Amsterdam University of Applied Sciences

Thesis

Tactical Demand Tailoring (TDT) on the framework of the ICAO FF-ICE concept.

Graduation Internship at LVNL

Aviation Engineering
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Creating Tomorrow

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Tactical Demand Tailoring (TDT) on the framework of the ICAO FF-ICE concept.

Graduation Internship at LVNL

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Preface

I have been conducting extensive research for the past five months in order to formulate my answer to the main research question, which was started by a desire for LVNL. I do not, however, consider this internship as a time when I was exclusively conducting research. Over these months, I've learned a lot that will benefit my future career and experienced a lot of new things as well. I attribute these experiences to the people I met at LVNL. I would like to express my gratitude to the following people for their contributions to this project while I worked on my graduation thesis.

First of all, despite his regular responsibilities, I would like to thank Mr. E. Westerveld for his assistance and direction to this project. He made time to help me whenever I needed it or had queries. I would like to express my gratitude to Mr. K. Noordeloos, my company supervisor, for his support and for letting me complete my graduation thesis at LVNL. I had the impression that I could always turn to him for assistance, even though I did not have any trouble getting to know the business or its members. I would also want to thank my supervising lecturer, Mr. A. Murrieta Mendoza, for supporting me and providing me essential information and comments, in addition to my LVNL supervisors.

I also want to express my gratitude to everyone I spoke with for interviews throughout this time. They were extremely open with me and really helpful to me with this investigation. I would also want to thank those who made it possible for me to spend some time at the operational decks of both KLM and LVNL during my internship. This was my favorite aspect of the internship because it provided me with an excellent amount of operational process insight.

Finally, I want to express my gratitude to LVNL for providing me with this wonderful opportunity and to everyone who supported me throughout the graduation process.

Summary

The air traffic control of the Netherlands (LVNL) proposed a tool called Tactical Demand Tailoring (TDT). This tool aims to reroute flights, while airborne, for a better runway load balancing at Schiphol. A study, conducted by LVNL, analyzed which city-pairs where suitable for TDT implementation. This research provides a recommendation for LVNL by answering the following main research question:

"To what extent can Tactical Demand Tailoring be realistically implemented within the ICAO FF-ICE framework, and what are the key operational requirements needed for its successful operationalization in the European aviation industry?"

This thesis investigates the feasibility and operational requirements to apply TDT for predefined city-pairs. Aligned with the ICAO Flight and Flow Information for a Collaborative Environment (FF-ICE) concept, this research aims to revolutionize air traffic management by introducing a new framework for Collaborative Decision Making (CDM). The ICAO FF-ICE concept defines standardized and machine-readable flight information, providing a common language for seamless data exchange in the air traffic management system.

The qualitative research approach yielded valuable insights into key operational requirements for TDT and communication flows among stakeholders. These insights informed three FF-ICE Use Cases for TDT, providing a resource for future operationalization.

Key stakeholders, including KLM Operations Control Centre (OCC), Air Navigation Service Provider (ANPS) of Karlsruhe (KUAC), and EUROCONTROL Network Manager, were considered in this research to give their opinion if TDT would be operational. Fuel efficiency, a crucial concern for airlines, was addressed, affirming minimal additional costs for TDT. Route changes within KUAC airspace were deemed feasible, emphasizing negligible impact with proper lead time management. To set up and an agreement with KUAC about inflight rerouting in their sector with the initiative from LVNL with the agreed lead time.

Flight Management Position (FMP) controllers at LVNL expressed TDT's feasibility and potential in preventing sector air traffic bunches. They emphasized the importance of simulating scenarios in their Decision Support Tool for effective implementation. EUROCONTROL Network Manager supported TDT's possibility but sought clarity on its integration with FF-ICE, indicating considerations for R2 and R1 releases.

The trigger for inflight rerouting should come from LVNL's FMPs, identified through the Decision Support Tool. Effective collaboration and communication among stakeholders are crucial for TDT's success, requiring seamless information exchange.

Recommendations for the successful implementation of TDT include performing simulations during peak traffic periods to assess real-world scenarios.

After that, begin trials with KLM, leveraging their significant flight volume for comprehensive testing. When the FF-ICE concept is fully operational, assess the integration of TDT within both FF-ICE R2 and R1 frameworks. Acquire the required certifications to ensure regulatory compliance.

TDT's operationalization is feasible within existing legislation, and the FF-ICE framework supports its integration. Effective communication strategies and collaborative efforts are crucial for overcoming regulatory challenges and ensuring successful implementation, ultimately revolutionizing air traffic management in the region.

Abbreviations list

Abbreviation	Defintion	Abbreviation	Defintion
ACC	Area Control Centre	FIXM	Flight Information Exchange model
ADS	Automatic Dependent Surveillance	FF-ICE	Flight & Flow Information for a Collaborative Environment
AIXM	Aeronautical Information Exchange model	FMP	Flight Management Position
AMAN	Arrival Manager	FMS	Flight Management System
ANSP	Air Navigation Service Provider	FOC	Flight Operations Centre
AoR	Area of Responsibilities	FRA	Free Route Airspace
ASM	Airspace Management	FUA	Flexible Use of Airspace
ASP	ATM Service Provider	GUFI	Globally Unique Flight Identifier
ATC	Air Traffic Control	IAF	Inital Approach Fixed
ATCO	Air Traffic Controller	ICAO	International Civil Aviation Organization
ATFM	Air Traffic Flow Management	IFPS	Initial Flight Plan Processing System
ATFCM	Air Traffic Flow and Capacity Management	IWXXM	ICAO Weather Information Exchange Model
ATM	Air Traffic Management	KLC	KLM Cityhopper
ATS	Air Traffic Service	KNMI	Royal Dutch Meteorological Institute
AUs	Airspace Users	KUAC	Karlsruhe Upper Are Control
B2B	Business to Business	LoA	Letter of Agreement
CASA	Computer Assisted Slot Allocation	LVNL	Air Traffic Control the Netherlands
CDM	Collaborative Decision Making	MTCD	Medium Term Conflict Detection
CHMI	Collaborative Human Machine Interface	NM	Network Manager
CIFLO	Collaborative Interface for Flow Optimization	NMB	Netwrok Manager Board
CNS	Communication, Navigation, and Surveillance	NMC	Network Manger Cell
COM	Current Operations Manager	NMOC	NM Operational Cenntre
CTOT	Calculated Take-Off Time	NMP	Network Manager Portal
DCB	Demand Capacity Balancing	NNHS	Nieuwe Normen & Handhavingsstelse
DST	Decision Support Tool	NOP Portal	Network Operations Plan Portal
EATMN	European Air Traffic Management Network	OCC	Operations Control Centre
ECAC	European Civil Aviation Conference	PFP	Preliminary Flight Plan
ERDA	En-Route Delay Absorption	SESAR	Singlu Europian Sky ATM Research
eASP	FF-ICE capable ATM Service Provider	SKV	Schiphol Chance Expectation
eAU	FF-ICE capable Airspace User	SWIM	System Wide Information Management
eFPL	FF-ICE Flight Plan	TBO	Trajectory Based Operation
EHFIRAM	Amsterdam Flight Information Region	TDT	Tactical Demand Tailoring
ETFMS	Enhanced Tactical Flow Management System	TMA	Terminal Manoeuvring Area
FAM	Flexible Airspace Management	XMAN	Cross-border Arrival Management

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1. Introduction

The responsibility for managing air traffic safely, effectively, and sustainably within the Amsterdam Flight Information Region (AMS-FIR) in the Dutch national airspace belongs to Air Traffic Control (ATC) the Netherlands (LVNL). The Netherlands' central location in Western Europe places it in one of the world's busiest air traffic regions. However, due to the country's relatively small size, LVNL faces challenges in handling the substantial air traffic volume it encounters. Notably, LVNL oversees Schiphol Airport, one of Europe's largest and busiest airports.

As flights approach Schiphol for landing, they need to be carefully sequenced in terms of their landing order. This sequencing is currently accomplished by ATC within the Terminal Manoeuvring Area (TMA) of Schiphol. These controllers provide arrival route clearances or vector navigation to Airspace Users (AU's). AU's, arriving aircrafts, approaching the Schiphol's TMA via one of the predefined specific points in the airspace, such points are called Initial Approach Fixes (IAFs). Figure 1 illustrates an operational scenario where two runways—18R and 18C—are available, with a three-IAF system connecting each runway to an IAF, namely the ARTIP, SUGOL, and RIVER IAFs. While this IAF system provides structure to the EHAM arrivals, it also limits the number of arrival routes that an aircraft can take. Besides, when entering AMS-FIR, arriving air traffic does not always present itself in equal amounts from each direction causing unbalanced runway and sector utilization.

In cases of imbalances, rerouting traffic from the planned IAF to another IAF attending to the other runway could help correct the imbalance (for instance, rerouting from RIVER to ARTIP). There are some restrictions and limitations in the process, such as ATC routes and airspace constrictions (military airspace and areas with very high navigation charges); therefore, it is not as simple as it might appear to re-route a flight just before arriving at one IAF point to the next (S. Vegter, 2023).

Figure *1*: EHAM IAF locations and common arrival tracks when landing on runways 18R & 18C

However, it is possible for flights to receive instructions to approach a different runway than the one corresponding to the arrival entry point. This deviation can occur due to variations in the distribution of arrivals from the IAFs and it may be necessary to maximize the airport's landing capacity. Schiphol is limited, by the government, to a maximum number of aircraft movements per year. So, LVNL must adhere to regulations governing runway usage, such as the Nieuwe Normen & Handhavingsstelsel (NNHS) (Rijksoverheid, Nieuw Normen- en Handhavingsstelsel Schiphol , 2023), which restricts the use of certain runways at Schiphol Airport (Gordijn, 2020). Such rerouting of arriving traffic within the TMA is occasionally required although it is also considered more challenging for air traffic controllers, due to the relatively small size of the Dutch TMA.

Currently, LVNL possesses tools for forecasting traffic several hours in advance. LVNL uses these forecasts to influence/re-route the traffic scheduled to pass through its airspace. This influence is exerted by the Flow Management Position controllers (FMP), who issue sector capacity regulations to specific airspace sectors (Area Control (ACC) sectors). These regulations on airspace capacity are then conveyed to the Network Manager (NM), who determines which flights can continue as planned and which will face delayed departures when passing through restricted airspace. However, this method primarily affects traffic well in advance, as delayed departures require flights to remain at their departure airports. It leads to undesirable delays, impacting individual flights, airline network operations, and the airports managing these delays. At times, these delays may even be imposed unnecessarily when evaluating operations retrospectively, owing to the unpredictability of flight arrival times.

LVNL proposed a way to influence the arriving air traffic before it enters AMS-FIR. This operational tool could improve the operations of LVNL and is called Tactical Demand Tailoring (TDT). By rerouting airborne flights before entering AMS-FIR. Preferably runway load balancing takes place during the flight planning phase. However, prior to departure there is still much uncertainty about the time of arrival of a flight at Schiphol airport, and load balancing will therefore have limited accuracy and effectiveness.

The ICAO Flight & Flow Information for a Collaborative Environment (FF-ICE) concept enables interactive re-routing of flights during flight execution, and FF-ICE could therefore provide a means to dynamically perform load balancing for Schiphol airport. TDT, with the help of the FF-ICE framework extends the influence LVNL has over Schiphol arrivals to outside of its area of operations. This tool will rely on the real-time sharing of information between different actors in the global aviation operation including Air Navigation Service Providers (ANSP's), Airline Operations Control Centers (OCC's), the EUROCONTROL Network Manager (NM) and others.

However, further research is required due to the expected difficulties in applying TDT in the European aircraft sector. This entails analyzing the key TDT stakeholders, comprehending their functions, and determining roles within the concept. Additionally, research is needed to comprehend how TDT will fit within the constraints set by the current FF-ICE concept.

1.1 Problem statement

In the dynamic realm of air traffic management, the current methods employed by Air Traffic Control (ATC) Netherlands (LVNL) at Schiphol Airport, relying heavily on pre-arrival forecasts and possessing limited real-time adaptability, result in inefficiencies and delays in landing sequencing. The intricate landscape of aviation regulations, particularly the Nieuwe Normen & Handhavingsstelsel (NNHS) (Rijksoverheid, 2023), further complicates the need for a more adaptive and real-time approach to capacity management. A critical challenge arises in implementing Tactical Demand Tailoring (TDT) to optimize air traffic operations while ensuring compliance with existing regulations.

The existing operational processes within the Terminal Manoeuvring Area (TMA) of Schiphol, managed by LVNL, are central to the sequencing of flights approaching for landing. Challenges emerge from variations in Initial Approach Fixes (IAFs), leading to imbalances in arrival distribution and the need for adherence to regulatory constraints. The proposed solution, TDT, aims to influence arriving air traffic before entering the Amsterdam Flight Information Region (AMS-FIR), introducing runway load balancing during the flight planning phase. However, uncertainties in arrival times and the need for real-time effectiveness pose challenges.

Collaboration and communication among key stakeholders, including LVNL, KLM-OCC, EUROCONTROL Network Manager, and adjacent centers, are imperative for TDT's successful deployment. This requires strategies to facilitate seamless information exchange and data sharing among stakeholders. Integrating TDT into the existing aviation framework, specifically the ICAO Flight & Flow Information for a Collaborative Environment (FF-ICE) concept, presents complexities that need to be explored.

The central problem lies in determining whether TDT can effectively coexist within the FF-ICE framework or if tailored adaptations are necessary to meet Schiphol-specific requirements. Understanding the operational processes associated with FF-ICE, roles of stakeholders, cockpit considerations for flight crews, and defining triggers and execution points for flow managers are crucial aspects for the successful implementation of TDT. The highly regulated nature of the aviation sector adds complexity, requiring alignment with existing regulations while advocating for necessary adjustments.

Addressing these challenges and ensuring the scalability and adaptability of TDT for future air traffic patterns and technologies is pivotal. The successful implementation of TDT holds the promise of revolutionizing air traffic management, optimizing runway usage, reducing delays, and enhancing sustainability in the Amsterdam Flight Information Region and beyond. Overcoming these complexities demands a concentrated effort, effective communication, and creative solutions within the intricate network of stakeholders, legal compliance, and technological integration.

1.2 Objectives

The main objective of this thesis is to comprehensively investigate and analyze the key operational challenges, relative legislation and requirements, and stakeholder involvement associated with the implementation of TDT within the European aviation airspace. All this should be on the framework of the ICAO FF-ICE concept, since this will be the new standard for information sharing in the future. This objective aims to provide an integral understanding of TDT, encompassing its viability, legislative considerations, and the essential information and communication systems involved.

These sub-objectives below will help to systematically gather and analyze relevant information, both from existing literature and through empirical research, to provide a comprehensive overview of the informational and operational requirements for the successful operationalization of TDT.

- Define Tactical Demand Tailoring (TDT) in the context of capacity management processes and elucidate its key objectives and principles.
- Conduct a detailed analysis to understand the unfolding of current operational processes at LVNL and KLM-OCC and identify any shortcomings within the existing operational procedures.
- Identify the key parties and stakeholders involved in TDT, and their role.
- Investigate how the ICAO FF-ICE concept contributes to interactive flight rerouting during flight execution. And understand the role FF-ICE plays in enhancing air traffic management adaptability and efficiency.
- Determine the adaptability of TDT within the existing ICAO FF-ICE framework. investigate whether there are specific requirements and unique implementations.
- Identify requirements for effective information exchange and data sharing when TDT is implemented.
- Assess the requirements and interests of KLM-OCC arising from the implementation of TDT.
- Elucidate the operational processes of key stakeholders during the implementation of the TDT concept.
- Identify triggers and execution points for the flow manager to initiate inflight rerouting. And understand how this process unfolds in real-time air traffic management scenarios.
- Examine how planned inflight rerouting is effectively integrated into the flight planning processes of the flow manager and flight crews. And identify the benefits and challenges arising from this integration.

1.2 Research Questions

From the problem statement [1.1], the following main research question has been formulated:

“To what extent can Tactical Demand Tailoring be realistically implemented within the ICAO FF-ICE framework, and what are the key operational requirements needed for its successful operationalization in the European aviation industry?”

The supporting sub-question to systematically lead to answer the main question are:

- What is Tactical Demand Tailoring (TDT) in the context of capacity management processes, and what are its fundamental objectives and guiding principles within the air traffic management framework?
- How does the current process of operations of LVNL and KLM-OCC unfold, and what are the shortcomings?
- Who are the primary parties and stakeholders involved in TDT, and what roles do they play in the execution and success of this air traffic management approach?
- How does the ICAO FF-ICE concept contribute to interactive flight rerouting during flight execution, and what role does it serve in enhancing air traffic management adaptability and efficiency?

- Is TDT adaptable within the existing ICAO FF-ICE framework, or are there specific requirements and unique implementations?
- What are the requirements for effective information exchange and data sharing when TDT is implemented?
- What are the requirement and interest of KLM-OCC by the implementation of TDT?
- What are the operational processes of the key stakeholders when implementing the TDT concept?
- What are the triggers and execution points for the flow manager to initiate inflight rerouting, and how does this process unfold in real-time air traffic management scenarios?
- How is planned inflight rerouting effectively integrated into the flight planning processes of the flow manager and flight crews, and what benefits and challenges arise from this integration?

1.4 Scope & Limits

This research will focus on operational processes, legislation, and stakeholders integral to implementing the FF-ICE concept. This includes close collaboration with key entities such as the NM, adjacent centers, the airline operational center (KLM-OCC), and a comprehensive understanding of cockpit processes. Developing communication links between key stakeholders, including LVNL as the initiator of the rerouting function.

The scope of this thesis is centered on the management of air traffic within the AMS-FIR in the Dutch national airspace, with a primary focus on Schiphol Airport. This is a continuation of a previous thesis, conducted by S. Vegter. This thesis investigated suitable city-pairs to apply TDT for the Amsterdam Schiphol Airport. There will only be looked at these city-pairs during this thesis. The study delves into LVNL's current tools and practices for forecasting and influencing air traffic within its airspace, involving FMP controllers and the NM. The thesis explores the potential integration of the TDT concept into ICAO FF-ICE.

Although the research addresses the real-time sharing of information among stakeholders, it does not provide detailed technical specifications or protocols for data exchange. While the thesis investigates key operational challenges, stakeholders, and the TDT process, it does not aim to provide specific solutions or technical implementations. The thesis does not provide an extensive historical review of how the suitable city-pairs are established. The research does not extend to the economic, environmental, or social implications of air traffic management but maintains its focus on operational and procedural aspects.

Overall, the thesis seeks to provide a comprehensive understanding operational requirements for the successful operationalization of TDT to enhance the capacity management with planned inflight re-routing in the European aviation industry. It aims to answer the research questions, and fulfill the objectives, to inform future developments and decision-making related to the implementation of TDT. This research will result in an advisory report which will describe an overview of informational and operational requirement to be taken to operationalize Tactical Demand Tailoring. With the prepared investigation, about implementing the TDT concept, the department of Performance & Development at LVNL, can decide on what to do with the provided information. The submission date for the final report is set at 21 January 2024.

2. Theoretical Framework

2.1 Literature review

Air traffic control is the management of air traffic by issuing clearances and directions to pilots. It is divided into three subdisciplines: general, approach, and local. LVNL is responsible for managing civilian airspace and its associated tasks, including providing air traffic control services within the Amsterdam flight information region, providing communication, navigation, and positioning services. LVNL must also comply with the Dutch Airport Traffic Decree, which outlines rules for route and runway usage and limits for noise, external safety, and local air pollution. (LVNL, sd)

LVNL currently manages all flights within Dutch national airspace under flight level 245, 24500ft, including those arriving at Schiphol. However, it lacks the ability to synchronize arriving traffic before airspace entry, resulting in inefficiencies. Air traffic controllers must manage sector air traffic bunches within the small airspace surrounding Schiphol. To address these inefficiencies, LVNL is exploring the potential of a new method of managing Schiphol arrivals. The Arrival Manager (AMAN) is an operational tool that helps LVNL anticipate traffic headings in certain sectors and provides recommendations for actions to enhance the arrival sequence of inbound traffic, such as a delay instruction (Hasevoets, 2010).

The ACC section of LVNL air traffic controllers is responsible for guiding Schiphol arrivals to the appropriate IAF for their descent to the airport. During inbound peaks, the workload for air traffic controllers can become demanding, leading to inefficient and potentially unsafe operations. LVNL predicts and monitors traffic flow and demand closely, making predictions multiple hours in advance and continually monitoring as the inbound peak approaches. FMP controllers make these predictions. If the traffic flow for an inbound peak is likely to exceed the set limit, the FMP controller issues a sector capacity regulation, which limits the amount of traffic that can fly through a certain part of airspace. This regulation is forwarded to the EUROCONTROL NM, who selects flights that have filed their route through the restricted airspace and issues an ATFM delay for some of these flights (EUROCONTROL, ATFCM OPERATING PROCEDURES FOR FLOW MANAGEMENT POSITION, 2014). These delays spread out the flow of Schiphol arrivals, reducing the peak load to the airspace and LVNL's operations. However, the costs of these delays are estimated at an average of 100 euros per minute of delay, making them a 'necessary evil' aimed at keeping operations safe while sacrificing efficiency and profits (Cook, 2015).

The European Commission appointed EUROCONTROL as the Network Manager to address increasing flight delays in the EU. The NM is responsible for operational and technological network performance in capacity and flight efficiency, bringing tangible daily performance benefits to the EU's aviation network and neighboring states. The Network Manager responds to both expected and unexpected challenges by reducing en-route delays and coordinating at the network level to limit the consequences of unexpected events like strikes or bad weather (Management, 2022).

These delays increase the sector's carbon footprint and add additional costs for airlines (Arrowsmith, 2020). Air Traffic Management (ATM) must address these challenges by fostering a system with scalable air traffic control capacity, reducing the environmental footprint, accommodating new entrants, and ensuring safety and security from cyberattacks. The Single European Sky (SES) initiative aims to improve ATM performance from safety, capacity, cost-efficiency, and environmental perspectives (Commission E. , Single European Sky , 2004). The Single European Sky ATM Research (SESAR) Project is the technological pillar of the EU's SES initiative aiming to modernize Europe's air and ground ATM infrastructure and operational procedures. SESAR defines, develops and deploys interoperable ATM solutions aiming to optimize the management of air traffic so that airspace users can fly safely the most efficient trajectories (The SESAR project, sd).

One of these SESAR projects to overcome the expected traffic growth while increasing operational efficiencies, is the trajectory-based operations (TBO) concept, developed by ICAO. The TBO concept describes an ATM environment where the flown flight path is as close as possible to the user-preferred flight path by reducing potential conflicts and resolving demand/capacity imbalances earlier and more efficiently (Operations, 2022). The TBO concept aims at bringing the operator to the heart of the system to ensure the safe and efficient execution of a flight. This is achieved by exchanging all flight plan-related information to help the operator build a 4D trajectory reflecting their needs (IATA, 2019). Simply put, the goal of TBO is to achieve the optimum system outcome with minimal deviations from the user-requested flight trajectory.

Working towards TBO, aviation stakeholders will need to address the gaps and limitations of the current ATM system (ICAO, GLOBAL TBO CONCEPT). TBO aims to improve the ATM operation across the following areas: utilization of the most accurate 4D trajectory data, increasing collaboration between ATM stakeholders on trajectory management, tactical decisions, reducing inefficiencies, and increasing predictability. In-flight re-planning and prioritization will be supported by an automated process. More accurate trajectories will result in the delivery of demand matched to capacity. Increased collaboration due to better information sharing. ATM actors will share information on constraints that affect airspace. These include meteorology, active military areas, and air traffic flow or capacity restrictions. AUs will create a trajectory based on this shared information to develop and submit a filled flight plan (ICAO, 2016).

One application of the TBO concept is Tactical Demand Tailoring TDT. The TDT concept consists of the tactical, in-flight alteration of the flight plans of aircraft approaching the airspace of an Air Navigation Service Provider (ANSP), or a TMA. As shown in Figure 2, traffic could be redirected from a pre-planned congested airspace to a less congested airspace using in-flight re-routing. Figure2 illustrates two distinct routes the orange and green, with a shared overlap in blue at the beginning of the trajectory, are two separate potential routes from a city-pair. A specific aircraft may be instructed to fly the congested "green" route and then, once airborne, be requested to change to the less congested "orange" route. The point where the routes diverge is called the ‘divergence point’. As the divergence point is closer to the destination airport, the window in which TDT can be applied increases. It provides the receiving ANSP with more tactical or ‘short-term’ influence over arriving traffic. The proper re-routing of traffic, for instance in arrivals, will help Network Managers to reduce the number of Air Traffic Flow Management (ATFM) delays and the ASNP to balance the air traffic. This is associated with environmental benefits at European levels due to the more balanced use of the airspace. A flight within the European traffic network could potentially be in contact with several ANSPs throughout its flight. Therefore, the TDT concept requires a large cooperation between different parties. Some of these parties would include neighboring ANSPs, the Airline OCC’s, and the NM. This approach assumes that the different stakeholders within the European network collaborate to make this re-routing possible (Vegter, 2023).

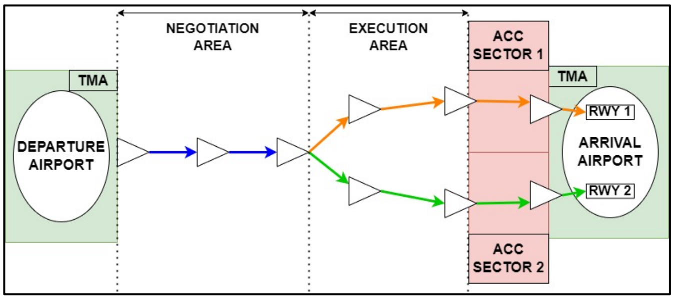


Figure 2. Schematic illustration of Tactical Demand Tailoring

The analysis of city-pairs suitable for re-routes led to the identification of 11 departure airports where TDT could be applied, which is shown in table 1 & 2. On average, a 5-hour period with high inbound traffic contains between 5 and 13 flights originating from TDT suitable city-pairs. This would allow LVNL to influence the direction of approach of these flights to better fit its operation. The analysis of the change to flying distance of these flights shows that for most of the identified city-pairs, the change to the length of the route is almost negligible, between 0,4 and 1,4%.

