Initial Target Time Over/Arrival Concept for Amsterdam Airport Schiphol

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Benefits and Stakeholder Analysis

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Executive summary

Amsterdam Airport Schiphol is among Europe's busiest with close to 500,000 commercial movements in 2017. The rapid growth of demand in recent years has outpaced capacity and this has led to increasing delays at Schiphol. One of the major sources of delay at Schiphol is the occurrence of so called 'traffic bunches', particularly at the boundary of the Amsterdam FIR. These traffic bunches lead to traffic density hotspots and they reduce planning flexibility and complicate the use of Arrival Managers (AMANs) for organizing inbound flows.

To combat hotspots, and balance demand with capacity, local ANSPs request the Network Manager (NM) in Brussels to regulate traffic by imposing delays on aircraft take-off times. These take-off delays result in new Calculated Take-Off Times (CTOTs) for aircraft. Unfortunately, these measures do not always have the desired effect. To improve the effectiveness of CTOT, SESAR has introduced a new complementary concept known as Target Time Over/Arrival (TTO/TTA). This concept is a first step towards working more cooperatively between ANSP and airlines. The concept has the potential to bring significant benefits to make execution of CTOTs more effective. Before this concept can be tested and implemented at Schiphol, it is necessary to properly study the technical foundations of the TTO/TTA concept, and how it could potentially fit into the existing operations at Schiphol.

This study first details the *SESAR* TTO/TTA concept, analyses best-practices of past-trials at other airports and uses these best-practices to assess the stakeholder acceptance of an initial TTO concept for the Schiphol situation. The results of this initial stakeholder acceptance study will support decision makers in defining next steps towards the introduction of a TTO proof of concept at Schiphol.

Based on this study, it is concluded that the initial Schiphol TTO/TTA concept has

the potential to improve the effectiveness of CTOTs by:

- Reducing hotspots;
- Reducing ATCO workload;
- Increasing overall airspace efficiency and capacity.

The flexibility of the concept enables Schiphol to implement it without significant changes with respect to their existing operational framework.

Regarding the trials that have been studied it can be concluded that TTO/TTA can be successfully implemented to realize different goals such as reducing traffic bunching, increasing predictability and improving airspace efficiency and capacity without substantially affecting workload for pilots and ATCOs. However, it should be noted that all trial goals were different and therefore the implementation of the TTO/TTA concept was different at each airport. None of the trials used the full implementation of the SESAR concept described in Chapter 2 and Appendix A.

To assess the stakeholder acceptance regarding TTO/TTA at Schiphol, this document proposes an initial TTO/TTA concept for Schiphol. Similar to the executed trials the initial Schiphol concept uses some basic building blocks of the SESAR concept. The aim of this initial concept is to reduce the occurrence of hotspots at the boundary of the Amsterdam FIR. The stakeholder acceptance study showed qualitatively that it is expected that the initial concept delivers benefits to all stakeholders in relation to a number of KPIs without significant implementation costs.

Because of the expected benefits, NLR recommends that a live proof of concept trial should be performed to quantitatively assess the actual benefits at Schiphol. The goal of a proof of concept trial is to find out if the initial Schiphol concept is compatible to current Schiphol operations and quantifying results for some relevant KPIs indicated by involved stakeholders. In addition to this the execution of a TTO/TTA proof concept trial can be seen as a first step towards work more cooperatively between ANSPs and airlines. If both results are promising the initial Schiphol concept is worth further investigation and development. To prepare for an initial live trial, NLR recommends that first a `trial plan’ is set up, to further design the initial TTO/TTA implementation for Schiphol, as well as to develop the experiment design for the trial.

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Benefits and Stakeholder analysis

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Contents

Abbreviations

ACRONYM	DESCRIPTION
ACARS	Aircraft Communication, Addressing and Reporting System
ACC	Area Control Center
ACDM	Airport Collaborative Decision Making
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
ADEP	Aerodrome of Departure
AO	Aircraft Operator
AOC	Airline Operations Center
ALDT	Actual Landing Time
ATC/ATM	Air Traffic Control/Management
ATCO	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATFCM	Air Traffic Flow and Capacity Management
ATOT	Actual Time of Take-Off
ATS	Air Traffic Services
ATT	Achievable Target Time
B2B	Business to Business
BSC	Balanced Score Card
CASA	Computer Assisted Slot Allocation
CDM	Collaborative Decision Making
CHMI	CFMU Human-Machine-Interface
CTA	Controlled Time of Arrival
CTOT	Calculated Time of Take-Off
DCB	Demand Capacity Balancing
ELDT	Estimated Landing Time
ETFMS	Enhanced Tactical Flow Management System
ETO	Estimated Time Over
FIR	Flight Information Region
FMP	Flow Management Position
FMS	Flight Management System
FOC	Flight Operations Center
IAF	Initial Approach Fix
IFPS	Initial Flight Plan Processing System
ICAO	International Civil Aviation Organization
KDC	Knowledge Development Centre

KLM	Koninklijke Luchtvaart Maatschappij
LVNL	Luchtverkeersleiding Nederland
MPR	Most Penalizing Regulation
MUAC	Maastricht Upper Area Control
NLR	Netherlands Aerospace Centre
NM	Network Manager
NMOC	Network Manager Operational Cell
OSED	Operational Service and Environment Document
PCP	Pilot Common Project
PMI	Plus-Minus Indicator
PRR	Performance Review Report
SAM	Slot Allocation Message
SESAR	Single European Sky ATM Research
SRM	Slot Revision Message
STA	Scheduled Arrival Time
SWIM	System Wide Information Management
TDI	Time Deviation Indicator
TOM	Time Over Metering
TOT	Take-Off Time
TMA	Terminal Manoeuvring Area
TTL	Time To Loose
TTM	Target Time Management
TTO/TTA	Target Time Over/Arrival
TW	Target Window
XMAN	Cross Border Extended Arrival Manager

1 Introduction

1.1 Background

Amsterdam Airport Schiphol is among Europe's busiest with close to 500,000 commercial movements in 2017. The rapid growth of demand in recent years has outpaced capacity and this has led to increasing delays at Schiphol. Because Schiphol is a major hub airport, delays generated at Schiphol can easily propagate throughout the entire European aviation system. This effect was highlighted by the latest Eurocontrol Performance Review Report (PRR 2017) which indicated that Schiphol was one of the main sources of Air Traffic Flow Management (ATFM) delays in Europe, contributing to 13.8% of the total ATFM delay. In addition to the economic costs of these delays to airlines, e.g. KLM and Transavia, the unpredictability caused by delays also have a significant negative effect on the workload imposed on LVNL Air Traffic Controllers (ATCOs), which further aggravates capacity. Additionally, when delays are a result of airborne vectoring, they also have a negative effect on the local environment (in terms of emissions and noise). Delays also negatively affect passenger experience and connections. Delay reduction is, therefore, an important step in the process to optimize the operations at Schiphol airport.

One of the major sources of delay at Schiphol is the occurrence of so called *hotspots*. An example of such hotspot is the occurrence of a bunch of traffic particularly at the boundary of the Amsterdam FIR. A hotspot occurs as a result of a situation where traffic demand is higher that capacity. These hotspots reduce planning flexibility, and complicate capacity forecasts for flow management ATCOs and creates an imbalance between demand and capacity, see Figure 1.1.

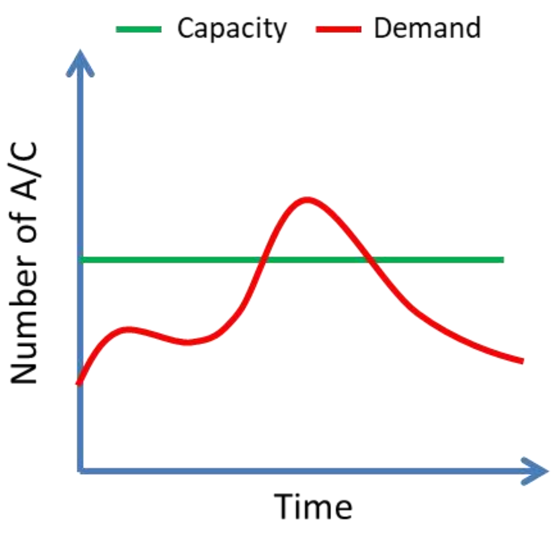

Figure 1.1: Demand and capacity as a function of time. When demand exceeds capacity a hotspot can occur.TTO/TTA can aid in the resolution of this imbalance.

To combat hotspots, and balance demand with capacity, ANSPs request the Network Manager (NM) in Brussels to regulate traffic by imposing delays on aircraft take-off times. These take-off delays result in new Calculated Take-Off Times (CTOTs) for aircraft. CTOTs should, in principle, alleviate hotspot, and therefore, reduce the need for path stretching actions from ATCOs. For Schiphol, the period in which the expected demand exceeds the available capacity, a request to the NM is sent to issue CTOTs. Practice has shown, however, that CTOTs do not have the full desired effect because flight crews aim to recover any CTOT imposed delays by flying faster and/or by requesting different routes (horizontally and vertically). In other words, hotspots continue to occur in spite of CTOTs.

To improve the effectiveness of CTOTs the Target Time Over/Arrival (TTO/TTA) concept is a potentially effective measure.. This study details the TTA concept, analyses best-practises of past-trials at other airports and uses these best-practises to sketch an initial TTA concept for the Schiphol operation which can be used in a first trial. The TTA concept fits the long term LVNL objective to move towards a more collaborative airport operation between ANSP and airline.

1.2 Project Goal

As indicated above, the TTO/TTA concept has shown promising results at other European airports. For the specific Schiphol situation, the TTO/TTA concept is a potential contributor to increasing the effectiveness of the CTOTs.. Before this concept can be tested and implemented at Schiphol, however, it is necessary to understand the technical foundations of the TTO/TTA concept, and determine how the concept could potentially fit with the existing operations at Schiphol. If the concept shows potential for Schiphol, a proof-of-concept trial should be organized after which its potential can be shown by data-analysis and questionnaires. This study takes the *first step* by assessing the stakeholder acceptance of the initial TTO/TTA concept for Schiphol and to sketch the proof-of-concept trial. To this end, the main goal of the study is to:

1. Understand the TTO/TTA concept from technical and stakeholder perspectives;
2. Analyse previous trials of TTO/TTA at other European airports to evaluate its benefits and pitfalls;
3. Assess the potential stakeholder acceptance of TTO/TTA at Amsterdam Airport Schiphol.
4. Sketch the proof-of-concept trial.

The results of this initial study will aid all involved stakeholders in deciding about further steps towards. The outcomes of this proof of concept trial may further lead to development of a more advanced Schiphol TTA concept.

1.3 Methodology

To achieve the goals mentioned above, a three pronged approach is used. First, an extensive literature study of relevant (SESAR) documentation is performed to understand the technical details of the TTO/TTA concept, as well as to analyse the results of the previous live flight trials of this concept. Subsequently, telephone interviews were conducted with the operational experts who were involved in the live trials to gain a further understanding of the specific goal, implementation and results of each trial; Table 1.1 below lists the details of the operational experts contacted for this purpose. Finally, an initial TTO/TTA concept for Schiphol was developed in close cooperation with the relevant local stakeholders; namely KLM and LVNL. The ‘Balanced Score Card’ (BSC) methodology was used to enable all stakeholders to discuss the benefits and pitfalls of the initial TTO/TTA concept proposed for a proof of concept trial at Schiphol, as well as to *qualitatively* determine the effect of the proposed concept on a number of KPIs, while taking into account the nature of the operations at Schiphol.

Table 1.1: Telephone interview participants

#	Organization	Title of Interviewee	Date of Interview
1	NATS	ACM[1] Manager	16-01-2019
2	DSNA	PJ25 xStream WP 7 Leader	21-01-2019
3	Skyguide	ACM[1] Manager	24-01-2019
4	Network Manager	TT/TTA Expert	24-01-2019

1.4 Report Structure

This report consists of six chapters. Following this introductory chapter, Chapter 2 provides definitions and a general overview of the TTO/TTA concept as envisioned by SESAR. Subsequently, Chapter 3 summarizes the goals, the specific TTO/TTA implementation, and the results of the previous TTO/TTA flight trials based on information contained in SESAR documents, and based on information gathered from telephone interviews with operational experts. Chapter 4 describes the initial TTO/TTA concept foreseen for Schiphol. Chapter 5 qualitatively assesses the stakeholder acceptance of this initial concept by means of the Balanced Score Card (BSC) approach. Finally, Chapter 6 provides the conclusions and recommendations of this study.

[1] ACM stand for Airspace Capacity Management

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2 SESAR Target Time Over/Arrival Concept

The current Air Traffic Flow and Capacity Management (ATFCM) approach used in Europe assumes that CTOT induced ground delays are evenly propagated along the planned routes of aircraft. The propagation of these delays should, in theory, resolve predicted hotspots. However, in reality, the effectiveness of CTOTs is reduced by the fact that flight crews often fly faster and/or request different routes (horizontally and vertically) to recover delays in an effort to achieve their scheduled arrival times. Additionally, other factors, such as 'ATC directs', interfere with the resolution of predicted hotspots.

To increase the effectiveness of CTOTs, SESAR has developed the so called 'Target Time Over/Arrival' (TTO/TTA) concept as a means to increase the predictability of the European aviation network. In fact, both TTO and TTA are included in SESAR Pilot Common Projects (PCPs) as a means to resolve hotspots, increase punctuality, and reduce flight delays. These concepts are part of so called 'Target Time Management' (TTM) solutions proposed by SESAR to increase the timing awareness of ATCOs and pilots, using 4D constraints. In this way, TTO/TTA, and more broadly, TTM, is expected to result in a better Demand-Capacity Balancing (DCB), as a first step towards working more cooperative between ANSPs and airlines.

