ATFCM plan prepared by LVNL at D-1 aims first and only at Schiphol. A national ATFCM entity and daily plan is considered a potential evolution where the centre of attention would shift from Schiphol to at least all four airports involved in the multi-airport concept.

A national air traffic flow and capacity management (ATFCM) entity could support in the balancing of demand and capacity in the timeframe from a week up to hours before actual operations. An ATFCM entity could anticipate predictable and unpredictable disruptions by preparing decision information for its stakeholders. Such ATFCM entity could also coordinate with adjacent ANSP's and Eurocontrol Network Manager on situations and conditions. On request it can support airports, airline operators and ATC, whilst reporting to the Eurocontrol NM and the Civil Aviation Authority.

The national ATFCM entity could also be responsible to establish a national daily ATFCM plan. This plan can provide a clear overview of the latest information on demand (scheduled flights) and capacity (weather conditions, special events in airspace, airport availability, planned runway configurations). When the demand exceeds the available capacity, the entity can decide on pre-tactical regulations. An initial plan could be prepared from D-7 until D-1 after which it will be officially published.

A fully operating ATFCM entity and daily plan will enhance optimised use of airspace and airport capacity in the pre-tactical timeframe, especially when predicted or ad hoc disruptions require attention of all stakeholders. It strongly relies on increased information sharing between the ANSPs handling air traffic at or over the airports involved. LVNL and the military ANSP will be integrated into a single ANSP by 2023. This would already allow for better sharing of information on airport operations and airspace booking.

6.4 Runway configuration management

Currently, the runway configuration at Schiphol frequently changes. At Schiphol, bound to environmental regulations, an average daily number of sixteen runway configuration changes significantly reduces the predictability of traffic flows, both inbound and outbound. The runway configurations must adhere to environmental rules such as a preferential runway selection system. Next to this a maximum number of simultaneous used runways is established by the *New Standards and Enforcement System* [24]. Also the other airports involved in the multi-airport concept decide on their runway configuration independently. This leads to unpredictability of the foreseen multi-airport concept.

The runway configurations of the airports could in the future be coordinated such that the arrival and departures routes to the airports in the multi-airport concept are more aligned. Rotterdam, Eindhoven and Lelystad are single runway airports. They decide on their runway configuration based on actual wind conditions. If wind speed is limited, the interests of the multi-airport environment could influence the runway configuration selected. This asks for coordination and sharing of information at a pre-tactical and tactical level between the airports and as a prerequisite an increased planning horizon for the runway configuration at Schiphol.

Runway configuration management can be made more predictable by shifting to more schedule-based runway configuration changes rather than a change based on tactical conditions. For AOs, a schedule-based runway configuration changes at Schiphol compared to current situation where tactical conditions determine the moment of change, would mean a more predictable and possibly fixed route through the TMA and hence a more reliable landing time on the runway, and in-block time at the gate

Runway configuration management is positioned as a pre-tactical measure. Improved coordination and predictability of the runway configurations would make arrival and departure trajectories more predictable, both lateral and vertical; also enabling other measures establishing a multi-airport environment.

6.5 STAM

STAM is a demand and capacity balancing procedure which allows FMPs to identify regulation hotspots and apply measures smoothing sector workload by reducing traffic peaks (SESAR, European ATM Master Plan: Edition 2015, 2015). It is a collaborative process that aims to involve all stakeholders in order to ensure that equity is maintained.

Normally ATFCM regulations result in a systematic allocation of departure slots to all flights through the congested area, regardless of how they contribute to the expected overload. This process is no longer favourable when the demand does not significantly exceed the available capacity and when traffic can be predicted in a more refined way. FMPs can play a key role in the reduction of traffic peaks by applying measures such as assigning minor ground delay, flight level capping or small re-routings.

MUAC FMP has advanced STAM procedures in place for Dutch upper airspace. In lower airspace, LVNL FMP could develop measures having minimum impacts on airspace users, such as cherry-picking of the flights causing the complexity, based on expanded information including weather, airport operations, runway occupancy and traffic complexity. Today already some measures are used by approach air traffic controllers by coordination with adjacent airports. An example is the Rotterdam runway 06 departures, which could be held near the runway to avoid interference with Schiphol traffic.

By definition this measure is applied tactically. NM tooling can provide support for STAM. The tooling allows for hotspot detection, a “what-if” function to assess potential measures and effecting measures.

6.6 Traffic synchronization

ATCO workload is often not only a function of the amount of traffic, but also traffic complexity like crossing traffic, crossing a busy stream of other traffic. Sometimes, a small adjustment to the departure time of a single crossing flight may reduce workload below levels where regulations would be required. An example of such a case is a departure from Eindhoven (EHEH) to the west. A delay of 5 or 10 minutes for this flight may avoid crossing a group of outbound flights from Schiphol.

To minimize interference, departing traffic can, under certain circumstances, be synchronized with other traffic flows in the multi-airport environment. This is especially an option for aerodromes where there is limited outbound demand. Traffic can be designated to take-off within a certain time window, before or after a certain time. Due to the nature of the departure operation, this would not be possible for Schiphol as this would affect the required high departure capacity, but would be more suitable for Rotterdam, Eindhoven and Lelystad. A technological enabler is the Departure Metering project for the London TMA and the Departure Spacing program in New York-Boston Northeast corridor. This measure for departure at multiple airports in proximity is also known as DMET.

Arriving traffic flows into the multi-airport can likewise be synchronized in such a way that flows into different airports do not conflict in the sectors but also not compromise the throughput at the largest airport Schiphol. Well in advance of entering Dutch airspace, potentially even before take-off, aircraft are assigned a TTA at the destination airport or a TTO an entry point, ensuring a distributed traffic rate into the airports. TTA/TTO strongly relies on the available arrival management concepts and tooling for multi-airports.

These techniques can be used in the tactical phase to prevent workload limits to be exceeded. Having this tactical measure could also be used to allow for a greater design margin when choosing capacity limits on a strategic level. For instance, the available capacity in a traffic stream is measured in a percentage at which a certain capacity can be guaranteed. Applying this method could permit choosing a less stringent percentage at which a competing traffic stream needs to be deconflicted, thereby increasing capacity levels.

To facilitate this concept element, certain systems support is likely to be required. Accurate trajectory information on conflicting traffic profiles needs to be available. Also, a conflict detection and resolution capability could assist the controller/planner in deriving an appropriate time constraint for a departure from one of the departure restricted airports.

6.7 Sector capacity measures

The data analysis has identified that multi-airport measures only are not sufficient, in particular in the 2035 scenario, hence a number of capacity improvements are suggested below. Note that those measures cannot be considered to be multi-airport measures, but it was considered useful to mention them.

6.7.1 Introduction of southeast flow

The DARP (*Programme Luchtruimherziening*) is considering the introduction of a new southeast flow for civil air transport. A new southeast flow for flights departing Schiphol airport would be positioned in between the current Schiphol flows to the east in ACC sector 2 and the south in ACC sector 3, crossing the Amsterdam FIR border south of Eindhoven (BROGY). The location of the current ACC sectors is shown in Figure 45, in Appendix A 1

This new flow would alleviate outbound demand pressure on the two busiest outbound streams from Schiphol. Together they make up over 50% of the total traffic. This would not only create new departure slots for traffic heading in this direction, it is also likely to free up slots in the current sector 2 and 3 outbound flows. This is to be expected as a sizeable portion of the traffic in sectors 2 and 3 is bound for a destination on this heading (eligible traffic in sector 2: 21%, sector 3: 28%). This measure can be applied on a strategic and pre-tactical level.

6.7.2 Reduction of minimum radar separation

When it becomes possible to reduce the minimum radar separation outside the TMA to a value of less than 5 nautical miles, it would be possible to reduce the value as used in the definition of a gap in the traffic flows to/from Schiphol airport. This would at least theoretically increase the numbers of gaps in the traffic flows and consequently the number of movements that could operate via all sectors.

This measure is to be used at a tactical level. The consequence of reducing the minimum radar separation in terms of controller workload and acceptance is unknown. New support tools to detect and resolve conflicts may become necessary. Note that this measure also sets requirements on the surveillance systems and may require adjustments to the legal framework, therefore it may be a measure for the mid-term.

6.7.3 Route duplication

Route duplication is a technique in which more than one route connects a sector entry gate (several entry points instead of one entry point) and a sector exit gate. The new navigation specifications make it possible to define (parallel) routes more closely together. And when flights are smartly allocated to the 2 or 3 or 4 (parallel) routes, the traffic flow capacity could significantly increase. The use of multiple closely spaced RNP routes with a common end point (e.g. IAF for arrivals or a coordination point with an adjacent center for departures) will likely not increase capacity. However, the use of multiple routes in a multi-airport concept can bring significant capacity benefits, for example closely spaced parallel routes entering the Dutch airspace that later on split into dedicated routes to the different airports or departures from different airports coming together not in one single route but in several closely spaced parallel routes towards multiple (again closely spaced) exit points to adjacent centers.

System support would be needed to allocate flights to the optimal route given its origin and destination and perhaps even down to the level of allocated take-off/landing runway. The creation of more than one route, between certain sector entry and exit points, is a design consideration. However, the allocation process to assign flights to one of the routes is a strategic measure and could be further fine-tuned during the flight planning phase and on the day of operation.

Issues to consider are the impact on ATCO (working method, system support, workload, complexity of operations) and the impact on adjacent centers. Instead of one transfer point, a gate with multiple transfer points will have to be handled and a higher complexity with potentially more traffic crossings may be the result (i.e. crossings after receiving traffic at the gate or before handing it over at the gate).

7 Assessment of potential multi-airport measures

In this chapter the potential measures as identified Chapter 6 are assessed. The potential multi-airport measures have been assessed against several performance indicators (PIs) related to traffic flow characteristics. The performance indicators identified to provide a first impression of the effectiveness of the multi-airport measures are:

- Sector capacity
- Regulations – it includes both the number of regulations and the duration of regulations.
- Traffic bunches - a traffic bunch occurs when packets of aircraft arrive at the same, unexpected time, in a congested area
- Traffic flow complexity
- Track miles flown by aircraft
- Resilience – ability of the ATM system to cope with non-nominal conditions. Indicators are loss of airspace capacity avoided and time to recover from non-nominal to nominal condition.
- Predictability – both the time and vertical aspects are considered.

The table below provides the PI scores of the six multi-airport measures (two strategic, two pre-tactical and two tactical measures). The scoring is based on engineering judgment of the project team members.

Table 13: Scoring table of the potential multi-airport measures

	Strategic		Pre-Tactical		Tactical	
Performance Indicator (PI) * (+) is less and (-) is more	1. Coordinated slot allocation	2. Strategic flight scheduling	3. National daily ATFM entity and plan	4. Runway configuration management	5. STAM	6. Traffic synchronisation
1. Capacity (Sector)	0	0	0	0	0	0
2. Regulations (number, minutes) *	0	+	+	0	++	+
3. Bunches*	+	0	+	0	+	++
4. Traffic flow complexity*	0	+	+	++	0	+
5. Track miles*	+	-	0	+	0	0
6. Resilience (% loss of airspace capacity avoided)	+	+	+	+	0	0
7. Predictability (time)	+	+	+	+	+	++
8. Predictability (vertical path)	0	0	0	+	0	0
Overall score ("+" adds one," 0" adds nothing, "-" subtracts one	4	3	5	6	4	6

Scoring legend	
++	significantly positive
+	slightly positive
0	neutral
-	slightly negative
--	significantly negative

It can be concluded that all measures have certain benefits. The measures are typically having a different impact on specific PIs. No two measures have the same impact on the PIs, though the two strategic measures are most common. It is argued that no obvious duplication is present; therefore each measure seems to be beneficial in itself. Furthermore, none of the measures has an overall negative score when considering all PIs for that measure. It is therefore recommended to proceed (for the time being) with all potential multi-airport measures in Chapter 8, the high-level concept description.