Airport	*ICAO-code*	*Country*
Bari	*LIBD*	*Italy*
Verona	*LIPX*	*Italy*
Venice	*LIPZ*	*Italy*
Porto	*LPPR*	*Portugal*
Lisbon	*LPPT*	*Portugal*

Table 1, Airports suitable for the application of TDT

Airport	*ICAO-code*	*Country*
Roma Fiumicino	*LIRF*	*Italy*
Florance	*LIRQ*	*Italy*
Zurich	*LSZH*	*Switzerland*
Catania	*LICC*	*Italy*
Milan Linate	*LIML*	*Italy*
Bologna	*LIPE*	*Italy*

Table 2, Airports where suitability is FPL-dependent:

The operation of LVNL in multiple areas could be significantly affected by changing the approach of 3 or 4 flights during one inbound peak. TDT could significantly reduce ATFM delays caused by regulations to IAF's. Currently, LVNL manages traffic flow through its ACC Sectors by issuing sector capacity regulations, limiting the amount of traffic allowed. However, delays can cost 100 euros per minute and are considered a 'necessary evil' to ensure safe operations. In-flight re-routing of Schiphol arrivals can help clear congested airspace. In 2022, multiple cases showed that re-routing several flights to a different IAF could have prevented capacity regulations, saving up to €53.200 of costs (Vegter, 2023).

TDT could also change LVNL's operations inside the TMA. Re-routing some traffic to approach the airport from a different direction allows these flights to land on a different runway than originally planned without requiring a re-route inside the TMA. TDT could help LVNL gain more influence over the balance of its runway load. By moving 3 to 4 aircraft to land on a different runway, LVNL could change that runway's utilization by up to 12% (Vegter, 2023).

The System-Wide Information Management (SWIM) concept provides a digital data-sharing infrastructure that facilitates the data sharing required by TDT. SWIM consists of standards, infrastructure and governance enabling the management of ATM-related information and its exchange between qualified parties via interoperable services (ICAO, 2015). SWIM delivers integrated digital aeronautical information, weather information, constraint information while enabling the data collection and data sharing necessary for user collaboration and improved constraint management (Lu M. K., 2019). This will enable increased common situational awareness and improved ATM Service Provider (ASP) agility to deliver the right information to the right people at the right time. TDT relies on a globally standardized exchange of data via SWIM (Lu K. W., 2022). The SWIM Global Interoperability Framework makes use of information exchange models, which are developed to make it possible to manage and distribute data for information services in digital format, such as Aeronautical Information Exchange Model (AIXM), ICAO Weather Information Exchange Model (IWXXM), and the Flight Information Exchange Model (FIXM). The FIXM, which is utilized for flow and flight information, is the domain used for TDT. (FIXM, 2023). SWIM is a technical infrastructure with set of data, services and protocol definitions that allow sharing of data between stakeholders in ATM. The so-called SWIM Yellow , based on open standards and low cost mainstream technologies, supporting any kind of information exchange (Videira, 2016), profile provides a flexible and secure way of unlocking data and LVNL is already connected (ICAO, 2015).

TDT requires a digital infrastructure capable of communicating relevant information regarding the 4D trajectory from and to relevant stakeholders. This will be based on the ICAO concept of FF-ICE (Flight & Flow Information for a Collaborative Environment) (Morioka, 2019). Building on SWIM, FF-ICE will represent a new dimension of how flight plan information is generated and handled, allowing all impacted parties to work together towards a common goal, which is that aircraft fly the trajectories as close as possible to that considered optimal, in terms of efficiency, safety, environmental impact, and any other factor that made part of the initial evaluation (ICAO, 2023). The trajectory will be exchanged between stakeholders using the FF-ICE with SWIM compatibility exchange format. All flight-related information will be exchanged over a SWIM network during the flight, and the aircraft will share their trajectory.

FF-ICE stands as a groundbreaking initiative in the realm of air traffic management. This global endeavor, spearheaded by the International Civil Aviation Organization (ICAO), transcends geographical boundaries to redefine how we approach the coordination of flight and traffic flow information.

The primary objective of FF-ICE is to foster a collaborative environment wherein the seamless sharing of flight and traffic flow information becomes the linchpin for trajectory optimization across all phases of a flight. Unlike current systems, FF-ICE goes beyond the status quo by incorporating a more extensive set of shared information, thereby elevating Collaborative Decision Making (CDM) to new heights (X.D. Lu N. K., 2022).

Facilitating the TBO concept is a key hallmark of FF-ICE. This means that the initiative is designed to propel the aviation industry toward operations where flight trajectories are meticulously optimized, resulting in heightened operational efficiency and a reduction in delays.

To ensure universal applicability and easy interpretation, FF-ICE defines standardized and machine-readable flight and flow information. By establishing a common language for data exchange, the initiative paves the way for smoother collaborations between various components of the air traffic management system.

FF-ICE is being implemented in a phased approach. The first phase, FF-ICE/Release 1, is dedicated to pre-departure operations. From flight planning to the moments just preceding takeoff, Release 1 streamlines processes, setting the foundation for enhanced collaboration (Mavoian, 2023).

Building upon the success of Release 1, FF-ICE/Release 2 extends the benefits into post-departure operations. This ensures that the collaborative and optimization advantages introduced in the pre-departure phase persist throughout the entirety of a flight.

In essence, FF-ICE is not just an acronym; it signifies a paradigm shift in air traffic management. By fostering collaboration, incorporating more shared information, and optimizing trajectories, FF-ICE charts a course toward a more efficient, safer, and globally interconnected airspace. This initiative invites the aviation community to collectively embrace a transformative journey and redefine the way we navigate the skies (ICAO, 2023).

The FF-ICE concept is split into two development cycles: provisions, standards, and guidance for the first FF-ICE development cycle (FF-ICE/R1) focus on flight planning and trajectory negotiation prior to departure. The initial concept for the second FF-ICE development cycle (FF-ICE/R2) focuses on the execution of the flight and post-departure trajectory negotiation. FF-ICE relies on the mutually agreed 4-Dimensional Trajectory (4DT) of an aircraft from gate to gate to allow ASPs and AOs an improved understanding of operational expectations (Wilson S. , 2017).

2.2 Related studies

There are none to be found while examining the application of the new TDT concept itself. Nevertheless, TDT depends on the FF-ICE concept being put into practice by ICAO by 2025. Other options that we can consider include avoiding AFTM delays and TBO implementations.

The study conducted by Gun-Young Lee in (2014) focuses on the development and implementation of international standards related to TBO in aviation. It aims to understand the evolution of these standards and their impact on air traffic management, safety, and efficiency. The study assesses how these standards are implemented across different aviation contexts, including countries and regions. It also analyzes the impact of TBO-standards on air traffic management, assessing areas like reduced delays, improved fuel efficiency, and enhanced safety. The study also identifies challenges and opportunities related to the development and implementation of TBO-standards, with the goal of achieving a seamless and efficient global air traffic system. The study provides valuable insights into the evolution of TBO-standards and their role in shaping the future of air traffic management, as well as the collaborative efforts among international aviation authorities and stakeholders in establishing and promoting these standards. In summary, this study aims to enhance the global air transportation system by examining the evolution of TBO-standards and their real-world impact.

Another enroute solution to prevent ATFM delays, is the study from Mijatovic in (2016). The study examines the impact of En-Route Delay Absorption (ERDA) on airport runway throughput, focusing on Amsterdam Airport. The research is part of the Cross-border Arrival Management (XMAN) project, which aims to reduce delays by shifting delay absorption from the TMA to the en-route phase. The study introduces the concept of "runway pressure" to manage planned delays in the TMA. The results show that ERDA can sometimes result in a small decrease in runway throughput, with aircraft experiencing 30 to 90 seconds later landing times during peak periods. However, it also reduces time spent in the TMA or holding pattern near the airport. The study provides valuable insights into runway management and air traffic control strategies.

The paper by Bertsimas and Patterson in (2000) presents a dynamic network flow model to manage air traffic flow in real-time. The model considers the dynamic and time-dependent nature of air traffic, allowing for real-time adjustments in aircraft routing to optimize traffic flow. Key concepts include time-dependent factors and decision variables, which optimize aircraft flow during disruptions. The primary goal is to minimize total delay and cost incurred by rerouting aircraft while meeting air traffic control constraints. The model can be used to reroute aircraft during adverse weather or airspace congestion, improving air traffic management efficiency and reducing delays in the National Airspace System. The model is designed to be responsive to real-time changes and constraints, offering a promising approach to improving air traffic management efficiency and performance.

An FF-ICE/R1 use case conducted by Lalor and Molbaek in (2023), explains what the AU must do if he wants filed desired route/ trajectory. The ATM system receives and processes eFPL submissions, extracting the desired trajectory. The desired trajectory is available for display to the local Flow managers and the ATCOs included in the sector-sequence for the flight. Based on the tactical situation, and considering the desired trajectory, the ATCO assesses whether constraints set in agreed trajectory and being inside the centre's AoR can be removed (bringing the flown trajectory closer to the desired trajectory). The ATCO will initiate the necessary coordination with other internal sectors or the next ATSU (receiving ATSU), and/or Flow Managers. Flow Managers will coordinate with the downstream Flow Managers/NM as needed. If the constraint can be removed, clearances are issued based on the trajectory with this constraint removed. The flown trajectory deviates from the initially received agreed trajectory and is closer to the desired trajectory. As the flown trajectory is closer to the desired (unconstrained) trajectory, the service to the AU is deemed improved.

This use case outlines the use of the AU's desired route/trajectory by the ANSP, as received in the eFPL. The ATM system receives and processes eFPL submissions, extracting the desired trajectory. The ATM assesses if constraints set in the agreed trajectory can be removed, bringing the flown trajectory closer to the desired one. If the constraint can be removed, clearances are issued based on the trajectory. The flown trajectory deviates from the initially received agreed trajectory, improving service to the AU.

A Study conducted by EUROCONTROL in (2009), aimed at enhancing the management of the European airspace network. It addresses the need to improve the efficiency, capacity, and overall performance of the European air traffic management system. This study outlined a scenario in which congestion in airspace results in the implementation of a regulation (ATFCM delays). The Air Traffic Flow Capacity Management (ATFCM) delays can be avoided with a re-filed flight plan in which the AO requests an en-route change in flight level. Now, the AU is able to enter a region of regulated airspace.

3. Methodology

The research methods chapter outlines the methodology employed in this research. This comprises the research type description (3.1) and the activities conducted during this research (3.2). Furthermore, a table (3.3) will serve as an overview of the sub-questions. This summary describes the method taken to address the sub-question and the area of the study that contains the solution.

3.1. Research type

In order to address the primary research topic, this thesis takes a qualitative research approach. In order to fully understand complexities, this research entails an organized and exploratory evaluation. This research tends to focus on the depth and context of social interactions, organizational processes, and personal experiences. The operations of LVNL and KLM OCC are the primary focus of this research. Desk research, on-site observations, chronologically ordered interviews with key stakeholders, and participation in a SESAR Knowledge Leveling Day are the qualitative methods used in this research.

3.2. Research phases

This paragraph elaborates on the different phases of the research. First, the required knowledge was gathered (3.2.1) after which the current situation was analyzed (3.2.2). This meant that the qualitative research could start by collecting data by interviewing key stakeholders (3.2.3). After that the ICAO FF-ICE concept needs to be investigated (3.2.4). The research ends with a concluding phase (3.2.6).

3.2.1. Gathering knowledge

This theoretical phase ensured that the project was fully comprehended and that the appropriate information was obtained. This includes the theory that is outlined in the theoretical framework. In order to ensure that the research was practical, it was also crucial to establish a precise project scope. Desk research was performed to review existing literature, documents, and materials related to air traffic control, airline operations, and the ICAO FF-ICE concept. This involves analyzing reports, articles, regulations, and other written sources to gain a comprehensive understanding of the background and context of the research.

3.2.2. Map out the current process

In response to completing desk research and discussions with company supervisors, the methodology involves mapping out the current process to gain a comprehensive understanding of why LVNL seeks to implement TDT and to identify existing challenges. The objective is to assess the alignment of TDT within the current operational framework, explore possibilities within existing systems, and determine the need for any adjustments to facilitate TDT implementation. Additionally, the mapping process aims to pinpoint the key stakeholders genuinely involved in TDT.

To initiate the process mapping, an initial review of existing procedure manuals related to ATFCM will be conducted through desk research. This step is crucial for establishing a theoretical foundation and identifying potential positions for interviews. The specific positions for interviews will be derived from the theoretical framework, ensuring alignment with the research objectives.

The subsequent phase involves shadowing and observing key stakeholders during their work. This approach aims to provide firsthand insights into the daily operations, challenges, and interactions within LVNL and, where applicable, external entities such as KLM OCC. The focus is on understanding the current processes, potential obstacles faced by stakeholders, and gaining insights into their perspectives on the TDT concept.

While the methodology will involve interviews, the emphasis is on the theoretical framework guiding the selection of positions rather than revealing specific names at this stage. The names of the individuals interviewed will be presented in the appendix for reference.

This approach ensures a systematic and theory-driven exploration of the current process, laying the groundwork for subsequent data collection and analysis.

3.2.3. Interviewing stakeholders

Interviewing key stakeholders is essential to gaining a comprehensive understanding of their perspectives on the TDT concept. The purpose of these interviews is to explore their opinions on the feasibility of TDT implementation within existing operations, assess their perceived level of involvement once TDT becomes operational, inquire about their systems' adaptability to accommodate TDT, and gather insights into their preferred approaches to TDT implementation.

The identification of key stakeholders was informed by the insights derived from desk research outlined in section 3.2.1. Semi-structured interviews will be conducted with the NM, FMP, Flight Dispatcher, Flow Controller, and the ANSP or KUAC to delve into their viewpoints and experiences related to TDT. The decision to employ a semi-structured interview format allows for a flexible yet focused approach, enabling the exploration of predetermined topics while also allowing for the emergence of additional areas of interest during the interview process.

The names of the interviewed individuals will be kept confidential and included in the appendix, adhering to ethical considerations and maintaining a focus on the overarching research objectives.

3.2.4. Investigate the ICAO FF-ICE

As the aviation industry transitions to the new ICAO FF-ICE concept, with TDT becoming an application of this concept, an examination of this concept is necessary. It involves understanding the specifics of the FF-ICE concept, discerning the differences between Release 1 & 2, exploring the contents of the new flight plan, the requirements for FF-ICE and therefore also TDT, and determining the integration of TDT within it. Of utmost importance is identifying the opportunities FF-ICE presents for enhancing the TDT concept. To gather this information, primarily desk research has been conducted, supplemented by attending the SESAR Network TBO Knowledge Leveling Event on the 14th of November. The first half is presented by EUROCONTROL project manager Gerard Mavoian and covered the FF-ICE R1 pre-departure. Daniel Chiesa, an expert airline organization at Airbus, discussed the FF-ICE release 2 post-departure in the second half. Subsequently, an online meeting will be conducted with both speakers to obtain their opinions on the TDT concept and whether it is feasible within the framework of FF-ICE, and can be found in section 4.2.

3.2.5. Forming the FF-ICE Use Case for TDT

After analyzing all the information provided by all the key stakeholders gained form all interviews, ICAO FF-ICE Use Cases for TDT can be made. These Use Cases will help LVNL and relevant stakeholders in the future, when TDT is operational. The Use Cases will present a suggested future course for the TDT process. Concerning the next stakeholder's initiative and the reason of the trigger for activating TDT. Appendix IV provides the interview with Magnus Molbaek, who is a deployment manager at SESAR and the author of the document, about his opinion of the TDT concept. This research will lead to a recommendation, that contains advice for LVNL on how they can prosecute with the implementation of TDT.

3.3 Overview of the research questions and objectives

An overview in a column of first the sub-question, followed by the relevant objective, and the methodology adopted to address them could be seen in Table 3. This table additionally features the paragraph with the answers to these sub-questions. The answer to the main question and objective can be found in chapter 5 of the conclusion.

Sub-questions and objectives	Method	Reference
1. What is Tactical Demand Tailoring (TDT) in the context of capacity management processes, and what are its fundamental objectives and guiding principles within the air traffic management framework? **2.** Define Tactical Demand Tailoring (TDT) in the context of capacity management processes and elucidate its key objectives and principles.	Literature study & desk research	2.1
3. How does the current process of operations of LVNL and KLM-OCC unfold, and what are the shortcomings? **4.** Conduct a detailed analysis to understand the unfolding of current operational processes at LVNL and KLM-OCC and identify any shortcomings within the existing operational procedures.	Interviews & observation	4.1.2 & 4.1.3
5. Who are the primary parties and stakeholders involved in TDT, and what roles do they play in the execution and success of this air traffic management approach? **6.** Identify the key parties and stakeholders involved in TDT, and their role.	Interviews, observations & desk research	4.1.2 & 4.4
7. How does the ICAO FF-ICE concept contribute to interactive flight rerouting during flight execution, and what role does it serve in enhancing air traffic management adaptability and efficiency? **8.** Investigate how the ICAO FF-ICE concept contributes to interactive flight rerouting during flight execution. And understand the role FF-ICE plays in enhancing air traffic management adaptability and efficiency.	Desk research, focus group,	2.1, 4.2 & 4.3
9. Is TDT adaptable within the existing ICAO FF-ICE framework, or are there specific requirements and unique implementations? **10.** Determine the adaptability of TDT within the existing ICAO FF-ICE framework. investigate whether there are specific requirements and unique implementations.	Desk research, Focus group & interviews	4.2, 4.3.2 & 4.4
11. What are the requirements for effective information exchange and data sharing when TDT is implemented? **12.** Identify requirements for effective information exchange and data sharing when TDT is implemented.	Desk research & focus group	4.2 & 4.3.2
13. What are the requirement and interest of KLM-OCC by the implementation of TDT? **14.** Assess the requirements and interests of KLM-OCC arising from the implementation of TDT.	Interviews	4.1.3 & 4.4
15. What are the operational processes of the key stakeholders when implementing the TDT concept? **16.** Elucidate the operational processes of key stakeholders during the implementation of the TDT concept.	Desk research & interviews	4.4
17. What are the triggers and execution points for the flow manager to initiate inflight rerouting, and how does this process unfold in real-time air traffic management scenarios? **18.** Identify triggers and execution points for the flow manager to initiate inflight rerouting. And understand how this process unfolds in real-time air traffic management scenarios.	Desk research & interviews	4.1.3 & 4.4
19. How is planned inflight rerouting effectively integrated into the flight planning processes of the flow manager and flight crews, and what benefits and challenges arise from this integration? **20.** Examine how planned inflight rerouting is effectively integrated into the flight planning processes of the flow manager and flight crews. And identify the benefits and challenges arising from this integration.	Interviews & observations	4.1 & 4.2.1

Table 3, overview of the sub-question

4. Results

The results of the methods outlined in Chapter 3 are covered in the following chapter. This research followed a qualitative approach, focusing on social interactions, organizational processes, and personal experiences within LVNL and KLM OCC. Utilizing methods like desk research, on-site observations, interviews, and participation in a SESAR Knowledge Leveling Day, the study progresses through distinct phases.

Sub-chapter 4.1 elaborates the current process, about where the shortcomings in the current procedures comes form. Followed by sub-chapter 4.2, which describes the FF-ICE concept, and how TDT will fit in this concept. The related legislation for TDT-concept, considering if this tool is possible, and the new legislation when implementing the FF-ICE concept can be found in sub chapter 4.3. At the end, sub-chapter 4.4 describing how TDT can be used in the future in the form of FF-ICE Use Cases.

The results are formed based on the all the information provided by the key stakeholder who were interviewed. They gave insight on what the key operational requirements needs to be by implementing TDT to enhance the capacity management. What the communication flows needs to be, and which stakeholder is going to inform the other.

4.1 Current Process

The current process is analyzed to understand the need for TDT. Attention is paid to the ATFCM procedures (4.1.1), the stakeholders (4.1.2) and their duties involved during the operational procedures (4.1.3). And at the end the capacity shortfalls caused by the operational procedures (4.1.4).

4.1.1 Air Traffic Flow & Capacity Management (ATFCM)

Capacity management operates on the fundamental principle of aligning ATM capacity with current traffic demand. Only when this adjustment proves insufficient to meet the total demand does the necessity for flow or traffic management measures arise. The optimization of capacity predominantly involves the dynamic adjustment of ATC sectorization or the allocation of military airspace reservations. This realignment is crafted to seamlessly accommodate traffic demand, thereby fostering more efficient flight trajectories, exemplified by the Flexible Use of Airspace (FUA) procedure (EUROCONTROL, 2014).

Conventional strategic ATM planning frequently fails to provide precise route or trajectory details, instead relying primarily on historical data and/or scheduled flight information. The crucial function of the Planning Service is to connect the gap between short-term planning based on filed flight plans and medium- to long-term ATM planning, which is based on flight schedules and historical traffic statistics. Gaining early knowledge of the underlying demand; that is, the demand unaffected by an FMP because of daily variations in airspace availability and ATFM measures, is essential for effective ATM capacity planning and management. Airspace Management (ASM)/ATFM uses these interventions, which are best illustrated by devices like the DST from LVNL, to either increase capacity or regulate demand to match available capacity. If early flight plans, the first indicators of demand, already include daily ATM measure adjustments, it becomes counterproductive and misrepresent the actual underlying demand picture. The first route or trajectory for a flight must be provided early enough to enable efficient resource planning activities related to ASM, ATFM, and airport planning in order to provide benefits. This means that, in actuality, a flight's starting route or trajectory should be filed before the daily airspace availability and ATFM measures are made public (Fernandez, 2020).

Confidence in the accuracy of the forecasted traffic demand should increase as more operators participate in early planning, as the process is expected to become self-enhancing. There will be less need for and/or effect from an applied ATM restriction because of this increased predictability. Planning will become more cautious once the process is in place, enabling the development of a more stable framework and the early insight of any necessary constraints and their effects. Alternatively, the operator may be encouraged to interact later because that is when the limitations and their associated constraints become clear, which is a self-deprecating strategy (Group, 2022).

The way that ATFM processes are currently performed may differ considerably across ASPs, especially when it comes to the operator interface. Therefore, the need of the development of a global strategy for the FF-

ICE-facilitated exchange of ATFM-related data. Nonetheless, referencing a relevant published restriction in the operator's input from an eASP is a feature of the FF-ICE Planning and Filing Services implementation. Furthermore, it has the capability of illustrating the impact of an ATFM restriction using a route/trajectory constraint, like a time constraint, flight level constraint, etc (ICAO, 2023).

4.1.2 Stakeholders

4.1.2.1 Air Traffic control the Netherlands (LVNL)

LVNL is the ANSP responsible for managing and controlling air traffic in the Netherlands. It provides air traffic control services, ensuring the safe and efficient movement of aircraft within Dutch airspace. LVNL also plays a crucial role in safety oversight, adhering to international safety standards and conducting safety assessments and audits. It manages the allocation and use of airspace for civil and military aviation, coordinating with neighboring countries' air traffic control authorities to optimize traffic flow. LVNL also provides communication and navigation services, facilitating effective communication between air traffic controllers and pilots. LVNL collaborates with airlines, airports, and other aviation industry stakeholders to coordinate and optimize air traffic movements. LVNL continually evaluates and integrates new technologies to enhance efficiency and safety. It is involved in the training and certification of air traffic controllers, ensuring they meet required standards for managing air traffic safely and efficiently. LVNL also develops and implements contingency plans to address unexpected events, disruptions, or emergencies that may impact air traffic operations. For the latest and most accurate information, it is recommended to refer to LVNL's official publications or directly contact them.

4.1.2.1.1 Flight Management Position (FMP)

The Flight Management Position (FMP) controller is a critical role in ensuring the stability and efficiency of air traffic flow. Key responsibilities include strategic planning to align airspace and aerodrome capacity with traffic demand, real-time adjustments during the tactical phase, collaborating with stakeholders, and issuing regulations to manage traffic during peaks.

The FMP, in collaboration with the NMD, has an essential function in delivering the most effective ATFCM service to both ATCs and AOs. Within this framework, the FMP ensures that the NM possesses all relevant data required for its responsibilities across all phases of ATFCM operations. The FMP constantly supports the NM with crucial data and updates, encompassing sector configurations and activations, monitoring values, traffic volumes, flows associated with a reference location, taxi times, runway configurations, monitoring values of aerodromes, and details of events impacting capacity at aerodromes or ACCs. Additionally, the FMP contributes 'local knowledge,' supplying data and information essential for the effective and efficient execution of the ATFCM task.

In a reciprocal exchange, the NM advises the FMP about events or information that could affect the service provided by its parent ACC(s). Both the NM and the FMP share joint responsibility for offering advice and information to ATC and Aircraft Operators, adhering to the defined Letter of Agreement (LoA). This collaborative effort ensures a comprehensive and informed approach to air traffic management, promoting effective communication and coordination between all involved parties (Rooij, 2023).

4.1.2.1.2 Air Traffic Controller (ATCO)

An Air Traffic Controller (ATCO) from LVNL is responsible for ensuring the safe and efficient movement of air traffic within Dutch airspace. ATCOs maintain safe separation between aircraft, issue clearances and instructions, and provide essential information and instructions. They coordinate with other ATC units and international airspace authorities for seamless operations. They also use radar systems to track aircraft movements and coordinate with ground services to manage aircraft movement. Their role is dynamic, requiring focus, communication skills, and quick decision-making to ensure air travel safety.

4.1.2.2 EUROCONTROL

EUROCONTROL is an organization that coordinates and improves ATM across European airspace. It is not an ANSP but acts as a collaborative platform for member states and stakeholders to enhance safety, efficiency, and effectiveness of air traffic operations. EUROCONTROL's key functions include network management, safety oversight, research and development, ATM training and education, data and information sharing, collaboration with stakeholders, implementation of common standards, and coordination of cross-border operations.

Network management ensures a seamless and efficient flow of air traffic, coordinating with national ANPs and other stakeholders. Safety oversight promotes aviation safety by establishing and implementing safety standards, best practices, and improvement initiatives. Data and information sharing facilitates the exchange of information among member states and stakeholders, enhancing situational awareness and decision-making. Collaboration with stakeholders, such as national ANSPs, airlines, airports, and regulatory authorities, aims to address common challenges and work towards harmonized air traffic management solutions.