As many trials that have been executed relate to the SESAR version of the TTO/TTA concept, the focus of this chapter is to provide an overview of the TTO/TTA concept as envisioned by SESAR. First, a summary of key definitions related to TTM and dynamic DCB is presented. Subsequently, an overview of the TTO/TTA concept is given. Using this overview as a starting point, the main building blocks, or components, of the TTO/TTA concept are described. For a more detailed description of the TTO/TTA concept, the reader is referred to Appendix A.

The information described in this chapter is sourced from the SESAR Operational Service and Environment Document (OSED) for dynamic DCB measures [1]. The chapter, therefore, describes TTO/TTA as per the original SESAR concept. For detailed descriptions of the actual operational implementations of this concept, the reader is referred to Chapter 3.

2.1 Definitions

Several definitions used throughout this report are listed in the table below.

Table 2.1: Basic Definitions related to Target Time Management (TTM) and Dynamic Demand Capacity Balancing (DCB)

Term	Definition
Arrival Manager (AMAN)	Arrival Manager is a planning system to improve arrival flows at one or more airports by calculating the optimised approach / landing sequence and Target Landing Times (TLDT) and, where needed, times for specific fixes for each flight, taking multiple constraints and preferences into account.
Calculated Take-Off Time (CTOT)	The time provided by the Network Manager Operational Cell (NMOC), taking into account the predicted European Civil Aviation Conference (ECAC) ATC flow situation, that an aircraft has been calculated to take off. The CTOT slot has a tolerance of – 5 to +10 minutes.

Hotspot	A traffic hotspot occurs when traffic demand is greater than capacity. A hotspot can be caused by a variety of factors including traffic bunching (see below)
Short Term ATFCM (STAM)	It includes cherry-picking, a measure impacting a selected flight or flow measures, a measure impacting a group of flights. It may be target-time, Minimum Departure Interval (MDI), rerouting, level-capping, SID change, Miles in Trail (MIT) etc.
Traffic Bunch	A traffic bunch occurs when packets of aircraft arrive at the same, unexpected time, in a congested area.
Target Time Arrival (TTA)	An ATM computed arrival time. It is not a constraint but a progressively refined planning time that is used to coordinate between arrival and departure management applications.
Target Time Over (TTO)	An ATM computed over-flight time. It is a progressively refined planning time that is used as an indication for flight planning and execution to coordinate at network level and enhance the effectiveness of the ATFCM measures.
Target Deviation Indicator (TDI)	In the execution phase, it represents the difference between the planned DCB Target Time (TT/TTA) and the Estimated Time (ETO/ETA)

2.2 Overview and Goal of the SESAR TTO/TTA Concept

The TTO/TTA concept is based on the assumption that DCB interferences in the network will be alleviated if the concerned actors (ANSPs, AOs, pilots) are **made aware** about so called ‘target time’ constraints to resolve hotspots along the routes of aircrafts. SESAR presumes that awareness leads to improved 3D+time adherence to flight plans during the execution phase, which in turn contributes to better resolution of hotspots and more effective CTOT delays. TTOs will therefore enable ANSPs and airlines to work more cooperatively.

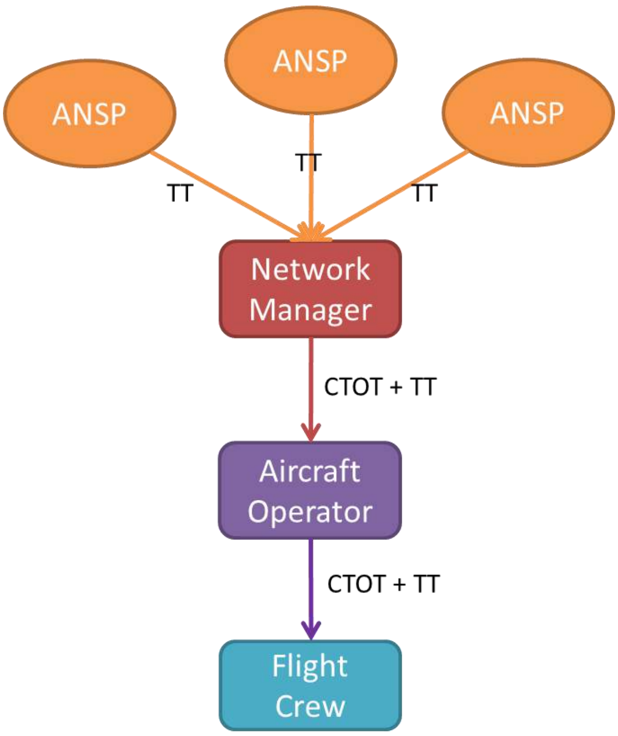

Figure 2.1: Overview of the SESAR Target Time (TT) Concept

Figure 2.1 provides a high level overview of the SESAR TTO/TTA concept. Here, the process begins when ANSPs predict a hotspot. Such a hotspot can be caused by a traffic bunch; see Table 2.1 for the definitions of hotspots and traffic bunches as used in this report. To resolve the hotspot, ANSPs assign TTOs/TTAs to selected flights. It is possible that multiple ANSPs assign TTOs/TTAs to the same flight. These TTOs/TTAs are then communicated to the Network Manager (NM). Based on the principal of Most Penalizing regulation, the NM selects the final TTO/TTA that is assigned to a particular flight. Subsequently, the CTOT is calculated from the TTO/TTA. In the SESAR concept this calculation is done by the NM which uses flight plan information and the selected TTO/TTA to compute the CTOT of each flight. The CTOT and TT pair is communicated by NM to AOs using standard Slot Allocation Messages (SAMs). AOs subsequently communicate the TTO/TTA of the affected flights to the corresponding flight crews prior to take-off (using ACARS). If flight crews adhere to the supplied CTOT and TTO/TTA, then the effect of the regulations is expected to increase.

Note that there is only a minor conceptual difference between TTO and TTA; TTO refers to target time constraints for en-route waypoints, whereas TTA refers to target time constraints in the arrival process. Because this difference is only minor, the rest of this report uses the term Target Time (TT) to refer to either TTO or TTA. The only exception to this is Chapter 3 which describes the previous trial results; in that chapter the terms TTO and TTA are used depending on the specific implementation of the concept at each trial location.

2.3 Building Blocks of the SESAR TT Concept

The basic components, or building blocks, of the SESAR TT concept are shown in Figure 2.2, and described in Table 2.2. Additionally, Figure 2.3 describes the roles of the various stakeholders in the context of the SESAR TT concept. Figure 2.3 is complementary to Figure 2.2. Note that the ‘reconciliation’ block for the NM indicates the use of the Most Penalizing Regulation (MPR) approach to determine the final TT for a flight as described in Appendix A.5.

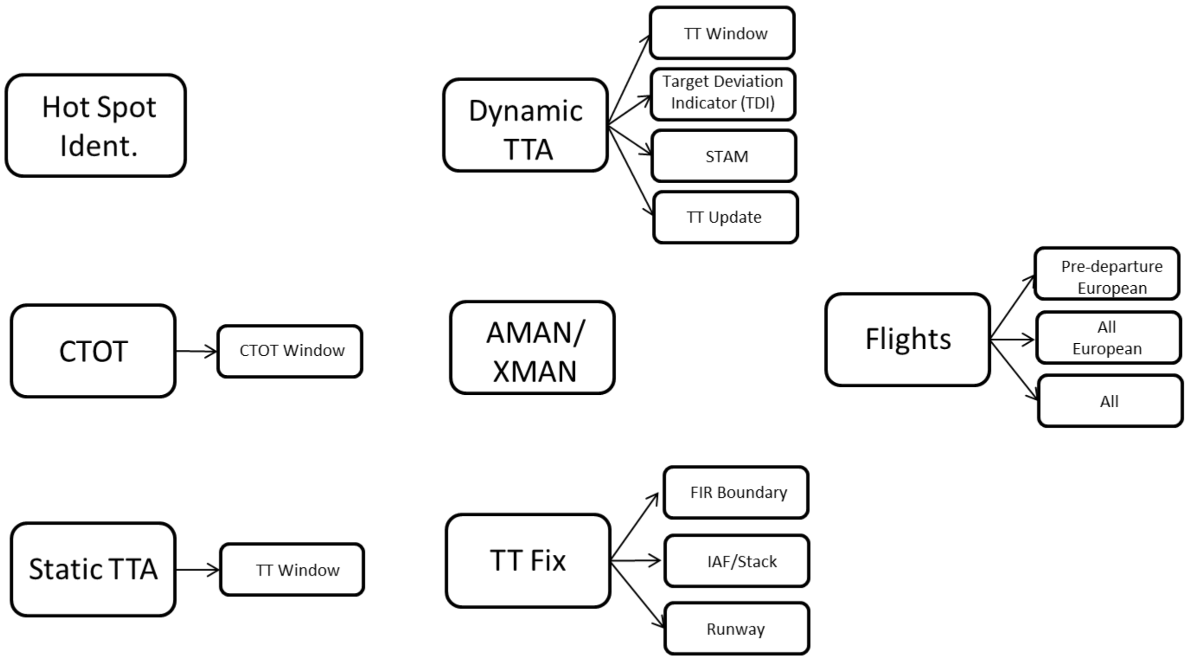

Figure 2.2: Basic components, or building blocks, of the SESAR TT concept

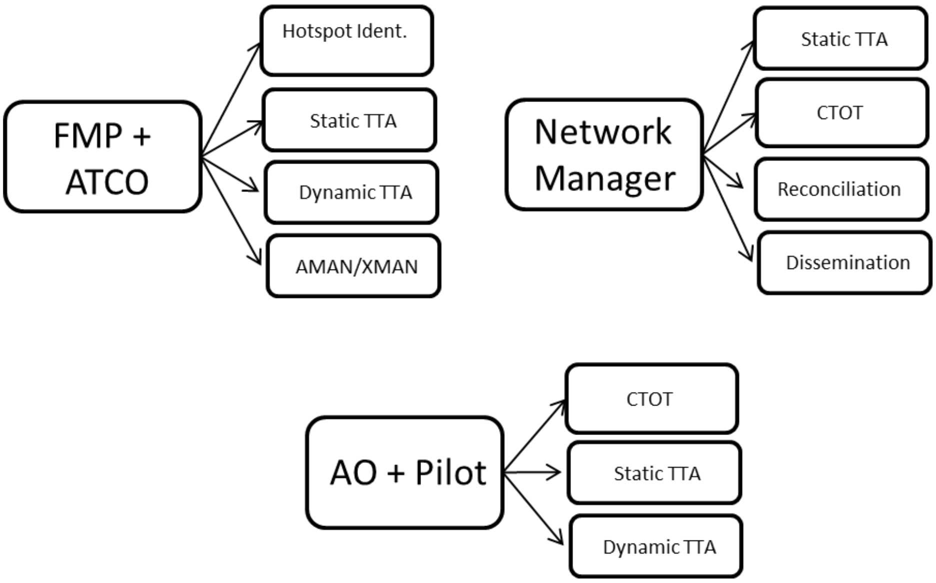

Figure 2.3: Stakeholder roles in the SESAR TT concept

Table 2.2: TT building block descriptions

Building Block	Description
Hotspot Identification	The first step of the TT concept is hotspot identification. This process, performed by the FMP, involves the determination of which flights contribute to the occurrence of a hotspot and at what times. For more details, the reader is referred to Appendix A.1.
Static TT	Once a hotspot is identified, the local DCB actor, namely the FMP, assigns TTs to individual fights. The TT is assigned in such a way that the detected hotspot is resolved if adhered to by the flight crew. A 'static' TT is a TT that is assigned prior to take-off and one that is not updated in flight. In addition to a nominal value, a Target Window (TW) is associated with static TTs. The TW can be seen as a fixed tolerance around the TT within which the flight crew should aim to arrive at the TT fix (see below), and which enables hotspot resolution. Experience has shown that the TW is smaller than the CTOT window (see chapter 3). For more specifics on TT calculation, TT window and TT dissemination, the reader is referred to Appendices A.1, A.4 and A.6, respectively.
Dynamic TT	In contrast to 'static TT', in 'dynamic' TT, the adherence to the initially prescribed TT is monitored in flight using the so called Target Deviation Indicator (TDI). The TDI is the difference between the TT and the ETA at the TT fix. If this TDI is outside the TW, then Short Term ATFCM Measures (STAM: level capping, rerouting etc.) can be used to enforce adherence, or if this is unfeasible, a new achievable TT can be communicated to the flight crew. As for static TT, dynamic TT is characterized by a nominal value and a TW. For more info on dynamic TT, the reader is referred to Appendix A.5.
CTOT	The Calculated Take-Off Time (CTOT) is reverse calculated from the desired TT to enable hotspot dissipation. The CTOT is calculated by the NM based on the TT that is determined to be the most penalizing regulation (i.e., largest delay). The CTOT is accompanied by a window of -5 +10 mins. For more information on how the CTOT is calculated by the NM, the reader referred to Appendix A.2 and A.3.
TT Fix	The TT fix refers to the geographical location that is assigned with a TT. Different types of location can be used; FIR boundary, IAF, stack entry point and runway are example TT fix locations.
Flights	TT can be applied to different types of flights. The most limited implementation of TT can focus on only pre-departure European flights. In this case, TT would be complementary to CTOT. It is also possible to assign to all European, for all flights in general, including long haul flights. In this case TT can be imposed on flights that are already en route. For such cases, there is no relationship between TT and CTOT.
AMAN/XMAN	The TT concept is compatible with AMAN and XMAN. In this case, SESAR states that TT should function as an input to AMAN/XMAN such that AMAN/XMAN only alters the ETA of a flight within its TW. This is described in more detail in Appendix A.7.

For more specific details on the SESAR TTO/TTA concept, the reader is referred to Appendix A. This appendix covers the following topics:

- Hotspot detection and target time assignment;
- Relationship between CTOT and TTO/TTA;
- Reconciliation of multiple target times;
- Target window;
- Target time deviation monitoring and revision process;
- Dissemination of target times;
- Link between target times and AMAN/XMAN.