8 High-level concept

In this chapter a proposal for the multi-airport concept for the Netherlands is provided. This CONOPS provides a high-level description of the operational use of the most promising measures from a user point of view for the time period 2023 up to 2035.

8.1 Assumptions and conditions

8.1.1 International regulations

Applicable EU regulations following from the Single European Sky Research Programme (SESAR) like the PCP [25, 12, 13, 11] are governing further developments. This also applies to other relevant EU regulations [26, 27, 28]. Together they prescribe the technical enablers and conceptual procedures that must be adhered to. This concept assumes the following PCP defined ATM Functionalities:

1. Extended AMAN and Performance Based Navigation in the High-Density TMAs
2. Airport Integration and Throughput
3. Flexible Airspace Management and Free Route
4. Network Collaborative Management
5. Initial System Wide Information Management
6. Initial Trajectory Information Sharing

8.1.2 European ATM Masterplan

The SESAR programme, in cooperation with their United States counterpart NextGen, as well as global authorities such as the International Civil Aviation Organization (ICAO), International Air Transport Association (IATA), Airports Council International (ACI) and Civil Air Navigation Services Organization (CANSO), prepares for and is in the deployment of transitioning towards harmonized operations that are more based on operational performance. For that reason, Performance Based Operations (PBO) is identified and assumed as the most significant trend to adhere to.

8.1.3 Dutch aviation vision (*Luchtvaartnota*)

The Netherlands is preparing its vision on aviation for the time period up to 2050. This vision, called the Luchtvaartnota, will be the foundation for the aviation policy and implementation agenda in the upcoming decades. The draft vision was expected late 2019, but has not been published up to date and thus cannot be assumed yet.

8.1.4 Civil military integration (*1ATM*)

The Netherlands is in a transition to integrate civil and military ATC into a single ANSP. From 2017 the civil and military ANSPs have been co-located. Currently the civil and military concepts of operation are being aligned in order to integrate into a single ANSP with a single ATC staff by 2023. For this concept it is assumed that this integration is completed.

8.1.5 Dutch airspace redesign (Programma Luchtruimherziening)

This Multi Airport concept is developed in parallel to the DARP. Therefore, it is not possible to incorporate all design considerations from the programme as the programme is still ongoing. It is agreed that the concept is limited to the level of traffic flows to and from the airports involved. At a certain moment the programme can elaborate traffic flows into route, sector and airspace design.

Although this concept does not refer to content of the airspace redesign program, it does refer to its objectives and requirements documented in *Notitie Reikwijdte en Detailniveau* [29]

Airspace users and their needs accumulated by the airspace redesign programme are listed in the *Integrale behoeftestelling herziening luchtruim* [30]. It can be assumed that those needs are relevant to this concept as well.

It is assumed that it will be fundamental to shift towards a planned way or working and to generally abandon the current highly tactical way of working. The background is that with a feasible degree of 3D procedural de-confliction in the TMA, supplemented by other elements like for instance traffic synchronisation, based on RNP (e.g. RNP1 or RNP0.3) and potentially a best equipped-best served principle to support and optimise the vertical flow of traffic, a systematic absorption of delays will not be possible inside the TMA any longer. Consequently, arriving flights will have to be delivered precisely and consistently at the TMA entry point and a planned way of working that combines speed adjustments and path stretching/shortening in ACC and UAC airspace is deemed necessary to consistently achieve a high precision at the TMA entry point to support the arrival management process in such an environment.

8.1.6 Air traffic numbers

From EUROCONTROL European aviation in 2040: challenges of growth [31], a 1.5% annual air traffic increase is forecasted for The Netherlands for the years up to 2040. This percentage is based on a baseline situation in 2018. This percentage applies to both terminal and en-route traffic.

8.2 Problem statement

The study results of the current situation and growth scenarios expose the following problems:

- ATFCM is not yet organised at national level, it is strongly focussed at Schiphol;
- Airport slot allocation and runway configuration are performed independently, not taking into account other airports in close proximity;
- There is no mechanism to minimise interaction between departure flows from the involved airports heading to the same airways;
- Arrival and departure traffic of Rotterdam and Eindhoven airports interfering in lower airspace with Schiphol traffic is managed tactically only;
- When no mitigation measures are taken, the expected traffic numbers in 2023 are predicted to exceed sector capacities in ACC sector 2 and 3 multiple times a day, while the numbers in 2035 are predicted to exceed these sector capacities almost continuously.

Figure 38 visualises the inbound and outbound flight trajectories for Schiphol (blue inbound, green outbound), Rotterdam (orange inbound, red outbound) and Eindhoven (purple inbound, yellow outbound), for a period in 2019 of several hours with one runway configuration per airport. It demonstrates the current use of Dutch airspace and adjacent airspace of the United Kingdom, Germany and Belgium. As Lelystad is not open to commercial air traffic yet, its trajectories are not shown. As can be seen, the traffic flows spread widely from all three airports, covering a large part of Dutch airspace.

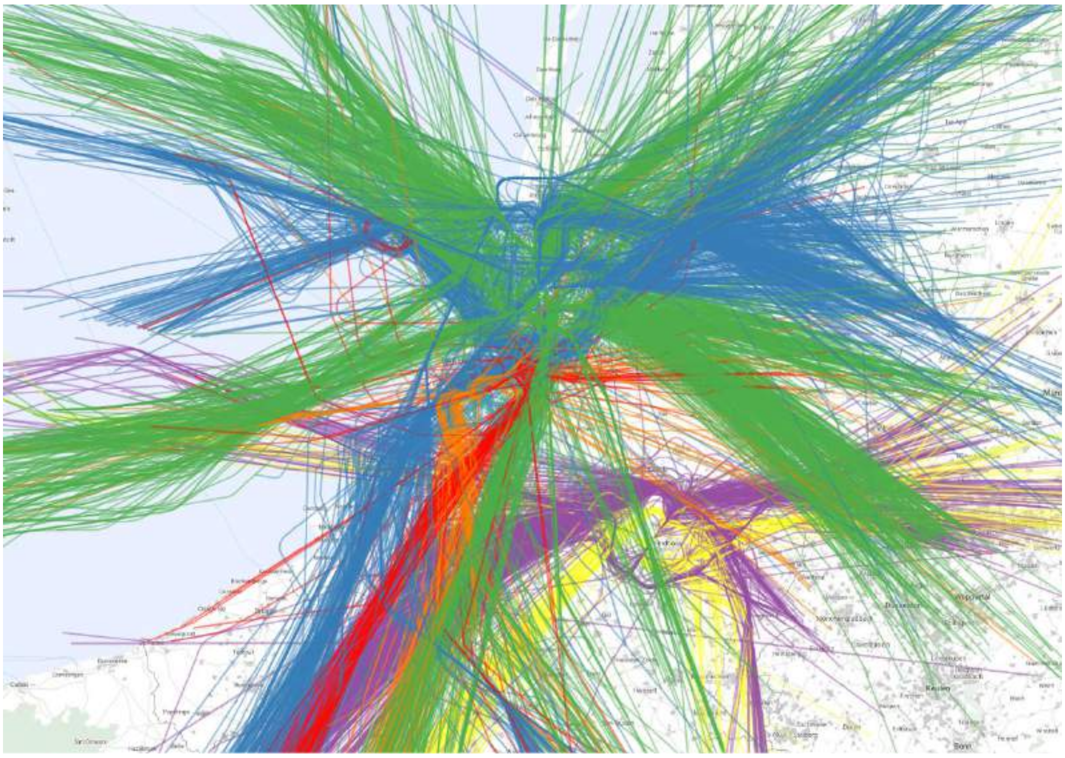

Figure 38: Inbound-outbound flight trajectories Schiphol, Rotterdam and Eindhoven, 2019

8.3 Concept description

With the expected growth of air traffic over Europe, technical deployments enforced by regulation and the user needs accumulated by the national airspace redesign programme, a new concept for the optimal utilisation of the limited airspace enclosing the multiple airports in close proximity is desired. An implementation of this concept with enhanced flight scheduling and ATFCM for Schiphol, Rotterdam, Eindhoven and Lelystad Airport can support in achieving the global objectives of the airspace redesign in the time period from 2023 up to 2035.

The assessment in Chapter 7 showed six measures that are candidate for a multi-airport concept. The measures, listed in Table 14, are categorized based on the timeframe the measure can be applied. Strategic measures can be applied from a year up to a week before operation. Pre-tactical measures take place between a week and a day before operations. The day of operation is considered the tactical timeframe.

Table 14 : Potential flight scheduling and ATFCM measure per planning timeframe

Nr.	Measure	Planning timeframe
1	Coordinated slot allocation	Strategic
2	Strategic flight scheduling	Strategic
3	National daily ATFCM plan	(Pre-)tactical
4	Runway configuration management	Tactical
5	Traffic synchronization	Tactical
6	STAM	Tactical

In Figure 39 the flight scheduling and ATFCM measures are visualised on a timeline indicating the mentioned planning timeframes.

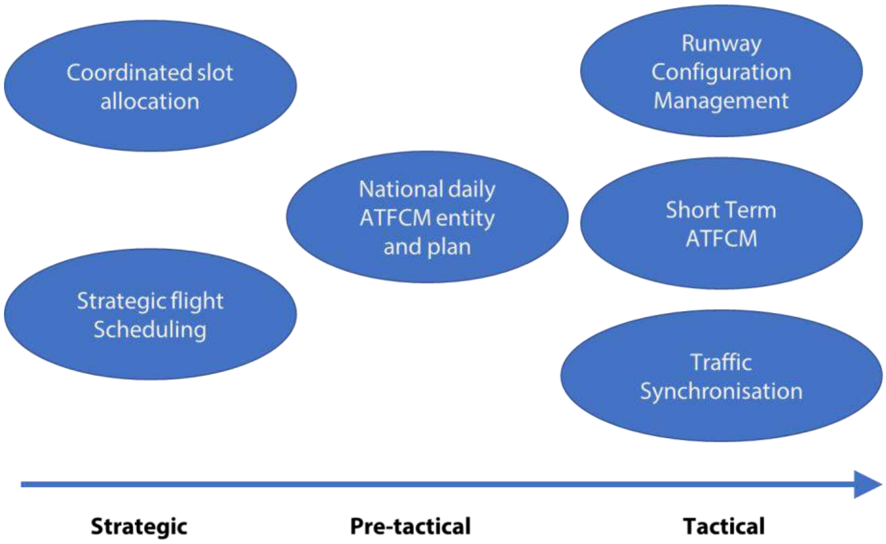

Figure 39: Measures placed in planning timeframe

Next the ATFCM measures are elaborated for the Dutch operational environment where costs and benefits will again be addressed. The description includes an estimated timeline for implementation. As the descriptions are rather abstract and in limited detail there are no requirements derived from them. Notwithstanding a summary of impacts is described in Section 8.5.