4.1.2.2.1 Network Manager Operations Centre (NMOC)

The Network Manager Operations Centre (NMOC) comprises key roles responsible for the effective functioning of ATFCM operations. The European Commission Regulation (EU) established the Network Management Board (NMB) under the framework of the EU Single European Sky Initiative. The European Commission has designated EUROCONTROL to be the Network Manager for 2020–2029 based on the Commission Implementing Decision. The NMB oversees the effectiveness of the network operations and establishes policies pertaining to their governance (EUROCONTROL, 2023).

The Current Operations Manager (COM) holds the highest authority within the NMOC. In instances of disagreement between the FMP and the NM, the COM takes responsibility for decision-making, ensuring cohesive actions by the NM.

The Network Management Cell (NMC) plays a pivotal role in enhancing ATFCM operations. Responsibilities include the preparation of the daily ATFCM plan and engagement in post-event analysis. The NMC actively contributes to strategic activities by coordinating specific projects related to special events or specific processes, alongside conducting CDM activities.

The NM Tactical Team manages the day-to-day execution of the ATFCM Daily Plan. Their activities encompass tactical flow management processes, monitoring traffic load and development, assessing the impact of implemented measures, and taking corrective actions as needed. Additionally, the team analyzes delays in slot lists, offers support and information to FMPs and AOs, notifies FMPs of operational issues affecting traffic flow, and executes contingency procedures.

Ensuring the competency of NMOC staff aligns with EUROCONTROL Safety Regulatory Requirements, emphasizing the importance of maintaining a skilled and qualified team for the seamless and safe execution of ATFCM operations (Smid, 2023).

4.1.2.3 KLM Operation Control Centre (OCC)

The OCC is a vital part of an airline's operational infrastructure, responsible for real-time monitoring, coordination, and decision-making to ensure safe and efficient flight operations. The OCC monitors the status of all KLM flights, ensuring they operate according to schedule. It also monitors weather conditions, assessing potential disruptions and coordinating with relevant departments. The OCC collaborates with air traffic control authorities and other airlines to optimize airspace usage and traffic flow. It may adjust flight routes or schedules in response to changes in air traffic management. The OCC works closely with the maintenance department to address any technical issues or maintenance requirements affecting the fleet. It may coordinate aircraft swaps or schedule changes to accommodate maintenance needs. The OCC manages crew schedules, ensuring all crew members are appropriately trained and available for assigned flights. It also plays a key role in decision-making during irregular operations. The OCC serves as a central communication hub for various operational departments, relaying critical information to flight operations, crew scheduling, maintenance, and customer service. It ensures flight operations comply with all relevant aviation regulations and standards. The specifics of the OCC's functions and operations can evolve over time, so it is recommended to refer to KLM's official publications or contact the operations department directly.

4.1.2.3.1 Flow controller

A flow controller coordinates and optimizes air traffic flows, ensuring optimal routes, minimizing delays, and enhancing efficiency. They collaborate with air traffic control units to ensure smooth operations. They assess weather conditions and airspace constraints to make informed decisions about routing and scheduling. Effective communication with pilots, air traffic controllers, and stakeholders is crucial (EUROCONTROL, 2014). Compliance with regulations and company policies is essential in all aspects of traffic flow management. Data analysis is used to make data-driven decisions for optimizing flows. Problem resolution involves addressing and resolving issues related to traffic flow, delays, or operational challenges that may impact efficiency (Palenstijn, 2023).

4.1.2.3.2 Flight Dispatcher

A KLM flight dispatcher is a vital role in the safe and efficient operation of flights. They work closely with pilots to create a comprehensive and safe flight plan, considering factors like weather conditions, air traffic, and fuel efficiency. They provide updated weather information to the flight crew and make necessary adjustments to ensure safety.

Fuel planning is a critical aspect of their role, considering factors like the planned route, alternate routes, and potential diversions. They ensure the aircraft's weight and balance meet safety regulations and maintain stability. They maintain continuous communication with the flight crew, liaising with air traffic control and ground services to facilitate smooth operations.

Another important role is the constant following of the flights assigned to them, tracking the aircraft's progress, and providing updates to the crew. They also provide emergency support in the event of an emergency or unexpected situation. Lastly, they must be knowledgeable about aviation regulations to ensure all flight plans and operations comply with safety standards and guidelines (Arnhem, 2023).

4.1.2.4 Karlsruhe Upper Area Control Centre

The Karlsruhe Upper Area Control Centre (KUAC) is ANSP for the upper airspace of Germany, figure 3 will illustrate size and location of KUAC.

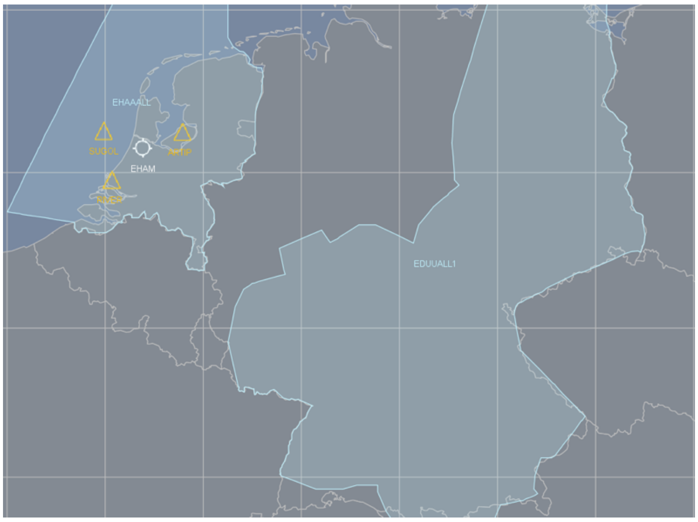


Figure 3, illustration and location of KUAC.

KUAC will be an important stakeholder when TDT is operational. This is because the inflight reroute form the predefined TDT suitable city-pairs, will be in their airspace. An interview with a senior ATFCM expert at KUAC, was held to get insight in what such a change will do with their operations (appendix III). What the impact will be for the capacity of KUAC and the workload for the ATCO when implementing TDT.

4.1.3 Operational procedures

ATFCM procedures follow a structured approach, divided into distinct phases, to effectively address various facets of air traffic flow and capacity. Each phase aligns with specific stages in the planning and execution of air traffic management, ensuring a cohesive and efficient approach. These phases serve certain functions, such as proactive planning that makes a proactive approach possible, ensuring anticipation and resource allocation well in advance. Flexibility and adaptability increase as phases progress, addressing real-time changes and dynamic factors. Collaboration is encouraged throughout phases, fostering information sharing among stakeholders and optimizing routes and capacity allocation. Efficient resource allocation is achieved through addressing different aspects of planning and execution in separate phases, optimizing resource use (ICAO, 2023).

In the Strategic Phase, the focus is on long-term planning to anticipate and manage future air traffic demand. This involves collaborative decision-making, strategic route planning, and capacity allocation, occurring weeks to months in advance (EUROCONTROL, 2009).

Moving into the Pre-Tactical Phase, plans undergo further refinement based on more current data, approaching real-time readiness. Activities include fine-tuning routes, assessing demand, and making initial capacity adjustments, with a timeframe spanning days to weeks in advance (ICAO, 2016).

The Tactical Phase involves real-time management of air traffic during the day of operation. Activities include monitoring and adjusting capacity, handling dynamic changes, and addressing current traffic situations, all on the day of operation.

Post Operations Phase serves the purpose of evaluation and feedback after completing operations. This phase involves reviewing performance, analyzing data, and identifying areas for improvement, occurring after the completion of the day's operations (IATA, 2019).

4.1.3.1 Duties FMP

The FMP, during the tactical phase, is responsible for monitoring load and comparing demand with the monitoring value of critical sectors using the NM Client Application. They take appropriate action when excesses of demand over monitoring value are detected, such as coordinating changes to ATC staff disposition, opening additional sectors, and implementing scenarios. They also request the NM to implement a regulation indicating the appropriate regulation cause.

The FMP monitors the effect of implemented measures and takes corrective action if necessary. They analyze delays in the slot list and try to resolve them in coordination with the NM. They provide support, advice, and information to ATC, airports, and AOs as needed. They discuss optimum sector configuration with the NM.

Tactical changes to environmental data, such as opening and closing airways, ATC sectors, runway changes, taxi times, and other factors, are passed to the NM. Changes in sector configurations, monitoring value figures, and procedures affecting flight profiles for the Area of Response (AoR) of the FMP are also discussed.

The FMP is responsible for notifying the NM of operational problems that could affect traffic flow, ATFCM incidents, and executing contingency procedures. They also monitor departure slot compliance for aerodromes within their area of responsibility.

According to the Network Operations Handbook (2014), one interesting duty of the FMP is to make sure the NM is informed when local tactical ATC measures (tactical reroutes of airborne traffic) are implemented or modified, as this could have an impact on the ATFCM situation. As part of the Strategic or Pre-Tactical planning operations, the planned use of tactical ATC measures that may affect the ATFCM situation in the Tactical phase should be coordinated with the NM as early as possible to avoid confusion and ensure compatibility with the ATFCM plan.

4.1.3.1.1 ATFCM Regulations

Schiphol arrivals are directed to the proper IAF to continue their descent to the airport. Every arrival at Schiphol will travel through an ACC sector en-route to the airport. Arriving traffic can show up in large quantities at a certain moment during inbound peaks. When combined with additional traffic inside the ACC sectors, ATCOs may have an increased workload. Overstretching ATCO demand could result in dangerous and ineffective operations. As a result, LVNL must carefully forecast and track the flow of traffic and associated demand on its controllers. This forecast is generated many hours ahead of time and is continuously tracked as the inbound peak gets closer.

With a background in ATM and a focus on capacity management and CDM, an FMP controller (Rooij, 2023) at LVNL, provides insight into the complex function that an FMP at LVNL plays in the process of his work. The interview (appendix I) emphasizes the critical nature of FMP responsibilities. These include strategic planning for airspace and aerodrome capacity alignment with traffic demand, real-time adjustments during the tactical phase, collaboration with stakeholders, and issuing regulations to manage traffic during peaks.

The FMP will issue a sector capacity regulation if it determines that the traffic flow during an inbound peak is likely to exceed the predetermined limit for that segment of airspace. The regulation, which is issued many hours in advance, restricts the volume of aircraft that are permitted to fly through a specific area of airspace.

During the shift, 12:00 – 18:00, his responsibility involves ensuring the evening inbound peak for Amsterdam Flight Information Region (EHFIRAM) is manageable for the ATCOs, and do not overload one IAF. The unpredictability of incoming traffic requires continuous monitoring and adjustment. If this limit exceeds and there is too much incoming air traffic planned during the inbound peak, we can set a regulation. This will depend on various factors, such as air traffic volume, complexity, runway availability, weather, and ATCO availability.

Figure 4, show an example of an ATFCM regulation, placed on 11 November 2023:

"On November 11, 2023, at 13:16 UTC, the total inbound air traffic during the inbound peak (17:20–18:20) for EHFIRAM was 75. Due to the weather, this was set to a maximum of 65. The total inbound air traffic that will fly through the sector of ARTIP was 39. The total inbound was too much on this day for LVNL, and the FMP decided to issue a regulation. After simulations in the DST of different scenarios, common knowledge and experience, the FMP decided to set a regulation of 30 over ARTIP. This is because the totals in the EHFIRAM do reach an acceptable level, but with a FIRAM regulation, the bunch cannot be removed from ARTIP.

Regulation: EHARTIP 17:00-18:40/30, reason ATC CAP HD

The regulation was set from 17:00-18:40 instead of the predicted inbound peak of 17:20-18:20, because of the uncertainty of the air traffic mentioned before. So, to be on the safe side, take an advance for later or earlier flights."

4.1.3.1.2 Flow Management Position Systems

These regulations are based on the Filed Flight Plans (FLP) submitted, indicating the number of flights heading towards Amsterdam. An interview (appendix V) with an LVNL FMP controller, provides additional insights into the systems used by FMPs, focusing on the Collaborative Interface for Flow Optimization (CIFLO) and the DST (Geurten, 2023).

CIFLO is a Collaboration Human Machine Interface (CHMI) service designed primarily for FMPs that provides capabilities specifically tailored for air navigation service providers. It gives access to ATFCM information to supervisors and managers in this domain, air traffic controllers, and air traffic flow and capacity managers from the FMP. Users can see data and graphical information (such as routes, route attributes, airspaces, flight plan tracks, etc.) via map displays from the CHMI, a stand-alone application that offers a graphical interface for network operations systems. With the use of this real-time data, CDM is possible for all partners.

The CIFLO indicates the expected traffic volume for a given time based on filed flight plans (FLP). An AO submits their FLP to the Integrated Initial Flight Plan Processing System (IFPS) of the NM. Once processed by the IFPS the FLP is sent to the Enhanced Tactical Flow Management System (ETFMS), where the system consolidates all FLPs to calculate all the flow and capacity. The ETFMS is the general system of NM used by all the ANSPs have insight in the flow and capacity. Figure 4, shows an picture of CIFLO which provides insight into the ETFMS for an FMP.

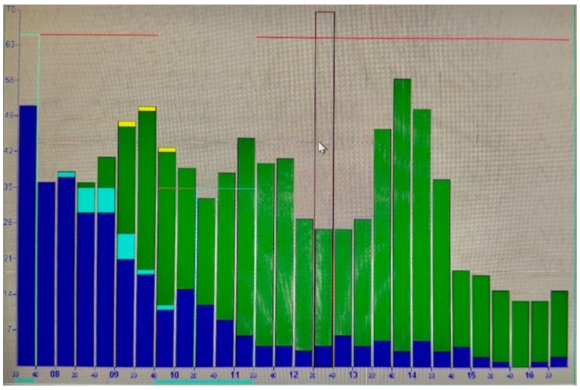


Figure 4, illustration of the CIFLO, total traffic count for EHFIRAM.

Blue represents flights that are already airborne, and green indicates those yet to depart. The red line indicates is the Monitoring Value (MV), determined by the FMP for the total EHFIRAM and set at 65. This value offers an indication of the typical situation for inbound air traffic on 2 runways. Through CIFLO, we can observe the incoming traffic at specific times and sectors. Figure 4 illustrates the total traffic count for EHFIRAM, but can also only illustrates ARTIP or RIVER. CIFLO can also display regulations submitted by other ANSPs. Additionally, there is the PREDICT function, which shows predictions for the upcoming days based on the past week. PREDICT helps us anticipate any special events.

4.1.3.1.3 Decision Support Tool (DST)

The DST is a tool that facilitates multiple-hour advance traffic flow prediction in EHFIRAM. These forecasts assist flow controllers in determining whether traffic regulations are necessary for EHFIRAM in order to guarantee that traffic flow does not surpass LVNL's or Schiphol's operating capability. The working of DST is comparable to the CIFLO, only CIFLO is an application of NM, and the DST is specifically designed for us.

In CIFLO we can insert the actual regulations, which are then incorporated through the system by NM. In the DST we can only simulate the regulation, therefore DST is only allowed to use for advisory purposes. Within CIFLO, we can divide the bars representing in- and outbound air traffic into time intervals of an hour and 20 minutes as seen in figure 4. However, CIFLO is an old system, and sometimes these bars can be misleading. For instance, if you have an inbound of 15 flights from 10:00 to 10:20 and another inbound of 15 flights from 10:20 to 10:40, CIFLO does not immediately show the distribution within these 20 minutes. It is possible that 10 out of the 15 flights from 10:10 to 10:20 arrive, and all 15 flights from the second bar arrive from 10:20 to 10:30. This would mean that 25 flights arrive in the 20 minutes from 10:10 to 10:30. This can create a distorted picture, which can be resolved by referring to the specific list provided by CIFLO, displaying all submitted flights and their exact times.

The DST can accurately illustrate when flights will exactly arrive the EHFIRAM. In this system, the bars are divided into 5-minute intervals and are constantly updated as seen in figure 5.

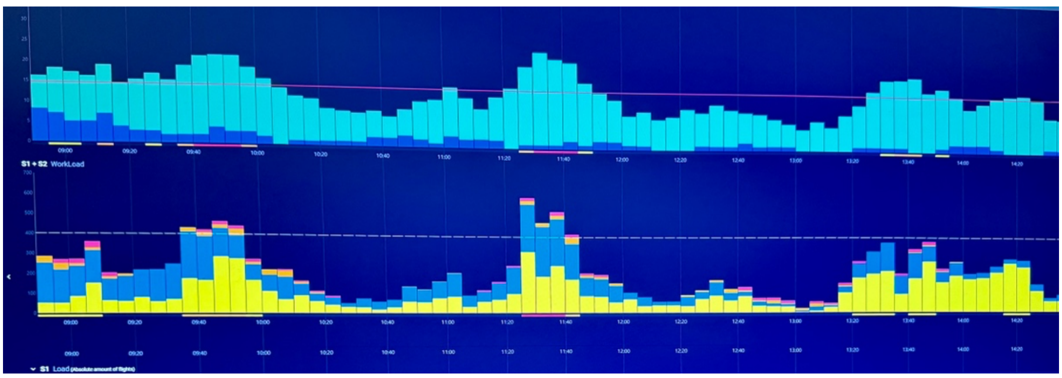
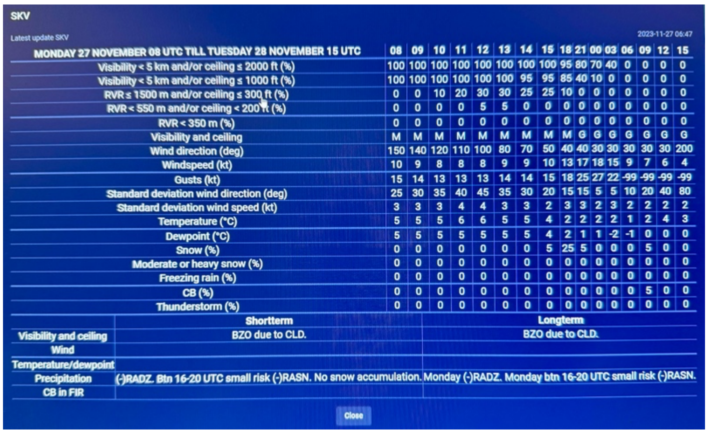


Figure 5, illustration of the Decision Support Tool

The DST is in a Business to Business (B2B) connection with the NM, therefore is constantly updated which results in a more precise distribution. The red line in figure 5 originates from the DST itself. This line serves as a type of MV, but the DST considers the complexity of air traffic on its own. It also considers the WLM (Work Load Model) and the weather. WLM is the workload model, which considers the expected workload of the ATCO, which can be seen in figure 6.

Figure 6, illustrate the Workload Model of the ATCOs

The weather is also updated into the DST and based figure 7 which illustrates the SKV (Schiphol Chance Expectation). Weather monitoring is done by the Royal Dutch Meteorological Institute (KNMI), but also by our own personnel here. The DST can, therefore, provide a much more specific expectation of anticipated capacity.



SKV

Latest update SKV 2023-11-27 06:47

MONDAY 27 NOVEMBER 08 UTC TILL TUESDAY 28 NOVEMBER 15 UTC	08	09	10	11	12	13	14	15	18	21	00	03	06	09	12	15
Visibility < 5 km and/or ceiling ≤ 2000 ft (%)	100	100	100	100	100	100	100	100	95	80	70	40	0	0	0	0
Visibility < 5 km and/or ceiling ≤ 1000 ft (%)	100	100	100	100	100	100	95	95	85	40	10	0	0	0	0	0
RVR ≤ 1500 m and/or ceiling ≤ 300 ft (%)	0	0	10	20	30	30	25	25	10	0	0	0	0	0	0	0
RVR < 550 m and/or ceiling < 200 ft (%)	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0
RVR < 350 m (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Visibility and ceiling	M	M	M	M	M	M	M	M	M	G	G	G	G	G	G	G
Wind direction (deg)	150	140	120	110	100	80	70	50	40	40	30	30	30	30	30	200
Windspeed (kt)	10	9	8	8	8	9	9	10	13	17	18	15	9	7	6	4
Gusts (kt)	15	14	13	13	13	14	14	15	18	25	27	22	-99	-99	-99	-99
Standard deviation wind direction (deg)	25	30	35	40	45	35	30	20	15	15	5	5	10	20	40	80
Standard deviation wind speed (kt)	3	3	3	4	4	3	3	2	3	3	2	3	2	2	2	2
Temperature (°C)	5	5	5	6	6	5	5	4	2	2	2	2	1	2	4	3
Dewpoint (°C)	5	5	5	5	5	5	5	4	2	1	1	-2	-1	0	0	0
Snow (%)	0	0	0	0	0	0	0	5	25	5	0	0	0	5	0	0
Moderate or heavy snow (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Freezing rain (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CB (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Thunderstorm (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Shortterm	Longterm
Visibility and ceiling	BZO due to CLD.	BZO due to CLD.
Wind		
Temperature/dewpoint		
Precipitation	(-)RADZ. Btn 16-20 UTC small risk (-)RASN. No snow accumulation.	Monday (-)RADZ. Monday btn 16-20 UTC small risk (-)RASN.
CB in FIR		

Close

Figure 7, illustration of the SKV

The DST is tailored to the requirements of LVNL and the Dutch airspace. For instance, the DST is configured based on the number of in- and outbounds. Meanwhile, other ANSPs prefer their systems to be set up based on Occupancy Count, which is the time an aircraft spends in the airspace. In the DST, an FMP can also simulate different scenarios; for instance, the weather can be made worse to observe its impact on the capacity.

4.1.3.2 Duties KLM OCC

4.1.3.2.1 Slot swapping

The Computer Assisted Slot Allocation (CASA) system, a subsystem of the NM ETFMS, operates in an automatic and centralized manner. From an AO's point of view, it operates in a passive mode, in which the act of filing a flight plan itself functions as a slot request.

Upon coordination with the FMP, the NM determines the necessity of activating regulations in specific locations. These regulations, as managed in ETFMS, encompass crucial details such as start and end times, location descriptions, entering flow rates, and various other parameters. For instance, as described in Remco's earlier regulation example, a total of 30 aircraft were regulated for the period between 17:00 and 18:20. Which means 30 slots for 80 minutes, the slots are separated by 2 to 3 minutes (17:00, 17:02, 17:04, etc.). Regulated flights have a departure window of -5 and +10 of CTOT, and unregulated flights -15 and +15.

Adhering to the 'First Planned - First Served' principle, the system identifies all flights entering the designated airspace, arranging them in the sequence they would have naturally arrived without any restrictions. Based on this sequence, the Calculated Take-Off Time (CTOT) is computed and subsequently transmitted to the relevant AO and the control tower at the departure aerodrome.

Due to a capacity regulation at ARTIP, ATFCM delays arise. The regulation from section 4.1.3.1.1 resulted in 432 minutes of delays, impacting all flights scheduled to arrive during the inbound peak at Schiphol. A significant portion of these flights belongs to KLM, reportedly accounting for 70% (Rooij, 2023). These delays have a substantial impact on KLM's overall fleet. This is particularly critical for flights carrying transfer passengers who need to make their connections at Schiphol. The flow controller endeavors to address and resolve these issues.

According to the interview in appendix VI with KLM OCC flow controller, the primary objective is to optimize the operation of the KLM City hopper (KLC) fleet for maximum efficiency. Utilizing the Network Manager Portal (NMP) Flight from NM EUROCONTROL, the scheduled flights for the day can be accessed. Flights departing within an hour or those that have already departed are generally not within immediate focus. In the event of a delay for a yet-to-depart flight, the goal is to address it through slot swapping and rerouting.

Slot swapping is initiated through the NMP Flight system, and the NM, can accept or reject this request from the flow controller. There is a three-time limit for slot swapping a particular flight, and automated systems assist in identifying other KLM flights that can benefit from this process. Essentially, the approach involves consolidating all delays onto one flight, enabling three other flights to proceed without delays. Subsequently, the initially delayed flight is rerouted, such as from ARTIP to RIVER, effectively eliminating the delay and ensuring optimal fleet operation efficiency (Palenstijn, 2023).

4.1.3.2.2 Rerouteing

The dispatcher is in control of these reroutes. The dispatcher uses LIDO to create routes. Lido Flight 4D supports airlines by providing advanced tools for flight planning, optimization, and navigation. It finds efficient routes, considering factors like air traffic and restrictions. Real-time weather data integration helps in decision-making to avoid adverse weather conditions. The system focuses on fuel efficiency, crucial for minimizing operational costs. Collaborative features facilitate communication between stakeholders (Lufthansa, 2023).

LIDO generates so-called 'company routes,' which are calculated routes considering factors like ATC costs, closed airspace due to personnel, wind, etc. LIDO chooses the most economical routes, and these routes are created six hours in advance and rechecked two hours before the flight. The dispatcher is responsible for this route, and it is filed by the NM.

The dispatcher is also responsible for a reroute, along with LIDO. The only issue with the LIDO system is that it doesn't take into account the altitude in the case of closed airspace. In the occasion of a delay emerging from a regulation along the filed route, a flight dispatcher can pinpoint its location using the NMP Flight. The NMP provides insights into the cause of the delay, whether it's due to a shortage of ATC staff or a congested airspace. By an overloaded airspace, a vertical representation in NMP Flight allows the dispatcher to precisely locate the affected area. For example, during the climb, the aircraft passes through an overloaded airspace. The dispatcher can adjust the route in NMP Flight, suggesting a slightly slower climb, to avoid and navigate below the overloaded airspace. After filing this route adjustment with NM, the dispatcher can verify its effectiveness and acceptability (COMMISSION, 2014).

KLM will stick to the most economical route, until a delay of 15 minutes. This is because a reroute can result in a longer distance, and therefore more fuel. Sometimes, a reroute is not always possible, regardless of the delays that may have occurred during a regulation. In Remco's example, where there was a regulation of 30 over ARTIP, the FMP at LVNL informs KLM OCC via telephone not to reroute over another IAF. If, at some point, too many flights reroute over the other IAF, there could be an overload over the entire EHFIRAM (Arnhem, 2023).

4.1.3.2.3 Direct Routing

Appendix VII provides an interview with an KLM flight dispatcher, according to this interview direct routing is a method used for ATC and AU purposes to avoid waypoints while the aircraft is airborne. The selection of KLM their Desired Trajectory involves opting for the most economical route. However, this trajectory is subject to adjustments by the NM. Subsequently, NM sends back the Agreed Trajectory, which encompasses all the constraints applied by NM. The trigger for a direct can come from the AU or the ANSP for that sector, but the clearance is always provided by the ANSP. Direct routing is always checked with the dispatcher to ensure that this maneuver is feasible in terms of fuel. This change is then implemented in the FMS so that the flight can continue (Arnhem, 2023).