2.4 TT concept in the PCP

The Pilot Common Projects (PCP) mandate states the following about TTA/TTO as part of Network Collaborative Management:

Calculated Take-off Time to Target Times for ATFCM purposes
Target Times (TT) shall be applied to selected flights for ATFCM purposes to manage ATFCM at the point of congestion rather than only at departure. Where available, the Target Times of Arrival (TTA) shall be derived from the Airport Operations Plan (AOP). TTAs shall be used to support airport arrival sequencing processes in the en-route phase.

System requirements

- Network Manager's systems shall support target time sharing. Systems shall be able to adjust Calculated Take Off Times (CTOTs) based on refined and agreed TTAs at the destination airport; TTAs shall be integrated into the AOP for subsequent refinement of the NOP
- Flight data processing systems may need to be adapted in order to process downlinked trajectory data (ADS-C EPP)

Furthermore it states that: *"Operational stakeholders and the Network Manager shall operate Network Collaborative Management as from 1 January 2022."*

The focus of the PCP is very much on the Network Manager which must make available target times (TTO/TTA) with the Calculated Take Off Times (CTOTs). These target times are intended to improve flight plan adherence and to improve the predictability and stability of the network operations. The TTA concept is intended to support airport arrival sequencing processes, as it is intended to prevent traffic bunches, but it is not intended in any way to replace arrival management functions.

3 Previous TT Experiences

The concept of TT has been trialled at several airports in Europe. Those TT trials were all part of different concept demonstrations within SESAR. Some of the trial results are still investigated and analysed. This is the case for xStream trials. Those trials took place in Zurich and Paris last year. Unfortunately, results of the xStream trials are not yet available.
The predecessor of the xStream trials are the iStream trials. The objective of the iStream (integrated SESAR Trials for Enhanced Arrival Management) project is to pave the way for evaluating concepts from the PCP within an integrated global collaborative management of arrivals. The project particularly addresses the Target Time Management. The iStream trials are the most relevant trials that the Schiphol concept can build on. Therefore, these trials are described in detail in this chapter. An overview of the trials that are discussed in this report can be found in Table 3.1. For every trial the goal, TT concept, results and recommendations are provided in this report.

Table 3.1: Overview of the discussed iStream TT trials

Airport	Start	End	Number of flights	Remarks	Goal
Zurich (ZRH)	15/06/2015	30/06/2016	~4800	Currently investigated under xStream trials	Avoid early arrivals over IAF
Paris (CDG)	Phase 1: 02/05/2016 Phase 2: 26/06/2016	16/09/2016	~1600	Currently investigated under xStream trials, included AMAN integration	Optimize arrival sequence
London (LHR)	May 2018	June 2018	N/A	Research based on iStream results	Optimize arrival sequence
Palma (PMI)	June 2013	June 2013	N/A	-	Enhance arrival management

To complement the literature study of the iStream projects experts from Skyguide, DSNA and NATS have been interviewed. The interview notes can be found in Appendix B. Based on both trial documentation and interviews an overview of the pros and cons regarding the TT concept is set up. This overview is provided in Section 3.5.

3.1 Zurich ZRH Trails

The Zurich (ZRH) trials were initially part of the FAIRSTREAM trial that took place in 2013. This trial was the predecessor of the iStream trials. Currently the TT concept is investigated as part of the xStream trials. The results of those trials are not yet available. In this section the goals, concept and results regarding the ZRH (iStream) trials are elaborated.

3.1.1 Trial Goals

The objective of the ZRH trial (referred as EXE-01.02-D-06.3 in iStream Demonstration Report [2]) was to demonstrate that overall compliance to Target Times can contribute to smoother arrival sequencing taking into account airspace users' preferences and providing a better service by integrating those preferences.

ZRH has a night ban and the first landing is allowed after 06:04 LT. For this reason flights that are expected to arrive before 06:04LT are placed into a holding pattern. In order to enhance the awareness of the concerned incoming flights during the first hour (06:04 – 07:00 LT) as well as to enhance their adherence to Scheduled Times of Arrivals (STA), a Target Time allocation and distribution procedure has been investigated. The main goal was to find out if the integration of the TT concept results in a reduction of early arrivals.

3.1.2 TT Implementation

Every trial has executed a unique TT concept that is based on both the SESAR concept and TT building blocks. In the ZRH concept the role of the FMP is vital. For this reason the task of the FMP is described first. The overall procedure can be found in
Table 3.2.
The FMP generates the arrival sequence over the approach fix (IAF) based on the Estimated Time Over (ETO) that is received from airlines (long-haul) or ETOs that can be taken from the CHMI (CFMU Human Machine Interface) for short/medium-haul flights.

In a chronological order, the undertaken actions are:

1. FMP generates the arrival sequence via an Excel tool and adjusts it manually if necessary.
2. FMP distributes the resulting TTs over the IAF via email to the different AOCs until latest 02:00LT.
3. FMP assesses requests for company specific operations
4. FMP monitors the adherence to the TT and provides feedback by noting it accordingly in a dedicated form.

In step 1 the FMP checked the generated sequence and assured a 2 minute gap between each estimated landing (ELDT). If this was not the case, the ELDT was adapted manually. In case of manual prioritization, flights closer to their Scheduled Time of Arrival (STA) were prioritized. Additionally, an amendment of +/- 5mins of the provided ETO was the limit for adaptions. If those exceed the +/- 5min range, the arrival sequence became voluntary for the airlines but a sequence was still generated and distributed.

The next step is the arrival sequence publication. This information is distributed among the airlines. An example is provided in Figure 3.1. The final step is to record the actual time over the IAF and the actual landing time, to assure proper post operations analysis.

Table 3.2 shows the complete overview and time-line of the procedure regarding the TT concept at ZRH.

Table 3.2: ZRH TT concept procedure

Phase	When	Who	What	Mean/Tool
Planning	EOBT – 10:00	AOC	Assign Strategic TT when filing the FPL	FPL
Planning	EOBT – 00:30	Crews	Manage Off-Block/TO in order to meet TT	Crew
Coordination	After Take Off	Crews	Fly speed according company policy	Crew
Coordination	TOC	Crews	Transmit ETO the designated IAF to AOC	ACARS
Coordination	01:00-01:30 LT (latest)	AOC	Analyse ETOs received for own flights and optimize TT assignments: - to ensure a maximum of passenger connections - to optimize Cost Index of involved flights Transmit ETOs to FMP ZRH incl. possible preferences	Email
Coordination	01:00-02:00 LT	FMP	Assign TTs for flights based on analysis of ETO/ STA/preferences or based on ETOs from CHMI	Excel tool
Coordination	01:00-02:00 LT	FMP	Transmit confirmed TTs for all flights to AOCs	Email
Execution	Upon TT reception	AOCs	Transmit TT to flights	ACARS
Execution	ASAP	Crews	Manage flight to reach designated IAF at TT	FMS
Execution	ASAP	ATC	The flights are inserted into the Arrival Manager in their order of arrival	AMAN
Post OPS	06:00LT onwards	FMP	Input the ATO and ALDT of the flights in the Excel sheet and fill the feedback tab	Excel tool

To get this procedure up and running several tools and communication flows have been initiated and developed. The tools and communication channels that have been used are listed in Table 3.3.

Table 3.3: Tooling required for ZRH TT procedures

Type	Name	Functionality
Tool	CHMI (CFMU Human-Machine Interface)	To provide the arrival flight list of 06:04-07:00 LT and the ETOs for short/medium-haul flights. The CHMI tool is provided by Eurocontrol.
Communication	ACARS	To receive ETOs from long-hauls' flight crews; to communicate designated TTs with flight crews
Tool	ZRH STA flight list	Excel file that contains the flight list in the relevant timing window
Tool	SWISS company tool	To provide the SWISS flights' sequence based on passenger connections and ETO messages. SWISS was allowed to request TT swaps[2].
Communication	ETO mails	Email from OCCs to transmit ETOs of long-haul flights
Tool	FMP excel tool	To generate the arrival sequence and tooling (email) to distribute the sequence towards AOCs

[2] Since SWISS was the only airline that had more than 1 arrival within the early arrival wave, swapping requests was only relevant for SWISS AOC.

Destination:	Sequence Number	Flight	IAF	TTO	Date:
LSZH / ZRH	1	SWR179	AMIKI	03:55	
	2	SWR139	RILAX	03:53	
	3	SWR155	AMIKI	03:59	
	4	SWR7K	GIPOL	04:02	
	5	SWR289	KELIP	04:00	
	6	ETD73	AMIKI	04:05	
	7	SWR87	GIPOL	04:08	
	8	SWR243	AMIKI	04:09	
	9	CPA383	AMIKI	04:13	
	10	SWR117R	AMIKI	04:15	
	11	SWR147	AMIKI	04:17	
	12	QTR093	AMIKI	04:20	
	13	SWR40KX	GIPOL	04:39	
	14	THA970	AMIKI	04:40	
	15	#N/A	#N/A	#N/A	
	16	#N/A	#N/A	#N/A	
	17	#N/A	#N/A	#N/A	
	18	#N/A	#N/A	#N/A	
	19	#N/A	#N/A	#N/A	
	20	#N/A	#N/A	#N/A	
	21	#N/A	#N/A	#N/A	
	22	#N/A	#N/A	#N/A	
	23	#N/A	#N/A	#N/A	

Figure 3.1: Example of an arrival sequence based on TTs [2]

3.1.3 Trial Results

The trial results for ZRH are focused on KPIs such as predictability, efficiency and safety & workload.
It should be noted that the general aim of the trials was to improve the arrival sequence and reduce the number of early arrivals (and indirectly: reduce the number of traffic in a holding pattern during the early morning arrivals).

3.1.3.1 Predictability

In every TTM related research the TT adherence is one of the most important measures. This is because TTA adherence is closely linked with traffic predictability. For the ZRH trials two TT (adherence) windows are generally used for the TT adherence analysis: [-3, 3] minutes and [-4, 4] minutes. The results are visualised in Figure 3.2. This figure shows that almost 70% of all flights adhere to TT regulations in the [-4, 4] minute TT window

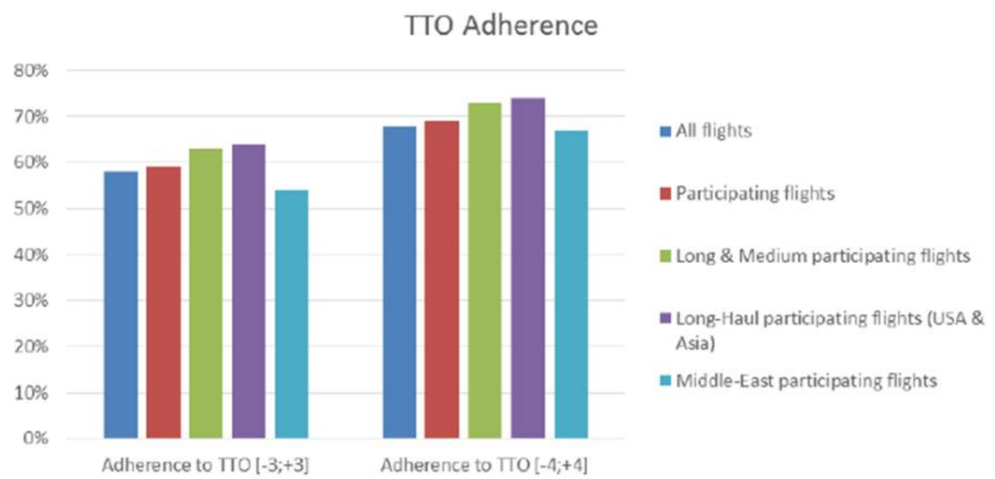

Figure 3.2: TTO adherence for [-3, 3] and [-4, 4] minute TTO window for ZRH trials [2]

Subsequently, it is relevant to consider the distribution of the TT deviation (also referred as TDI, see paragraph 2.2) for different relevant research categories. The participating airlines, long-haul and medium and short-haul flights are taken into account here.
The TT deviations of those categories are visualised in Figure 3.3.