8.3.1 Strategic phase

Air traffic demand and capacity imbalances are the consequence of assigned airport slots that match with local airport capacity, but altogether exceed the declared capacity in airspace. Traffic flow imbalances occur primarily due to uncoordinated demand between the slot coordinated airports, causing traffic peaks, or bunches, in the inbound and outbound flows from and to TMA and ACC sectors, as well as MUAC. The main consequences are increased controller workload due to excessive radar vectoring and moreover flight delays.

Improvement of the air traffic demand and capacity balance within Dutch airspace and its airports can be achieved by reorganising strategic airport slot allocation for all involved airports together, rather than the individual processes for each airport. Airport slots for flights with destinations along the same airway need to be distributed in time where the demand meets the flow and sector capacity. After rebalancing the use of airspace by redistributing the available airport slots for all four airports, regulation needs to be refined to monitor slot compliance by airspace users. Market valuation and stakeholder incentivisation can contribute to this compliance.

Compliance of airport slots can be achieved by structural verification of flight schedules and flight plans with the assigned airport slots. Technical enablers are already becoming mandatory in the European Union, and most stakeholders are equipped or ready to validate new concepts, procedures and technical support. The tolerances on airport slot deviations can be agreed upon between all stakeholders, yet may be significantly reduced compared to present day values. Performance monitoring needs to be developed in order to periodically evaluate each airspace user.

Market incentives can be used to differentiate for airport slots in high or low demand. Incentives must also be considered as enabler for stakeholders that perform in compliance with the regulations. Performance indicators on stakeholder compliance and adherence to planning should contribute to changed behaviour.

Strategic planning improvements such as coordinated airport slot allocation and flight schedule compliance are expected to have significant impact to a more balanced use of airports and airspace, as all resources are more evenly utilized causing less inflictions to capacity. These measures require political agreement amongst stakeholders, enhanced performance monitoring based on existing parameters. No major new technology is required, allowing for a relatively short timeframe to implement these measures.

8.3.2 Pre-tactical phase

Disruptions can either be predictable or unpredictable, yet they require enhanced anticipation and resilience to assess impact on the use of airspace and ground resources, including traffic flows and airport capacity. At local level an APOC may be able to predict the change in demand through an AOP and in the network the NM establishes a Network Operations Plan (NOP). After all at national level there is currently no entity nor plan that balances traffic demand and capacity earlier than at the day of operations. There is a need for enhanced collaborative decision making in the pre-tactical timeframe to anticipate and sustain air traffic operations.

A national ATFCM entity could anticipate on predicted and respond to unpredicted disruptions by preparing decision information for its stakeholders. Such an ATFCM entity could also coordinate with adjacent ANSP's and the NM on situations and conditions. Moreover, it can continuously support airports, AOs and ANSPs with the latest predictions, whilst reporting to the NM and the CAA.

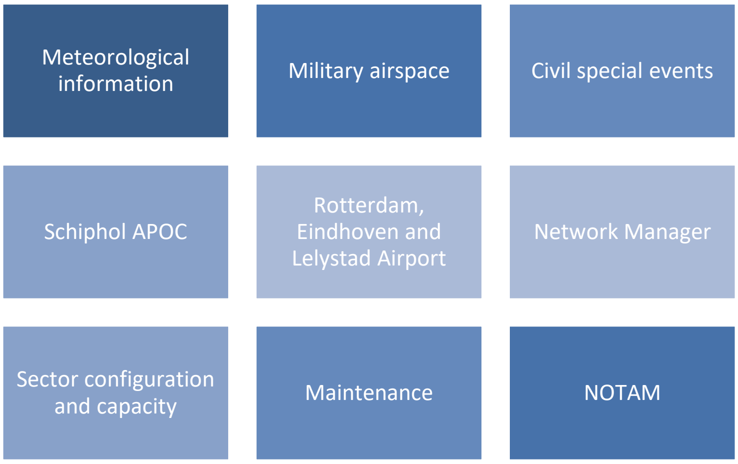

Figure 40: Elements in a national daily ATFCM plan

Thorough post-operational analysis after the day of operation, can provide a baseline for a national ATFCM plan for next year's operation. This baseline plan drafted by the entity can already include preliminary traffic forecasts, planned events and ATCO duty rostering. Traffic forecasts are in the meantime finetuned with the support of data analyses. Likewise, duty rosters are detailed by the rostering bureau. Planned events such as national events, air shows or military exercises are carefully collected in an agenda. The impact of these events on demand or capacity is assessed by the entity itself. Figure 40 presents a list of potential elements that can become part of the daily plan.

Between D-7 to D-1, the latest traffic predictions, the latest weather forecasts and the latest military airspace bookings can be added to the plan in more detail. The entity can then turn this information into expected runway configuration at the airports and a sector opening scheme at the ANSPs. Also, they advise on the need for pre-tactical ATFCM measures when demand is expected to exceed the available capacity. The plan could at several moments in advance of D-1 be already shared with the stakeholders. The plan shall be officially published at D-1 the latest.

The creation of an ATFCM entity and plan may require cooperation and approval from the CAA, as well as enablers to facilitate the need for forecasts and information, including performance monitoring and dashboard functions. ATFCM highly depends on ATM functions already present within the ANSPs, but also requires an interface with the AOP and NOP. It is essential that this will be developed in line with the NM vision on AOP and NOP [32]. Figure 41 shows the interaction between APOC, ATFCM entity and NMOC.

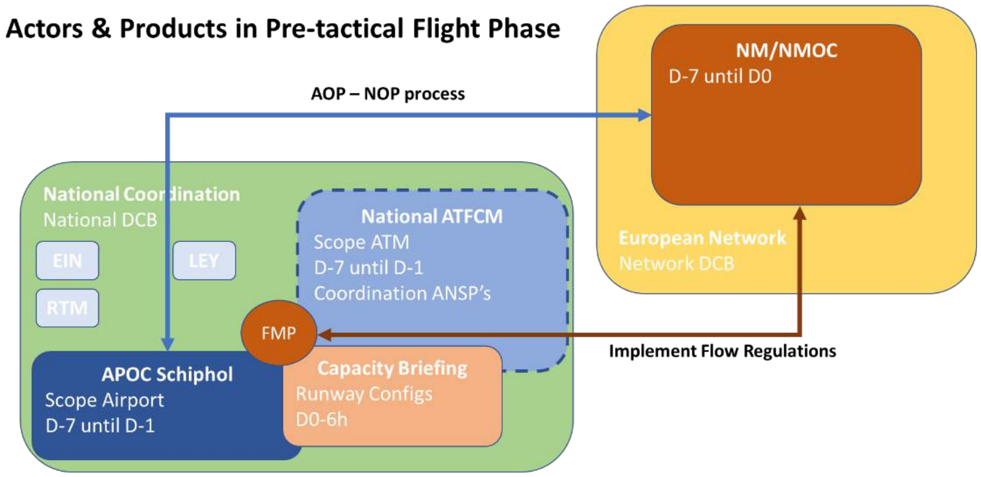

Figure 41: Place of the national ATFCM entity in context of APOC and NMOC

8.3.3 Tactical phase

Runway configuration management

Runway configuration management can be made more predictable by shifting to more time-based runway configuration changes rather than changes based on tactical conditions. For AOs, a time-based runway configuration changes at Schiphol compared to current situation where tactical conditions determine the moment of change, would mean a more predictable and possibly fixed route through the TMA and hence a more reliable landing time on the runway, and in-block time at the gate. It also allows for better prediction of the vertical flight path of arrivals, increasing the performance of other tactical measures like traffic synchronisation and STAM. The increased predictability could eventually allow for a reduction in flight schedule buffers at AOs and sector capacity buffers at ANSPs, improving the resource utilisation at both AO and ANSPs. This may help compensate for the compromised throughput during high demand.

For ANSPs this would impact the current working method. It shifts from the flexibility of radar vectoring and runway configuration changes maximising throughput into stable and predictable flows to the runways. This increased predictability could nevertheless affect throughput during high demand or in rapidly changing weather conditions. Potential mitigation measures for this lower throughput could be technological innovations like time-based separation and/or RECAT-EU.

Coordinated and schedule-based runway configuration changes by collaboration of multiple stakeholders from all airports could reduce the ATCO workload and increase predictability for AOs.

STAM

STAM are taken in the phase where flights can still be influenced by measures that impact on the flight planning or trajectory. The measures also aim to avoid congestion in airspace or at airports but at the same time having minimum impact on airspace users.

The FMP could apply measures having minimum impacts on airspace users, such as MCP of flights causing the complexity, based on expanded information including weather, airport operations, runway occupancy and traffic complexity. Possible measures include the allocation of minor ground delays to specific flights and flight level reassignments or route changes negotiated with airspace users.

These measures can also be prepared beforehand and coordinated with adjacent centres in so-called scenarios. These scenarios can then easily be implemented when the traffic situation demands.

A typical scenario could be to temporary assign flight level caps to short distance flights to avoid interference. Another scenario could be to temporary reroute flights in southern direction from sector 3 to 4 or eastern direction from 2 to 1. NM tooling can provide support for STAM. The tooling allows for hotspot detection, a “what-if” function to assess potential measures and effecting measures.

Traffic synchronisation

Traffic synchronisation aims to avoid congestion in airspace or at airports and preserve ATCO workload. For the departure phase, flights in the multi-airport environment to the same merge or exit points can be automatically planned by applying the DMET concept. Flights originally conflicting at merge or exit points, can be assigned a minimal ground delay so that demand and capacity in a specific time bracket is balanced again. Pre-requisite for the implementation of DMET is A-CDM. A-CDM is a concept applied at Schiphol airport and currently 40+ airports throughout the European network. It enables predictability for departures at an airport. When multiple airports apply this concept, its departures can be coordinated through pre-departure sequencing mechanisms.

Point of attention is that where airports are situated close to each other, the effect of traffic synchronisation is limited caused by the variety in actual departure times (CTOT adherence -5 / +10 minutes) resulting in traffic situations that simply can’t be planned in advance for this reason. Improved adherence to a reduced tolerance window shall be a prerequisite for this measure to be effective.

For the arrival phase, flights in the multi-airport environment to any of the airports involved can be systematically synchronized by applying the TTO concept. It can support coordination of traffic flows into multiple airports in the same vicinity to enable a more accurate delivery to the runways and enable the controller to manage the interaction of flows in an efficient way without overload situations. A TTO and ultimately a TTA can be assigned prior or during the flight with support of the NM. A TTO is the target time at FIR or TMA entry point while a TTA is the target time at a runway of the destination airport. The actual flight plans are calculated based on the TTA/TTO and both ANSP and AO are required to adhere to these times.

The implementation would require AMAN at the airports involved. It also needs an additional arrival planning component CMAN which accompanies the AMANs of the airports. The CMAN generates a combined planning for several arrival flows into different airports by calculating the sequence of aircraft flying towards a sector or TMA where their routes intersect. By imposing an adequate spacing of the aircraft in that area, a TTL for the appropriate upstream sector is calculated to meet this constraint. The ATCO in the upstream sector will be presented with the superimposed TTL and required sped from the AMAN and the CMAN. The CMAN aims to increase efficiency, enhance predictability, and timely avoidance of traffic bunching in the airspace sectors.

Point of attention is that AMAN and CMAN do not take conflicts between inbound and outbound traffic into account. These conflicts can require tactical actions by the ATCO (flight level changes, route deviation) during actual operations, possibly threatening TTAs.