Direct routing offers several advantages, including delay compensation, improved flight efficiency, and reduced fuel usage. It compensates for delays caused by factors like late departure or adverse weather conditions. Direct routing also reduces flight time, making it beneficial in emergency situations where timely arrival at a designated aerodrome is crucial. This approach also contributes to environmental concerns and financial savings for airlines .

Sometimes, pilots also request a direct route from the ATCO to offset fuel consumption. Airlines consistently carry the exact amount of fuel calculated for their flight. Many aircraft encounter challenges during departure, as they are required by the ATCO to maintain a low altitude to ensure separation from other aircraft during takeoff. This results in high fuel consumption at the beginning of the flight, leading to a deficit towards the end. A direct route is now requested to reduce the distance and compensate for fuel consumption (EUROCONTROL, 2014).

Direct routing is a popular technique for aircraft clearance, but it has certain situations and circumstances that need to be considered. It may cause the aircraft to leave the flight planned path, which should be coordinated with the next ANSP of that sector (Arnhem, 2023).

4.1.4 ATFCM shortfall & solutions

The ATFCM shortfalls from the operational procedures like a slot tolerance and direct routing, will cause uncertainties in when the incoming air traffic will arrive at EHFIRAM.

The FMP ensures, based on submitted flight plans and slot times, that the capacity is well distributed. The predictions of the FMP are based on the CTOT, but the regulated flights have a departure window of -5 and +10 of the CTOT, and unregulated flights have -15 and +15. So, there is a window of 15 to 30 minutes flexibility between the time an aircraft can depart. It is possible that all these flights depart in the first or last minutes., and this can result in simultaneous arrivals. Additionally, aircraft occasionally miss expected slot times and depart later than scheduled.

To save fuel and make up for lost time, airlines then choose direct routing. Clearing multiple flights on direct routings may have a negative impact on the applicable flow control measures. Direct routing clearances may lead to an excessive number of aircraft arriving too early, which would cause sector (and controller) overload because capacity planning (and sector management) depend on the assumption that aircraft will fly their planned trajectory. In fact, a direct routing clearance could lead to an increase in fuel burn. For instance, the aircraft could have to hold if it comes earlier than scheduled.

All these uncertainties in when an aircraft will arrive in the EHFIRAM, can lead to an unexpected bunch of air traffic in the same sector. An ATCO can only see the total inbound air traffic when it is presented on their screens of their sectors. All the aircraft can arrive at the same time, which will result in a holding (noise and environmental), an increase in workload for the ATCO, and safety issues. That’s why the implementation of TDT could result in great benefits, rerouting incoming flight during the flight to another IAF. TDT will help the FMP by preventing that they need to put a flow restriction to overcome bunching at one runway. Thus, all routes from the south via RIVER, landing on the Polderbaan, by intervening and diverting the route to ARTIP (Zwanenburgbaan). This prevents bunching on the Polderbaan.

4.2. FF-ICE - Flight & Flow Information for a Collaborative Environment

This chapter contains information about FF-ICE and what this concept will mean for TDT. The information was obtained while participating in the SESAR Network TBO Knowledge Leveling Event on the 14th of November. The first half was presented by EUROCONTROL project manager Gerard Mavoian and covered the FF-ICE R1 pre-departure. Daniel Chiesa, an expert airline organization at Airbus, discussed the FF-ICE release 2 post-departure in the second half.

4.2.1 FF-ICE Release 1

The first release of the ICAO FF-ICE concept deals with pre-departure. About what key stakeholders can do to optimize the ATFCM, for a better and efficient operations. FF-ICE/R1 strives to establish standardized and machine-readable flight and flow information. This commitment to standardization streamlines communication and data processing between different stakeholders (ICAO, 2022).

The air traffic management system faces numerous challenges, including a lack of collaboration between Air Traffic Management (ATM) entities and aircraft operators, which hinders flight trajectories and operational efficiency. A more integrated approach to planning is needed to unlock the full potential of collaborative decision-making. Inefficient resource allocation contributes to congestion and delays in airspace, necessitating strategies to maximize resource use for a more efficient air traffic flow (Mavoian, 2023). The current infrastructure lacks real-time information exchange facilities, resulting in less-than-optimal responses to real-time events and operational changes. Enhancing instantaneous communication and data sharing is crucial for a more agile and responsive air traffic management system. Despite advancements in avionics technology, underutilization is limited due to integration and compatibility challenges. Maximizing the potential of advanced avionics is essential for efficiency gains and overall flight operations. These limitations result in inefficient aircraft operations, resulting from suboptimal planning, underutilized resources, and a lack of real-time information exchange. Addressing these issues is crucial for achieving a more streamlined and optimized air traffic management (EUROCONTROL N. M.).

The FF-ICE concept is relevant for TDT because this will be the new standard for all AUs, ANSPs and NM. It comes with an new flight plan (eFPL)(5.1.4), containing new and extra information about the flight trajectory for a greater 4D trajectory. All AUs operating in the EATMN Airspace are mandated by this regulation to fulfil the obligation explained in the CP1 regulation (6.4) and file eFPL the latest 31st December 2025. Thus, the question is not whether they will collaborate, but how will the TDT-concept fits in the FF-ICE framework (ICAO, 2023).

4.2.1.1 FF-ICE R1 services

FF-ICE services play a crucial role in supporting distinct processes within the air traffic management framework. These services are tailored to enhance planning, filing, and trial scenarios, ensuring a more efficient and collaborative airspace environment. FF-ICE services will also be used by TDT in the future due to the fact it is a planned in-flight reroute. This indicates that the planning phase can already include the predefined TDT suitable city pairs. Figure 8, shows an overview of the FF-ICE R1 services (ICAO, 2022).

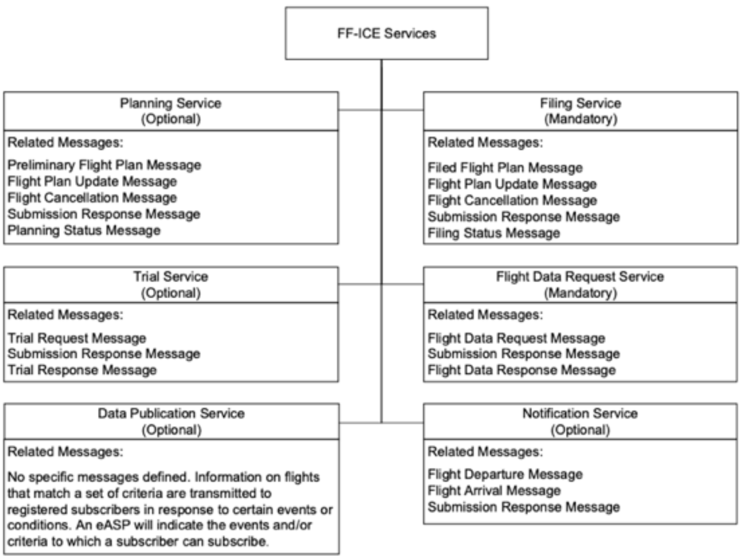


Figure 8, overview of the FF-ICE services.

4.2.1.1.1 Planning Service

The Planning Service within FF-ICE facilitates the transfer of flight intent through the Preliminary Flight Plan (PFP). The Planning Service allows an eAU to submit PFPs for operational evaluation against constraints and conditions anticipated for applicability at the time of the flight. If accepted, the data may be used for ATFM and load/capacity balancing purposes, until a filed eFPL is accepted and provides a more definitive reference. The service also includes provisions for PFP Updates and Flight Cancellations. This process is exclusively focused on planning and does not involve the transmission of data to the ATC function. It serves as the initial step where airspace users outline their intended flight trajectories without impacting ongoing ATC operations (Woollin, 2023).

The FF-ICE/R1 planning service establishes a collaborative environment where AUs, NM, and ANSPs seamlessly collaborate to optimize flight trajectories during the preliminary phases of flight planning. The commitment to standardized information exchange, careful consideration of constraints, and robust support for AUs in decision-making collectively contribute to a more efficient and collaborative approach to air traffic management (A. Gheorghe, 2021).

The FF-ICE/R1 framework emphasizes active participation from AUs who initiate collaboration by sharing vital flight information, including intent or PFP, with ATM systems. AUs engage in comprehensive flight planning, considering various constraints like airspace restrictions and weather conditions. The collaboration extends to NM and ANSPs, collectively optimizing trajectories and ensuring efficient airspace utilization. Real-time information exchange and enhanced what-if facilities provided by NM and ANSPs empower AUs to make informed decisions. FF-ICE/R1 aims to establish standardized and machine-readable flight and flow information, facilitating communication and data processing among stakeholders (ICAO, 2022).

AUs have the flexibility to engage in preliminary flight planning, with optional what-if analyses to explore alternative scenarios. This step allows adaptability based on individual needs and provides additional insights. The final step mandates AUs to actively manage their flight plans, including the mandatory submission of finalized plans to relevant authorities, ensuring adherence to established protocols.

The TDT concept could potentially make use of the planning service in the future. This is because it concerns predefined city pairs suitable for TDT. It is already known at LVNL that these flights can perform an in-flight reroute, avoiding additional costs such as extra track miles (fuel) or ATC charges. Through the planning service, this information can also become known to the AU departing from a TDT-suitable city pair, indicating the possibility of a reroute during their flight to EHFIRAM. The change in route, for these TDT flights, needs to be added in the new eFPL.

4.2.1.1.2 Filing Service

Filing Service allows an eAU to file an eFPL for network wide use as the definitive flight intent. This will be subject to operational evaluation against relevant constraints and conditions anticipated for applicability at the time of the flight. If accepted, the flight plan and its route/trajectory will be used by the relevant ANSPs along the route of flight for ATC purposes and by the NM for ATFM and other NM services. The filing service also includes provisions for Flight Plan Updates (to the filed eFPL) and Flight Cancellations.

The FF-ICE/R1 Filing Service aims to simplify the submission of flight information from AUs to the NM. A proactive initiative, it involves AUs sharing crucial flight details, such as intent or PFPs. AUs actively lead in submitting comprehensive flight information to the NM, fostering collaborative decision-making and optimizing flight trajectories. The service emphasizes proactive engagement and sharing essential details well in advance, ensuring streamlined decision-making processes among stakeholders (ICAO, 2022).

The FF-ICE/R1 Filing Service serves as a proactive and collaborative mechanism where AUs take the initiative to submit essential flight information, including intent and preliminary flight plans, to the NM. If TDT can be added in the eFPL, crucial flight information like the change in route can be shared with NM and en-route ANSPs. This way NM can share TDT with relevant stakeholders, so that they are aware of this possible change in route. This approach fosters efficient communication, strengthens collaborative decision-making, and establishes the groundwork for optimizing flight trajectories in the early phases of flight planning within the FF-ICE framework (FilingService, 2023).

4.2.1.1.3 Trial Service (What-If)

The Trial service offered by an eASP is a valuable tool for operators to explore alternatives to existing flight plans, both Preliminary and Filed. It is treated as a separate transaction, ensuring no impact on existing data. AUs can submit a Trial Request to evaluate alternative routes without modifying existing flight plan data. The eASP receiving a Trial request does not retain information related to the request and may not be aware of the previously submitted flight plan, especially if the Trial Request proposes a routing different from the original plan (ICAO, 2022). An AUs can submit a Trail request to evaluate TDT, the change in route, and analyze the impact it will have on the capacity in the other sectors.

Flight Data Request features are included in the Trial Service, often known as the What-If scenario. This includes the Request for Proposal (RQP) and Request for Quotation (RQS) processes, which let users of airspace investigate different situations and evaluate the possible effects of modifying their flight plans. What-If CDM allows parties to trade hypothetical route and trajectory suggestions and, if needed, counter propose to determine whether the flight data is acceptable. With this feature, an AUs can analyze the acceptance What-if we are fly the TDT route.

The Trial Request is submitted by the operator to relevant eASP(s) following the published procedure, and the route/trajectory in the request should be a Negotiating route/trajectory. The eASP performs evaluations like Preliminary or Filed Flight Plans, and the originator associates the Trial Response with the originating request using the Message Identifier data item. The Trial service provides a dynamic tool for operators to assess alternative routes efficiently within the collaborative environment. The Trial Service is covered by FF-ICE/R1, and it is anticipated that FF-ICE/R2 will also cover the phases of departure planning and flight execution (TrialService, 2023).

4.2.1.1.4 Flight Data Request Service

The provision of the flight data request service is mandatory for an eASP. Optionally, an operator can offer a flight data request service, enabling, at the very least, an eASP to access the most up-to-date version of a flight plan.

Within the FF-ICE environment, a Flight Data Request message serves to acquire information about a flight. While the message is structured to permit tailored flight data inquiries, the minimum set for implementation should encompass the following:

1. **Flight Plan**: This entails requesting a copy of the flight plan, akin to the utilization of the RQP ATS message.
2. **Supplementary Plan**: This involves requesting a copy of the supplementary data filed for the flight, equivalent to using the RQS ATS message.
3. **Flight Status**: This pertains to requesting a copy of the latest Planning or Filing status for the flight.

Any request for flight plan data should explicitly pertain to a Filed Flight Plan. It is important to note that a Preliminary Flight Plan should not be returned in response to a flight plan request.

Additionally, an operator has the option to provide a query and reply service, allowing an eASP to inquire about flight data. This is particularly valuable in situations where the information held by the eASP is limited or of uncertain quality. It is especially useful for obtaining information that is required on an ad hoc basis and/or is typically only available shortly before departure. The Flight Data Request service is intended for use by ASPs to obtain necessary information about a flight or by operators primarily seeking the status of their own flights concerning the queried eASP (ICAO, 2022).

In instances where an eASP is approached or receives an update for a flight without having the corresponding flight plan, a flight data request can be employed to solicit the flight plan from another eASP or from the operator, provided the operator has implemented this service. When an operator is uncertain about the status of a flight plan, they can initiate a query with the relevant eASP to obtain the flight plan status. It is essential to note that an operator should only request information about their own flights (FlightDataRequestService, 2023).

4.2.1.1.5 Notification Service

Notification Service within the FF-ICE framework serves the purpose of informing relevant entities, either eASPs or eAUs, about significant events in the flight life cycle. These events typically correspond to physical milestones in the flight progression, such as off-block, airborne, or landed, rather than system-specific statuses (ICAO, 2022). The information conveyed by the notification service holds significance for the further processing of the flight within the ATM system. Therefore, it is essential for the provider of this information to receive confirmation of its reception, like the acknowledgment received when filing a flight plan (NotificationService, 2023).

4.2.1.1.6 Flight Data Publication Service

The Data Publication Service is an optional service that an eASP may offer to effectively distribute flight information to several stakeholders.

An eASP has the capability to offer a Data Publication Service, allowing authorized subscribers to access information related to flights relevant to their operations. These subscribers may encompass airspace users, including military authorities, ATM providers, aerodrome service providers such as aircraft maintenance and ground/gate service providers, general aviation fix-based operators, and other groups like Customs and Immigration requiring the data (ICAO, 2022).

Utilizing the Data Publication Service enables subscribers to receive updates on changes to flight plans and trajectory information, providing them with advanced notice of alterations that will impact their relevant flights. This proactive information proves valuable to subscribers, aiding them in making necessary adjustments to effectively manage their operations (A. Gheorghe, 2021).

To access the Data Publication Service, an eASP should publish information about its availability in the AIP or other relevant documentation. This should include details outlining the service provided and conditions related to access (PublicationService, 2023).

4.2.1.2 Implementation of FF-ICE/R1 in ECAC area

Implementing FF-ICE/R1 within the European Civil Aviation Conference (ECAC) Area involves a strategic integration of various technologies and frameworks.

Transparency is key. ANSPs and the NM should communicate effectively with AUs, keeping them informed about any constraints that might impact their flights. This proactive communication ensures that AUs are well-prepared for any potential challenges. To empower AUs in making informed decisions, the NM and ANSPs should provide enhanced what-if facilities. These tools allow AUs to simulate different scenarios, helping them assess the impact of potential changes and make optimized decisions. Leveraging trajectory and flight-specific performance data is critical for precise decision-making. ANSPs and the NM should utilize this data to enhance the accuracy of their assessments and recommendations (H. De Smet, 2023).

The backbone of FF-ICE/R1 implementation in the ECAC Area relies on SWIM services. SWIM facilitates the seamless exchange of information across the aviation ecosystem, ensuring that all stakeholders are interconnected in a cohesive information-sharing environment. FF-ICE/R1 employs a business-to-business services model. The NM B2B Services serve as an interface offered by EUROCONTROL NM, enabling system-to-system access to its services and data. Users can retrieve and integrate this information into their own systems, facilitating real-time information exchange on a global scale and enabling the implementation of collaborative global ATFCM (EUROCONTROL, 2023).

The utilization of the SWIM Yellow-profile infrastructure is integral to FF-ICE/R1 implementation. This framework provides a standardized structure for data exchange, fostering interoperability and consistency across different systems and platforms. FF-ICE/R1 relies on both the request/reply and publish/subscribe communication patterns (Fernandez, 2020). This versatile approach accommodates diverse communication needs, allowing for direct queries as well as the dissemination of relevant information to interested parties.

Standardization of data is achieved using the FIXM 4.3 and NM extension. These standards ensure uniformity in the representation of flight and flow information, fostering compatibility across systems (ICAO, 2022).The NM, acting as the FF-ICE service provider (eASP in Europe), takes a central role in deployment. This entity not only deploys SWIM services but also manages access through authentication and authorization processes, ensuring secure and controlled information exchange. To facilitate a smooth onboarding process, the NM provides a dedicated test platform. This allows stakeholders to validate their systems and processes within a controlled environment before transitioning to live operations (ICAO, 2022).

4.2.1.3 The new eFPL

The new flight plan that will be used will consist of the ICAO 2012 flight plan data + 4D Trajectory Data, Flight Specific Performance Data, Globally Unique Flight Identifier (GUFI). And will be in a machine-readable format by using FIXM (Mavoian, 2023). There are two different types of eFPLs provided by EUROCONTROL; The filed eFPL, appendix VIII, designates the flight information that is sent by an AU to the NM using the FF-ICE Filing Service. And the distributed eFPL, appendix IX, designates the flight information that is sent by the NM to ANSPs using the FF-ICE Publication Service. All what is marked green in the eFPL is new and different from the old 2012 FPL (EUROCONTROL, Requirements , 2023).

4.2.1.3.1 Globally Unique Flight Identifier

The GUFI is designed to serve as a distinctive reference for a particular flight, whether civil or military. Its primary objective is to aid in linking a message to the accurate flight and to facilitate differentiation between similar flights. In situations where there are multiple flight plans sharing the same aircraft identification and departure point, it may not always be evident whether these plans represent different versions of the same flight or pertain to distinct intended flights (ICAO, 2022).

4.2.1.3.2 Flight Information Exchange Model

The FIXM is an exchange model capturing Flight and Flow information that is globally standardized. The main FIXM components are FIXM Core, FIXM Applications and FIXM Extensions.

4.2.1.3.2.1 FIXM Application

A FIXM Application is a constituent of FIXM that meets the needs to the implementation of FIXM Core within a specific context. Its relevance can span global, regional, or local domains based on the particular context. Essentially, an FIXM Application furnishes context-specific 'message data structures' and 'message templates,' facilitating a standardized representation of FIXM-based messages exchanged through SWIM information services (FAA, 2023).

A demonstration of a FIXM Application is the FF-ICE Application, this application is tailored to address the utilization of FIXM Core within the specific framework of FF-ICE. It furnishes standardized FF-ICE Message data structures (such as those for representing the FF-ICE Filing Status, the FF-ICE Planning Status, etc.) and FF-ICE message templates (for instance, the template for the FF-ICE Filed Flight Plan Message, the template for the FF-ICE Flight Cancellation Message, etc.) in accordance with the FF-ICE Implementation Guidance Manual (ICAO, 2022).

4.2.1.3.2.2 FF-ICE Messages

The FF-ICE message data structures constitute the specific data elements that characterize FF-ICE Messages. While they don't delineate a flight, they play a crucial role in comprehending the purpose and significance of an FF-ICE information exchange (FAA, 2023). The FF-ICE Application models the following FF-ICE message data structures:

1. A model element that generically represents an FF-ICE Message, including its identifier, timestamp, type, etc. An enumeration outlines the possible types of FF-ICE Messages, such as Filed Flight Plan messages, Submission Response messages, and Filing Status messages.
2. Model elements representing various FF-ICE statuses along with their potential values:
    - Planning statuses: CONCUR / NEGOTIATE / NON_CONCUR
    - Filing statuses: ACCEPTABLE / NOT_ACCEPTABLE / PENDING
    - Submission statuses: ACK / MAN / REJ
3. Model elements representing FF-ICE participants and their properties, used for identifying operational stakeholders sending and receiving FF-ICE messages, or the list of relevant ASPs, etc.

4.2.1.3.3 Desired Trajectory

A new element in the eFPL is the Desired Trajectory, this is the 4D trajectory that is requested and generated by the AU with its knowledge of the ATM systems' configuration and published restrictions. It is the shortest and most economical route that the AU wants to follow, without the constraints from the NM. An airline will file their desired route in the systems, IFPS, of the NM. The NM will send back the Agreed Trajectory, this is the route will all the constraint that apply on their trajectory.

With the new features of the FF-ICE services they want to share the desired trajectory with the en-route ASNPs. The Use CASE (Use of AU Filed Desired Route/Trajectory), made by SESAR, provides a representation of sharing the desired trajectory. This Use Case is about the NM sharing the desired route of the flight to enroute ANSPs. So, that the enroute ATCO assesses whether constraints set in the agreed trajectory and being inside the centre's AoR can be removed and bringing the flown trajectory closer to the desired route. The ATCO will initiate the necessary coordination with other internal sectors or the next ANSP, and/or flow managers. Flow managers will coordinate with the downstream flow managers and NM as needed, depends on the impact (D. Lalor, 2023).

This will offer significant possibilities if the TDT-concept, the predefined change in route, can be in the eFPL and distributed the same way as the desired route. According to Magnus Molbaek, author of the SESAR document and deployment manager at SESAR, the idea of sharing the TDT the same way will be possible if the whole concept is deployed (Molbaek, 2023).

4.2.1.3 Transition phase and mixed mode in Europe

As Europe navigates the transition phase towards the adoption of FF-ICE/R1, a mixed-mode scenario has emerged to accommodate varying levels of readiness among AUs and ANSPs. This interim period presents unique challenges and demands a flexible approach to ensure a smooth integration of FF-ICE/R1 capabilities.

Acknowledging the diverse landscape, not all AU have fully embraced FF-ICE/R1 capabilities. This necessitates a transitional approach to accommodate both capable and non-capable AUs. Similarly, not all ANSPs are uniformly FF-ICE/R1 capable. The transition phase requires a nuanced strategy to bridge the gap between varying levels of readiness among ANSPs.

The NM assumes a pivotal role in supporting both FF-ICE/R1 capable and non-capable AU. This involves seamlessly receiving and managing both ICAO2012 and eFPL submissions. The NM efficiently handles the reception of both traditional ICAO2012 flight plans and the modern eFPL submissions. This dual capability ensures that AUs can continue operations irrespective of their FF-ICE/R1 readiness. The NM's support extends to handling messages from both the legacy Aeronautical Fixed Telecommunication Network (AFTN) and the modern SWIM. This ensures a seamless flow of information across diverse communication platforms (SESAR, SESAR Master Plan D5, 2008).

Non-capable European ANSPs receive support from the NM in translating eFPL and related messages into the traditional ICAO 2012 format. This translation mechanism ensures compatibility with existing systems during the transition phase. On the other hand, capable European ANSPs benefit from the NM's capability to convert ICAO 2012 flight plans and related messages into the modern eFPL format. This facilitates interoperability with FF-ICE/R1 systems and fosters a smooth transition to advanced data exchange protocols (Mavoian, 2023).

4.2.2 FF-ICE Release 2

The second release is about the post-departure, about trajectory revision while the flight is airborne. The TDT-concept will fit perfectly within the second release, the only problem for this investigation is that this feature of FF-ICE will launch approximately in 2030, if not later, according to (ICAO, 2023).

The execution phase of trajectory management is crucial for enabling adjustments initiated by AUs, NM, or local FMP, fostering operational agility and collaboration. Dedicated services facilitate communication and coordination among stakeholders, accommodating inputs from AUs, NM, and local FMP for real-time information exchange. A robust technological infrastructure supporting trajectory revisions must be agile, responsive, and interoperable. Scalability and adaptability are crucial for varying levels of complexity. The execution phase encourages collaboration among AUs, NM, and local flow management, fostering an environment of collective decision-making. Focus on supporting FF-ICE/R2 Trajectory Revision underscores the commitment to aligning trajectory adjustments with overarching operational goals. The aviation ecosystem can navigate trajectory revisions with agility, precision, and a collaborative spirit by addressing diverse needs. (Chiesa, 2023).

4.2.2.1 Problem Statement

4.2.2.1.1 Trajectory changes/revision in execution on AU initiative

In the current aviation landscape, trajectory changes during the execution phase are predominantly facilitated through the controlling ANSP. However, this approach presents challenges that warrant reconsideration to enhance efficiency and collaboration, particularly when initiated by AUs.

The primary avenue for altering a flight plan mid-execution is reliant on the controlling ASNP, impeding system agility and introducing complexities in response to dynamic operational requirements put forth by AUs.

Recognizing the need for flexibility, the pilot, being the primary stakeholder in the cockpit, often initiates trajectory changes. However, the current process places a manual and resource-intensive burden on ATC, undermining the potential for streamlined operations. The manual nature of implementing trajectory changes initiated by pilots amplifies the workload for ATC, consuming valuable time and introducing potential points of error. This highlights the necessity for more automated and collaborative approaches.

A critical gap in the current framework is the absence of mechanisms for proposing end-to-end trajectories initiated by AUs. This limitation restricts the optimization potential during execution, hindering the system's ability to holistically assess and propose comprehensive trajectory adjustments.

Upon the completion of a route and its subsequent distribution by the NM, there is a noticeable gap in CDM processes. The lack of systematic assessment of the overall trajectory impact hinders optimal decision-making during execution, leaving room for potential inefficiencies.

Unlike the pre-flight phase facilitated by FF-ICE/R1, the current execution phase lacks mechanisms for sharing detailed trajectory information. This absence stifles collaborative decision-making, preventing the exchange of critical trajectory details between stakeholders.