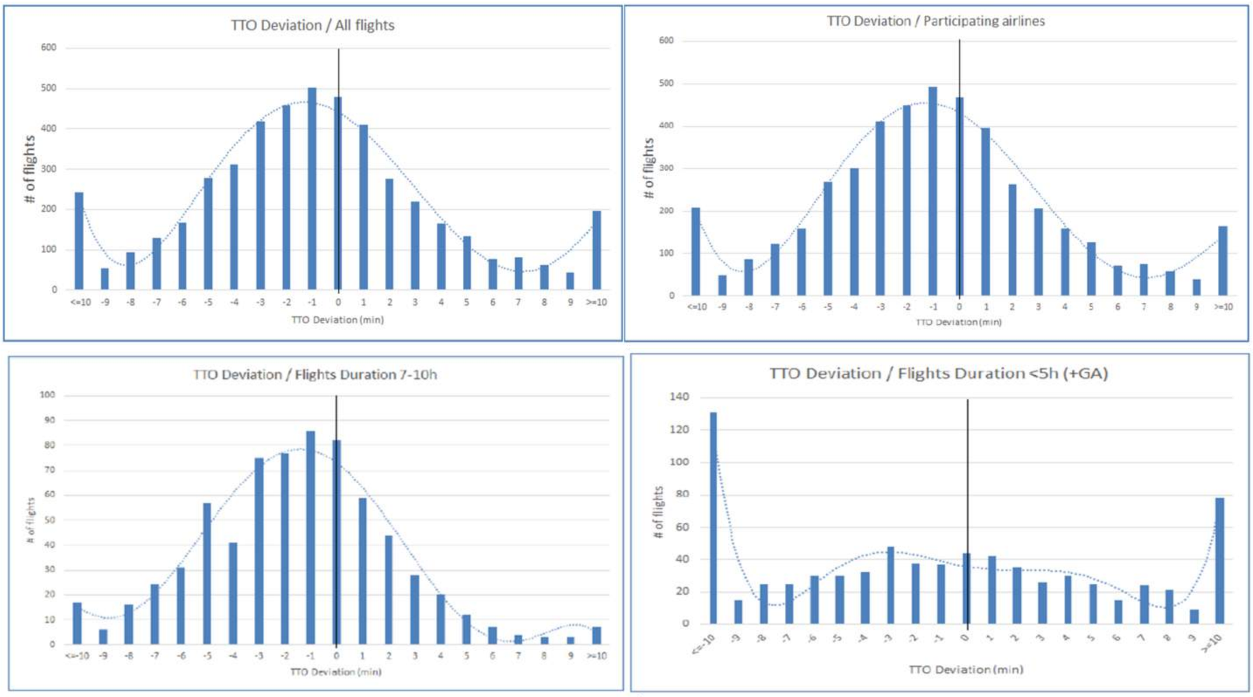

Figure 3.3: TTO deviation during the ZRH trials based on four different categories [2]

In Figure 3.3 (a) the TT deviation for all flights is visualized. A slight difference can be observed when looking at Figure 3.3 (b). This figure only contains data regarding participating airlines. From this figure it can thus be concluded that almost every airline participated in the trials. Figures 3.3 (c) and (d) show the TT deviations for long-haul and medium + short-haul flights respectively.
In Figure 3.3 (d) a greater disparity in TT adherence for the (short- and medium-haul) flights, where the ETO was mainly provided by the CHMI is observed. This points out the lack of accuracy of the CHMI tool and shows that the concept in this form is less applicable for medium- and short-haul flights. In this situation it is better to also receive flight information (ETO) via e.g. the Aircraft Operator. Overall it can be concluded that traffic predictability increased due to the introduction of the TT concept.

3.1.3.2 Efficiency

Efficiency is closely related to cost reduction and emissions. For this reason flight efficiency is often linked with aircraft speed and flown distances. In order to reach their TT, pilots (probably) had to adapt aircraft speed during cruise phase. For this reason an impact on fuel consumption was expected. Since there was already a reduction of cruise speed within SWISS procedures during the trials (change of cost-index), the impact of TT regulations and cruise efficiency could not be evaluated for most of the flights.
For the approach phase, an analysis regarding the average distance flown in the Zurich TMA over 3.5 years is conducted. The results are visualised in Figure 3.4.

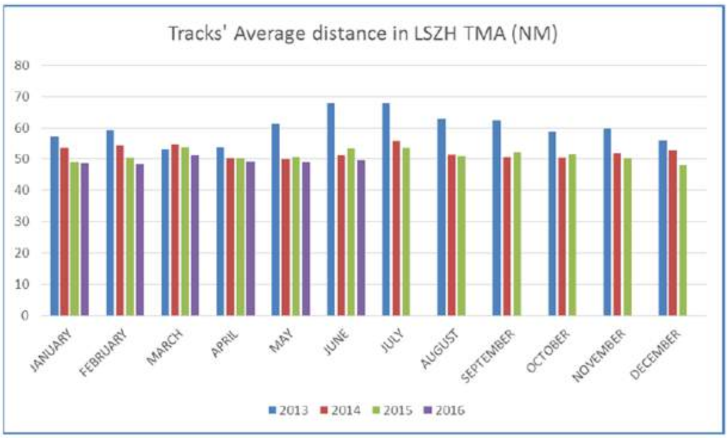

Figure 3.4: Average distance flown in the ZRH TMA during the early arrival wave [2]

This clearly shows that the distance flown in the TMA reduced due to the introduction of TT regulations[3]. Besides the distance flown in the TMA, it is also relevant to have a look at the amount of early arrivals at the IAF. Due to the night ban of Zurich, aircraft arriving at the IAF before 05:49 LT are put into a holding pattern. The TT regulations should have resulted in less aircraft arriving too early. This is visualised in Figure 3.5. From this figure it becomes clear that due to TT regulations, less aircraft arrived early and thus less traffic was put into a holding. This also resulted in a decrease of fuel burn and an efficiency increase. With respect to a baseline measure from 2008, a reduction of 96% in holding and 30% of less arrival distance flown was achieved during the iStream trials (June 2015 until June 2016)

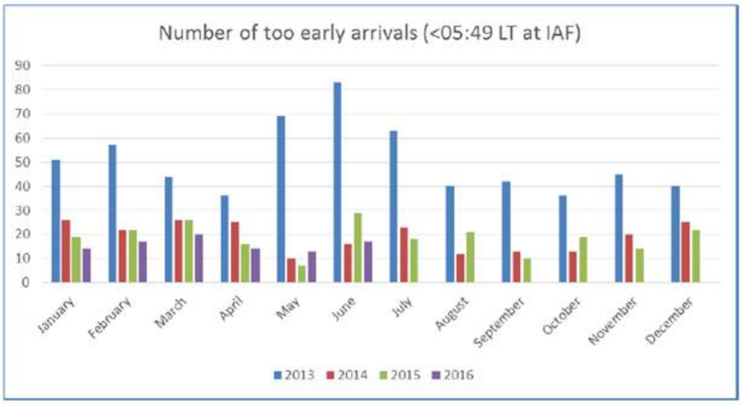

Figure 3.5: Number of early arrivals at ZRH before and during the TTO trials [2]

3.1.3.3 Safety & workload

One of the negative effects regarding the introduction of a TT concept may be an increase of workload and a reduction of safety. Because both measures are very important within aviation, the effect on safety & workload was assessed. Both safety & workload analysis have been performed based on questionnaires. Most of the stakeholders that were involved during the trials are included in this analysis.

[3] In 2014, the "Early Wave procedure" was established, which already instituted Target Times for SWISS and Edelweiss flights. In 2015 the iStream trials started.

Air traffic controllers
Zurich Approach ATCOs were informed about the trials but were not actors. The trials aimed to be transparent on the ATC side. No specific issues, neither on workload nor safety, were reported.

FMP
A total of 51 questionnaires from FMP controllers were collected. 64% of the FMP controllers think that the trials did not compromise safety. The demo report stated that this percentage is low due to a misunderstanding of one of the questions in the questionnaire [2]. This statement is also supported by the fact that no incidents have been reported during the trials. Regarding workload, 48% of the FMPs claimed that they had the feeling that workload increased. However, 82% disagree that the trials affected their overall performance.

Flight crew
A total of 113 questionnaires from the flight crews participating during the trials were collected. Safety was never compromised during the trials for 92% of the crews. As well as the workload did not increase for 83%.

3.1.3.4 Conclusions and recommendations for iStream Zurich trials

Both conclusions and recommendations that can be drawn from the ZRH trials that were part of iStream, can be found in the Demonstration Report of iStream [2]. The trials allowed optimizing a Target Time concept to reach an operationally sustainable and profitable procedure to all aviation stakeholders in the ZRH environment. The concept showed promising results regarding the predefined goals, see paragraph 3.1.1.

In order to enhance benefits for the arrival flow through the concept, the main recommendations are:

- NMOC to optimize flights profiles' updates in order to have accurate flight time profiles, especially for long-hauls.
- To be able to integrate the TT information into the future AMAN system, and to distribute this TT information or speed / time constraints at other points to the adjacent centres (upstream ATC), so upstream ATC can manage the flights with full knowledge of their time targets.
- TTs known by en-route ATC and departure airport / ATC should be in favour.
- Arrival sequence / TT to be communicated to NMOC and taken into account in the flights' profiles. The TTs of the short and medium haul flights shall be integrated into the TT/CTOT distribution process by NMOC.
- Performant data exchange between Airspace Users, ATC and NMOC is desirable via for example SWIM.

Many of those recommendations are taken into account during the xStream trials. Although the results of the xStream trials are currently being compiled, operational experts involved in the trials stated that the first results are very promising. In addition they mentioned that the (iStream) ZRH TT concept is taken into daily operation.

3.2 Paris CDG Trials

The large scale demonstration trials in Paris CDG are part of the iStream project and are split over two different exercise phases. The first phase (referred as EXE-01.02-D-01) concerns the transmission and execution of Target Times for regulated flights inbound CDG during the second morning peak (08:00-09:30 LT). During this morning peak traffic demand exceeds capacity and ATFM regulations are –normally - needed.
During the second trial phase (referred as EXE-01.02-D-03) the option to *revise* the TT was added. For this exercise tooling called iAMAN was used by the FMP to optimise the sequence of TT for selected flights.
The trials are executed according to the time scheme provided in Table 3.4.

Table 3.4: Time scheme for the CDG trials

Exercise	Description	Exercise execution start date	Exercise execution end date	Start analysis date
EXE-01.02-D-01	Initial TT transmission and execution for IFPS flights[4]	02/05/2016	16/09/2016	31/07/2016
EXE-01.02-D-03	TT revision & execution	30/06/2016	16/09/2016	16/08/2016

3.2.1 Trial Goals

The general aim of the second phase TTA trials in Paris was to improve the CTOT based on the TT concept and to optimize the arrival sequence for CDG (by making use of the iAMAN tools). The relation between CTOT and TT is described in Appendix A.2.

3.2.2 TT Implementation

Since there are two different TT trial phases, two different procedures were executed. For the EXE-01.02-D-01 (from now on referred as D-01) exercise the procedure is visualized in
Table 3.5. For exercise EXE-01.02-D-03 (from now on referred as D-03) the trial procedure is shown in
Table 3.6.

Table 3.5: CDG TT D-01 concept procedure

Phase	When	Who	What	Mean/Tool
Planning	D-1, around 10:30 LT	FMP	Send upstream ANSP potential traffic volume to be regulated on D	-
Planning Coordination	EOBT – 03:00	AOC	AOC submits FPL to IFPS	FPL
	Continuous monitoring	FMP	Detect hotspot requiring CASA regulations. Request CASA regulations to	-

[4] IFPS flights are flights that depart from the IFPS zone, including Europe, Turkey and Morocco.

			NM. Monitor evolution of solution	
Coordination	After previous step	NM	Create CASA regulation as instructed by FMP. Publish regulation.	-
Coordination	EOBT – 02:00	NM	SAM (CTOT + TT) calculated and transmitted	-
Coordination	EOBT – few minutes	AOC	Update FPL to match TT. Send CHG message.	-
Coordination	EOBT – few minutes	NM	SRM with CTOT changed in line with CHG message received. TT remains unchanged	-
Execution	Before EOBT – 00:10	AOC	Transmit TT to flights	ACARS
Execution	Before EOBT	Crew	TT available in cockpit. Crew may inform ADEP TWR of their TOT to respect TT	R/T
Execution	Before ATOT	ATC	Whenever possible, ATCOs manage the flights in accordance with the wish of the crew	R/T
Execution	After ATOT	Crew	Crew may introduce TT into FMS and do their best to safely achieve target within ICAO rules and limits of company policy (cost index, cruise speed limits). Current flown speed variations of 0.04 Mach are coordinated with ATC	-
Execution	After ATOT	ATC	Apply safety standard rules and ensure flight separation. No priority rules for trial flights; whenever possible, ATCOs manage the flights in accordance with the wish of the crew	-

Table 3.6: CDG TT D-03 concept procedure

Phase	When	Who	What	Mean/Tool
Planning	D-1, around 10:30 LT	FMP	Send upstream ANSP potential traffic volume to be regulated on D	-
Planning	EOBT – 03:00	AOC	AOC submits FPL to IFPS	FPL
Coordination	Continuous monitoring	FMP	Detect hotspot requiring CASA regulations. Request CASA regulations to NM. Monitor evolution of solution	-
Coordination	After previous step	NM	Create CASA regulation as instructed by FMP. Publish regulation.	-
Coordination	EOBT – 02:00	NM	SAM (CTOT + TT) calculated and transmitted	-
Coordination	After previous step	FMP	Inform upstream ANSP about morning exercise status (Go/No go). Send regulated flight list impacting upstream ANSP sectors, including changes	Phone
Coordination	Hotspot – 01:30	AFR AOC	May send Paris FMP “AFLEX” request (swapping).	Phone
Coordination	Hotspot – 01:30	FMP	May optimise TT sequence by performing moves/swaps on the iAMAN timeline, for ATC purposes, or AFLEX request. Send the request to NM using iAMAN “PUSH” command, and phones the NM to advise of the demands	iAMAN, Phone
Coordination	Hotspot – 01:30	NM	Visualises the request on a dedicated HMI.	-

			Enters the CTOT in the NM OPS system. Advises Paris FMP of the outcome of the process. Coordinates with Paris FMP in case of partial acceptance. SRM (CTOT + TT) calculated and transmitted.	
Coordination	Hotspot – 01:30	FMP	Advises AFR of the outcome of the process	Phone
Coordination	EOBT – few minutes	AOC	Update FPL to match TT. Send CHG message.	-
Coordination	EOBT – few minutes	NM	SRM with CTOT changed in line with CHG message received. TT remains unchanged	-
Coordination	Before EOBT – 10 minutes	AOC	Transmit TT to Flight Crew	
Execution	Before EOBT	Crew	TT available in cockpit. FC may inform TWR of their Take-Off Time to respect TT	
Execution	Before ATOT	TWR ATC	If possible, ATCOs manage the flights in accordance with the wish of the flight crew	
Execution	After ATOT	Crew	Crew may introduce TT into flight management and do their best to safely achieve target within ATS ICAO rules and limits of company policy. Current flown speed variations of 0.04Mach or more are coordinated with ATC	
Execution	After ATOT	ATC en-route	Apply safety standard rules and ensure flight separation. No priority rules for trial flights; if possible, ATCOs manage the flights in accordance with the wish of the flight crew.	