8.4 Operational scenarios

The two operational scenarios in this section provide a high-level introduction to how the concept elements can support in actual situations.

8.4.1 Normal operations

This scenario describes a rather normal day of operations in the airspace over The Netherlands in 2035. It is meant to give an introduction of the strategic measures only.

In the strategic domain airport slots are already coordinated within the multi-airport environment. Furthermore, the airport slots have a reduced time window in which the flight plan is destined to start or end. Airport slots for flights in specific directions have been coordinated with airport slots at the other airports involved. With respect for historical rights, traffic from the largest airport Schiphol still shows waves of long-haul aircraft operations from and to certain directions such as North and South America or Asia-Pacific. However, there is also airspace capacity planned for flights at the other airports involved.

With ACNL actively monitoring AO performance, the flexibility in flight planning is significantly reduced. To compensate, new concepts such as User-Driven Prioritisation Process (UDPP) and airport slot swapping allow AOs to maintain their business model where flights of economic value have priority over other flights within their schedule.

Because of improved adherence of flight scheduling, more resilience is built within the daily airport capacity and demand planning. Capacity buffers are spread throughout the day, different from the year 2020 where these so-called fire breaks are planned in between traffic peaks.

Distributing airport slots and flight plans not only at the saturated airport Schiphol, but also over Eindhoven, Rotterdam and Lelystad, has the effect that in nominal scenarios the airspace demand will be more evenly spread, and traffic flows are increasingly stable towards and from all major directions, creating spare capacity to accommodate flight deviations or unpredicted disruptions. Resilience and robustness are a major gain resulting in less unpredicted flight deviations or cancellations.

By design, and as direct consequence of more balanced airline schedules in adherence to airport slots, this planned distribution of traffic will result in better airline punctuality and less delays, because the actual flight operation closer approximates flight plan and schedule.

8.4.2 Forecasted western storm

This scenario describes a typical western storm in January passing over The Netherlands in 2035, which is forecasted some days in advance. With its severe wind speeds and gusts, it impacts air traffic for between 4 and 8 hours in the early morning and afternoon and reduces capacity significantly. The focus in this scenario is on the pre-tactical and tactical measures.

In the pre-tactical domain weather forecast are reviewed daily in the national ATFCM cell, and refined predictions of the duration, location and impact of the storm are shared as the national daily ATFCM plan amongst stakeholders of all airports, including Schiphol APOC. At the peak of the storm, strong gusts limit the runway configuration at Schiphol to runway 27 only, for a maximum of 2 hours. Mixed mode operations are anticipated. Prior and after that also runway 24 is available, increasing capacity for departures and arrivals, between 2-4 hours.

Schiphol APOC, the national ATFCM cell and the NM continuously share updated information on the airport operations, providing situational awareness to all stakeholders through use of one platform, which is also available to Eindhoven, Rotterdam and Lelystad. These predictions are input for resource management at the airport and ANSP. The AO uses the information to ultimately decide on flight rescheduling and cancellations, as well as passenger stay-overs. Flights without transfer passengers are pro-actively rescheduled from Schiphol to other airports like Eindhoven and Lelystad, so that these flights can still be operated at the scheduled date. Frequent train connections will bring passengers to their destination conveniently. AO also anticipate by rebooking passengers to other flights, minimizing stayovers. Airports prepare for large passenger volumes and delayed flights. Actual diversions, delays and knock-on effects are minimized due to frequent involvement of all actors in early phases.

After all the storm requires AOs to cancel 10% of the scheduled flights in advance, spread through the most certain period of the storm as confirmed by the meteorological service provider. A national rule determines which AOs needs to cancel flights proportionally at all airports involved. Schiphol is affected the most as it handles the largest number of flights.

In the tactical domain the ATC supervisors and airport authorities are determining whether runway configurations can be used as predicted, or different runway configurations are needed. Runway capacity determines the ground delay. A larger runway threshold departure buffer is foreseen during mixed mode operations on runway 27, in order to achieve maximum throughput during the peak of the storm.

The inbound flights are heavily regulated and receive a TTA, generated by the AMAN, which clearly reflects the reduced inbound capacity during the storm. In the Amsterdam FIR fixed arrival flights combined with Interval Management (IM) can sustain continuous descent approaches, although on occasion flight crews request, and ATCOs facilitate, radar vectoring approaches.

Runway capacity is the bottleneck during the storm, tactical tooling for DMET and traffic synchronisation are less critical. There is at this moment hardly interference between the operations at Schiphol, Rotterdam, Eindhoven and Lelystad.

With limited runways available and mixed mode operations sustaining throughput is of essence. Because of reduced inbound rates, fixed approach routes with continuous descent approaches remain possible in the airspace. The combination of optimising throughput with predictable arrivals during a severe storm also enables predictable departure rates, and hence a limited yet stable operations.

When the storm starts decreasing, a gradual recovery of runway capacity is planned. Assuming the regional airports were also regulated, the arrival flow rates into Schiphol can be increased until the declared airspace capacity. A-CDM procedures in combination with DMET, grounded aircraft are being push-backed at increasing rates, filling the cleared airspace and recovering the flight schedules throughout the evening.

8.4.3 Traffic flow disruption caused by network regulations

This scenario describes a rather normal day of operations in the airspace over The Netherlands in 2035. During the day of operations the operation at Eindhoven and Rotterdam was disrupted for a short period of time and is now recovering. The focus in this scenario is on tactical measures only.

Rotterdam and Eindhoven feed most of their departures into the southbound departure flows which are during daytime usually already saturated with traffic from Schiphol and Lelystad. To minimise executive workload for ATCO, traffic synchronisation is a mechanism which calculates the demand on the exit points. The purpose of this pre-departure tooling is to avoid outbound traffic bunches at TMA or FIR exit points.

For departures DMET technology intends to achieve a traffic rate over a dedicated waypoint taking into account aircraft performance. It computes expected TTO this waypoint to determine revised TTOT at the ground. As a result of the calculation Eindhoven and Rotterdam departures will receive small ground delays in order to merge into the southern traffic route at a time where some capacity is available.

When applied in the timeframe in the last two hours before off-block time, DMET can be considered a tactical measure. Whether applied by area controllers in coordination with approach controllers, or automated by technical enablers, the effect remains to avoid excessive radar vectoring and an efficient flight path.

Eindhoven departure synchronization

Figure 42 shows an example of ground delay appointed to a departure from Eindhoven intending to merge into an outbound flow from Schiphol. DMET assigns the Eindhoven departure with a small ground delay in order to have the flight enter the airway separated from the flight right before. This ground delay needs to have a significantly smaller tolerance window in order to ensure a smooth synchronisation. In contrast, the ATFM CTOT tolerance windows (-5, +10 min) would be ineffective for traffic synchronisation.

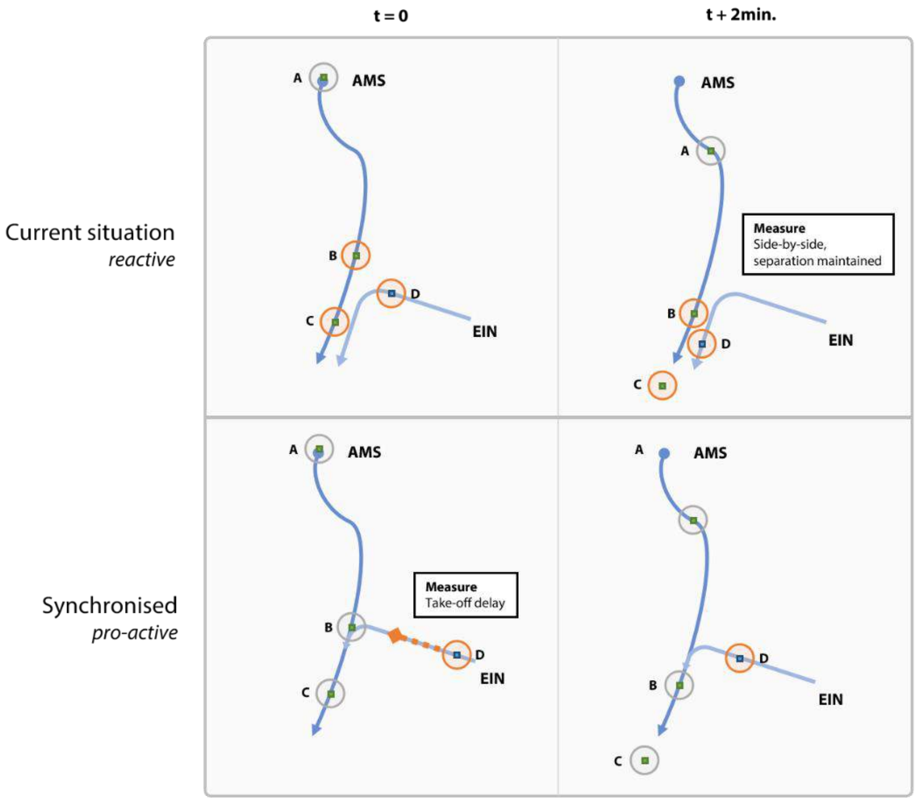

Figure 42: Departure from EIN synchronizing with AMS outbound flow

Rotterdam departure synchronization

Another example of traffic synchronization is presented in Figure 43 for a Rotterdam departure taking off in northern direction from runway 06, intending to merge with a southbound departure flow from Schiphol. A minor DMET assigned ground delay could be beneficial for the flight path of the Rotterdam departure, whilst minimizing the additional workload for the approach controllers.

These measures require a granularity which currently exceeds the possibilities for the NM to apply for regulations by means of CTOT. Yet these measures are helpful when collaborate decisions are made on common situational awareness of the departure planning and impact on traffic flows.

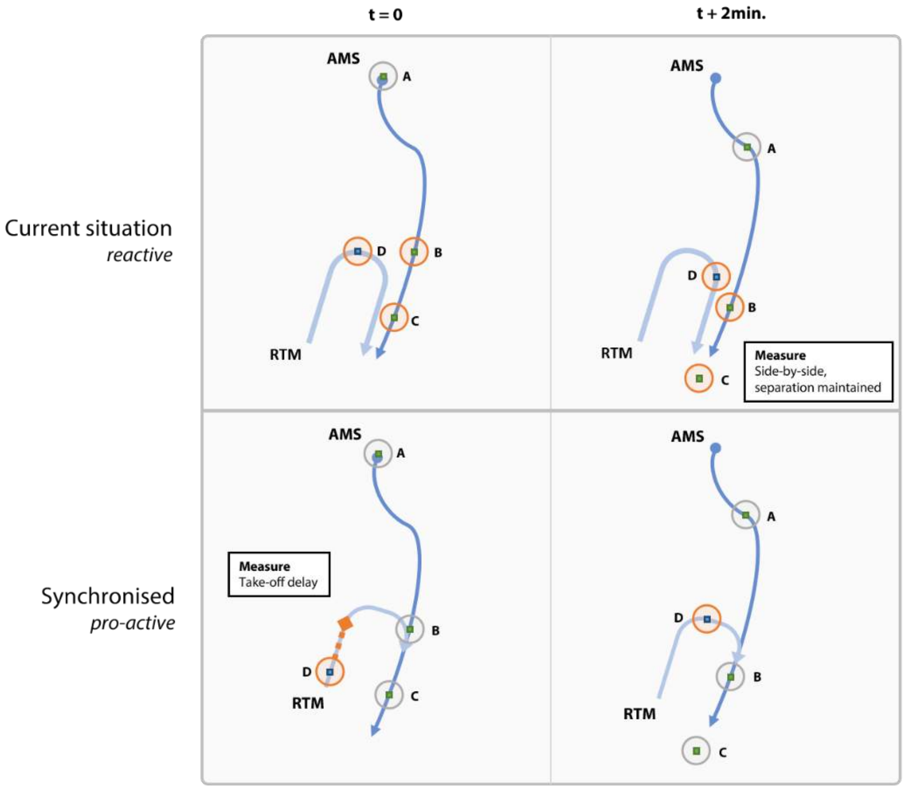

Figure 43: Departure from RTM synchronizing with AMS outbound flow

8.5 Summary of impacts

The following table provides an overview of the impact the individual measures as part of the high-level concept have at an organisational, technical and procedural level.