4.2.2.1.2 Trajectory changes/revision in execution on NM initiative

During the execution phase under the NM initiative, trajectory changes are communicated by ATC through clearances. This involves directives given to aircraft to alter their planned trajectories in response to real-time operational considerations.

Notably, there is no anticipation of trajectory changes in the current process. Changes are initiated and communicated as immediate adjustments based on the prevailing operational requirements.

The communication of trajectory changes, particularly those related to the Demand Capacity Balancing (DCB) initiative, predominantly occurs through voice communication with ATC. This method is identified as significant effort-consuming, potentially impacting efficiency. Currently, there is an absence of CDM involving the FOC. The lack of integration in decision-making processes may result in a disjointed approach to trajectory changes, potentially impacting the overall effectiveness of the initiative.

4.2.2.2 FF-ICE/R2 Targeted Scope

FF-ICE/R2 introduces enhancements to the negotiation process between eAU and eASPs, focusing on changes to the agreed trajectory. The focus is on continuous negotiation, which guarantees coherent conversations and adaptability throughout the flight. The negotiation only concerns modifications to the mutually agreed trajectory; ATCO is not involved in any way, simplifying the procedure for efficient management.

Central to FF-ICE/R2 is the concept of the agreed trajectory, shared and maintained across relevant eASPs for a unified trajectory management process. The goal is to provide timely clearances aligned with the agreed trajectory, contributing to operational efficiency. The post-departure planning framework establishes agility, adaptability, and efficient negotiation processes.

The dynamic trajectory is actively managed in real-time, adapting to changing circumstances during the flight. The framework allows trajectory re-optimization in response to operational conditions, ensuring alignment with evolving requirements. Collaboration with ATC is crucial for promptly providing the new agreed trajectory, enabling timely re-clearance. The FF-ICE/R2 framework navigates trajectory dynamics, establishing a resilient and responsive structure for post-departure trajectory planning in air traffic management's evolving landscape.

4.2.2.3 FF-ICE/R2 Key Features

FF-ICE/R2 adopts an optional approach, avoiding a disruptive implementation out of nowhere. This flexibility allows for a gradual transition, fostering a mixed-mode environment where stakeholders can adapt at their own pace. Essential to FF-ICE/R2 is its dependency on FF-ICE/R1. This mutual dependence ensures that the foundation laid by FF-ICE/R1 processes is retained, underscoring the evolution as a complementary and progressive phase. Thus, the question in the future is if TDT should also be in the FF-ICE/R1 processes, due to the fact TDT is a planned inflight reroute.

FF-ICE/R2 empowers negotiation between FF-ICE/R2-enabled stakeholders, specifically the eAU and eASPs. This negotiation revolves around defining a New Agreed Trajectory, developing adaptability and precision. process. While ATCOs are not directly involved in negotiations, their role is pivotal in the clearance delivery process. FF-ICE/R2 recognizes the importance of ATCOs in ensuring smooth clearance delivery, aligning the negotiated trajectory with operational requirements. For example, the change of route by flight from Bari to

Amsterdam will be at the KUAC. The ATCO of this sector will need to provide the clearance for a reroute but is left out of the negotiation the ATCO can focus on his duty.

FF-ICE/R2 maintains the existing ATC coordination procedures, ensuring compatibility with established protocols. This approach implies that post-departure negotiation might be limited across certain FIR boundaries, preserving operational consistency. For ANSPs that are not FF-ICE/R2-enabled, flexibility is retained. These non-enabled ASPs may accept route changes through their airspace, provided the adjustments occur before entering their designated airspace and are coordinated in advance.

4.2.2.4 Negotiation Process

The negotiation process is a crucial interaction between the eAU and the planner(s) representing one or more eASPs. The primary objective is to achieve a consensus on a new Agreed Trajectory, contributing to effective trajectory management. The negotiation process is a two steps process involving the R2 trial service followed by a decision to modify the Agreed Trajectory through a revision request. The trial service is conducted, providing an opportunity for both parties to assess and discuss the proposed trajectory. This phase serves as a preliminary exploration of the trajectory's acceptability. Following the trial service, the negotiation progresses to the decision phase. Here, a formal request for the modification of the Agreed Trajectory is made. This step signifies a mutual understanding and commitment to adjust the trajectory based on the negotiations. Throughout the negotiating process, there are three types of responses:

CONCUR: In this scenario, the flight plan, including the route and trajectory, is deemed acceptable without the need for modification. The implication is that if the flight plan were to be filed, it would receive acceptance. This represents a harmonious agreement without the necessity for adjustments.

NEGOTIATE: This step acknowledges that the flight plan, specifically the route and trajectory, is acceptable and would receive approval if filed. However, additional constraints or ATM configuration factors applied by the eASP might result in a trajectory slightly deviating from the Desired trajectory. Negotiations in this phase revolve around these nuanced adjustments.

NON-CONCUR: In the event of non-concurrence, the flight plan is found to be non-compliant with published airspace/route availability or established restrictions. Filing such a flight plan would lead to rejection or an unacceptable status. This outcome signifies a misalignment that needs resolution through further negotiation or adjustment.

4.2.2.4.1 Difference between FF-ICE R1 and R2 Trial Services

Understanding the differences between FF-ICE R1 and R2 Trial Service is crucial for grasping the evolution in trajectory management processes. The **R1 Trial Request is** a standalone transaction submitted for the evaluation of an alternative (e.g., change of route) to an existing flight plan, whether Preliminary or Filed. With no impact on the flight data on record. R1 aims to obtain applicable restrictions/constraints and negotiate a possible trajectory adjustment.

The R2 Trial Request marks a continuity from pre-departure to execution, emphasizing a seamless trajectory management process. R2 leverages the established R1 service, ensuring a cohesive transition from the pre-departure phase. The R2 description requires an update to reflect the execution status as an option, recognizing the trajectory's evolution during execution. Use of Trial service remains optional, and obtains feedback, thus providing flexibility for finding an optimal solution.

4.2.2.4.2 Revision Request

The Revision Request stands as a pivotal element in the post-departure negotiation landscape within the FF-ICE framework. It operates in conjunction with Trial Requests, collectively contributing to the development of alternate trajectories during the flight's operational phase.

Trial Requests play a complementary role in the trajectory development process. They are initiated to assess the feasibility and acceptability of alternative trajectories. It is imperative to dispatch Trial Requests to all relevant eASPs, ensuring a comprehensive evaluation of potential trajectory changes.

Revision Requests serve the purpose of modifying the agreed trajectory based on the outcomes and insights gained from Trial Requests. These requests are instrumental in adapting the trajectory to align with operational requirements or unforeseen circumstances. When a Revision Request is initiated and the agreed trajectory requires modification, all relevant eASPs are promptly informed. This proactive communication ensures that stakeholders are aware of the trajectory changes, fostering collaboration and shared understanding among the involved parties. Figure 10, illustrates the how the services will work when the request is accepted. The figure shows that all downstream eASPs are addressed of the change in route. This revision request means a new FPL for the eASPs that were added to distribution as result of the route change. The FOC will provide the new agreed trajectory to the FMS.

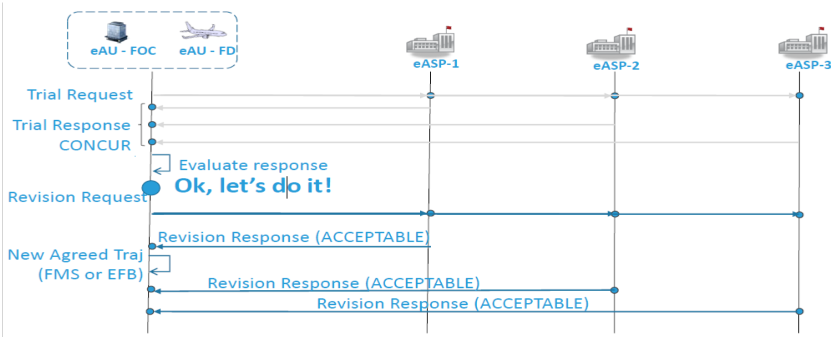


Figure 9, illustration about the process of the FF-ICE R2 Trail & Revision service

4.2.2.4.3 Negotiation Horizon

The negotiation horizon is a point along the Agreed Trajectory, beyond which strategic negotiations are permitted to result in an alteration to the Agreed Trajectory. The point may be a specified distance or time ahead of the aircraft present position. The point of divergence (between the clearance and Agreed Trajectory) must occur beyond the point of concern to the current ATCO. According to Andrea Pleger, the lead-time that KUAC need for an inflight reroute will be around 2 hours.

The negotiation horizon is invented because the R1 services were not created to support post- departure negotiations. R2 capabilities/services are focused on supporting post-departure negotiations. The R2 includes ATC as an engaged (tactical) actor as the flight progresses as well as the complementary planning function, which is sometimes referred to as strategic. A structured mechanism is necessary to determine when/where requested alterations (or changes) to the agreed trajectory do not require involvement of ATC.

ICAO defined the following types of zones that will affect the location of the negotiation horizon. The implementation of TDT, the negotiation horizon, must be outside these predefined zones:

- Zone of Tactical Interest: Time or distance beyond the aircraft present position within which the Agreed trajectory may not be altered by strategic negotiation. For strategic negotiations, the point of alteration must be beyond the Zone of Tactical Interest.

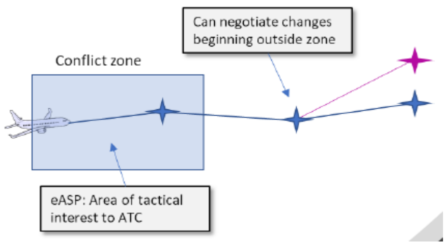


Figure 10, Zone of Tactical Interest defined by ICAO.

- Coordination Zone: A time or distance surrounding a coordination boundary within which the Agreed Trajectory may not be altered by strategic negotiations. For strategic negotiations to occur, the point of alteration must be beyond the Coordination Zone. Figure 12, will illustrate the considerations of the coordination zone and

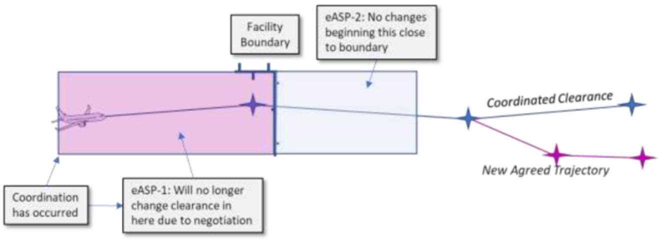


Figure 11, Coordination Zone defined by ICAO.

- Terminal Zone: Time after departure from or before arrival to an aerodrome during which strategic changes to the Agreed Trajectory are not permitted when the aircraft is in this Terminal Zone. Upon departure, strategic negotiation requires the point of alteration from the Agreed Trajectory to be beyond the Terminal Zone. For arrivals, strategic negotiation within the terminal zone cannot take place once the relevant aircraft enters the Terminal Zone at the destination aerodrome.

4.2.2.5 FF-ICE R2 Scenario

Figure 13 illustrates a scenario, provided during the knowledge levelling day, where the trajectory revision is on airport initiative. This was an operational need to balance the south and north arrival flow of the airport of Parijs (Charles de Gaulle). This scenario describes the TDT concept, only then the initiative will be from LVNL In particular the FMP of LVNL, further details are described in the chapter of the Results.

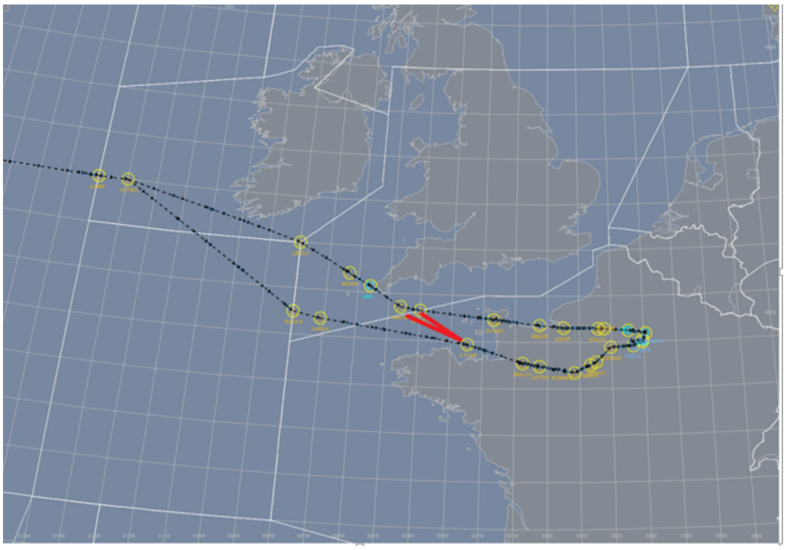


Figure 12, illustration of FF-ICE R2 scenario.

4.3 Laws, regulations and requirements

This chapter contains information related to TDT, if inflight rerouting is allowed by the current laws and regulations. Additionally, this chapter will also give insight in the legislation of the ICAO FF-ICE concept.

4.3.1 TDT legislations

In the law and regulations for TDT, it is necessary to examine existing processes resembling in-flight rerouting, as well as those of ATFCM. This is crucial to determine whether TDT is currently feasible within the legal framework. This has been done by reviewing various manuals.

4.3.1.1 DOC 44444 - Procedures for Air Navigation Services

Doc 4444 discusses various aspects related to air traffic control services, radar vectoring, the use of radar in air traffic control, Automatic Dependent Surveillance (ADS) services, and the role of the NM in improving airspace utilization and reducing delays. Let's explore the key points and their potential relation to in-flight rerouting:

Radar controllers are instructed to issue clearances during vectoring or providing direct routing to maintain prescribed obstacle clearance until the pilot resumes own navigation. This emphasizes the need for obstacle clearance during changes to the aircraft's route, which is relevant to in-flight rerouting scenarios. If a rerouting is necessary, ensuring obstacle clearance is crucial for safety.

Radar information is used to improve airspace utilization, reduce delays, provide direct routings, and enhance safety. The use of radar to provide direct routings aligns with the concept of in-flight rerouting. Radar information helps controllers assess the airspace and suggest or approve rerouting options to optimize flight profiles and reduce delays.

ADS is used to improve airspace utilization, reduce delays, and provide for direct routings. ADS services contribute to efficient airspace utilization and direct routings, aligning with the objectives of in-flight rerouting to optimize flight paths and reduce delays.

The Network Manager is responsible for continuous improvement of network operations, ensuring the Network Strategy Plan contributes to union-wide targets, and coordinating cooperation between operational stakeholders for efficient airspace use. The Network Manager identifies operational safety hazards, supports stakeholders in airspace improvements, and develops procedures for ATFM delay attribution. The Network Manager's responsibilities include identifying alternative routings to avoid congested areas, offering rerouting options, and supporting flexible use of airspace. This is directly relevant to in-flight rerouting, as it involves proactive measures to optimize airspace use and reduce delays.

Airspace design projects must be compatible and consistent with the European Route Network Improvement Plan (Union, 2019). The Network Manager, in coordination with local ATFM units, identifies alternative routings to avoid or alleviate congested areas. The emphasis on compatibility and coordination for airspace design projects, as well as the identification of alternative routings, aligns with the principles of in-flight rerouting to ensure smooth integration with overall airspace plans and reduce congestion (ICAO, 2001).

4.3.1.2 ICAO Annex 2 Rules of the Air

Chapter 3 outlines rules of the air related to flight planning, adherence to flight plans, changes to flight plans, and communication requirements during flight operations. These rules are crucial for ensuring safe and efficient air traffic management.

Flight plans must be submitted before departure or transmitted during flight to the appropriate air traffic services unit. For flights under ATC service, the flight plan should be submitted at least sixty minutes before departure or at a time ensuring its receipt by ATC ten minutes before reaching specific points. The requirement to submit a flight plan in advance and update it during flight is crucial for ATC to anticipate and manage air traffic efficiently. In the context of in-flight rerouting, adherence to these rules ensures that ATC is aware of the planned route and any changes, facilitating a smoother process if rerouting becomes necessary due to unforeseen circumstances.

Changes to a flight plan, whether for IFR or controlled VFR flights, must be reported as soon as practicable to the appropriate air traffic services unit. Aircraft must adhere to the current flight plan unless a change has been requested and clearance obtained from the appropriate ATC unit. If in-flight rerouting is required due to weather, air traffic congestion, or other reasons, the rules emphasize the importance of promptly informing ATC about changes. This ensures that ATC is informed and can provide necessary clearances for the rerouted flight, contributing to overall safety and efficiency.

Requests for changes to cruising level or route must include specific information, such as aircraft identification, requested new details, and revised time estimates. In the context of in-flight rerouting, if a change of route or cruising level is necessary, providing detailed information as outlined in this section is crucial. This information helps ATC assess the feasibility of the proposed changes and manage the overall air traffic flow effectively (ICAO, 2005).

4.3.1.3 ICAO DOC 9426 Air Traffic Services Planning Manual

Chapter 1 on Air Traffic Flow Management and Flow Control, discusses the challenges and inefficiencies in the current utilization of airspace. It highlights the discrepancy between ATC capacity and users' demands, leading to various issues during peak traffic periods. The rigid fixed route structure is identified as a restriction on the optimal use of airspace and the cost-effective execution of flight operations. Moreover, problems with Communication, Navigation, and Surveillance (CNS) systems, along with a lack of harmonized system development, contribute to existing limitations.

The text emphasizes the consequences of these shortcomings, including delays, flight re-routing, and disruptions, all of which negatively impact flight regularity and efficiency. The need for a comprehensive ATM plan is stressed to effectively manage the growing demand for air traffic and optimize airspace usage.

In the subsequent sections (1.2.4), the text explores ATFM and the challenges faced in achieving an optimum flow of air traffic. It discusses constraining factors such as conflicting user requirements, air navigation system limitations, and unexpected weather conditions. The introduction of flow control measures, including delays, in-flight holdings, uneconomic flight levels, re-routing, and diversions, is presented as a response to alleviate issues when the current air traffic system is unable to cope with the volume of traffic.

Furthermore, the text delves into the intricacies of determining air traffic system capacity, involving assessments of traffic demand and the regulation of traffic flow. It emphasizes the importance of accurate predictions, preparation in advance, and collaboration between ATFM services and ATC to address peak traffic conditions effectively. The preference for applying flow control measures, particularly delays, to aircraft on the ground rather than those in flight is also highlighted.

In the context of in-flight rerouting, the text indirectly points to the challenges that necessitate rerouting, such as congestion, delays, and disruption, and emphasizes the importance of proactive measures to manage air traffic flow efficiently. The outlined issues set the stage for the further exploration of in-flights rerouting as a potential solution to address the identified challenges is subsequent of the thesis (ICAO, 1984).

4.3.1.4 Commission Regulation No 255/2010

In navigating the complex airspace of the European Air Traffic Management Network (EATMN), a robust legislative framework becomes imperative to ensure seamless and efficient air travel operations. This section delves into the legislative provisions, specifically Articles 5, 6, 7, and 9, that outline the obligations of Member States, ATS units, and operators concerning inflight rerouting within the ATFM system.

Article 5 underscores the responsibilities of Member States regarding the central unit for ATFM, emphasizing key obligations:

Identification of Alternative Routings:

- Member States must collaborate with local ATFM units to identify alternative routes, strategically circumventing or alleviating congested airspace. The impact on the overall performance of the EATMN is a critical consideration in this decision-making process.

Offering Re-Routing Options:

- The central unit for ATFM is tasked with proactively offering re-routing options to flights, maximizing the benefits of the identified alternative routes.

Monitoring Flight Plans:

- Ensuring vigilance, the central unit for ATFM monitors instances of missing flight plans and multiple flight plans being filed.

Article 6 delineates the general obligations of ATS units, emphasizing their responsibility to promptly provide specific data to the central unit for ATFM. This includes deviations from flight plans, contributing to real-time data exchange within the ATFM system.

Article 7 places obligations on operators, emphasizing the necessity of maintaining a single, accurately reflective flight plan for each intended flight. Additionally, it stresses the integration of all relevant ATFM measures and changes into planned flight operations, ensuring effective communication to pilots.

Article 9 addresses the consistency between flight plans and airport slots. Member States are mandated to facilitate the exchange of accepted flight plans between the central unit for ATFM or local ATFM units and airport slot coordinators or managing bodies of coordinated airports. This exchange of information ensures alignment and harmonization of flight operations at coordinated airports.

This legislative framework serves as a cornerstone for the integration of inflight rerouting measures within the broader context of air traffic management, fostering a systematic and collaborative approach to optimize airspace utilization and enhance overall operational efficiency (EUR-LEX, 2010).

4.3.1.5 Commission Regulation No 716/2014

Chapter 3 of this regulation is about Flexible Airspace Management (FAM) and Free Route Airspace (FRA). In this chapter, delves into the legislative landscape surrounding FAM and FRA operations. FAM and FRA represent pivotal components that empower airspace users to navigate closer to their preferred trajectories, unbounded by fixed airspace structures. This legislative framework ensures the seamless integration of operations, balancing the diverse needs of airspace users, including scenarios like military training.

The goal of Airspace Management (ASM) and Advanced Flexible Use of Airspace (A-FUA) is to provide flexibility in managing airspace reservations based on user requirements. This involves dynamic airspace management without rigid route networks. System requirements include supporting forecast demand, enabling cross-border activities, and facilitating a cooperative decision-making process among operational stakeholders.

System Requirements:

- Support for fixed and conditional route networks, Direct Routings (DCTs), FRA, and flexible sector configurations.
- Capability to respond to changing airspace demands.
- Enhancement of the Network Operations Plan (NOP) through cooperative decision-making.
- Support for cross-border activities, ensuring shared use of airspace.

ATC System Requirements:

- Flexible configuration of sectors for optimized dimensions and operating hours.
- Continuous assessment of the impact of changing airspace configurations on the network.
- Correct depiction of configurable airspace reservations in ATC systems.

Data Sharing:

- Airspace configurations accessible via Network Manager systems.
- Timely and accurate information for airspace users available through Network Manager systems.

Interface Requirements:

- Secure interfaces among ASM, ATFCM, and ATC systems.
- Modification of ATC systems to comply with relevant regulations.

Free Route, implemented through Direct Routing Airspace and FRA, offers lateral and vertical freedom with entry/exit conditions. The system requirements for Free Route cover flight plan processing, dynamic re-routing, ATFCM planning, traffic load management, and more.

The system requirements for the effective implementation of Flexible Airspace Management (FAM) and Free Route operations encompass various functionalities within network management and ATC systems. These requirements are crucial for seamless and adaptive airspace management. Here's a breakdown of the specified system requirements:

Network Management Systems:

- **Flight Plan Processing and Validation:** Implementation of robust processing and validation mechanisms for DCTs and FRA.
- **IFPS Routing Proposals:** Generation of routing proposals based on FRA by the IFPS.
- **Dynamic Re-Routing:** Capability for dynamic re-routing to accommodate changing airspace conditions and requirements.
- **ATFCM Planning and Execution:** Integration of ATFCM planning and execution functionalities within FRA.
- **Traffic Load Calculation and Management:** Proficient calculation and management of traffic loads to optimize airspace utilization.

ATC Systems:

- **Flight Data Processing System:** Inclusion of Human-Machine Interface (HMI) for trajectory and flight planning, independent of fixed Air Traffic Service (ATS) networks.
- **Flight Planning Systems:** Implementation of flight planning systems supporting FRA and cross-border operations.
- **ASM/ATFCM Management:** Integration of functionalities for managing FRA within the ASM and ATFCM systems.
- **Medium Term Conflict Detection (MTCD):** Deployment of MTCD, including Conflict Detection Tools (CDT), Conflict Resolution Assistant, Conformance Monitoring, and APW for dynamic airspace volumes/sectors within FRA. Trajectory prediction and de-confliction support an automated MTCD tool adapted for FRA and, when necessary, for DCT.
- **Airspace Users' Systems:** Implementation of flight planning systems by airspace users to manage dynamic sector configurations and FRA.
- **Flight Data Processing System (FDPS):** Support for FRA, DCT, and Advanced Flexible Use of Airspace within the Flight Data Processing System.
- **Controller Working Position:** Adequate support for operating environments as needed by the controller working position.

Flexible Airspace Management and Free Route operations apply to airspace above flight level 310 in the ICAO EUR region, falling under the responsibility of Member States.

This legislative overview sets the stage for understanding the intricate relationship between regulations and the implementation of inflight rerouting, ensuring a comprehensive exploration of the airspace management landscape (COMMISSION, 2014).

4.3.2 ICAO FF-ICE legislations

Common Project 1 (CP1) aims to harmonize and improve ATM across the European Union. The regulations and requirements for CP1 are established through a combination of EU regulations, legal acts, and implementing regulations. Airspace Users are required to update their flight planning systems and start filling eFPL to support the exchange of FF-ICE release 1 Filling Service by December 31, 2025.

CP1 comprises specific ATM functionalities, including extended arrival management, integrated AMAN/DMAN in high-density terminal areas, airport integration and throughput, flexible airspace management and free route airspace, network collaborative management, systemwide information management, and initial trajectory information sharing.

- FAM and FRA (AF 3): This functionality allows airspace users to fly as closely as possible to their preferred trajectory without being constrained by fixed airspace structures or fixed route networks, promoting flexibility and minimizing impacts on other airspace users.

Under the framework of CP 1 Regulation, specific provisions pertaining to FF-ICE/R1 have been outlined, emphasizing the imperative role of SWIM in advancing air traffic management. Key elements of this regulation are detailed in AF 5 (SESAR, 2023), focusing on the integration of ATM sub-functionalities on common infrastructure components and the SWIM Yellow Profile technical specifications:

- The regulation under AF 5 recognizes the significance of ATM sub-functionality integration on common infrastructure components. This underscores the need for a cohesive approach in deploying functionalities that enhance the overall efficiency of air traffic management.
- Furthermore, AF 5 delves into the integration of ATM sub-functionalities specifically on the SWIM Yellow Profile technical infrastructure. This technical alignment ensures a standardized and interoperable framework for information exchange within the aviation ecosystem.
- The regulation, particularly in section 5.1.6, provides specifications for ATM sub-functionality on flight information exchange, specifically adhering to the Yellow Profile. This establishes a common ground for the exchange of critical flight-related information.
- Initial Trajectory Information Sharing (AF 6 or i4D): This functionality improves the use of target times and trajectory information, including the use of on-board 4D trajectory data by ground ATC and Network Manager systems. It aims to reduce tactical interventions and enhance de-confliction.