Compared to the first exercise (D-01) a few tools were developed and validated for the execution of exercise D-03. This includes development of:

- The Paris ATFM tool (iAMAN) to be able to generate Target Times based on local defined constrains (by FMP). The tool should be able to distribute the proposed Target Times with the Network Manager;
- Development of an airline tool (Air France) to visualize the arrival sequence in order to identify swapping possibilities and communicate those with relevant stakeholder(s);
- Development of NM tooling to display iAMAN proposed Target Times;
- Upgrade of the XMAN portal by MUAC to link it with iAMAN information.

Before the actual trials took place a lot of stakeholder training was executed. The trial experts mentioned during an interview that this stakeholder training was a key factor regarding the success of the trials.

3.2.3 Trial Results

Exercise D-01 was executed according to the scenario design, on all days where regulations were enforced for Paris-CDG early morning arrivals (between 08H00 and 09H30 local time), between May 2nd and September 16th, 2016. Exercise D-03 required trained staff from Paris FMP that were able to work with the iAMAN tool, and for this reason was only implemented on pre-defined days, when regulations were enforced for Paris-CDG early morning arrivals, between June 30th and September 16th.

The effect of the iAMAN tool is best described by an example. During one of the trial days a regulation was enforced on northern CDG arrivals. The Paris FMP tries to optimize the hotspot resolution by advancing Target Times from the North (in this specific case: North-West). The effect of this optimization is shown in Figure 3.6.
When the initial TT sequence (CASA) was published, two bunches of traffic were noticeable. Here the FMP is needed to bring some further Target Time optimization. The final TT sequence has no bunches at all. The reduction of traffic bunching also resulted in a reduction of ATFM delay.

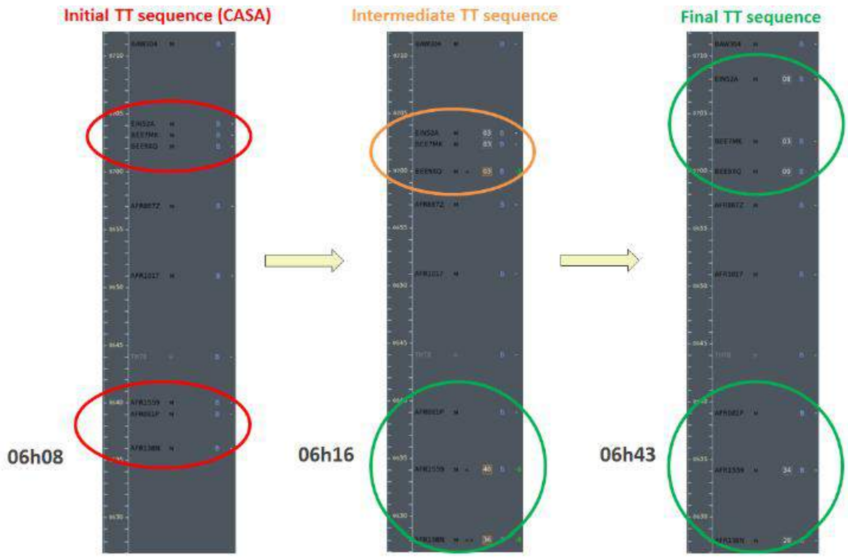

Figure 3.6: Example situation where traffic bunching for North-West CDG arrivals was managed with TTs [2]

3.2.3.1 Predictability (D-01)

The TT adherence measure is used to draw conclusions with regard to traffic predictability. The predictability of the flights participating in the trials slightly improved with respect to a baseline period (2015). This is both the case for all regulated flights and participating flight from Air France/HOP. Both results are respectively visualised in Figure 3.7. When the TT adherence of the TT windows [-3, 3] and [-4, 4] minutes is investigated, it seems that the baseline and trial flights (including AFR/HOP) show a similar percentage with respect to the baseline. However, if the graphs are further analysed it seems that the standard deviation (and thus variance) over the TT adherence distribution shown in Figure 3.7 decreased with respect to the baseline (-11%). This reduction of the standard deviation implies that traffic predictability increased.

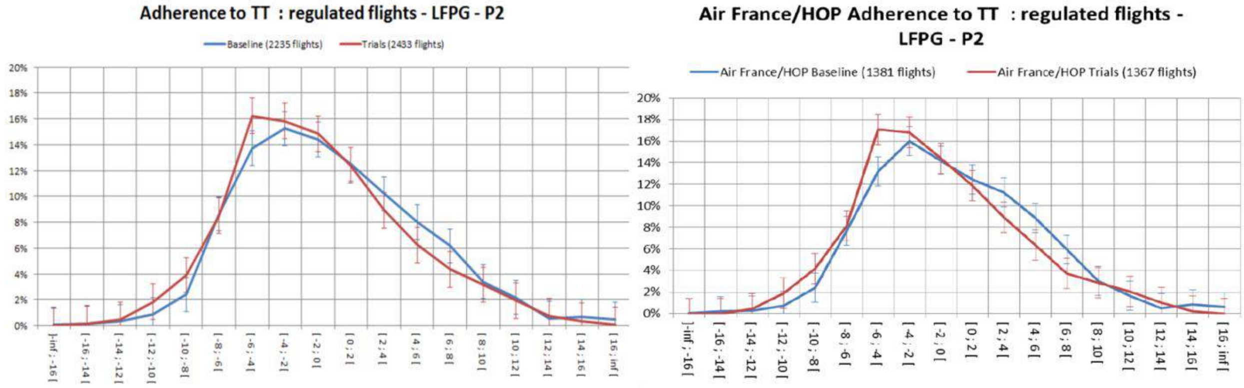

Figure 3.7: Adherence to TT for both all regulated flights and Air France/HOP flights [2]

With regard to the graphs in Figure 3.7 the demo report noted that ATFM delay was different in the baseline and trial situation. This makes this data not suitable for comparing trial results with the baseline [2]. For this reason the conclusion that there is an increased predictability must be viewed with a critical view. Another note is made regarding SWISS operations from Zurich. Due to Airport Collaborative Decision Making (A-CDM) systems in Zurich, SWISS crews were unable to adhere to their take off requests. Because their flight times were short, their options to adhere to the TT were limited.

3.2.3.2 Efficiency & capacity (D-01)

With respect to the baseline (May to mid-September 2015), the average extra flight time within the CDG TMA due to traffic congestion decreased with 30 seconds.
On top of that the TT procedure did not result in an increase of fuel usage. In addition to this it should be noted that due to the distributed Target Times some flights were able to depart earlier. This improved the overall departure punctuality.

Regarding the Paris-ACC capacity, no impact was indicated by local FMPs.

3.2.3.3 Safety & workload (D-01)

Safety & workload were investigated during the trials. Questionnaires were distributed among flights crews and involved ATM stakeholders.

Flight crew
The analysis of the 22 received pilot's questionnaires show no report of safety concerns related to the Target Time concept. Also no impact on workload was mentioned.

Paris FMP and ATCOs
The analysis of the questionnaires filled in by the Paris FMP and ATCOs show:

- The amount of coordination (with Flight Crew, adjacent sectors and NM) did not increase;
- The traffic complexity was not increased (nor reduced);

- Situational awareness was not affected during the trials;
- ATCOs were confident working with trial flights;
- Safety was not compromised due to trial operations.

Additionally, no explicit workload or safety issues were reported during the trials.

Network Manager
During the D-01 trials no safety and workload issues were reported by the NM. NM also did not receive any negative feedback coming from non-participating FMPs or airports that were involved as iStream traffic.

3.2.3.4 Predictability (D-03)

The results regarding traffic predictability are comparable to the D-01 trial.

3.2.3.5 Efficiency & capacity (D-03)

With respect to the D-01 trials no noticeable effect on flight time in the CDG TMA (and extended TMA) is reported. Regarding traffic efficiency the results are comparable to the D-01 trial. The TT integration with iAMAN thus does not result in an extra efficiency increase.
Regarding ATFM delay for CDG a decrease of 18% is reported with respect to the baseline (exercise D-01). This is visualized in Figure 3.8.

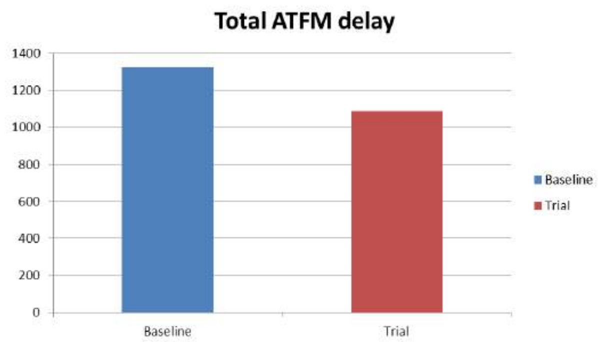

Figure 3.8: Visualization of ATFM delay for both the D-01 (baseline) and D-03 (trial) [2]

During the D-03 trials Target Times of 51 flights changed. 84% of the Target Times improved. On average the Target Times decreased with 4.6 minutes.

3.2.3.6 Safety & workload (D-03)

Safety & workload were investigated during the trials. Questionnaires were distributed among flights crews and involved ATM stakeholders.

Flight crew

Flight crews did not face any difference in procedures with respect to D-01. No workload and safety change was measured.

Paris-ACC ATCO

ATCOs in Paris-ACC did not mention a noticeable change in:

- ATC-Flight Crew communications;
- Adjacent ATS unit coordination;
- Traffic complexity and situational awareness.

From the Paris-ACC ATCO perspective no change in workload and safety was present.

Paris FMP

FMPs experienced an increase regarding their workload. All involved FMPs were clear about the workload aspect (100% agreed with the statement: “My workload increased compared to routine operations”). The main rationales for this increase are the coordination with other stakeholders (NM and CDG-supervisor) and focus on both iAMAN and CHMI systems.

None of the FMPs felt that safety was compromised during the trials.

Network Manager

A slight increase of NM workload was mentioned. This was due to the manual Target Time changes that were executed. If the iAMAN tool is directly linked with NM tools (via B2B), the workload effect will disappear.

The current increase of workload did not compromise safety.

3.2.3.7 Conclusions and recommendations for iStream Paris trials

Both conclusions and recommendations that can be drawn from the CDG trials that were part of iStream, can be found in the Demonstration Report of iStream [2]. The results for both trial phases can be combined to draw conclusions with regard to TT Management for Paris arrivals.

TT Management has been trialled on the complete arrival flow. No excessive workload increase and safety incidents were measured or reported.

The variance/standard deviation of the Target Time adherence improved with respect to the 2015 baseline. However, it should be noted that the baseline and trial results cannot be fairly compared due to difference in ATFM delay.

With respect to the 2015 baseline, the time that each flight flew in the TMA reduced with 30 seconds (on average). This results in higher flight efficiency. Due to the Target Time information that was available in the cockpit better departure time management and thus improved departure punctuality was achieved.

Besides the positive effects, there are also some proposed recommendations for further investigation during the xStream trials:

- Development of a full B2B exchange between iAMAN and NM systems: to reduce both FMP and NM workload;
- Study for possible improvements in iAMAN tool;
- Study for more advanced forms of slot swapping: e.g. possibility to swap TT fix;
- Include long haul flights;

- Take into account airport departure procedures (e.g. departure clearance and taxi time) when determining Target Times;
- Integrate ATFCM and ATC (e.g. integration of Target Times with XMAN concept)

3.3 London LHR Trials

The London Heathrow (LHR) trials were part of SESAR PJ24 (Project 24). In this section the trial goals, used TT concept and trial results will be described based on PJ24 documentation and an interview with an operational trial expert [3]. It should be noted that less documentation and information was available with respect to the ZRH and CDG trials.

3.3.1 Trial Goals

The main goal of the LHR TT trial was to optimize hotspot management to reduce the number of holdings that are needed for a safe landing throughput. Within PJ24 a DCB tool was developed. During the trials this DCB tool was tested in addition. The tool was able to compute Target Times for relevant flights that were part of a planned landing rate and arrival sequence. In this tool the Target Time is calculated from the provided CTOT.

3.3.2 TT Implementation

With regard to the SESAR concept, described in paragraph 2.2, there are no large differences with the concept that is used at LHR. The main difference is that the trials did not include a dynamic TT concept.
Generally the TTA (and CTOT) is calculated to introduce a proper arrival sequence over the four holding fixes at LHR. In this process the ATCO knows that there are regulations, but is not aware of any specific calculated and distributed TTs.
Initially a CTOT is calculated for the flight stacks to realize the – by FMP - desired landing rate. This implicitly means that for short-haul flights only a CTOT is initially distributed. However it is technically possible to include the TT in e.g. a slot allocation message. For long-haul flights, that do not have a CTOT, a TT is provided via the AOC. ACARS technology can be used for this.
The TTs are determined by NATS tooling and are subsequently checked by the local actor (FMP). The FMP checks if the predicted demand (coming from a predicted traffic situation) exceeds the predicted landing rate within a certain time frame. For every flight that is expected to enter the arrival sequence during this time frame, a final CTOT (in case of short-haul) and TT are calculated.
The TT that is calculated by NATS is distributed with the NM via additional tooling. The NM will calculate a (more accurate) CTOT based on the received TT. The resulting CTOT/TT[5] is subsequently sent to the airspace users via SAM/SRM.
It should be noted that the initial actual arrival window was [-15, 15] minutes. The introduction of the TT concept included a TT window that reduced this arrival window to [-5, 10] minutes.

[5] As mentioned: short-haul flights receive a CTOT, long-haul flights receive a TTA.

In this concept the TT is used as input for the AMAN planning in order to further refine the arrival sequence. In this sense it should be taken into account that the TT concept is used for ATFCM purposes and that AMAN needs ATCO involvement.

3.3.3 Trial Results

The trial results described in this subsection refer to the trial that took place in September 2018. Currently all involved stakeholders are preparing trials that will take place in March 2019.