Table 15: Summary of impacts

Nr.	Measure	Organisational	Technical	Procedural
1	Coordinated slot allocation	Key is agreement among stakeholders; Legal framework may need adjustments	Limited	UDPP for AO
2	Strategic flight scheduling	No impact	No impact	Limited
3	National daily ATFCM entity and plan	ATFCM entity needs to be initiated	Limited	ATFCM plan process needs to be designed
4	Runway configuration management	ATCO training is required for tower/approach controllers	Limited	Medium impact on ATCO procedures
5	Traffic synchronization	ATCO training is required for all controllers	Complete implementation requires large system support: A-CDM, DMET, XMAN, CMAN	Medium impact on ATCO procedures
6	STAM	FMP should be trained on STAM	Already available	Small impact on FMP procedures

8.6 Potential implementation timeline

The various concept measures have different implementation timelines based on feasibility and required preparations. Also they can be categorized on impact on resource Demand and Capacity Balancing, or Predictability and Efficiency for operations. Figure 44 shows the measures on a timeline within the time period from 2023 up to 2035. It should be highlighted that traffic synchronisation can follow a gradual implementation. Full implementation of this measure may require large system support. Nevertheless by starting with the implementation of A-CDM on the regional airports followed by the implementation of DMAN before CMAN, each step can already yield gains in predictability,

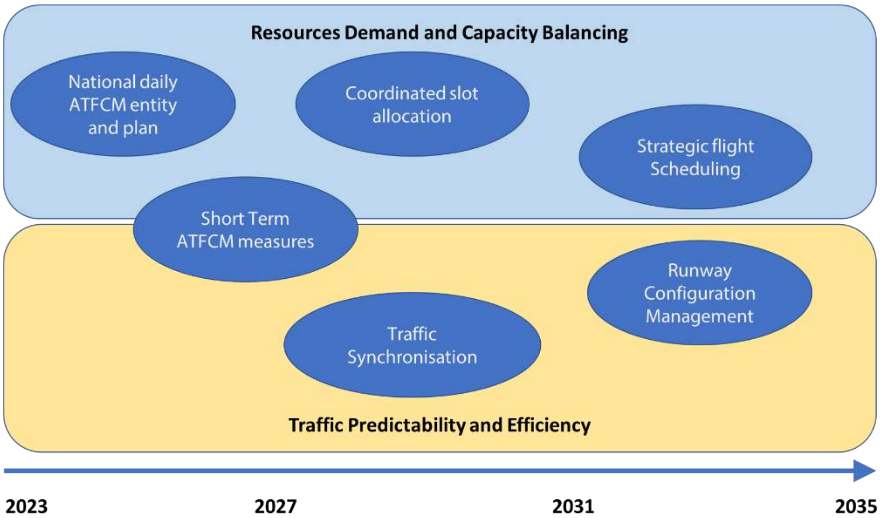

Figure 44: Potential implementation timeline for measures

9 Conclusions and recommendations

This chapter describes the conclusions that can be drawn from this study into a multi-airport environment for The Netherlands. The conclusion come along with recommendations.

9.1 Conclusions

One of the project goals was to study options of flight scheduling and integral ATFCM for the Dutch airports of Schiphol, Rotterdam, Lelystad and Eindhoven. Although ATFCM over multiple airports may be missing in Dutch airspace, the study showed that LVNL and the Dutch Air Force already have several mechanisms in place to control flows and manage airspace capacity.

The study also explored multi-airport enabling technologies resulting from Eurocontrol and SESAR research programmes. For comparison, an overview of airspace, sector, route design and more specifically ATFCM around airports in the London and Paris region is provided.

Besides the qualitative research, air traffic flows around the Dutch airports were studied quantitatively. The method to identify so-called hotspots was based on an analysis of a theoretical remaining capacity based on gaps in the traffic flows to/from Schiphol in a certain ATC sector and the demand of Lelystad, Eindhoven and Rotterdam regarding that same sector. In actual flight data of 2018, a hotspot in Amsterdam ACC sector 3 is identified that coincides with the opening times at Eindhoven and Rotterdam in the early morning. With the predicted demand in 2023 and 2035, hotspots will (further) develop in sectors 1, 2 and 3. With an autonomous growth of the four airports, traffic flow hotspots will appear during large parts of the day in sectors 2 and 3. No hotspots will develop in sectors 4 and 5 based on the growth scenarios.

In case hotspots are only occurring during certain limited times of the day, multi-airport measures could be effective to better distribute the capacity surplus over the day. In case hotspots are occurring during (almost) the entire day (sector 2 departures and sector 3 arrivals and departures in 2035) then a general capacity issue will develop. Multi-airport measures alone will not be sufficient to address this issue; other measures will be needed to generate additional capacity.

The study identified and assessed six multi-airport measures in the strategic, pre-tactical and tactical domain. These measures were integrated into a high-level concept of a multi-airport environment that can improve the management of traffic flows in the Dutch airspace from 2023. Coordinated slot allocation and strategic flight scheduling are measures that can lead to a more robust and resilient airspace utilisation. A national daily ATFCM entity and plan can improve situational awareness of all operational stakeholders by sharing information already at the pre-tactical level. To support the effect of tactical measures, improved runway configuration management for all airports is a precondition. At the tactical level, technology supporting the traffic synchronisation of arrivals and departures of arrivals and departures as well as STAM, can strongly increase predictability of flights and can support managing air traffic controller workload. Enhanced predictability can generate significant benefits through reducing sector and flight schedule buffers, however this still needs to be assessed against reduced airline flexibility. Airline-driven priority processes and tools can largely mitigate for a potential loss of flexibility.

9.2 Recommendations

The area of interest in the study was on strategic flight scheduling and ATFCM. The quantitative research on hotspots in Dutch airspace showed that with the predicted demand in 2035 there would be hotspots (almost) the entire day in what is nowadays called ACC sector 2 and 3. Recalling from the conclusions, only measures within the domain of the study would no longer be sufficient and capacity improvements are needed.

The introduction of a southeast traffic flow seems to be an adequate measure to increase route capacity and to relieve current ACC sectors 2 and 3. This supports the strategy the DARP is following by moving military training areas elsewhere. Another measure that was identified and could be considered is reducing separation standards, this could slightly increase capacity without impact on the route design, particularly in a multi-airport concept with flows to mixed destinations. However, there may be training or new support tools involved. Lastly, new navigation specifications make it possible to define (parallel) routes more closely together. When flights are smartly allocated to the two, three or four (parallel) routes, the route capacity could be significantly increased. Note that the use of closely spaced (parallel or near parallel) RNP routes with a common end point (e.g. IAF for arrivals or a coordination point with an adjacent center for departures) will likely not increase capacity. However, the use of closely spaced parallel routes in a multi-airport concept can bring capacity benefits. This may also involve support tools and commitment of adjacent centers is key.

In the introduction the principle was explained that traffic flows should be analysed before the route design and that airspace boundaries are the aftereffect. The study analysed traffic flows and made recommendations for the route design. For the definition of airspace boundaries, it is recommended to primarily consider the protection of the route design and the segregation between types of service provision. Types of service provision refers to different types of air traffic (civil/military), flight rules (VFR/IFR) or ATC unit (approach control/area control/adjacent centre).

On top of the suggested measures enhancing predictability, fixed arrival routes are considered a further enhancement of predictability. Probably the technology of IM is needed to sustain current runway capacity. Radar vectoring shall still act as fallback for the fixed arrival routes.

When the stakeholders decide that more coordination between the Dutch airports will become necessary, contrary to or in addition to separating route structures (as in London and Paris), it is recommended to study the six multi-airport measures in more detail and to update and refine the measures itself and high-level concept with the results of those studies, thereby providing a detailed CONOPS.

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[32] E. Leeman, . T. Popova and D. Phythian, *Airport Network Integration - Concept for establishment of an Airport Operations Plan (AOP) – Network Manager,* November 2018.

[33] DSNA, "Press release: Collaborative Advanced Planning," 2016.

A ATC sector configurations

A 1 Amsterdam ACC

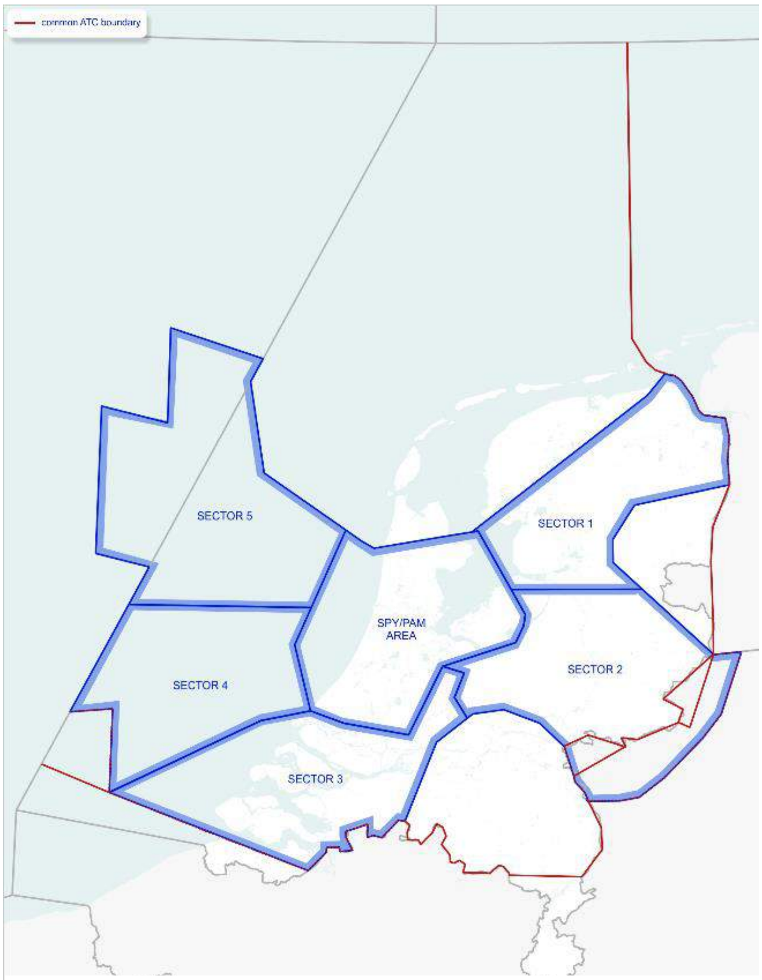


Figure 45 Amsterdam ACC sectors, source: LVNL operations manual [9]

Amsterdam ACC can open up to five sectors depending on traffic demand. Historically the sectors represent the flow directions into Schiphol Airport. All sectors share the responsibility within the SPY/PAM area. One specific controller is responsible to detect and coordinate conflicting overflying traffic within this area: the ACOMAN.