To ensure a seamless integration, the implementation of FF-ICE/R1 services must comply with applicable SWIM specifications. This compliance guarantees the standardized exchange of information and interoperability across aviation stakeholders. Stakeholders operating ATM systems are mandated to enable the use of flight information exchange services. This requirement ensures that all components of the air traffic management system actively contribute to the collaborative and efficient exchange of vital flight-related data.

It is notable that the FF-ICE Planning Service is not mandated by CP 1. While other FF-ICE/R1 services are integral to compliance, the Planning Service is exempt from the regulatory mandate.

In conclusion, CP 1 Regulation serves as a guiding framework for the integration of FF-ICE/R1 services, emphasizing the importance of standardized information exchange, compliance with SWIM specifications, and active participation of stakeholders in advancing the efficiency and collaboration within the aviation ecosystem (Lepori, FF-ICE in the EU CP1 regulation, 2023).

The deployment of FF-ICE and its associated requirements is governed by Commission Implementing Regulation (EU) No 116/2021 (CP1), which supersedes (EU) No 716/2014, commonly referred to as the "Pilot Common Project (PCP)," dated June 27, 2014. FF-ICE R1 Services are mandated to be deployed in a timely, coordinated, and synchronized manner, aligning with all ATM functionalities mature for implementation and contributing to the essential operational changes outlined in the European ATM Master Plan (Commission T. E., 2021).

All operational stakeholders within the EATMN, excluding airports, are required to adopt FF-ICE services. This encompasses the NM, AUs, and ANSPs. The EATMN, as defined in (EU) 549/2004, constitutes the systems listed in Annex I to Regulation (EC) No 552/2004. This collection enables the provision of air navigation services within the Community, encompassing interfaces at boundaries with third countries. Annex I to Regulation (EC) No 552/2004 further categorizes the EATMN into eight systems, covering airspace management, air traffic flow management, air traffic services procedures, communications systems, navigation systems, surveillance systems, aeronautical information services, and systems for the use of meteorological information (SESAR, 2022).

CP1 mandates that all Airspace Users operating in the EATMN Airspace, including overflights, must adopt FF-ICE. In practical terms, all Airspace Users operating in this airspace are required to commence filing eFPL by December 31, 2025, at the latest. This implementation requirement was clarified and mutually agreed upon with the European Commission during a bilateral meeting with EC-SDM on October 6th, 2022, (EUROCONTROL, 2023)

The implementation of CP1 and its functionalities, such as flexible airspace management and initial trajectory information sharing, relates to the concept of in-flight rerouting. The emphasis on free route airspace allows for more flexibility in aircraft trajectories, enabling optimized and dynamic rerouting during flight to achieve better efficiency and reduce delays. Additionally, improved trajectory information sharing supports better coordination and de-confliction, contributing to the overall effectiveness of in-flight rerouting procedures (COMMISSION, Common Project One, 2021).

4.4 FF-ICE Use Cases for TDT

The gathered information from key stakeholders to three FF-ICE Use Cases (UC) for TDT. The use cases describe how the communication flow could be when TDT is operational. These use cases can be used in the future, to determine which strategy will work best and be most convenient for all stakeholders involved. There shouldn't be an increase in workload as a result of TDT deployment. The use case that minimizes load should be chosen when utilizing the cases. To determine which use case steps proves most effective for the stakeholders involved. The use cases are made with the help of Magnus Molbaek, who was mentioned earlier.

The use cases will be in the format (table 4) provided by EURONTROL (Lepori, 2023):

Name	Name of the Use Case, used for mnemonic and readability purposes.
Description	Brief description of the use case
Trigger Event	What causes the use case to occur?
Affected stakeholders	The stakeholders that are involved when TDT is operational
Assumptions	Assumptions of certain actions, conditions and systems in place
Preconditions	Requirements that must be in place prior to the use case
Use Case Steps	Description of the essential steps of the use case procedure
Postconditions	Requirements that must be in place following the use case
Benefits	Non exhaustive list of benefits expected from the use case

Table 4,. EUROCONTROL format for FF-ICE Use Cases.

After many discussions it became clear that the trigger for TDT, an inflight reroute, needs to come from the FMP at LVNL. The trigger in all the three use case is the same because, an unexpected bunch of air traffic monitored by the FMP controller using his DST. The trigger indicates when TDT should be activated, the FMP will contact the next stakeholder, depending on which UC, about the flight that needs to be rerouted (TDT) to the other sector.

The stakeholders from chapter 4.1.2 are the ones involved when TDT is operational:

- The FMP who indicates the trigger for TDT.
- The NM is the one that eventually approves the change in route, on the basis of their ETFMS.
- The ANSP of KUAC, is the one that coordinates the change in route with the pilot.
- The FOC, flow controller and flight dispatcher, will validate with the pilot if the change in route is possible, considering the amount of fuel onboard.

During the process of TDT the assumption for all the three the UC are that the predefined TDT suitable city-pairs are known and programmed in the DST. The extra track miles flown, due to an inflight trajectory change, are negligible. Therefore, the aircraft will not have any fuel problems. And that an inflight trajectory change won't led to an overload of the capacity in the other sector.

4.4.1 FF-ICE Use Case 1

Table 5 describes use case 1, the FMP controller of LVNL utilizes their DST to monitor unexpected traffic congestion over the RIVER IAF. The DST, similar to the NM CIFLO system, provides direct access to ATFCM information, offering insights into the status of in- and outbound air traffic and ATFCM status. This tool enables the FMP to monitor, detect, and investigate issues related to sector capacities.

Upon detecting an overload in the RIVER airspace, the DST suggests rerouting TDT-suitable city-pairs to the ARTIP IAF. This rerouting aims to alleviate the workload for LVNL's ATCOs and prevent the need for airborne holding. Consequently, the flight route from the south, initially passing through RIVER (Polderbaan), is altered to ARTIP (Zwanenbrugbaan) through intervention.

The FMP, with a 2-hour lead time, communicates the inflight reroute from RIVER to ARTIP to the FOC. The FOC, in turn, proposes the new route to the NM. Following NM's approval of the trajectory change, the flight dispatcher notifies the pilot of the updated route.

Additionally, the ANSP of KUAC is informed by the NM about the new trajectory change, and this information is subsequently updated in the EFTMS.

Description: This use case describes the process of Tactical Demand Tailoring. The FMP of LVNL monitors, via their Decision Support Tool (DST), an unexpected traffic bunch over RIVER. The DST is a system, relatable to the NM CIFLO system, which gives direct access to ATFCM information. It provides the FMP with the status of in- and outbound air traffic, and the status of ATFCM allowing traffic monitoring, detection, and investigation of problems in the management of sector capacities. The DST indicates an overload in RIVER and suggest rerouting of TDT suitable city-pairs to ARTIP. This will reduce the workload for the LVNLs ATCOs and prevent a holding. So, the route from the south via RIVER (Polderbaan), by intervening, the route is changed to ARTIP (Zwanenbrugbaan). The FMP will inform, with a 2-hour lead-time, the FOC about an inflight reroute from RIVER to ARTIP. The FOC will propose a new route by NM. Once NM approves the trajectory change, the flight dispatcher will inform the pilot. KUAC is informed by the NM, the new trajectory change is updated in the EFTMS.
Trigger Event: Unexpected bunch of air traffic over RIVER, monitored by FMP using DST
Affected Stakeholders: • LVNL FMP • NM • FOC (pilot and dispatcher) • ANSP from KUAC
Assumptions: 1. It is assumed that the predefined TDT suitable city-pairs are known and programmed in the DST. 2. It is assumed that the extra track miles flown, due to an inflight trajectory change, are negligible. Therefore, the aircraft will not have any fuel problems. 3. It is assumed that an inflight trajectory change won't led to an overload of the capacity in the other sector.
Preconditions: 1. All stakeholders have an NM B2B certificate with an FF-ICE profile enabling the use of the trial service.
Use Case Steps: 1. The FMP identifies an unexpected bunch of air traffic over RIVER. 2. The FMP communicates to the airline's FOC, proposing an inflight reroute to ARTIP. 3. The flight dispatcher initiates a Trial request to NM through NMP Flight (EFTMS). 4. NM responds with a "Negotiate" message. 5. The Flight Dispatcher engages in negotiations with the pilot regarding the proposed new trajectory.

6. The pilot accepts the proposed new trajectory. 7. The flight dispatcher submits a revision request to NM via NMP Flight, including the updated trajectory. 8. NM responds with approval, and the newly agreed-upon trajectory is integrated into IFPS by the flight dispatcher. 9. The updated trajectory is disseminated to all stakeholders through the EFTMS system. 10. The flight dispatcher shares the mutually agreed-upon trajectory, incorporating the route into their Flight Management System (FMS).
Postconditions: 1. The aircraft is rerouted to a less congested sector (ARTIP). 2. Improved runway load balancing at Schiphol. 3. Decreased workload for ATCOs. 4. Cost savings for the airline by preventing a holding. 5. Environmental benefits with lower emissions at low altitude. 6. Reduced noise disturbance for inhabitants in the area due to the prevention of a holding at low altitude.
Benefits: Rerouting the flight from the selected TDT city-pair to a less congested sector (ARTIP) allows the aircraft to land on the other runway. As a result, Schiphol will benefit from improved runway load balancing utilize and a decrease in workload for the ATCO. In addition, it will save the airline money by preventing a holding, and it will improve the environment by lowering emissions at low altitude. Additionally, inhabitants in the area will experience reduced noise disturbance when a holding at low altitude is prevented.

Table 5 Use case 1

Figure 13 illustrates the communication flows between the stakeholders, using the FF-ICE R2 Trail- and Revision Request services described in section 4.2.2.4.

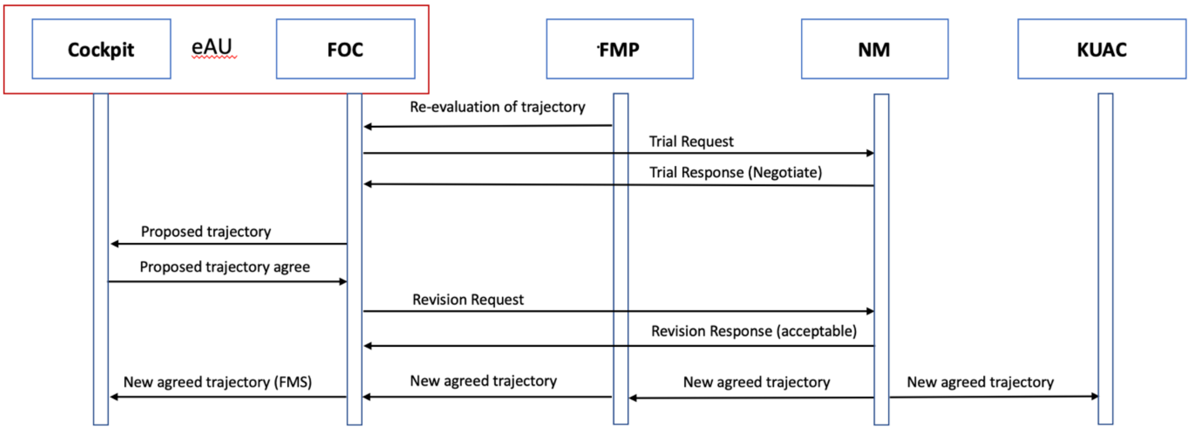


Figure 13, overview of the communication flows between the stakeholders.

4.4.2 FF-ICE Use Case 2

Table 6 ,outlines use case 2, the TDT process, initiated by the FMP of LVNL, to address an unexpected traffic buildup over the RIVER IAF.

The FMP utilizes the DST, a system comparable to the NM CIFLO system, providing direct access to ATFCM information. The DST offers insights into the status of in- and outbound air traffic, along with ATFCM status, enabling the FMP to monitor, detect, and investigate issues related to sector capacities.

Upon detecting an overload in the RIVER airspace, the DST suggests rerouting TDT-suitable city-pairs to the ARTIP IAF. This rerouting aims to reduce the workload for LVNL's ATCOs and prevent airborne holding. Consequently, the flight route from the south, initially passing through RIVER (Polderbaan), is intervened and changed to ARTIP (Zwanenbrugbaan).

The FMP notifies the ANSP of KUAC that the flight from the predefined TDT-suitable city-pair can be rerouted from ARTIP to RIVER with a 2-hour lead-time while the flight is airborne.

KUAC proposes a new route to the NM, informs the airline FOC about the reroute from RIVER to ARTIP in KUAC, and calculates a new route through the flight dispatcher. The flight dispatcher then informs the pilot of the new route, and the pilot updates the FMS accordingly.

<table>
<tr><th>Use Case 2: Trajectory revision on LVNL FMP initiative for balancing the runways at Schiphol</th></tr>
<tr><td> Description: This use case describes the process of Tactical Demand Tailoring. The FMP of LVNL monitors, via their Decision Support Tool (DST), an unexpected traffic bunch over RIVER.
The DST is a system, relatable to the NM CIFLO system, which gives direct access to ATFCM information. It provides the FMP with the status of in- and outbound air traffic, and the status of ATFCM allowing traffic monitoring, detection, and investigation of problems in the management of sector capacities.
The DST indicates an overload in RIVER and suggest rerouting of TDT suitable city-pairs to ARTIP. This will reduce the workload for the LVNLs ATCOs and prevent a holding. So, the route from the south via RIVER (Polderbaan), by intervening, the route is changed to ARTIP (Zwanenbrugbaan).
The FMP will inform the ANSP of KUAC that the flight from the predefined TDT suitable city-pair can be rerouted form ARTIP to RIVER with a 2-hour lead-time while the flight is airborne.
KUAC proposes new route by NM.
KUAC will inform airline FOC about a reroute form RIVER to ARTIP in KUAC. The flight dispatcher will calculate new route. The flight dispatcher will inform the pilot with the new route, the pilot will update the new route in the FMS. </td></tr>
<tr><td>Trigger Event: Unexpected bunch of air traffic over RIVER, monitored by FMP using DST</td></tr>
<tr><td>Affected Stakeholders:
LVNL FMP
NM
FOC (pilot and dispatcher)
ANSP from KUAC</td></tr>
<tr><td>Assumptions:
It is assumed that the predefined TDT suitable city-pairs are known and programmed in the DST.
It is assumed that the extra track miles flown, due to an inflight trajectory change, are negligible. Therefore, the aircraft will not have any fuel problems.
It is assumed that an inflight trajectory change won’t led to an overload of capacity in the other sector.</td></tr>
<tr><td>Preconditions:
All stakeholders have an NM B2B certificate with an FF-ICE profile enabling the use of the trial service.</td></tr>
<tr><td>Use Case Steps:
The FMP identifies an unexpected bunch of air traffic over RIVER.</td></tr>
</table>

2. The FMP notifies the Air Navigation Service Provider (ANSP) of KUAC to reroute traffic in their sector from RIVER to ARTIP.
3. KUAC initiates a Trial request to NM through NMP Flight (ETFMS).
4. NM responds with the message "Negotiate."
5. KUAC informs the airline's FOC of the newly proposed trajectory.
6. The Flight Dispatcher engages in negotiations with the pilot regarding the proposed new trajectory.
7. The pilot agrees to the new trajectory.
8. The Flight Dispatcher notifies KUAC about the newly agreed trajectory.
9. KUAC sends a revision request to NM via NMP Flight, including the updated trajectory.
11. NM responds with acceptance, and the newly agreed-upon trajectory is integrated into IFPS by the flight dispatcher.
10. The newly agreed trajectory is shared with all stakeholders through the EFTMS system.
11. The Flight Dispatcher shares the mutually agreed-upon trajectory with the pilot, incorporating the route into their Flight Management System (FMS).

Postconditions:

1. The aircraft is rerouted to a less congested sector (ARTIP).
2. Improved runway load balancing at Schiphol.
3. Decreased workload for ATCOs.
4. Cost savings for the airline by preventing a holding.
5. Environmental benefits with lower emissions at low altitude.
6. Reduced noise disturbance for inhabitants in the area due to the prevention of a holding at low altitude.

Benefits: Rerouting the flight from the selected TDT city-pair to a less congested sector (ARTIP) allows the aircraft to land on the other runway. As a result, Schiphol will benefit from improved runway load balancing utilize and a decrease in workload for the ATCO. In addition, it will save the airline money by preventing a holding, and it will improve the environment by lowering emissions at low altitude. Additionally, inhabitants in the area will experience reduced noise disturbance when a holding at low altitude is prevented.

Table 6 Use case 2

Figure 14 illustrates the communication flows between the stakeholders, using the FF-ICE R2 Trail- and Revision Request services described in section 4.2.2.4.

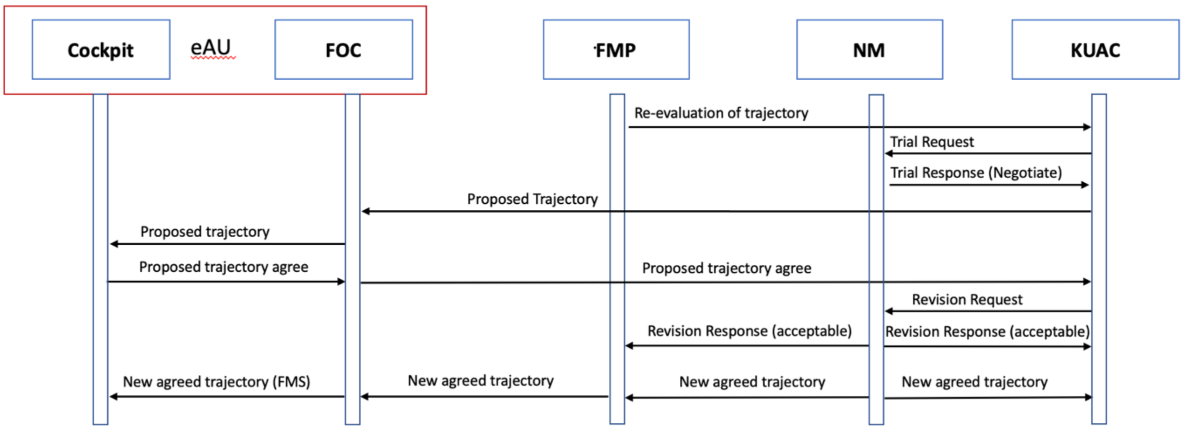


Figure 14, overview of the communication flows between the stakeholders.

According to an interview (appendix II) with an EUROCONTROL NM expert, the process of the Trail service can also be done another way (Smid, 2023). During the interview, he told that based on the current procedures: the NM is not involved when TDT is operational, in such a way that there is manual interaction taking place. Changes in routes while the flight is airborne are notified to the flow management system (ETFMS) via an AFP (ATC FPL Proposal). This changes the route in ETFMS and, most importantly, will update the counts for all sectors involved. So, a flight arriving via ARTIP is counted in sector 2, when it is TDT'd to RIVER it will, after an AFP, be additionally counted in sector 3.

This changes the route in ETFMS and, most importantly, will update the counts for all sectors involved. So, a flight arriving via RIVER is counted in sector 3, when it is TDT'd to ARTIP it will, after an AFP, be additionally counted in sector 2. The FMP monitor the ETFMS system through CHMI/NMP-Flow and see the same information NM.

In this specific case, RIVER to ARTIP, because ARTIP is close to the border with KUAC and EDGG2, the FMP or planner-ATCO needs to coordinate with them so that the route can be changed. KUAC (>F245) or EDGG2 (Dusseldorf <F245) should then send an AFP with the new route to RIVER to ETFMS. This ensures that the counts in the various sectors are updated by ETFMS, which is visible to the FMP in CHMI. The NM is informed by an AFP via B2B in our ETFMS. Through ETFMS, there is coordination between ATCO and ANSPs systems. The ETFMS updates the counts in the various sectors simultaneously. KUAC is ultimately the one who, after the FMP trigger, sends the AFP and then coordinates with the FOC to inform them of the new route.

4.4.3 FF-ICE Use Case 3

Table 7 outlines the TDT process, initiated by the FMP of LVNL, in response to monitoring an unexpected traffic bunch over the RIVER IAF.

The FMP utilizes their DST, a system akin to the NM CIFLO system, providing direct access to ATFCM information. The DST furnishes the FMP with real-time status updates on both in- and outbound air traffic, along with ATFCM status, facilitating traffic monitoring, detection, and investigation of issues related to sector capacities.

Upon detecting an overload in the RIVER airspace, the DST suggests rerouting TDT-suitable city-pairs to the ARTIP IAF. This strategic rerouting aims to alleviate the workload for LVNL's ATCOs and prevent airborne holding, effectively changing the route from the south via RIVER (Polderbaan) to ARTIP (Zwanenbrugbaan) through intervention.

The FMP engages in negotiations with the NM about an in-flight reroute, ensuring a 2-hour lead-time for effective planning. Subsequently, the FMP informs the airline's FOC about the planned in-flight rerouting on their flight. The ANSP of KUAC is informed by the EFTMS as the flight plan is updated by the FOC in the IFPS. This ensures seamless communication and coordination among stakeholders during the TDT process.

Use Case 3: Trajectory revision on LVNL FMP initiative for balancing the runways at Schiphol
Description: This use case describes the process of Tactical Demand Tailoring. The FMP of LVNL monitors, via their Decision Support Tool (DST), an unexpected traffic bunch over RIVER. The DST is a system, relatable to the NM CIFLO system, which gives direct access to ATFCM information. It provides the FMP with the status of in- and outbound air traffic, and the status of ATFCM allowing traffic monitoring, detection, and investigation of problems in the management of sector capacities. The DST indicates an overload in RIVER and suggest rerouting of TDT suitable city-pairs to ARTIP. This will reduce the workload for the LVNLs ATCOs and prevent a holding. So, the route from the south via RIVER (Polderbaan), by intervening, the route is changed to ARTIP (Zwanenbrugbaan). The FMP will negotiate with NM about an inflight reroute, with a 2-hour lead-time. FMP will inform airline's FOC about an inflight rerouting on their flight. The ANSP of KUAC is informed by the EFTMS systems, as the FPL is updated by the FOC in IFPS.

Trigger Event: Unexpected bunch of air traffic over RIVER, monitored by FMP using DST

Affected Stakeholders:

- LVNL FMP
- NM
- FOC (AO and dispatcher)
- ANSP from KUAC

Assumptions:

1. It is assumed that the predefined TDT suitable city-pairs are known and programmed in the DST.
2. It is assumed that the extra track miles flown, due to an inflight trajectory change, are negligible. Therefore, the aircraft will not have any fuel problems.
3. It is assumed that an inflight trajectory change won't led to an overload of capacity in the other sector.

Preconditions:

All stakeholders have an NM B2B certificate with an FF-ICE profile enabling the use of the trial service.

Use Case Steps:

1. The FMP identifies an unexpected bunch of air traffic over RIVER.
2. The FMP initiates a Trial request to NM via NMP Flight (EFTMS).
3. NM responds with the message "Negotiate."
4. The FMP informs the airline's FOC of the newly proposed trajectory.
5. The Flight Dispatcher negotiates with the pilot about the new trajectory.
6. The pilot agrees to the new trajectory.
7. The Flight Dispatcher informs the FMP about the newly agreed trajectory.
8. The FMP sends a revision request to NM via NMP Flow, containing the new trajectory.
9. NM responds with acceptance, and the newly agreed-upon trajectory is integrated into IFPS by the flight dispatcher.
10. The newly agreed trajectory is shared with all stakeholders via the EFTMS system.

The Flight Dispatcher shares the mutually agreed-upon trajectory with the pilot, who will insert the route into their FMS

Postconditions: Postconditions:

1. The aircraft is rerouted to a less congested sector (ARTIP).
2. Improved runway load balancing at Schiphol.
3. Decreased workload for ATCOs.
4. Cost savings for the airline by preventing a holding.
5. Environmental benefits with lower emissions at low altitude.

Reduced noise disturbance for inhabitants in the area due to the prevention of a holding at low altitude.

Benefits: Rerouting the flight from the selected TDT city-pair to a less congested sector (ARTIP) allows the aircraft to land on the other runway. As a result, Schiphol will benefit from improved runway load balancing utilize and a decrease in workload for the ATCO. In addition, it will save the airline money by preventing a holding, and it will improve the environment by lowering emissions at low altitude. Additionally, inhabitants in the area will experience reduced noise disturbance when a holding at low altitude is prevented.

Table 7 Use case 3

Figure 15 illustrates the communication flows between the stakeholders, using the FF-ICE R2 Trail- and Revision Request services described in section 4.2.2.4.

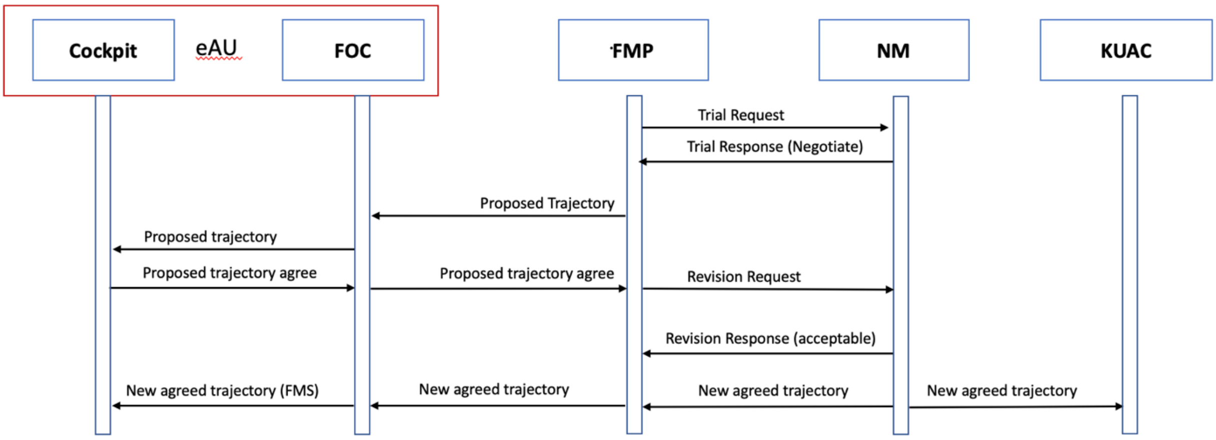


Figure 15, overview of the communication flows between the stakeholders.