The September 2018 trial results are promising with regard to airspace capacity. Due to the window reduction ([-15, 15] to [-5, 10] minutes) more aircraft arrived on time at the holding fix. This resulted in a capacity increase of 16%. In addition, the trial showed improvement in traffic predictability. Due to this increase in predictability a better execution of the proposed arrival sequence was achieved. This reduced holding times, which is directly related to a more efficient operation (e.g. less fuel burn). It is not investigated whether the trials affected stakeholders’ workload. However, no workload issues were mentioned during the trials.

3.3.3.1 Conclusions and recommendations for London trials

Given the results that were mainly provided during the interview with NATS, it can be concluded that the TT concept worked out positive during the September 2018 trial. The trial showed an increase of predictability, efficiency and there were no negative workload effects mentioned. The smaller arrival window resulted in less traffic bunching and a reduction of holdings.

Besides the positive effects the following pitfalls were mentioned during the interview executed with the operational trial expert:

- TT may cause traffic complexity, if more airports within the same TMA start with TT operations (relevant for the LHR situation);
- The TT concept will fail if ATCO workload increases;
- If more and more airports start making use of the TT concept the most penalizing constraint (from NM perspective) will reduce or reverse the positive effects of the concept.

It should be noted that flight crews were extensively briefed about the trials. It seemed that communication of the trial goal is a key factor regarding concept acceptance. Additionally TT adherence can be analysed afterwards. It is possible that airlines that often do not achieve their TT will face sanctions in the future.

During the trials in March 2019 the following concept updates will be taken into account:

- End-to-end testing with NM;
- NATS tool is able to send 400 messages per minute;
- NM can process 50 messages per minute;
- All aircraft will have a TT, short-haul flight are provided with a CTOT only;
- ATCO supervisors will be updated about the trial.

3.4 Palma PMI Trials

3.4.1 Goals and TT implementation

In June 2013 a trial regarding the TT concept was executed at Palma de Mallorca airport (PMI) during the Saturday morning arrival peak [4]. The trials were initiated to obtain better arrival information to enhance the arrival management and arrival flow. In addition, the TT concept was integrated to reduce delay knock-on effects on aircraft departures. Both the benefits and pitfalls of the TT concept in terms of flights adhering to planning targets were investigated. During the trials the TTs were calculated by the NM and automatically communicated with AOCs of the participating airlines (Air Berlin, Air Europa and EasyJet). The AOCs were subsequently distributing the acquired TTs via ACARS. Airlines were able to modify the default TT window of [-3, 3] minutes.

3.4.1.1 TT adherence

The dissemination of TT towards the FMS did not result in any technical problems. Since pilots were briefed well, there was a high participation by both airlines and flight crews. During the trials most crews decided to reduce their speed to adhere to their TT. Very few pilots made use of the Required Time of Arrival (RTA) functionality.

The increased TT adherence for participating airlines is visualized in Figure 3.9. In contrast to this graph, some flight crews noted that there were two main factors reducing their capability to adhere to the TT:

- For domestic flights: departure time fluctuations result in less time to overcome e.g. delays.
- For long-haul flights: ATC instructions often result in a decrease of total flight time

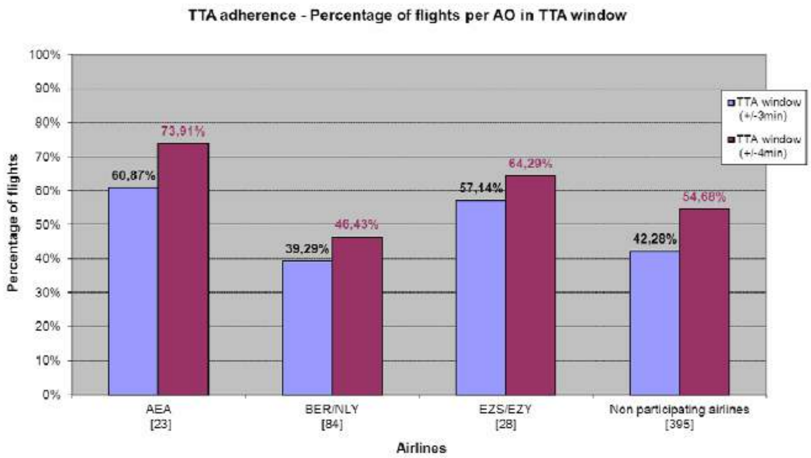

Figure 3.9: TTA adherence per airline for the PMI trials [4]

During the trials also a certain "TT" learning curve is observed. This also implies that training and communication are important factors when initiating a TT trial. The learning curve is visualized in Figure 3.10.

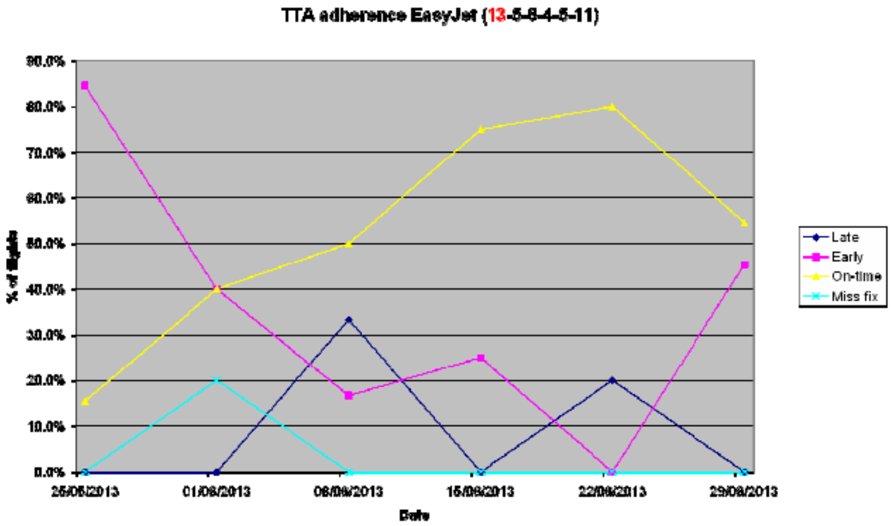

Figure 3.10: TTA adherence for EasyJet flight over time. A learning curve becomes visible [4]

3.4.1.2 Workload

No increase in terms of workload was reported by participating flight crews. Also no workload statements were provided by the NM and ATCOs.

3.4.1.3 Conclusions and recommendations for Palma trials

From the Palma trials it can be concluded that a better TT adherence improves predictability for both arrival and departure times. Higher flight predictability may directly result in an optimized capacity in both air and on the ground. However, further tooling and automation may result in further optimizations in terms of TT adherence. Additionally, trial experts expect that integration with arrival management (AMAN tools) will further optimize traffic predictability. This will result in a more efficient arrival sequence. During the current trials the FMP acted as an observer. In further trials a more active role for the FMP should be considered.

3.5 Summary of Trial Experiences

A fundamental part of this research is to include the experience and expertise of operational experts regarding the TT concept. For this reason interviews took place with different stakeholders that were part of the trials that are elaborated in this report. Interviews took place with trial experts and a Network Manager. Given the answers that they provided an overview of pros and cons regarding the TT concept have been composed. This overview can be found in Table 3.7

Table 3.7: Summary of Trial Experiences based on interviews

Category	Pro	Con
Paris Trial	• Less delays were noticed • Less distance has been flown within the CDG TMA • Slight improvement of traffic predictability due to better TT adherence	
Zurich Trial	• Fewer holdings due to less early arrivals • Results were that beneficial that the TT concept is now incorporated into ZRH morning operations	
London Trial	• Optimized arrival sequence have been achieved	
Network Manager	• NM is very flexible to support each ANSPs TT concept • Schiphol high level concept description is very acceptable for the Network Manager	• New tooling to enable e.g. AMAN and B2B services is needed for proper communication with NM • Operational results are very dependent on quality of predictions of the NM (e.g. Zurich noticed that the planning based on NM was not as good as directly getting information from the airline) • Most penalizing regulation may negate benefits when more airports make use of the TT concept • Different goals for different ANSPs increases complexity for the NM. However, this is accepted by the NM.
TT adherence	• TT adherence is better than expected • No penalties are given to flights/pilots • TT window is smaller compared to the CTOT window (for the Zurich case 70% within [-4, 4] minutes)	• Adherence is dependent on flight duration. Adherence is better for long-haul flights • Benefits in terms of traffic bunching will only be realized if target windows is less than the current CTOT window (note: this was the case in most trials)
Workload	• No extra workload for ATC during execution was reported	• Workload issues can be solved by using proper software/tooling. This may require some investments.

Airlines	• Airlines are able to integrate (slot) swapping procedures with regard to the TT concept • SWISS has positive experience with slot swapping

Given both the trial results and interviews with trial experts, the most relevant conclusions and recommendations that are provided in Table Table 3.8.

Table 3.8: Most relevant iStream conclusions and recommendations for Schiphol

Trial	Conclusion	Recommendation
Zurich	TT resulted in an operational and sustainable procedure to all involved aviation stakeholders	
Zurich	Less holdings and less distance flown in ZRH TMA	
Zurich	For medium and short-haul flights NM data was of poor quality. Flight profiles and TTs could not be determined very accurately for those flights	
Zurich		Upstream ANSPs should be aware of trial/TT concept
Zurich		Find out what data quality of NM is and optimize data if necessary
Zurich		Proper communication plan should be conducted to get all important stakeholders involved (and aligned)
Paris	No excessive workload increase and safety incidents were measured or reported	
Paris		Conduct a separate study for including and improving iAMAN tooling
Paris		Investigate the possibility of slot swapping
London	Increased traffic predictability and efficiency is measured	
London	A small TW (Target Window) result in a better TT adherence and less traffic bunching	

Regarding the trial results, an overall increase of fuel burn is not reported. However, it should be noted that on an individual basis it can be expected that some flights burn additional fuel to adhere to their TT. When developing the Schiphol concept this should be taken into account, since additional fuel burn may result in a discouragement of TT adherence for airlines. In addition to this, if pilots see the execution of the concept (TT adherence) as an increase of workload, this may further harm the TT adherence. Both the effect on fuel burn and possible workload increase in the cockpit should, therefore, have to be properly considered.

4 Initial TT Concept for Schiphol

The long-term goal is to create a cooperative way to balance capacity and demand at Schiphol airport. This balance will be achieved by an active dialog between LVNL and the airlines. The short-term goal of the TT concept at Schiphol is to make regulations more effective. A first step towards this short-term goal is to define an initial TT concept for Schiphol that can be used to execute a proof-of-concept trial. With the aid of subsequent trials this will eventually result in achieving these goals. It is important to note that the initial TT concept is not aimed at completely solving the hotspot problem; instead the goal is to reduce it. The initial concept has been determined during a group discussion with some major Schiphol stakeholders, the literature study and the experiences and results of the past trials.

A major advantage of the initial concept proposed here is that it can be trialled within a relatively short time frame if required. This makes it possible to first assess whether TT is compatible with existing Schiphol operations, before committing the resources needed to realize a more extensive TT concept. Using such a step-by-step approach will reduce the R&D risk associated with TT in comparison to using a more extensive concept as a starting point.

The high level vision for an initial TT concept developed for Schiphol, including the roles of the stakeholders, is displayed in Figure 4.1. This figure makes use of the building blocks described in section 2.3.

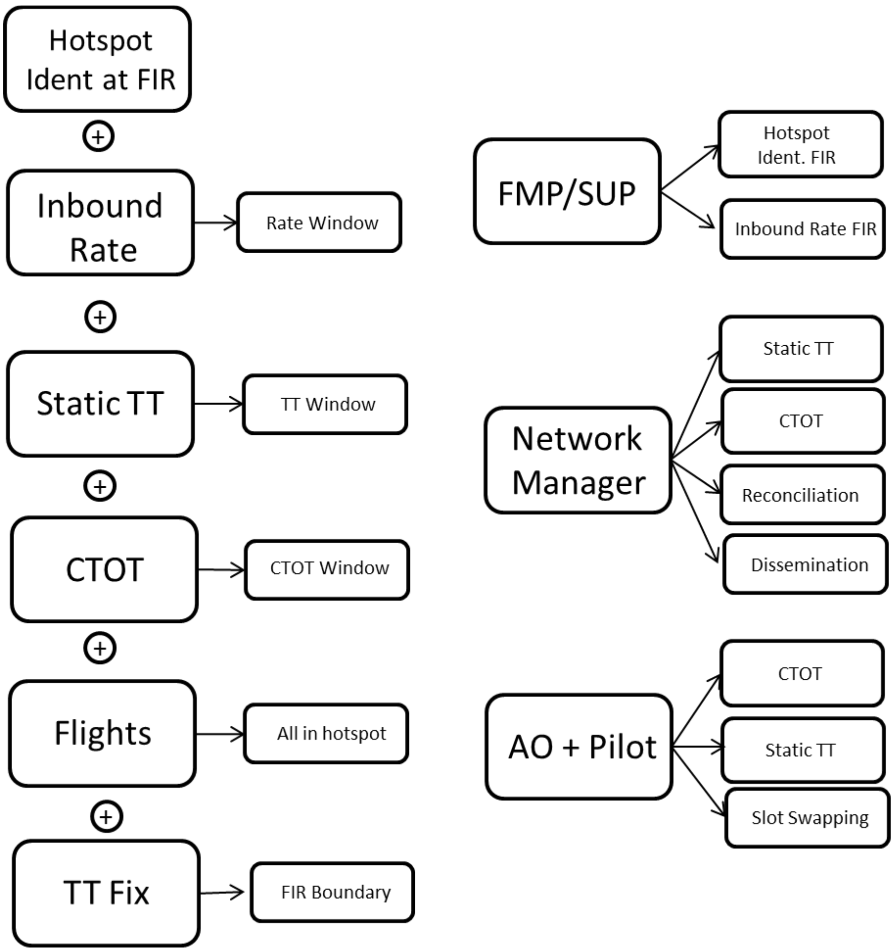

Figure 4.1: Initial TT concept for Schiphol and the role of stakeholders using building blocks

As indicated in Figure 4.1, the process begins when the FMP predicts a hotspot at the FIR boundary (a situation in which demand exceeds capacity). To solve the hotspot, the FMP requests a regulation with a reduced inbound rate to the Network Manager (NM). Using data from ETFMS and the requested inbound rate, a TT for all involved trial flights at all the entry points to the Amsterdam FIR is calculated. As for all previous trials, a static TT is used for Schiphol. This means that the TT is not updated during the execution phase. Using the approach described in Appendix A.2, the NM also calculates the CTOT for all ECAC flights involved in the hotspot, and communicates both the CTOTs and TTs to the AOs using SAM and SRM messages[6]. AOs then inform the corresponding flight crew of their CTOTs and TTs prior to departure. The communication to the flight deck can take place via an application/tool on a tablet (e.g. KLM's Avio connect application) or using ACARS messages. The AO may decide to swap CTOTs and accompanying TTs based on their specific business requirements (such as reducing delays for flights with a lot of connecting passengers).