Common sector combinations for Amsterdam ACC are sector 1 and 2 and sector 4 and 5. At night-time all sectors are combined and manned by a single team of one radar controller and one planning controller. Sector 2 and 3 can even be split into an inbound and executive sector. For sector 2 this is common in traffic peaks, for sector 3 this is in development and may be implemented by the summer of 2020.

All traffic from and into Schiphol and Rotterdam Airport cross one or more ACC sectors, sequentially. Amsterdam ACC overall has a baseline declared capacity of 150 flights per hour in 2018 (NOR 2018).

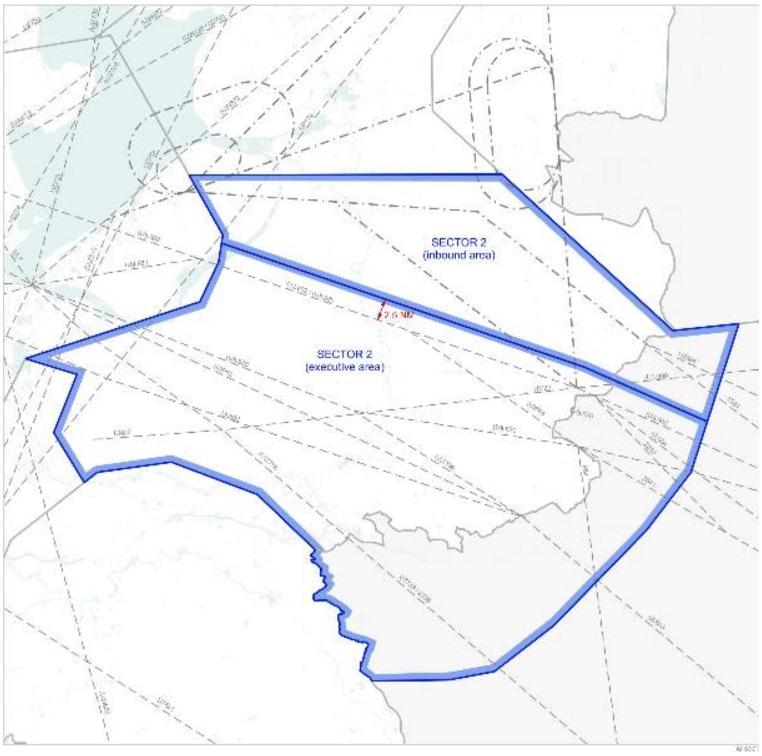


Figure 46 Amsterdam ACC sector 2 [9]

A 2 MilATCC Schiphol Area

MilATCC Schiphol Area, co-located at LVNL, can open up to two sectors depending on traffic demand: Lower 1 and 2. The Lower 1 sector services air traffic in the northern part, while the Lower 2 sector services the southern part of Dutch airspace. Air traffic from and into Lelystad Airport crosses at least the Lower 1 sector and depending on the direction also the Lower 2 sector. Air traffic from and into Eindhoven Airport always enters the Lower 2 sector and a fraction also the Lower 1 sector. MilATCC Schiphol Area has no declared capacities for their sectors. It should be noted that the MilATCC sectors overlap with the Amsterdam ACC sectors. MilATCC will normally not control aircraft in the Amsterdam ACC sectors. In case of a military need and after notification, MilATCC can control military flights in the ACC sectors. For these situations it is for both parties clear whether the Lower 1 or 2 is in control of those flights.

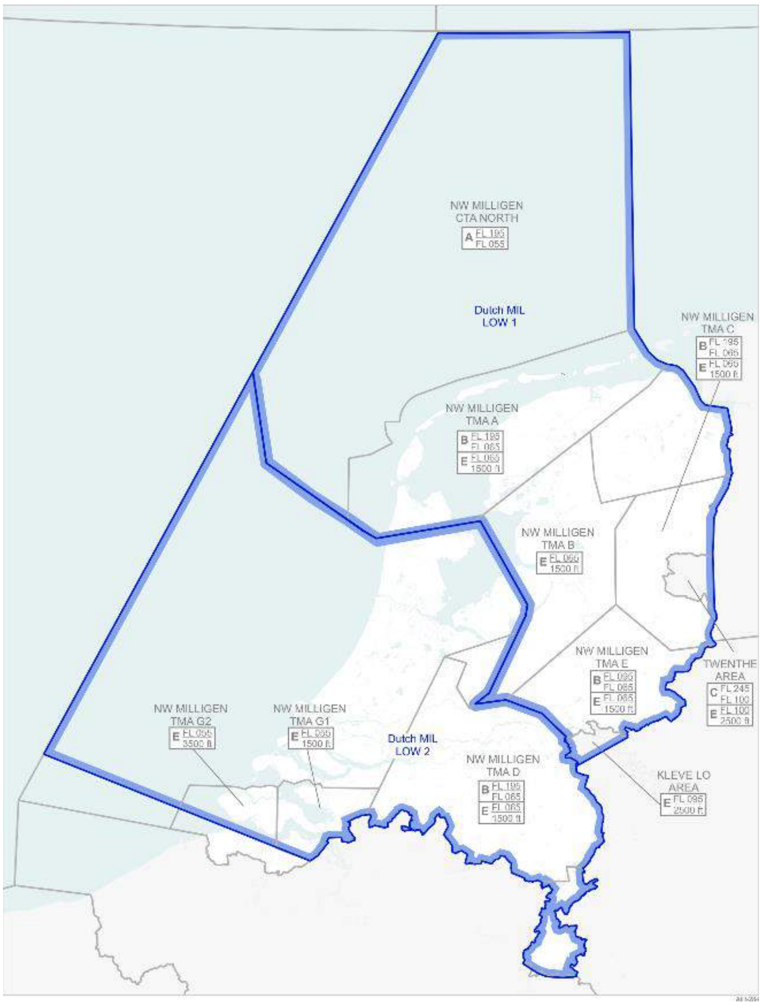


Figure 47 MilATCC Lower 1 and 2 sectors [9]

A 3 MUAC

Contrary to Amsterdam ACC and MilATCC Area, MUAC, located in Maastricht, provides services in the upper airspace from flight level 245 and above. This large area of responsibility, extending over The Netherlands, Belgium, Luxemburg and parts of Germany, can be divided into many ATC sectors. The sectors of MUAC are grouped into the Brussels, Deco and Hannover sector groups and can open a total number of 22 sectors. MUAC can open up to seven sectors in (and in the vicinity of) Dutch airspace depending on traffic demand. Two of these sectors are largely and two others partly defined in Dutch airspace: the Delta sector in the south, the Jever sector in the north and the Munster and Ruhr sectors in the east. MUAC sectors all consist of a separate high sector, vertically divided from the elementary sector. The Delta sector even has a middle sector in between the elementary and high sector. MUAC overall has a baseline declared capacity of 329 flights per hour in 2018 (NOR 2018).

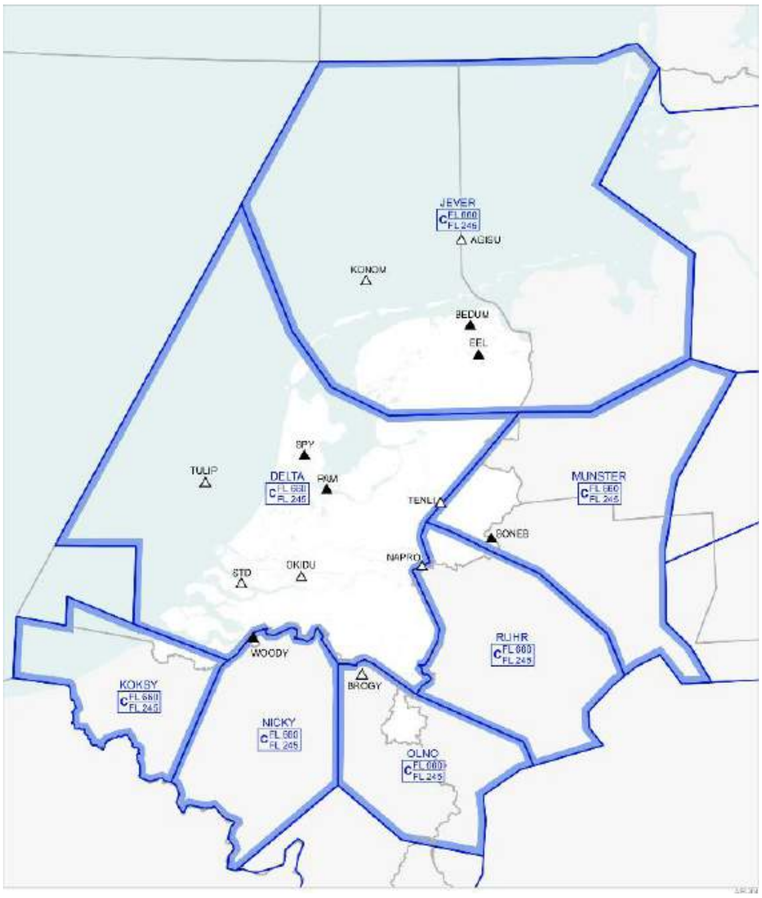
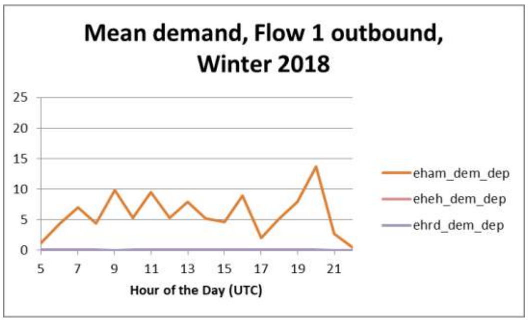


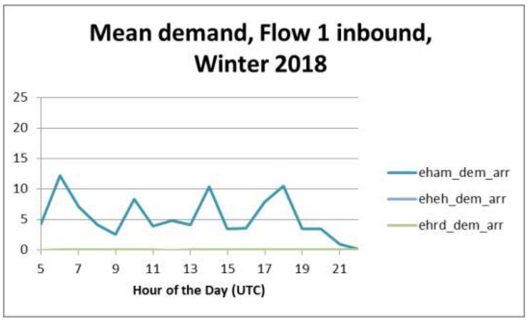
Figure 48 MUAC main sectors [9]

B Traffic flow analysis - winter season

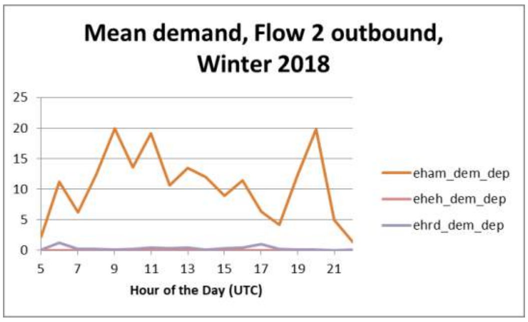
B 1 Actual demand (number of movements) for winter season 2018