4.5 Findings

Shortfalls in current procedures, such as slot tolerance and direct routing, can lead to uncertainties in arrival times and impact flow control measures and contribute to congestion and delays in airspace. Direct routing may cause an excessive number of aircraft arriving too early, leading to sector and controller overload. Challenges due to the limited real-time information exchange contribute to operational inefficiencies.

The TDT concept involves several key stakeholders, each playing specific roles in its execution and success. The NM is responsible for overall network management, collaborating with the FMP during the Tactical Phase, receiving notifications about operational problems, supporting both FF-ICE/R1 capable and non-capable AUs, and translating messages between ICAO 2012 and eFPL formats.

The FMP is involved in real-time monitoring and management of air traffic flow, monitoring load during the Tactical Phase, coordinating changes, opening sectors, and implementing regulations. It also analyzes delays and provides support to ATC, airports, and AU.

AUs are key participants in the FF-ICE/R1 services and TDT, submitting Preliminary Flight Plans (PFP) for operational evaluation, filing eFPL, engaging in collaborative decision-making during the planning phase, adopting FF-ICE services, and sharing desired trajectory with NM. The ANSPs play a critical role in FF-ICE/R1 implementation, implementing FF-ICE services, facilitating flight information distribution, effectively communicating constraints to AUs, and participating in SWIM services. The CHMI systems enhances collaboration by providing real-time data, route information, and traffic volume predictions to FMPs.

The ICAO FF-ICE concept is an innovative approach to air traffic management that enhances the flexibility and efficiency of in-flight rerouting. It provides pre-departure optimization services, such as planning, filing, and trial services, which enable AUs to submit PFPs for operational evaluation. The trial service allows operators to explore alternative routes without modifying existing flight plan data.

In-flight rerouting capabilities include interactive trajectory adjustments, which allow real-time adjustments initiated by AUs, the NM, or FMP. The negotiation process between eAUs and eASPs ensures adaptability throughout the flight. Real-time re-optimization allows for continuous re-optimization in response to operational conditions, unforeseen circumstances, or changes initiated by pilots.

The transition to FF-ICE/R2 is gradual, depending on FF-ICE/R1 processes, ensuring smooth integration of enhanced capabilities. Integration with the TDT concept is expected to occur by 2030 or later, enhancing the overall adaptability and efficiency of air traffic management during flight execution. System-Wide Information Management (SWIM) integration is also essential, with FF-ICE/R1 services complying with SWIM specifications to facilitate information exchange across the aviation ecosystem.

The implementation deadline for FF-ICE is December 31, 2025, as per Common Project 1 regulations. The ICAO FF-ICE concept contributes significantly to interactive flight rerouting, enhancing air traffic management adaptability and efficiency by allowing real-time adjustments, continuous negotiation, and dynamic trajectory re-optimization.

The adaptability of TDT within the existing ICAO FF-ICE framework, including both R1 and R2, can be assessed because the FF-ICE R1 primarily focuses on pre-departure activities. Aiming to optimize ATFCM. It introduces several services such as Planning, Filing, Trial, Flight Data Request, Notification, and Flight Data Publication to enhance collaboration and decision-making among key stakeholders. The new eFPL mandated for all AUs operating in the EATMN Airspace includes additional information about the flight trajectory. Due to the face that the TDT-concept is a planned inflight reroute, the concept has to adapt within the services of R1. These services it emphasizes the need for collaboration, real-time data exchange, and optimization of flight trajectories during the preliminary phases of planning.

FF-ICE R2 focuses on post-departure trajectory revision while the flight is airborne. It highlights continuous negotiation between stakeholders for changes to the agreed trajectory, allowing adaptability throughout the flight. FF-ICE R2 is expected to integrate the TDT concept, suggesting a recognition of the importance of in-flight rerouting for adaptability and efficiency during the execution phase of trajectory management, but it might not be available until 2030 or later.

The FF-ICE framework outlines the requirements for effective information exchange and data sharing when TDT is implemented. FF-ICE emphasizes the standardization of machine-readable flight and flow information to improve communication and data processing across different stakeholders. Services such as Planning, Filing, Trial, Flight Data Request, Notification, and Flight Data Publication facilitate information exchange among stakeholders, enabling collaborative decision-making, optimization of flight trajectories, and timely sharing of critical information.

The eFPL mandates a new flight plan for all AUs operating in EATMN Airspace by December 31, 2025, which includes additional information about the flight trajectory. The eFPL also includes the Desired Trajectory, representing the 4D trajectory requested by the AU. TDT could be in the eFPL the same way as the desired trajectory, this way TDT is shared with the relevant stakeholders.

5. Conclusion

The goal of this research was to investigate whether Tactical Demand Tailoring, planned inflight rerouting, was feasible for the predefined TDT suitable city-pairs. This report provides a recommendation on how communication between the stakeholders can be initiated. To comprehensively investigate the TDT implementation challenges, legislation, and stakeholder involvement within the FF-ICE framework.

The problem of this research outlines inefficiencies and delays in landing sequencing at Schiphol Airport due to limited real-time adaptability in current ATC methods. The intricate aviation regulations, particularly the NNHS, added complexity to the need for a more adaptive approach. TDT emerged as a proposed solution to optimize air traffic operations within the AMS-FIR, integrating runway load balancing during flight planning. The core challenge lay in ensuring TDT's compatibility with the FF-ICE framework, necessitating tailored adaptations and addressing Schiphol-specific requirements.

The findings, synthesized from the results, unveiled the structured approach of ATFCM procedures and the need for proactive planning and collaboration among stakeholders. FMPs at LVNL played a critical role in monitoring traffic flow, issuing regulations, and utilizing decision support tools. EUROCONTROL Network Manager affirmed the feasibility of TDT but highlighted uncertainties related to FF-ICE's upcoming releases.

The key stakeholder and their role when the TDT-concept is operational are identified. One of them is KLM OCC, and the primary requirement they emphasized was fuel. Airlines are profitable businesses, and everything they do ultimately revolves around making a profit. Therefore, the exact calculated amount of fuel is taken for a flight. Due to the previous study by S. Vegter, the additional track miles required for the proposed city pairs are negligible. The amount of extra fuel would consequently be minimal and should not result in additional costs.

Based on the research by the ASNP of KUAC, a route change within the airspace of KUAC could be feasible. The impact would be negligible, provided it involves a small number of flights per day. Investigation declares that KUAC would need a lead time of 2 hours to manage the changes in the other sector to prevent an overload. An overload is, of course, not desirable, so there should be a future examination of what the impact would be if 3 to 4 flights are rerouted to another sector during the inbound peak.

According to the FMP's at LVNL, TDT is definitely feasible and provides opportunities to prevent unexpected sector air traffic bunches over a sector. They can identify and monitor these bunches in their Decision Support Tool (DST). The DST can program and simulate scenarios, so a TDT scenario will need to be programmed in the future. This should include the TDT city-pairs in the system, allowing them to simulate the impact on the air traffic bunch when flights are rerouted. However, they also mentioned, like the requirements of KUAC, that in the future, consideration should be given to the impact on the other sector.

Based on the EUROCONTROL Network Manager, TDT should be possible. The NM already have systems that can enable TDT. Whether it should follow the approach of the NM in section 4.4.2 or with an ATC FPL Proposal or use the Trail service of FF-ICE is not yet clear to them. That's because FF-ICE concept is still in progress and the first release is set to launch in 2025. Therefore, in the future, consideration should also be given to FF-ICE R2 and R1, determining how TDT fits within this concept. Whether they want to depend entirely on release 2, as in the example D. Chiesa provided during the Knowledge Leveling Day (4.2.2.5), or if TDT can already be included in the planning and filing service of R1, as it involves a "planned inflight reroute."

The FF-ICE concept will be a new framework for CDM in de future, according to the International Civil Aviation Organization. FF-ICE defines standardized and machine-readable flight and flow information. By establishing a common language for data exchange, the initiative paves the way for smoother collaborations between various components of the air traffic management system. FF-ICE introduces a new flight plan, where TDT must fits in if it wants to be operational.

A detailed exploration of FF-ICE/R1 and R2 services underscored their relevance to TDT implementation. The transition from ICAO 2012 to eFPL, inclusion of Desired Trajectory, and gradual integration of FF-ICE/R1 and R2 capabilities were crucial aspects. The legislative framework, including CP1 and AF functionalities, mandated FF-ICE adoption by operational stakeholders, providing a standardized approach to information exchange.

Addressing legal aspects, the study delved into regulations such as DOC 4444, ICAO Annex 2, Commission Regulations No 255/2010 and No 716/2014. These regulations emphasized the importance of obstacle clearance, timely flight plan updates, and flexible airspace management, aligning with the goals of in-flight rerouting.

In conclusion, Tactical Demand Tailoring can be realistically implemented within the ICAO FF-ICE framework, provided careful considerations and adaptations are made. Key operational requirements, including the integration of FF-ICE/R1 and R2 services, collaboration among stakeholders, adherence to legislative frameworks, and addressing Schiphol-specific needs, are imperative for successful operationalization. The findings contribute to the integral understanding of TDT, marking a significant stride towards revolutionizing air traffic management, optimizing runway usage, and ensuring sustainability in the European aviation industry and beyond. The future of air traffic management lies in the effective integration of innovative solutions within standardized frameworks, and this research paves the way for such advancements.

6. Recommendation

Considering the findings from the research, it is recommended that LVNL proceed with the operationalization of Tactical Demand Tailoring (TDT) for the predefined TDT suitable city-pairs. The feasibility has been affirmed by key stakeholders, including KLM OCC and EUROCONTROL Network Manager, indicating that TDT aligns with existing legislation and the forthcoming FF-ICE framework.

To initiate this process, it is crucial to conduct simulations to assess the impact of TDT on other sectors, particularly during internal peak periods in busy seasons, such as summer. Simulations will provide valuable insights into potential challenges and help optimize the implementation strategy. These simulations should specifically evaluate the performance of TDT in preventing sector air traffic bunches and minimizing operational disruptions.

After conducting simulations, there must be an agreement with KUAC about inflight rerouting in their sector with the initiative from LVNL. This removes the repeated question of whether it is allowed and possible. In this agreement, the standard lead-time of 2 hours indicated by KUAC needs to be discussed and maybe can considered less.

As KLM represents a significant share, approximately 70%, of all flights, it is advisable to conduct trials with KLM. They need to be identified about the TDT suitable city pairs in their flight schedule, and that the extra fuel consumption is negligible. This will allow for a thorough examination of TDT's effectiveness and operational implications. The trials should involve real-world scenarios to validate the feasibility and performance of TDT in practical situations.

Furthermore, for the future acceptance and integration of TDT, a comprehensive evaluation within the FF-ICE framework is essential. This includes assessing how TDT fits into FF-ICE Release 2 and Release 1. It should be explored whether TDT aligns with the standardized and machine-readable flight and flow information introduced by FF-ICE.

Lastly, consideration should be given to obtaining the necessary certification for TDT. This step is crucial for regulatory compliance and industry-wide acceptance. Collaborating with regulatory authorities and industry partners is recommended to navigate the certification process smoothly. An investigation has to verify what certification is need when implementing the TDT concept.

In conclusion, by following these recommendations, LVNL can proceed with the implementation of TDT, ensuring thorough testing, stakeholder collaboration, and alignment with emerging industry standards through FF-ICE.

8. Reflection

This report's final chapter offers a commentary on the findings. In addition to the things that may have been done differently to obtain a more comprehensive response to the primary research question, consideration has been given to the information that I discovered during the investigation and my experiences working with LVNL as a client and firm to do my thesis research at.

Research improvements

When looking back at the research there is always room for improvement. At the start of the project, it was all about getting familiar with the problem, ATFCM procedures, abbreviation, and the current process. The problem was that TDT is a new tool, and there was no other concept like this. About implementing a tool planned inflight rerouting. During my education, flight operation engineering, we rarely talked about ATM. Knowledge about the all the AFTCM processes was therefore very much required to create a clear scope of this project. Looking back at these first weeks where I gained a lot of knowledge in a short period of time, I can say this was a bit too much. All the different, expansive manuals with many new subjects, concepts and terms, made it very difficult to understand everything. I think I lost a bit too much time on understanding the ATM profession, since it was just way more complicated than I thought.

Nevertheless, once I created a scope and the project plan was formed, I started collecting information. I reached out to all the different stakeholders who were involved in TDT, and I quickly found out that this turned out to be quite challenging. It's difficult to get in touch with the right people, and then they also need to be interested and willing to assist you. This report would have had a better outcome if more interviews had been conducted with experts.

Personal development

With so much new information and various manuals, it was challenging to form a clear picture of the direction I wanted to take with this research. I realized that crafting a methodology was crucial. This was something I encountered later on; it wasn't initially clear to me how to structure this report. What I will definitely take with me into the future is an understanding of how important a research plan is in the process of creating a thesis.

Personally, what I struggled with, and what would have certainly helped me shape this report, was the communication with my HvA supervisor. Improved communication, with more asking of questions, could have facilitated addressing issues earlier, ultimately resulting in a better report.

Communication has always been a weakness of mine; I tend to believe that I don't need help and want to show my supervisors that I can handle it. However, communication has improved now; there was good communication with the company supervisor regarding my progress at LVNL. On the other hand, I have been very disciplined in coming to the office every day and truly making something out of this thesis, despite the freedom we had to manage our time.

LVNL

Being able to conduct my graduation thesis at LVNL was a source of immense motivation. The company provides excellent opportunities to acquire extensive knowledge about the aviation industry, particularly in the realm of air traffic control. Witnessing the interconnectedness among various departments, each contributing to the overall functioning, proved to be highly fascinating. The support extended by everyone at LVNL who was aware of this project was invaluable and greatly aided me in my research. The positive working atmosphere at LVNL made going to the office a joy, and the multitude of opportunities they offered allowed me to learn and experience as much as possible. As a result, I developed new interests that could prove beneficial in my future career.

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Appendices

The appendices contain information about the conducted interviews that are performed during this thesis project. Additionally, the new ICAO FF-ICE flight plan that will be used in the future by all aircraft users.

Appendix I: Interview with Remco de Rooij

Interviewee: Remco De Rooij (FMP LVNL)
Interviewer: Wester Kuijpers
Date: November 11, 2023, at 12:00
Location: Operational deck at LVNL

Wester (I): Good afternoon, thank you for taking the time for me. Let's begin by discussing your background. Could you provide an overview of your experience in air traffic management and what led you to pursue a Flight Management Position (FMP) at the Air Traffic Control of the Netherlands (LVNL)?

Remco (C): Thank you for having me. I have been working in the field of air traffic management for the past few years, with a focus on capacity management and collaborative decision making (CDM). My interest in the complexities of managing air traffic flow and capacity drew me towards the Flight Management Position at LVNL.

I: That sounds intriguing. Could you delve into your understanding of the role of an FMP? What, in your opinion, are the primary responsibilities and key tasks associated with this position?

C: Certainly. The Flight Management Position is a critical role in ensuring the stability and efficiency of air traffic flow. Key responsibilities include strategic planning to align airspace and aerodrome capacity with traffic demand, real-time adjustments during the tactical phase, collaborating with stakeholders, and issuing regulations to manage traffic during peaks.

I: Collaboration seems to be a significant aspect. How do you envision working with stakeholders such as airlines, the Network Manager (NM), and other Air Traffic Control Units (ATCUs) to achieve efficient traffic management?

C: Collaboration is fundamental. Working closely with airlines to communicate regulations, address rerouting concerns, and implementing measures in coordination with the NM and other ATCUs is vital. This ensures a shared understanding of capacity limitations and facilitates the implementation of effective traffic management measures.

I: You address rerouting, what do you mean by that?

C: When flights are facing ATFCM delays, because of a regulation, set by us, over a sector or over the whole AMSFIR. We address airlines to reroute their flight to a different sector so that they lose their delay. We only do this if this is favorable for us. KLM already does this on its own, they reroute their flights over RIVER or SUGOL when we put a regulation over ARTIP.

I: Can you show me an example about the current process of capacity management in which demand capacity is matched?

C: Certainly, our current challenge is to efficiently handle capacity during the evening inbound peak. Based on all flights arriving in the EHFIRAM airspace around the inbound peak, we need to ensure that there are not too many flights and that they do not all fly over the same sector. Therefore, we implement regulations to control capacity and reduce the workload for an Air Traffic Control Officer (ATCO). We also implement regulations because the actual amount of incoming traffic at the agreed-upon time is always uncertain. These regulations are based on the Filed Flight Plans (FLP) submitted, indicating the number of flights heading towards Amsterdam.

I will provide you with an example of exactly what we do:

"On November 11, 2023, at 13:16 UTC, the total inbound air traffic during the inbound peak (17:20–18:20) for EHFIRAM (Flight Information Region Amsterdam) was 75. Due to the weather, this was set to a maximum of 65. The total inbound air traffic that will fly through the sector of ARTIP was 39. The total inbound was too much on this day for LVNL, and the FMP decided to issue a regulation. After simulations in the DST of different scenarios, common knowledge and experience, the FMP decided to set a regulation of 30 over ARTIP. This is because the totals in the EHFIRAM do reach an acceptable level, but with a FIRAM regulation, the bunch cannot be removed from ARTIP.

Regulation: EHARTIP 17:00-18:40/30, reason ATC CAP HD"

The regulation was set from 17:00-18:40 instead of the predicted inbound peak of 17:20-18:20, because of the uncertainty of the air traffic mentioned before. So, to be on the safe side, take an advance for later or earlier flights.

These uncertainties arise from various aspects. As seen in the example, there is a regulation on ARTIP for 30 aircraft. Due to this regulation, all flights currently passing through ARTIP have been assigned a slot, a designated time for departure. Slots are allocated by NM (Network Manager) on a first-come, first-served basis. This means that the first one to file their flight plan at 17:00 will receive the slot. The others must then join the queue. So, if you allow 30 aircraft to pass through ARTIP in an hour, 17:20-18:20, you have a departure every 2 minutes (17:00, 17:02, 17:04, etc.).

Now, regulated flights have a departure window of -5 and +10 of Estimated Takeoff Time (ETOT), and unregulated flights have -15 and +15. This sometimes results in flights arriving simultaneously, creating a bunch of air traffic, adding extra workload for the ATCO, who must sequence all these flights safely to the runway. Here, TDT would be beneficial because it allows you to advise flights to fly over RIVER at the last moment.

We inform KLM OCC via telephone during a briefing that there will be a regulation on ARTIP during the inbound peak in the evening. We advise KLM OCC not to reroute over another Initial Approach Fix (IAF) because doing so would exceed the maximum total inbound traffic over EHFIRAM. We work closely with KLM because 70% of all flights are operated by them.

Due to this regulation, there was a total of 432 minutes of ATFCM delay, over all the flights that were planned to arrive Schiphol during the inbound peak.

I: On the basis of which factors are regulations established or not?

C: The regulations are set on various factors namely; Amount of air traffic, complexity, number of runways, weather, number of ATCOs.

I: The use of technology is advancing rapidly in air traffic management. How do you stay updated on the latest technological developments, and how do you see technology playing a role in your role as an FMP?

C: I stay updated through continuous professional development, attending relevant workshops, and being an active member of professional networks. Technology, especially the Collaborative Human Machine Interface (CHMI), plays a crucial role in enhancing decision-making processes and improving real-time adjustments. Embracing these advancements is key to the success of an FMP.

I: Thank you for sharing your insights.

Appendix II: Interview with Simon Smidt

Interviewee: Simon Smidt (Senior Network Operations Coordinator, EUROCONTROL NMOC)
Interviewer: Wester Kuijpers
Date: December 4, 2023, at 15:00
Location: Online meeting at LVNL

Wester (I): Thanks for having this meeting, can you please begin with your role at the Eurocontrol?

Simon (C): I've been working in aviation since 1986, first in Air Traffic Control in The Netherlands, since 1993 at Eurocontrol in Brussels. And more than 25 years of experience in ATFCM. As a senior network operations coordinator for NMOC, the main duty is to manage and execute the rolling network planning processes from D-6 to the day of operations, or earlier as required, and the post operational evolution.

(I): Can you explain the processes for inflight rerouting, TDT, done by NM.

(C): Based on the current procedures we in NM are not involved in this TDT in such a way that there is manual interaction taking place. Changes in routes while the flight is airborne are notified to our flow management system (ETFMS) via an AFP (ATC FPL Proposal). This changes the route in ETFMS and, most importantly, will update the counts for all sectors involved. So, a flight arriving via ARTIP is counted in sector 2, when it is TDT'd to RIVER it will, after an AFP, be additionally counted in sector 3.

(I): How are these flights counted to another sector, through which systems?

(C): This changes the route in ETFMS and, most importantly, will update the counts for all sectors involved. So, a flight arriving via ARTIP is counted in sector 2, when it is TDT'd to RIVER it will, after an AFP, be additionally counted in sector 3.

(I): When implementing TDT, who should indicate that rerouting is possible to effectively balance the load on the runways? I think LVNL FMP should provide the indication because they are the ones who should trigger when a sector becomes overloaded. When I participated FMP, they mentioned that you have the tools to monitor the load.

(C): Indeed, but FMPs also have these tools; they monitor our ETFMS system through CHMI/NMP-Flow and see the same information as we do in NM.

(I): What will be the processes of inflight rerouting when FF-ICE R2 is active, and what we be the role of NM?

(C): As far as I can assess it now, it's purely B2B information that updates the counts in the various sectors. Therefore, there will be no manual intervention on our part.

(I): Can you explain how the relevant parties are informed by TDT?

(C): In this specific case, ARTIP to RIVER, because ARTIP is close to the border with KUAC and EDGG2, the FMP or planner-ATCO needs to coordinate with them so that the route can be changed.

KUAC (>F245) or EDGG2 (Dusseldorf <F245) should then send an AFP with the new route to RIVER to ETFMS. This ensures that the counts in the various sectors are updated by ETFMS, which is visible to the FMP in CHMI. At NM, we are informed by an AFP via B2B in our ETFMS. Through ETFMS, there is coordination between ATCO and ANSPs systems. Our ETFMS updates the counts in the various sectors simultaneously. KUAC is ultimately the one who, after the FMP trigger, sends the AFP and then coordinates with the FOC to inform them of the new route.

(I): Thank you for the clear explanation; this will greatly assist me in creating a Use Case for TDT. It will help delineate the interactions between various stakeholders.

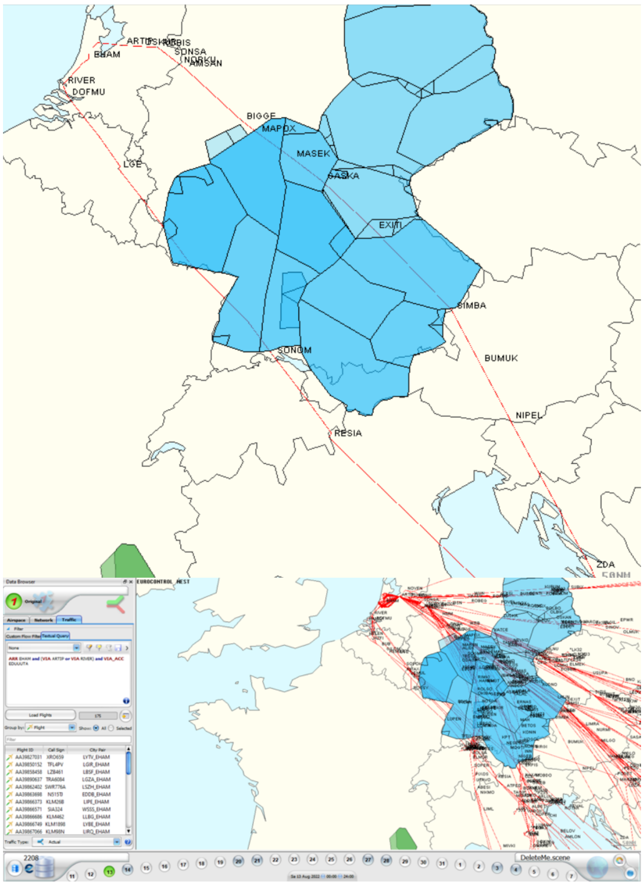
Appendix III: Interview with Andrea Pleger

Interviewee: Andrea Pleger (Senior ATFCM Expert KUAC)
Interviewer: Wester Kuijpers
Date: November 28, 2023, at 10:00
Location: Online meeting at LVNL

Wester (I): Thanks for meeting me. By implementing TDT, and a possible change in route in your sector KUAC. I was wondering what the impact would be for the capacity of KUAC and the workload for the ATCO. And if this is even possible in your opinion.

Andrea (C): No problem, I was curious about the plans at LVNL. I tried to find traffic from LIBD – EHAM via ARTIP or RIVER. I took the AIRAC 2208 and found 1 or 2 flights a day. That is not too much and wouldn´t make a real impact, but they will affect 2 completely different clusters and traffic volumes. So, if we are talking about 1 or 2 flights for the whole day, this is negligible.

The next step would be to identify traffic via ARTIP or RIVER ARR EHAM, DEP „anywhere" and to identify how many flights per hour will be „no schows" for the one cluster/counts and „unanticipated traffic" for the other.



You see, we have now 175 flights per day 13.08.2023 and would have to analyze, how many per hour of them will change the sector sequence within KUAC. Then we can talk about possible impacts. But generally spoken, changing the sector sequence in advance could cause overloads in the new sectors and we would have to regulate them, we need a leadtime of 2hrs to get the regulation effective.

I hope, i could clarify, what TDT could cause for KUAC and how we would have to react on it, if this causes an overload. If the sector sequence would have been unchanged, then the impact could be a more complex traffic picture and by this reducing capacity.

Appendix IV: Interview with Magnus Molbaek

Interviewee: Magnus Molbeak (SESAR Deployment Manager)
Interviewer: Wester Kuijpers
Date: November 9, 2023, at 11:00
Location: Online meeting at LVNL

Wester (I): Hello Magnus, thanks for meeting on such short notice. I had a few questions about the document you wrote regarding FF-ICE R1 Use Cases.

Magnus (C): Hello Wester, no problem I'm happy to help you. I was very interested in the information you send me about the implementation of TDT.

(I): I'm happy to hear that. My first question was about 5.15 ANSP Use Case 15: ANSP Use of AU Filed Desired Route/Trajectory. In this Use Case you mention that the desired route/trajectory is available for display to the local Flow managers and the ATCOs included in the sector-sequence for the flight. Can you explain this use case for me?