It is important to note that this concept does not target individual flights. Instead, it targets entire traffic flows to make regulations more effective. This first concept sketch assumes that the NM calculates the TT. Depending on the outcome of the trial, another approach could also be used in a later stage, see the conclusions for some suggestions.

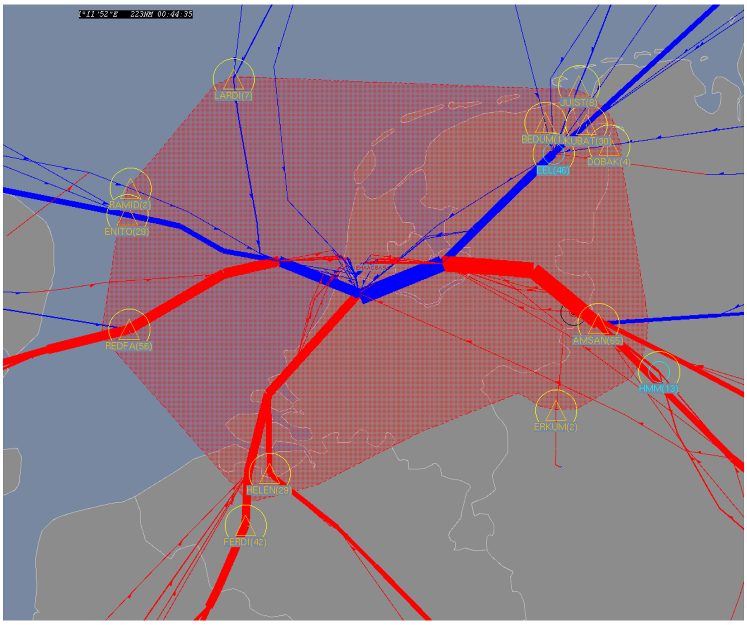

Figure 4.2: Waypoints of the EHAACBAS region where the NM will compute TTs for the initial Schiphol TT concept. The prevailing inbound flows are indicated.

The NM will assign TTs at the following boundary waypoints of the EHAA FIR:

- AMSAN
- DOBAK
- BEDUM
- EEL
- ENITO
- ERKUM
- FERDI
- HELEN
- HMM
- JUIST
- KUBAT
- LARDI
- LUGAX
- RAMID
- REDFA

These waypoints intersect with the prevailing inbound flows into the EHAACBAS region which is the airspace region that is the basis for most of the current ATFM regulations.

[6] Note that inter-continental flights from outside the ECAC do not receive CTOTs. These flights only receive TTs.

The high level concept depicted Figure 4.1: Initial TT concept for Schiphol and the role of stakeholders using building blocks results in no significant changes for LVNL. Nonetheless, it will be necessary to create technical agreements between LVNL and NM so that the TTs calculated do indeed have a beneficial effect for hotspot resolution. Moreover, FMPs and ATCOs should be made aware of a change in operations and on the new way of working with TT.

The main change in the operation that this TT concept brings is for the Aircraft Operators (AOs) and the pilots. Most notably, pilots are responsible for TT adherence, and have to take TT into account *as much as possible* during flight execution. Although previous trials have shown that this extra task does not significantly increase workload in the flight deck, this aspect would need to be monitored closely if the concept is to be tested using live trials at Schiphol. On the other hand, adherence to TTs should result a number of positive effects including reduced delays, holding and vectoring for pilots, as well greater predictability for ATCOs and FMPs. These benefits may offset any workload increase, but the extent of such benefits will need to be investigated in any live trials.

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5 Stakeholder Acceptance of the initial TT Concept for Schiphol

In this study, the stakeholder acceptance for initial TT at Schiphol is supported by making use of interviews with operational (TT trial) experts, discussions with stakeholders and execution of a Balanced Score Card study. The results of this process forms an input to the go/no go process of executing proof of concept live trials at Schiphol.

In the evaluation of the proof-of-concept trial, the trial results will be compared to the expectations of the stakeholders.

5.1 The Balanced Score Card (BSC) Methodology

In this study, the so called ‘Balanced Score Card’ (BSC) is used to qualitatively determine the expectations that involved stakeholders have when operating a proof of concept trial based on the initial TT concept for Schiphol. The BSC methodology uses stakeholder opinions to qualitatively judge the effect of a new concept on a number of Key Performance Indicators (KPIs). It is often used as a means to gain *an initial understanding* of the potential benefits and pitfalls of a new concept from multiple stakeholder perspectives.

There are several advantages of using the BSC approach. First and foremost, the BSC facilitates meaningful and structured discussions between the different stakeholders impacted by TT, such as LVNL and KLM. Another major advantage is that the BSC is relatively easy to understand. Each stakeholder simply indicates the effect of a new concept, in this case TT, on each KPIs using ‘plusses’ and ‘minuses’, and the number of ‘plusses’ and ‘minuses’ determines the magnitude of the expected benefit or pitfall for each KPI.

However, as for all methods, the BSC approach has some limitations. The output of the BSC is purely based on expert opinion, and this makes the results quite subjective. Consequently, different representatives from the same stakeholder may interpret the scoring criteria differently, resulting in different final scores. Furthermore, it is crucial that all stakeholders have a clear and common understanding of the specific details of the concept that they are judging; this can be difficult to achieve since the BSC is often used to assess future concepts that are not yet in operation.

The negative effects are limited by providing the concerned stakeholders with instructions on how to interpret the specific scoring criterion used in this study; see section5.4. Additionally, the TT concept for Schiphol was determined with close consultation with the stakeholders to ensure that everyone involved has understanding of the concept that they are assessing.

For these reasons, the BSC results presented in this chapter can be used as a first step to understand the potential benefits and pitfalls of TT for each stakeholder and for all stakeholders in general. This assessment will, therefore, help policy makers to determine if more effort should be spent on further investigating this concept for Schiphol, including the use of proof of concept live fight trials.

5.2 Stakeholders

The stakeholders that contributed to the BSC study are listed in Table 5.1.

Table 5.1: Stakeholders that filled in the BSC

Stakeholder	Filled in by
Upstream ANSP	LVNL ACC ATCO and LVNL FMP
LVNL	LVNL ACC ATCO, LVNL FMP and LVNL technical experts
Pilot	KLM and Transavia pilots
Aircraft Operator	KLM Operations expert
Network Manager	TT expert at NM (Eurocontrol)

5.3 Key Performance Indicators (KPIs)

In total, the BSC used 14 different KPIs to assess stakeholder acceptability of TT on the safety, efficiency, feasibility and environmental impact for the operations at Schiphol. These KPI's were determined in cooperation with the stakeholders. The KPIs are listed in Table 5.2.

Table 5.2: KPIs used in the Balanced Score Card (BSC)

#	Category	KPI	Description
1	Safety	Workload	Number and difficulty of tasks. This also takes into account the flexibility of controlling traffic / flying aircraft.
2	Efficiency	Effectiveness of Regulations	Duration and scope of regulations. More effective if duration is less and fewer aircraft are affected.
3	Efficiency	Traffic Bunch Dissipation	Frequency of occurrence and intensity of traffic bunches in live operations (not just during planning). Traffic bunch is defined in Table 2.1.
4	Efficiency	AFTCM Ground Delays and Costs	Delay due to CTOTs. Can affect airline crew costs and scheduling and passenger connection costs.
5	Efficiency	Inflight Delays and Costs	Delay due to extra distance flown as a result of vectoring or holding + crew and extra fuel costs.
6	Efficiency	Average Flight Punctuality	Average punctuality of all flights arriving at the considered airport, or for all flights of a particular airline.
7	Efficiency	Airspace Capacity	Number of aircraft that can be accommodated in a given sector. Can more aircraft be handled by the same number of controllers?
8	Efficiency	Traffic Complexity	The difficulty of controlling the same number of aircraft. Does TT make it easier or harder to control the same number of aircraft? Traffic complexity is a function of conflict rate.
9	Efficiency	Runway Usage	Runway throughput. Note that under-delivery will lead to poor runway usage. Over-delivery will lead to delays and increased use of environmentally less preferred runways
10	Feasibility	Ease of Implementation	How easy is it to implement in the existing system. New tools and training reduce the ease of implementation. May differ from ANSP and AO perspectives.
11	Feasibility	Implementation Costs (infra and training)	Monetary costs of new planning tools, procedures and training
12	Feasibility	Operational Compatibility/Usability	Does the concept fit well into the exiting concept of operations? Is there a good relationship between CTOT and TT?
13	Feasibility	Cooperation with AMAN/XMAN	Does it interfere, or aid, with the working of AMAN/XMAN systems. (Only relevant for ANSP, and ATCO)
14	Environment	Fuel Burn + Emissions	Amount of fuel used and corresponding environmental emissions. Directly proportional to distance flown.

5.4 Scoring Criteria

The grading criteria used by the BSC are depicted in Figure 5.1. As shown in this figure, the stakeholders were required to judge the impact of TT on each KPI using a scoring system that ranges from +4 to -4. Additionally, it is important to note that the experts were instructed to fill in the BSC *relative to the current operations at Schiphol*. Consequently, a score of +4 implies that TT significantly improves performance relative to current operations, while a score of -4 implies that TT significantly degrades performance. Likewise, a score of 0 implies no change relative to current ops, while 'N/A' is used to indicate that a particular KPI is irrelevant from the perspective of a particular stakeholder.

Scoring Criteria	
++++	4
+++	3
++	2
+	1
0	0
-	-1
--	-2
---	-3
----	-4

Figure 5.1: Scoring Criteria of the BSC

5.5 Results

Table 4.3 and Figure 4.4 display the BSC results of the initial TT concept proposed for Schiphol. All scores in Table 5.3 are above zero, i.e. all score are positive. This suggests that the concept proposed for Schiphol is acceptable to all stakeholders considered.

Table 5.3: Summary of BSC results

	Upstream ANSP	LVNL	AO	Pilot	NM
Total Score	6	19	5	6	7
Average Score	0.7	1.6	0.5	0.5	0.6
Average Score After Implementation	0.9	1.4	1.0	0.7	0.8

#	Category	KPIs	Upstream ANSP	LVNL (Cooperate + ATCO)	Aircraft Operator	Pilot	Network Manager
1	Safety	Workload	+	+	0	-	0
2	Efficiency	Effectiveness of regulations	+	++	+	0	+++
3	Efficiency	Traffic-bunch dissipation	+	+	+	+	+++
4	Efficiency	ATFCM ground delay and costs	N/A	++	+	+	0
5	Efficiency	Inflight delay and costs	N/A	N/A	+	0	0
6	Efficiency	Average flight punctuality	N/A	N/A	+	+	0
7	Efficiency	Airspace capacity	+	++	N/A	+	+
8	Efficiency	Traffic complexity	+	+	N/A	N/A	0
9	Efficiency	Runway Usage	0	+	N/A	+	N/A
10	Feasibility	Ease of Implementation	N/A	++	--	0	0
11	Feasibility	Implementation Costs (infra and training)	N/A	+++	-	-	0
12	Feasibility	Operational compatibility/usability	0	++	+	+	0
13	Feasibility	Cooperation with AMAN and XMAN	0	+	N/A	N/A	N/A
14	Environment	Fuel burn + Emissions	+	+	++	++	0

Figure 5.2: Balanced Score Card (BSC) for the initial TT concept proposed for Schiphol

Note that in the above figure, the total and average scores per stakeholder considers all KPIs. On the other hand, the average score after implementation does *not* consider KPIs 10 and 11, namely 'Ease of implementation' and 'Implementation costs'.

The following paragraphs summarize and interpret the results from the perspective of each stakeholder. Finally, an overall judgement is made from the perspective of all stakeholders.

Based on the qualitative analysis, it is concluded that the initial TT concept is acceptable to all stakeholders at Schiphol airport. While all stakeholders expect to benefit from TT in some form, the BSC reveals that the main beneficiary is LVNL, particularly since the proposed TT concept for Schiphol requires no substantial capital investment, but at the same time, results in several benefits such as reduced workload. That said all stakeholders, including the AOs and pilots, also expect to benefit from the introduction of TT at Schiphol, for instance because of the reduced fuel burn and emissions expected as a result of TT.

The fact that TT is acceptable to all stakeholders can be seen in the graphs below. These graphs show that the total score of all KPIs, and the average score per KPI, is positive for all stakeholders. This is because a positive score indicates that the benefits of TT outweigh any disadvantages, and the graphs show that this is true to varying degrees for all stakeholders.