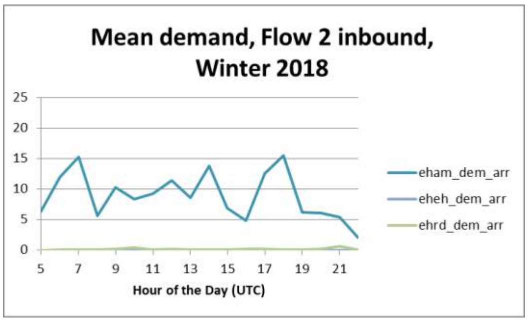
Sector 1



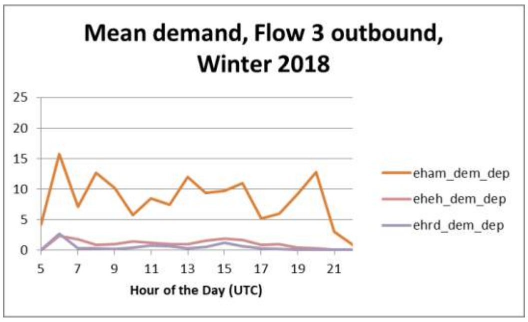


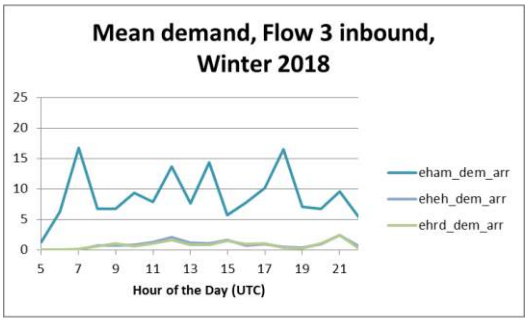
Sector 2



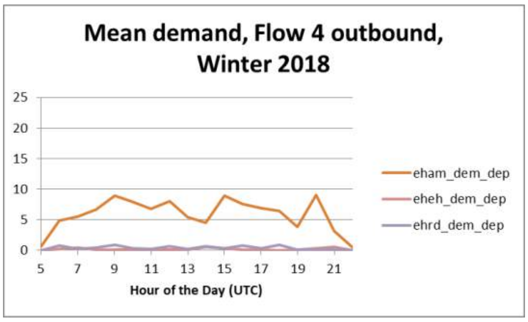


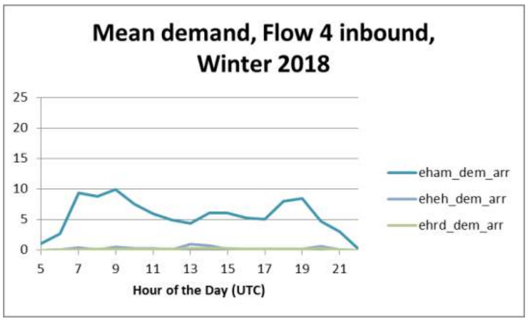
Sector 3



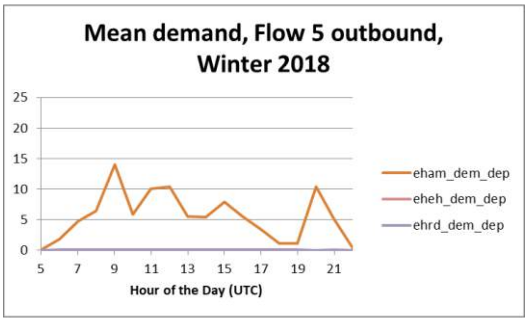


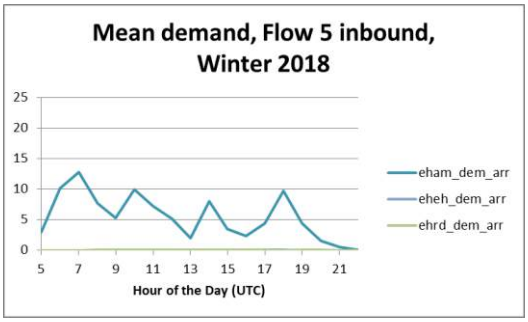
Sector 4





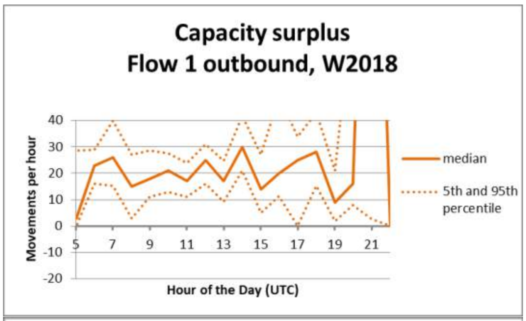
Sector 5

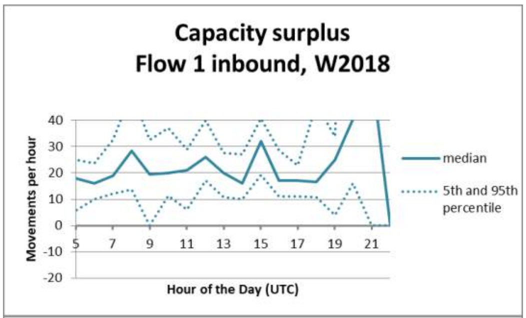


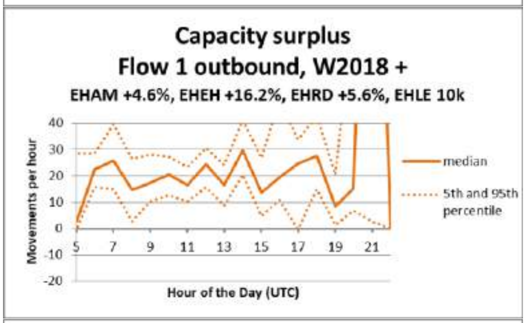


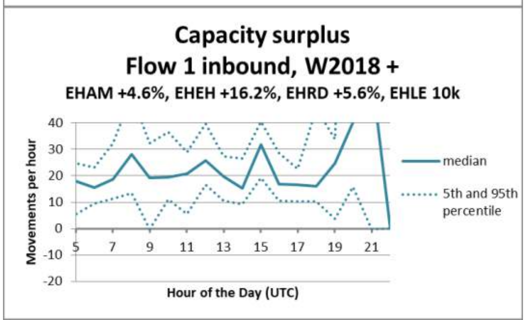
B 2 Capacity surplus - winter season (2018 actuals and growth scenarios 1and 2)