(C): Yes, the difference between the desired and agreed route is; the agreed route is after all restriction have been applied. An airline will file their desired route, the route they want to fly and is the most cost beneficial to them. This is received by NM, they will negotiate and apply all constraints, that they are aware of, to the route. The agreed route is sent back and shared to the relevant ANSP.

This Use Case is about the NM sharing the desired route of the flight to enroute ANSPs. So, that the enroute ATCO assesses whether constraints set in the agreed trajectory and being inside the centre's AoR can be removed (bringing the flown trajectory closer to the desired route. The ATCO -as needed- will initiate the necessary coordination with other internal sectors or the next ATSU (receiving ATSU), and/or flow managers. Flow managers will coordinate with the downstream flow managers/NM as needed (depends on impact).

(I): Okay that's very interesting for me. Because TDT is a planned inflight reroute, we want to give LVNL the opportunity to reroute a flight, which is suitable for TDT, to another sector. This will reduce the workload of the ATCO, the flight doesn't need to get in a holding, and we have a more efficient utilization of both runways. So, somehow, we want to let the FMP or NM know that the suitable flight for TDT can be rerouted during an inbound peak. Is it possible that this information about TDT can be shared the same way as you want to do with the desired route?

(C): Okay I understand, interesting case. The need for this Use Case is that NM hears form en-route ANSPs that they want to know the desired route of flights. So, you want to reroute to have an optimal runway usage at LVNL. So, this is relevant, because how would they wanted to reroute according to their own desire. Know, with this use case, NM would have the possibility of sharing the desired route (And maybe TDT).

Airlines have already constraints in their system (CFSP), so the desired route is already with constrains. This route will be different then the agreed route, with all the constrains from Nm. So, the real desired route without constrains will be later when the planning service of FF-ICE R1 is implemented. ANSP think this will have benefits, when they know the desired routes. How we are going to share this information is not yet known to us. We're working on that matter right now at SESAR.

(I): What I understand is that this a relative new scenario, but I see some opportunities for TDT. If we can add the extra or alternative route in the eFLP than you can share it the same way as you would share the desired route.

(C): Yes, that will be possible, only I don't know if TDT can be added to the eFLP. That's something that needs to be investigated in the future, but with FF-ICE and the 4D trajectory, this will not be a problem. Have a look about this website, this is the one we use and contains the information that is added in the new eFLP.

(I): Thanks, I will look at this for sure. I also had one more question; by the implementation of TDT, who's going to need to give the trigger to perform a reroute?

(C): From FMP or NM, but I think for inflight your FMP because they are the one checking the capacity of your TMA.

(I): I think making several Use Cases for TDT, with different trigger events would be the best option for the future.

(C): Yes, pay attention to all the stakeholders. Who's involved, and who's letting everybody now that a reroute is performed.

Appendix V: Interview with Steven Geurten

Interviewee: Steven Geurten (FMP LVNL)
Interviewer: Wester Kuijpers
Date: November 6, 2023, at 10:00
Location: Meeting room at LVNL

Wester (I): Good afternoon, thank you for taking the time for me. Based on my previous interview with Remco de Rooij, I had some questions for you about the different systems a FMP used, and I was curious about what you could do with those systems. Last time Remco told me about the CIFLO, could explain this system to me?

Remco (C): Of course, CIFLO is the CHMI for FMP. CIFLO indicates the expected traffic volume for a given time based on submitted flight plans (FLP). An AO submits their FLP to the IFPS of the NM. The IFPS is then processed in the EFTMS, where the system consolidates all FLPs to calculate expectations. CIFLO provides insight into the EFTMS for an FMP. The EFTMS will later become the iNM. Blue represents flights that are already en route, and green indicates those yet to depart. The red line you see is the Monitoring Value (MV), determined by us (FMP) for the total EHFIRAM and set at 65. This value offers an indication of the typical situation for inbound air traffic on 2 runways. Through CHMI (CIFLO), we can observe the incoming traffic at specific times and sectors. It can also display regulations submitted by other ANSPs. Additionally, there is the PREDICT function, which shows predictions for the upcoming days based on the past week. PREDICT helps us anticipate any special events.

I: Okay that’s interesting, and what is the difference between the CIFLO and the DST. Because they look the same to me when I look at the screens?

The CIFLO is an application of NM, and the DST is specifically designed for us. In CIFLO, we can also input actual regulations, a capability not available in the DST, which we are only allowed to use for advisory purposes. Within CIFLO, we can divide the bars representing in- and outbound air traffic into time intervals of an hour and 20 minutes. However, CIFLO is an old system, and sometimes these bars can be misleading. For instance, if you have an inbound of 15 flights from 10:00 to 10:20 and another inbound of 15 flights from 10:20 to 10:40, CIFLO does not immediately show the distribution within these 20 minutes. It is possible that 10 out of the 15 flights from 10:10 to 10:20 arrive, and all 15 flights from the second bar arrive from 10:20 to 10:30. This would mean that 25 flights arrive in the 20 minutes from 10:10 to 10:30. This can create a distorted picture, which can be resolved by referring to the specific list provided by CIFLO, displaying all submitted flights and their exact times.

The DST can accurately depict when flights will exactly arrive. In this system, the bars are divided into 5-minute intervals and are constantly updated. Here, you can see the precise distribution because the DST is in a B2B connection with NM. The red line you see originates from the DST itself. This line serves as a type of Monitoring Value (MV), but the DST takes into account the complexity of air traffic on its own. It also considers the WLM (Work Load Model) and the weather. WLM is the workload model, which takes into account the expected workload of the ATCO (Air Traffic Controller). The weather is updated based on the SKV (Schiphol Chance Expectation). Weather monitoring is done by the KNMI, but also by our own personnel here. The DST can, therefore, provide a much more specific expectation of anticipated capacity. In the DST, we can also simulate different scenarios; for instance, we can worsen the weather in the afternoon and observe its impact on capacity.

I: Okay, but it sounds like the DST is a better system than CIFLO. Why isn't NM using it as well?

C: That's because the DST is tailored to our requirements and our airspace. For instance, the DST is configured based on the number of in- and outbounds. Meanwhile, other ANSPs prefer their systems to be set up based on Occupancy Count, which is the time an aircraft spends in the airspace. So, it varies for everyone, but NM is in the process of transitioning to a different system.

I: Okay, understandable. Are there any other systems that are relevant in relation to TDT?

C: What we additionally use is the CCIS, where you can find various information such as weather, routes, and airport details. This system comes from LVNL and is utilized by entities like KLM, Schiphol, and the military. Everyone can see in CCIS when we have implemented a regulation.

We use the NOP Portal solely to monitor current events within Europe. It helps us identify any particularities we need to consider, whether there are changes in military airspace availability, or if certain routes can be used again. In emergencies, it can serve as a backup for CIFLO.

Another system that might be useful to know regarding TDT is the CHMI NMP FLOW. This NM system is used to communicate reroute requests. Sometimes, we submit a reroute request in the NM's IFPS, and through this system, we can promptly determine whether it's feasible or not. The NM's system takes into account factors like closed or congested airspace. This may be relevant to TDT, and NM manages the overview. While we could handle this ourselves using DST, it would require programming in DST. This programming would need to consider factors like potential congestion in the other sector when rerouting, the impact of adding two extra aircraft to that sector, and when they would arrive. TDT could propose potential scenarios, similar to how we handle weather scenarios.

I: What do you think of the new TDT tool, and how do you anticipate it will assist your team?

C: For us, the tool would be a valuable implication; it could reduce the workload for ATCOs. In the case of an unexpected "bunch" of air traffic in a sector, there is now the possibility to handle it more efficiently and reroute it to another sector. This will also have an environmental impact, as ATCOs will have fewer aircraft to safely guide to Schiphol. It helps prevent unnecessary low-level holdings, resulting in reduced unnecessary fuel emissions.

I: When TDT becomes operational, who is ultimately responsible, or who monitors that certain flights can be rerouted?

C: It's hard to say; it could come from either us or NM. NM has tools like NMP Flow, where they can select a flight and specify "avoid ARTIP." NM can essentially determine whether the other sector can handle the extra load because ANSPs provide the capacity for that sector, allowing them to assess compatibility. Perhaps the initiative should come from us since we are the ones aiming to reduce workload. We can contact NM through our dedicated line or inform them through a proposal in CIFLO or another application. The trigger might need to come from us, and then NM can proceed to reroute the selected flights.

We could also have the selected flights from Sven programmed into the DST. We can set it up as a scenario, similar to how we handle scenarios for inclement weather or a closed runway. DST would then be the trigger, and we can inform NM accordingly.

I: Thank you for this explanation; it provides me with a lot of insight into how TDT could potentially function. I will let you know the outcome of the investigation.

C: No problem, I'm curious about the final result. Also, take a look at the ATM portal at MUAC; they make proposals for alternative routes to inform ANSPs that they are flying through their airspace.

I: Thanks for the tip, I will do that.

Appendix VI: Interview with Kees Palentijn

Interviewee: Kees Palenstijn (KLM Flowcontroller)
Interviewer: Wester Kuijpers
Date: November 10, 2023, at 14:00
Location: KLM OCC

Wester (I): Good afternoon, thank letting me see how you operate here at KLM OCC. To begin, could you briefly introduce yourself and provide an overview of your role as a flow controller at KLM OCC?

Kees (C): Thank you for having me. My name is Kees, and I am currently serving as the flow controller at KLM OCC. My role involves overseeing and optimizing the flow of operations within the airline's Operational Control Center (OCC).

(I): Can you elaborate on your key responsibilities as a flow controller? What specific tasks and duties fall under your purview?

(C): Certainly. As a flow controller, my main responsibilities revolve around ensuring the smooth and efficient operation of flights. This includes managing the allocation of aircraft, crew, and other resources to meet the airline's schedule. I also monitor the real-time status of flights, weather conditions, and any operational disruptions that may occur.

(I): How does the current process work in terms of coordinating and controlling the flow of operations at KLM OCC?

(C): At KLM OCC, our process is intricately designed to balance the airline's schedule with various operational factors. We receive information from multiple sources, including flight crews, air traffic control, and weather services. Using this data, we make real-time decisions to optimize the use of our resources and maintain a punctual and safe operation.

(I): Last time, I was allowed to join the operation of LVNLs FMP. That day, they set a regulation of 30 inbound air traffic. Afterwards, they called KLM OCC with the instructions to not reroute your flights. I was wondering if you could explain to me how you handle such regulations, and the AFTCM delays caused by these regulations.

(C): Of course, I'll explain what we mainly focus on. As mentioned earlier, our goal is to operate the fleet, in this case the one of KLC, as efficiently as possible. Using our systems, we can see which flights are scheduled for today. We don't do much with flights departing within an hour or those that have already departed. If a delay occurs for a flight that is yet to depart, we try to resolve it. This delay can be caused by factors like regulations imposed by LVNL or passenger-related issues. Each flight is assigned a slot, a departure time. We use the LIDO system to identify flights that are crucial for us, especially those with a significant number of passengers making connections at Schiphol. If such a flight is delayed, we engage in slot swapping, and here's how it works.

Slot swapping is requested in NMP Flight, a system provided from the NM, and they either accept or reject it. We are allowed to slot swap a particular flight three times, and our systems help us identify other KLM flights that would benefit from this. Essentially, what we do is give one flight all the delays, allowing three other flights to operate without delays. We then proceed to reroute the initially delayed flight, for example, from ARTIP to RIVER. This eliminates the delay, ensuring that we operate our fleet as efficiently as possible.

(I): How is such a reroute conducted, and if LVNL says you're not allowed to do it, what happens then?

(C): As I mentioned earlier, some flights are crucial for us. If we have no other option, we still proceed because not doing so would cost us too much money. A reroute is executed by the dispatcher, who selects a route from LIDO. LIDO generates so-called 'company routes,' which are calculated routes considering factors like ATC costs, closed airspace due to personnel, wind, etc. LIDO chooses the most economical routes, and these routes are created six hours in advance and rechecked two hours before the flight. The dispatcher is responsible for this route, and it is filed by the NM. Until a delay of 15 minutes, we will stick to the most economical route, as rerouting could incur higher costs. Essentially, we spend the entire day optimizing our fleet to operate as efficiently as possible.

(I): Thanks, I think a meeting with a flight dispatcher would be great. To see how they operate and prepare those routes. I also had a question about the desired and agreed trajectory. And especially the principle of direct routing, this causes a lot of uncertainties for LVNL. Can you explain the working direct routing to me?

(C): Naturally, we choose the most economical route, which is our Desired Trajectory, but this is always adjusted by NM. NM then sends back the Agreed Trajectory, including all constraints applied by NM. During the flight, the pilot can request a direct routing from the ANSP of the current sector. This involves asking if they can skip waypoints, reducing the distance and allowing them to reach their destination more quickly. This is also requested when a flight is delayed, by this way he can make up for the lost time. Direct routing can only happen in consultation with the relevant ANSP of that sector, who must provide clearance.

Direct routing is also employed to avoid adverse weather, turbulence. This can be requested by the ANSP or the AO, often the AO to avoid turbulence as it is more comfortable for passengers on board. A Direct routing is always checked with the dispatcher to ensure that this maneuver is feasible in terms of fuel. This change is then implemented in the FMS so that the flight can continue.

Another reason for direct routing is a shortage of fuel on board. This can occur when aircraft are kept at a low altitude for too long during takeoff by the ATCO. This leads to excessive fuel consumption at the beginning of the flight, potentially causing issues later on. By requesting direct routing, the flight distance is shortened, preventing fuel-related problems.

(I): I can understand that direct routing has his pros and cons, sometimes is results in an uncertainty for LVNL about the exact arrival in the TMA of the Netherlands. Such a change in the route, which stakeholders are communicating whit each other?

(C): The communication is between the AO and the relevant ANSP which gives the clearance. But the ANSP also have communicated with ANSP located next to them, because sometimes the aircraft will enter their sector at another waypoint.

(I): What do you think of the concept of TDT, what is for us important to consider by the implementation?

(C): If you talk about an inflight reroute, we will look at the amount of track miles that will be added compared to the agreed trajectory. In other words, by the implementations we will consider fuel as the most important component. Because nowadays we operate on the most economical way, and we take the exact amount of fuel with us calculated for a flight. So, the question is if we must carry extra fuel for that flight, because of the possibility to reroute. Who's going to pay the extra fuel we carry if we don't perform the reroute. Because if we don't, we must carry more weight, which mean more fuel consumption. This will also result in an environmental issue.

(I): I understand that very well, and I will certainly include it in my report. In the previous study, calculations were made to determine which city pairs were suitable for TDT. This involved assessing the additional track miles that would need to be flown, and it was almost negligible. From an environmental perspective, TDT will help us avoid holdings at low altitudes, resulting in reduced emissions, making this trade-off manageable. Therefore, the implementation of TDT would, in principle, not be a problem for you. How would this work in practice for your operations?

(C): From my current understanding, the implementation would involve an in-flight reroute in the same manner as direct routing. The new route would be checked by the dispatcher for fuel considerations and then integrated into the FMS.

(I): Thank you for sharing insights into your role as a flowcontroller at KLM OCC. It's been a pleasure learning about the intricacies of your responsibilities and the processes in place to ensure the efficient flow of operations.

Appendix VII: Interview with Rob Arnhem

Interviewee: Rob Arnhem (KLM Dispatcher)
Interviewer: Wester Kuijpers
Date: Decemeber 4, 2023, at 9:00
Location: KLM OCC

Wester (I): Good morning, thanks for letting me observe KLM's operations again. Following my previous visit to flow control, I was curious about the duties of a Dispatcher. Eventually you will play a significant role by the implementation of TDT. Could you briefly describe the specific duties that you perform?

Rob (C): No problem; you're always welcome. Similar to flow control, we monitor delays caused by ATC regulations along the route. In the NMP (Network Manager Portal) of EUROCONTROL, we can see where the delays are. When we submit a FLP, it gets corrected by the systems of the NM (EFTMS). If there's a delay along the route we filed, we can identify its location in the NMP. We can also see what's causing it, such as a shortage of ATC staff or an overloaded airspace. In the case of an overloaded airspace, we can use a vertical representation to pinpoint the location. If we take this example, during the climb, the aircraft passes through an overloaded airspace. We could then adjust the route in NMP, suggesting a slightly slower climb, to avoid and navigate below the overloaded airspace. By filing this adjustment with NM, we can check if it worked, and in this case, it did (VALID).

(I): The route you submit to NM is generated by the LIDO system, right?

(C): That's correct. Our LIDO system creates the company routes, and we choose the most cost-effective one, taking into account routes and restrictions filed under these routes. However, the NMP is where we ultimately submit the routes and is essentially our point of contact with NM. LIDO doesn't consider altitudes, so we need to check if flying over or under an overloaded airspace is possible.

(I): I asked Kees on the possibility of in-flight rerouting the last time. Could you provide more details on your role, especially with reference to fuel considerations?

(C): When I receive an inflight reroute request, I assess its feasibility based on the available fuel. Using LIDO, I check the impact of the fuel used in rerouting a flight over a different sector. I examined the onboard fuel and the additional fuel required for the reroute. If it's viable, I send the new route to the pilot, who inputs it into the FMS. For instance, if I take a flight from Italy and change the route in the area of KUAC, I might find that it needs an extra 200 kilograms of fuel. In such a case, it wouldn't be feasible, as we didn't load enough fuel at the beginning of the flight. The reroute's feasibility also depends on the runway combination LVNL is using, as certain combinations may result in a longer reroute. In LIDO, we can specify the preferred landing runway.

(I): That's understandable; it's indeed a handy system. From the calculations of the previous study by Sven, the additional track miles were negligible, so that wouldn't matter much. I was wondering about the fuel on board, as you sometimes need to enter a holding pattern. Which fuel is used for this, and how long could you potentially be in a holding? Could this fuel also be used for an inflight reroute, or could fuel be taken from the alternate fuel, final reserve fuel, or contingency fuel I read about?

(C): KLM operates with a minimum amount of fuel and, as a standard, does not carry holding fuel. We taxi, fly from A to B, have an alternate airport, and must have a minimum of 30 minutes of fuel in the tanks after landing. This does not include holding fuel. If, for instance, the Meteo predicts specific weather conditions at a destination, we may recommend additional fuel to accommodate holding. If a holding occurs and no extra fuel has been loaded, the pilot will calculate how long they can hold and still safely divert to the alternate airport. It's possible that the actual fuel consumption during the flight is less than what LIDO calculated (perhaps due to a tailwind along the route). If not, the pilot may use fuel intended for reaching the alternate airport. However, the only option then is to land at the destination, and diversion is no longer possible. This principle could potentially apply to an inflight reroute, but it must be ensured that a landing is guaranteed. When implementing TDT, the pilot and LIDO both execute calculations and take the amount of fuel left on board into account. It is definitely not supposed to use the final fuel reserve. It is legally required to land with at least 30 minutes of fuel remaining. If they didn't comply, they would have to declare a fuel emergency with the ATC for priority attention. The pilot would then have to write out an explanation for the landing with so little fuel.

It's important to remember once more that fuel is expensive and that we don't usually carry extra fuel. Additionally, the heavier the aircraft, the more fuel we consume.

(C): Would you like to explain the different types of fuel on board?

(I): The alternate fuel is used to fly from the intended destination to the selected alternate aerodrome. In the case of this route, Brussels Airport as well as Rotterdam the Hague airport has been selected as the alternate destination. EASA (AMC1 CAT.OP.MPA.150(b) Fuel policy) states the following about the alternate fuel.

“(4) Alternate fuel, which should: (i) include:

(A) fuel for a missed approach from the applicable DA/H or MDA/H at the destination aerodrome to missed approach altitude, taking into account the complete missed approach procedure;
(B) fuel for climb from missed approach altitude to cruising level/altitude, taking into account the expected departure routing;

(C) fuel for cruise from top of climb to top of descent, taking into account the expected routing;
(D) fuel for descent from top of descent to the point where the approach is initiated, taking into account the expected arrival procedure; and

(E) fuel for executing an approach and landing at the destination alternate aerodrome;

(ii) where two destination alternate aerodromes are required, be sufficient to proceed to the alternate aerodrome that requires the greater amount of alternate fuel (EASA, 2019).

(ii) where two destination alternate aerodromes are required, be sufficient to proceed to the alternate aerodrome that requires the greater amount of alternate fuel.”

Final reserve fuel requirements can be found in the EASA legislation Acceptable Means of Compliance (AMC) - AMC1 CAT.OP.MPA.150 (b) - Fuel policy. In the case of this particular flight, the alternate destination is Brussels Airport. Therefore, the legislation stated below is valid for Brussels Airport.

“(5) Final reserve fuel, which should be:

(ii) for aeroplanes with turbine engines, fuel to fly for 30 minutes at holding speed at 1,500 ft (450 m) above aerodrome elevation in standard conditions, calculated with the estimated mass on arrival at the destination alternate aerodrome or the destination aerodrome, when no destination alternate aerodrome is required

(ii) for aeroplanes with turbine engines, fuel to fly for 30 minutes at holding speed at 1,500 ft (450 m) above aerodrome elevation in standard conditions, calculated with the estimated mass on arrival at the destination alternate aerodrome or the destination aerodrome, when no destination alternate aerodrome is required.”

Contingency fuel is extra fuel (a percentage of the trip fuel). This fuel may be used for unforeseen circumstances such as higher wind speeds or ATC deviations. According to EASA (AMC1 CAT.OP.MPA.150(b) Fuel policy), it states that:

“(3) Contingency fuel, except as provided for in

(B) not less than 3 % of the planned trip fuel or, in the event of in-flight re-planning, 3 % of the trip fuel for the remainder of the flight, provided that an en-route alternate (ERA) aerodrome is available”.

Appendix VIII: Filed eFPL

The filed eFPL	
Data Category	Data Item
Message Information	List of Recipients
	Message Originator
	Request for Translation and Delivery
	Requested Recipients
	Request for Forwarding
	Relevant ASPs
	Message Date-Time
	Message Identifier
	Type of Request/Response
	AFTN Address
	Contact Information
Flight Identification	GUFI
	Aircraft Identification
Flight Status	Operator Flight Plan Version
Flight Characteristics	Flight Rules
	Type of Flight
	Special Handling
	Flight Plan Originator
	Remarks
	Operator
	Equipment and Capabilities
	Supplementary Information Source
	Required Runway Visual Range
	EUR Special Handling
Aircraft Characteristics	Total number of aircraft
	Registration
	Aircraft Address
	SELCAL Code
	Mode A Code
	Number and type of aircraft

	Wake Turbulence Category
	Aircraft Approach Category
Departure/Destination Data	Departure Aerodrome
	Destination Aerodrome
	Estimated Off-Block Time
	Departure Airport Slot Identification
	Destination Airport Slot Identification
	Departure Runway
	Destination Runway
Alternates	Alternate Destination Aerodrome(s)
	Alternate Take-Off Aerodrome(s)
	Alternate En-Route Aerodrome(s)
Desired Route/Trajectory	
Route/Traj. Group	Aircraft Take-off Mass
	Requested Cruising Speed
	Requested Cruising Level
	Total Estimated Elapsed Time
	General Flight Constraint
Route/Traj. Element	
	Along Route Distance
	Route Element Start Point
	Route to Next Element
	Route Truncation Indicator
	Requested Change
	Route/Trajectory Constraints
	Trajectory Point
	Geo Position
	Time
	Level
	Predicted Airspeed
	Predicted Ground Speed
	Wind Vector
	Assumed Altimeter Setting

	Temperature
	Trajectory Point Property
	Planned Delay
	Weight at Point
Route/Traj. Aircraft Performance	Performance Profile
	Speed Schedule
Route to Revised Destination	Revised Destination
	Route String to Revised Destination
Dangerous Goods	Dangerous Goods Information
AIRAC	AIRAC Reference
Supplementary Information	Fuel Endurance
	Persons on Board
	Emergency Radio
	Survival Capability
	Life Jacket Characteristics
	Aircraft Colour and Markings
	Pilot in Command
	Dinghies
	Remarks
Other European Items	*Stay Information*
	EUR Special Handling

Appendix IX: Distributed eFPL

Content of the distributed eFPL	
Data Category	**Data Item**
Flight Identification	GUFI
	Aircraft Identification
Flight Status	Operator Flight Plan Version
	Revalidation Status
	Revalidation Status Explanation
Flight Characteristics	Flight Rules
	Type of Flight
	Special Handling
	Flight Plan Originator
	Remarks
	Operator
	Equipment and Capabilities
	Supplementary Information Source
	Required Runway Visual Range
Aircraft Characteristics	Total number of aircraft
	Registration
	Aircraft Address
	SELCAL Code
	Mode A Code
	Number and type of aircraft
	Wake Turbulence Category
	Aircraft Approach Category
Departure/Destination Data	Departure Aerodrome
	Destination Aerodrome
	Estimated Off-Block Time
	Departure Airport Slot Identification
	Destination Airport Slot Identification
	Departure Runway
	Destination Runway
Alternates	Alternate Destination Aerodrome(s)

	Alternate Take-Off Aerodrome(s)
	Alternate En-Route Aerodrome(s)
Desired Route/Trajectory	
Agreed Route/Trajectory	
Route/Traj. Group	Aircraft Take-off Mass
	Requested Cruising Speed
	Requested Cruising Level
	Total Estimated Elapsed Time
	General Flight Constraint
Route/Traj. Element	
	Along Route Distance
	Route Element Start Point
	Route to Next Element
	Modified Route Indicator
	Route Truncation Indicator
	Requested Change
	Route/Trajectory Constraints
	Trajectory Point
	Geo Position
	Time
	Level
	Predicted Airspeed
	Predicted Ground Speed
	Wind Vector
	Assumed Altimeter Setting
	Temperature
	Trajectory Point Property
	Planned Delay
	Weight at Point
Route/Traj. Aircraft Performance	Performance Profile
	Speed Schedule
Route to Revised Destination	Revised Destination
	Route String to Revised Destination

Dangerous Goods	Dangerous Goods Information
AIRAC	AIRAC Reference
Supplementary Information	Fuel Endurance
	Persons on Board
	Emergency Radio
	Survival Capability
	Life Jacket Characteristics
	Aircraft Colour and Markings
	Pilot in Command
	Dinghies
	Remarks
Other European Items	Route Text
	Ifps Identifier
	Stay Information
	AO What-If ReRoute Indicator
	Replacement Flight Plan Indicator