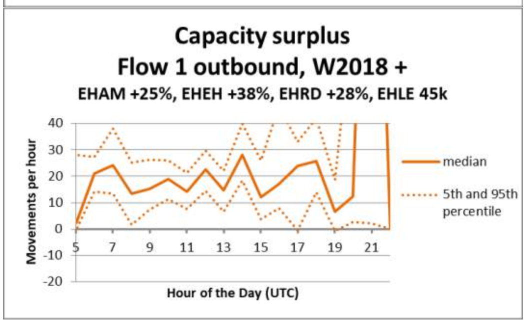
Sector 1

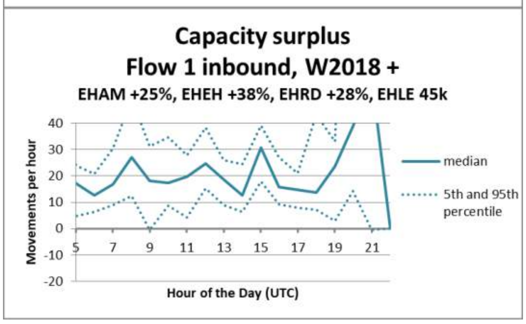




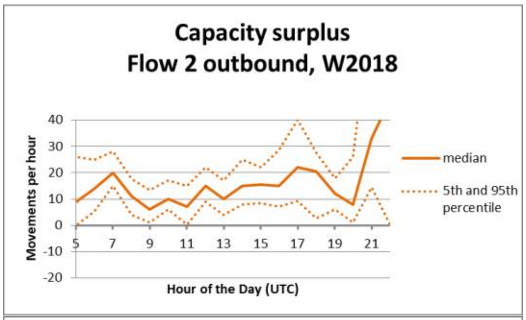


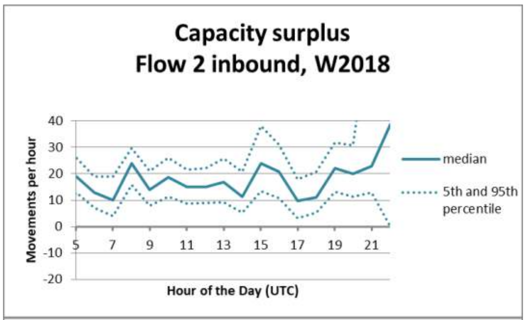


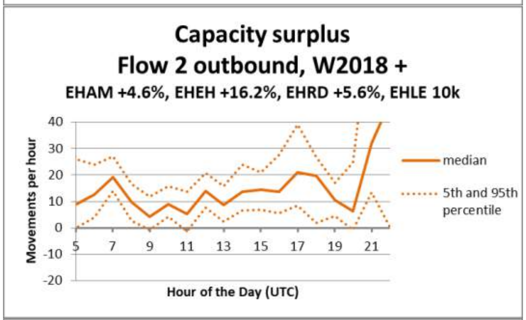


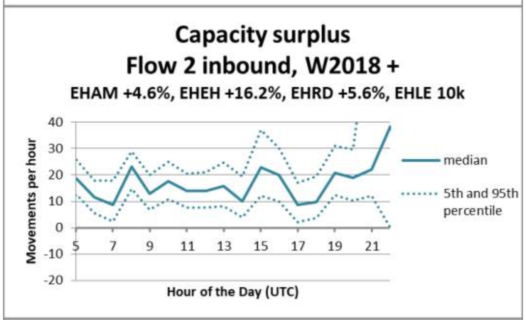


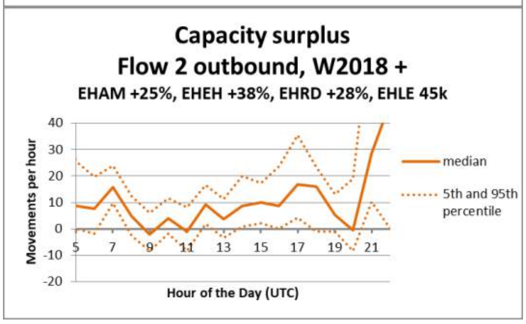
Sector 2

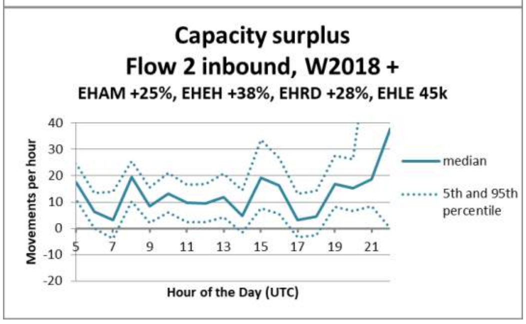




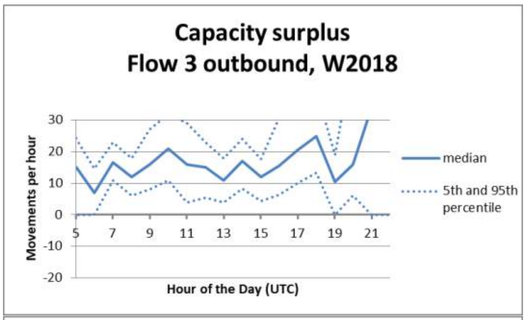


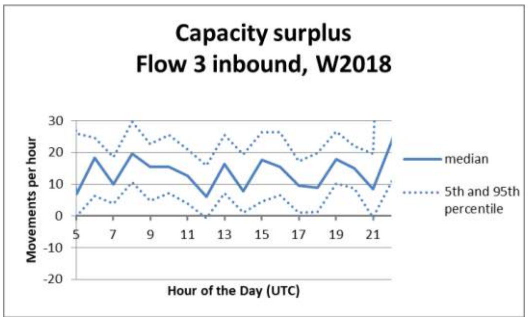


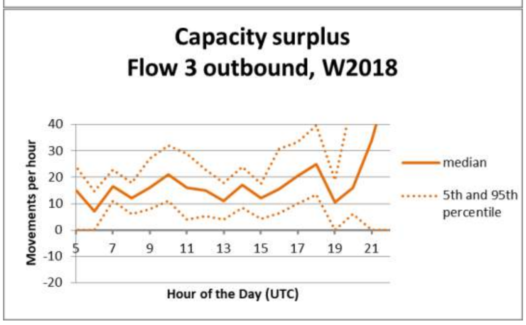


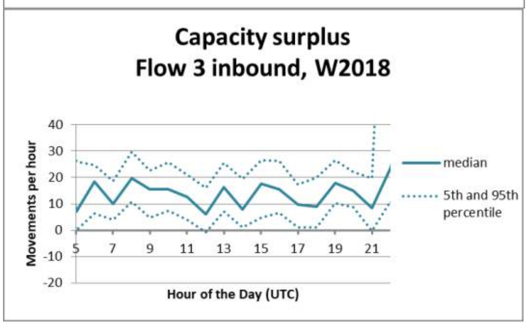


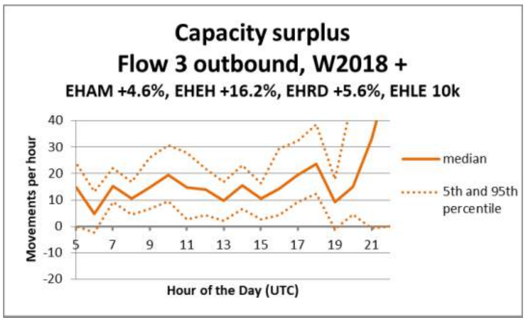
Sector 3







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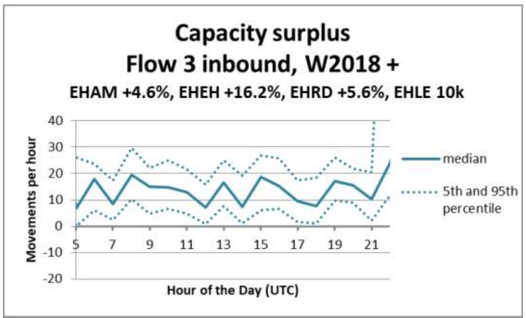
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile


Capacity surplus
Flow 3 inbound, W2018 +
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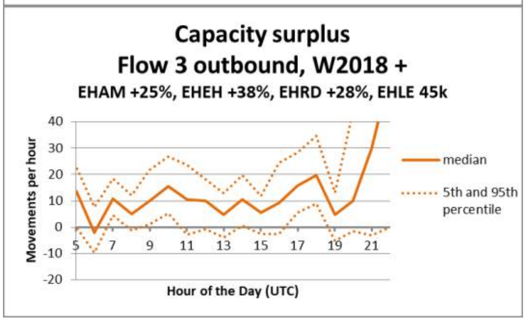
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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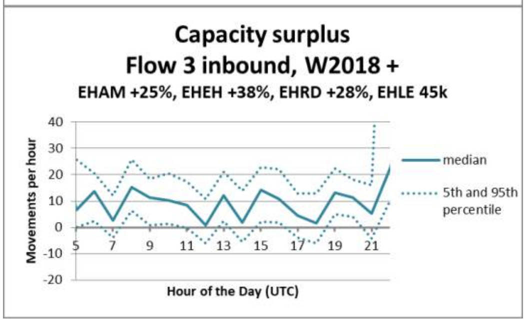
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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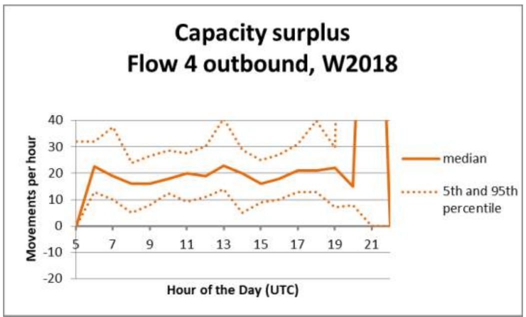
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile

Sector 4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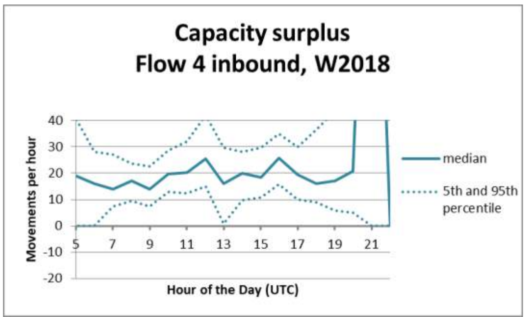
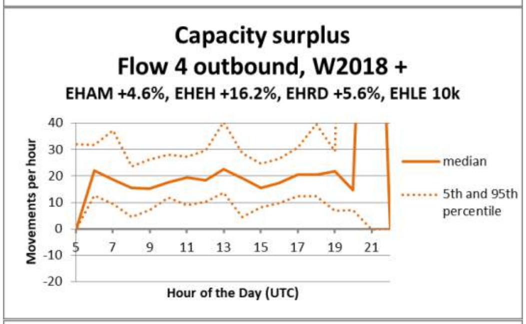
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile


Capacity surplus
Flow 4 inbound, W2018
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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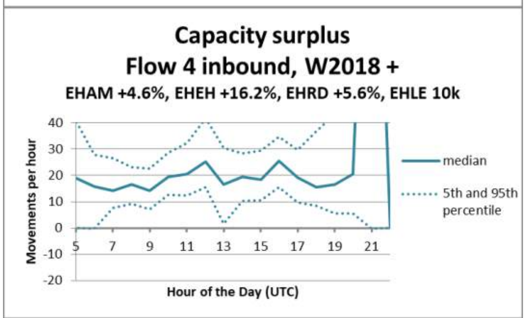
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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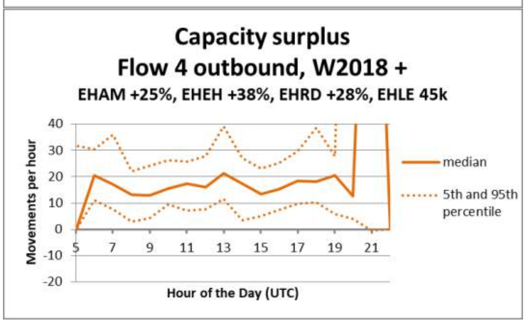
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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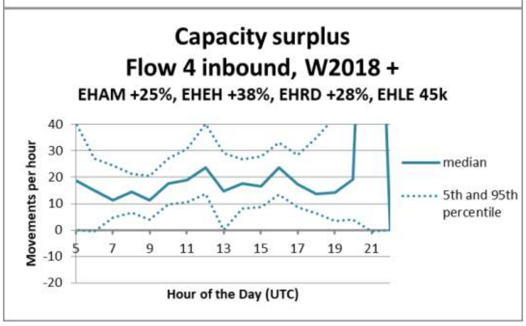
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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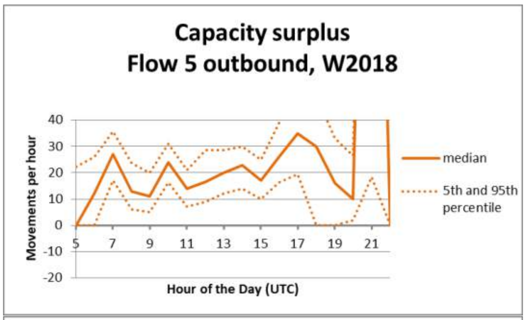
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile

Sector 5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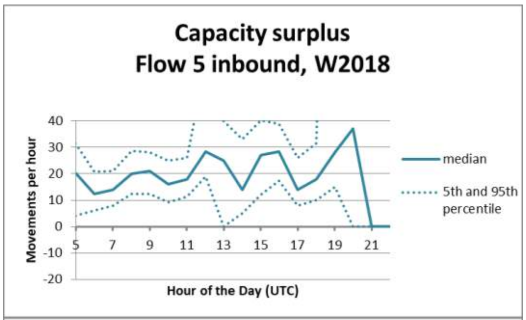
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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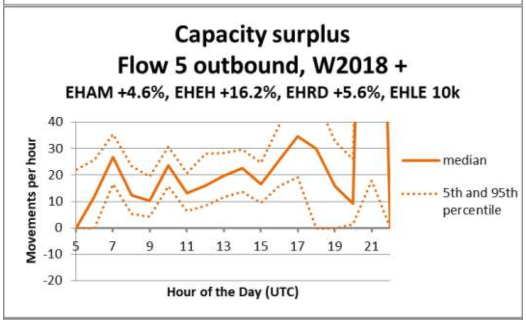
Flow 5 inbound, W2018
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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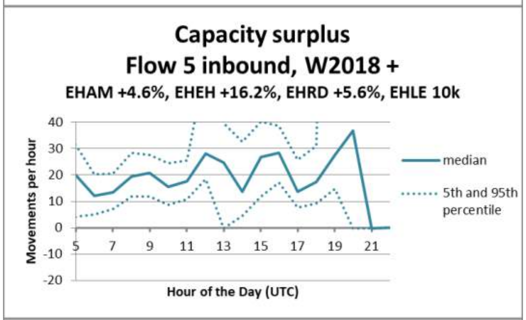
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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Movements per hour
Hour of the Day (UTC)
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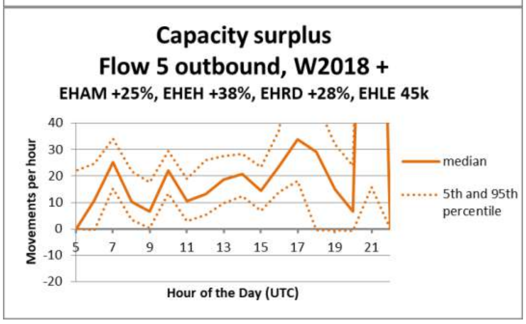
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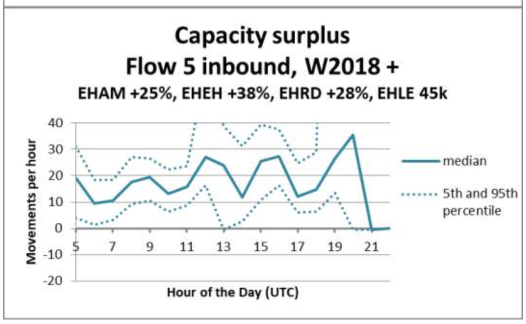
Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile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Movements per hour
Hour of the Day (UTC)
median
5th and 95th percentile