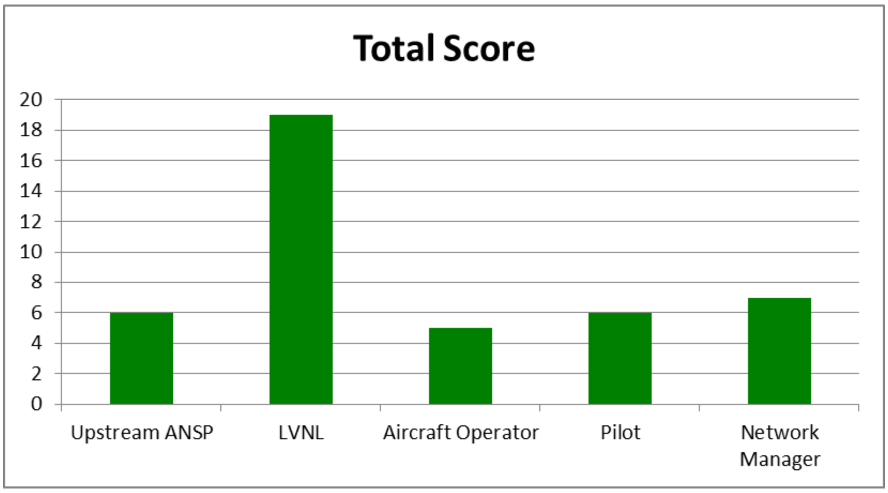

Figure 5.3: Total score of all KPIs per stakeholder

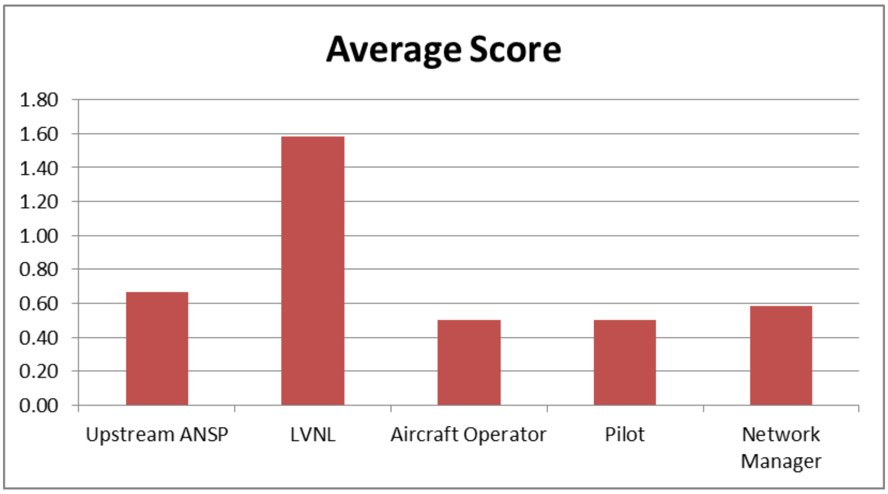

Figure 5.4: Average score per KPI per stakeholder

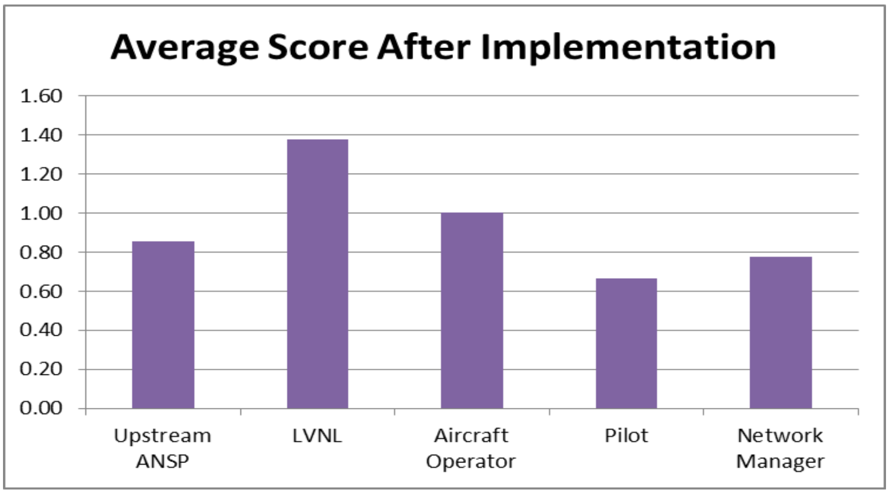

Figure 5.5: Average score per KPI after implementation per stakeholder

Figure 5.5 is particularly interesting. Unlike the previous two graphs, in Figure 5.5, the difference between LVNL and the aircraft operator decreases significantly. This is because implementation costs and ease of implementation are not considered in Figure 5.5. This indicates that once TT is fully operational, and the initial costs for implementing TT do not have to be considered anymore, then the concept is almost equally advantageous to LVNL and to AOs when looking at the average result per KPI.

5.5.1 Upstream ANSP

As for all previous implementations of TT, the concept proposed for Schiphol does not make executive ATCOs aware of the TTs of each aircraft. As such ATCOs are not required to assist flight crews in achieving TTs, but may do so if this does not affect their other tasks. Furthermore, flight crews must always prioritize ATCO instructions over TT adherence. For these reasons, Upstream ANSPs are not significantly impacted by TT operations at Schiphol. In fact, they indirectly benefit from TT at Schiphol because this should mean that there is a lower probability that hotspots will propagate backwards into their sectors. For this reason, TT is moderately beneficial for Upstream ANSPs. This is indicated by the fact that all relevant KPIs are rated with either a single ‘+’ or a ‘0’.

5.5.2 LVNL

The LVNL stakeholder includes both the corporate and operational (ATCO) perspectives. The BSC shows a positive result of TT for LVNL. This because the initial TT concept for Schiphol allows LVNL to use current procedures, tooling and training since LVNL operations remains largely identical to the situation without TT. As such, from the perspective of the LVNL, many of the benefits of the TT concept, such as reduced ATFCM ground delay etc. may make it possible for LVNL to release latent capacity into the system, and thereby make better use of the available capacity without any substantial increases in workload or capital expenses. Moreover, in comparison to other capacity improvement options that are being developed, such as XMAN, TT provides benefits with very low investment (which is why implementation costs were scored with three plusses). For this reason, LVNL (corporate and ATCOs) is expected to be the main beneficiary of the TT concept for Schiphol. This is emphasized by the largest total score of all stakeholders.

5.5.3 Aircraft Operator and Pilot

The BSC columns for AO and pilot indicate greater extremes than those of the other stakeholders. On the one hand, TT results in greater punctuality and reduced fuel usage due to reduced holdings. The latter aspect is particularly beneficial since fuel is one of the main expenses of airlines, and it was therefore scored as a '++'. On the other hand, however, it is ultimately up to the pilots to meet the TTs provided to them. As such, it increases the pilot's workload, and it also requires some additional capital investment in terms of new training and procedures. Consequently, the workload KPI was scored with '-'. Regarding the aircraft operator, a negative score of '--' in ease of implementation was filled in. But *new hardware is not needed* to implement the basic TT concept for Schiphol, since most modern Flight Management Systems (FMS) on board aircraft already have the Required Time of Arrival (RTA) functionality that facilitates TT adherence[7]. The main burden here is implementing the TT concept into an existing (iPad) application that KLM pilots use during their flight preparation and execution. However, the BSC indicates that the benefits of TT outweigh its potential pitfalls, and this is indicated by positive total and average scores.

It should be noted that the trends described above for the AO and pilots are true not just for the TT concept proposed for Schiphol, but they are also true for all other existing implementations of the concept at other European airports. This is because pilots are the only stakeholders that contribute to TT adherence in all the TT concepts developed thus far. Additionally it should be noted that the number of pilot-respondents was limited in this study.

5.5.4 Network Manager

The BSC column for the NM indicates that most KPIs are not relevant or do not change as a result of introducing TT at Schiphol. But the increased regulation effectiveness and reduced traffic bunching that is expected as a result of TT is extremely positive from the perspective of the NM as it increases the predictability of the total European network. As such, the proposed TT concept for Schiphol is seen as a positive step by the NM. This was also very clear when the NM was interviewed as part of this study.

[7] Note that the use of the RTA function is, strictly speaking, not required for the initial TT concept proposed for Schiphol. Nonetheless, it is a FMS function available to pilots to aid with TT adherence.

6 Conclusions and Recommendations

Based on the literature study, the iStream trials and stakeholder opinion (via discussions and BSC), the conclusion is that the TT concept is a promising and acceptable concept for Schiphol to decrease hotspots. In addition, the PCP states that the Network Manager must make target times available, in order to support arrival sequencing processes, by 2021. The logical next step is to start preparations for a proof of concept live trial by creating a trial plan. This chapter provides guidelines for creating such trial plan.

6.1 TT concept

TT is a promising concept that has the potential to improve the effectiveness of CTOTs by providing flight crews and ATCOs with additional information about the required arrival time at busy waypoints in the European network. Adherence to TT can potentially reduce hotspots, and thereby reduce ATCO workload and increase the overall efficiency and capacity of the airspace. The flexibility of the TT concept enables each airport to implement this concept without significant changes of their existing operational framework.

TT concepts have been trialled at several European airports, and these trials have shown that TT can be successfully implemented to realize local stakeholder goals:

- Zurich (Skyguide): TT used to reduce early arrivals. Now integrated in daily morning operations;
- Paris (DSNA) and London (NATS): TT used to optimize arrival sequences;
- Palma (ENAIRE): TT used to increase punctuality for arrivals and departures.

The trials have shown that TT has the potential to resolve hotspots , increase predictability and improve airspace efficiency and capacity without substantially affecting workload for pilots and ATCOs. Promising trial results have enabled further development of the TT concept. Such developments may allow TT to be integrated as part of regular ATC operations in Europe.

Based on the results described in the previous chapters, this study proposes an *initial TT concept* for Schiphol operations that is compatible with the current operational model. In addition to this the NM agrees with the initial TT concept for Schiphol as described in this document. The next step will be a to validate the expectations of the stakeholders by means of a trial. This trial will focus on the “proof-of-concept” of the initial TT concept for Schiphol.

6.2 Initial TT Trial at Schiphol

The execution of a proof of concept trial can be seen as a first step towards a more cooperative environment between ANSP and airlines. Several aspects need to be considered when preparing for live proof of concept TT trail at Schiphol. For instance, good communication is vital for the success of the trials. This was also stated by Skyguide. For example, participating airlines – and in particular their pilots - should be informed about the goal and benefits of TT and should be instructed on how they have to operate during the trials. Referring to previous successful trials and in particular workload results – no increase in workload was measured in most of the trials - will help in this process. In addition LVNL and upstream ANSP ATCOs should be made aware that a TT trial is executed in the Schiphol operation.

It is recommended to start the trial with KLM only and to gradually expand the trial to involve other airlines as well. In order to collect sufficient data it is recommended to allow for a long trial period. The trial should be phased from KLM only to include more and more airlines. As more airlines join this will result in a high percentage of participating traffic. In this case the actual benefits (and pitfalls) of the concept may become clear (e.g. if only 50% of the traffic participates, the chance that the TT trial result in less traffic bunching is rather low). In addition, airlines delivering most of the arrival traffic within a certain time frame allows for the development of additional procedures that make e.g. TT swapping possible. This may – on the airline side – be another tool to increase passenger connection punctuality. SWISS airlines reported successful results using such tools during the Zurich trials.

To be able to do a proper analysis of trial results, it is recommended that a number of parameters are continuously monitored during the TT trial. Those parameters include:

- Adherence to TT target window (*note: the target window should be smaller than the CTOT window*);
- Adherence to TT by airline;
- Analyse quality of NM data
- Average ATFCM ground delay for inbound Schiphol flights;
- Workload of pilots, FMP and ATCOs using questionnaires.

In addition, baseline data with identical flight and weather condition should be gathered when the trials are not executed. This allows a fair comparison between the baseline and trial situation.

Furthermore, for a successful trial, the following recommendations should be taken into consideration:

- The success of the TT concept is dependent on TT adherence. Therefore, to convince stakeholders, it is necessary to clearly communicate the benefits of TT prior to the execution of live flight trials. Making agreements with the NM on the TT concept and its resulting responsibilities is a vital part of this.
- TT requires improved trajectory management in the cockpit during flight execution. Because the change that TT brings is relatively straight-forward, pilots should be instructed on how to take the TT into account during flight planning.
- To analyse the full operational benefits of TT, the main airlines at Schiphol, namely KLM and Transavia should be invited to participate at a minimum. An attempt can be made to include as many other airlines as possible. Furthermore, for simplicity, trials do not need to be restricted to certain time periods; in other words, full days of operations can be considered.
- To avoid conflicts with other trials that may be taking place during the same time period, up-stream ANSPs should be informed in advance that a TT trial is taking place in Schiphol.
- It should be assessed if and how it is possible to include intercontinental flights in the process.

6.2.1 Evaluation of the initial TT trial

After execution of the proof of concept trial an evaluation of the trial needs to be performed. To be able to do a proper analysis of trial results, it is recommended that a few parameters are continuously monitored during the TT trial. Those parameters include:

- Adherence to TT target window (note: the target window should be smaller than the CTOT window);
- Adherence to TT by airline;

- Analysis of NM data quality;
- Average ATFCM ground delay for inbound Schiphol flights;
- Effectiveness of regulations;
- Workload of pilots, FMP and ATCOs using questionnaires.

In addition, baseline data with identical flight and weather condition should be gathered when the trials are not executed. This allows a fair comparison between the baseline and trial situation.
Furthermore, the results of a proof of concept trial should be compared with the outcomes of the stakeholder acceptance of the initial TT concept for Schiphol (results of the BSC performed in this study). In this manner stakeholder expectations can be evaluated with regard to the operational execution of a proof of concept live trial.

6.3 Future TT Trials at Schiphol

If the initial trial is considered a success, subsequent steps can be taken to improve the initial concept. These steps are dependent on the outcome of the initial trial. However, the following aspects should be taken into account when defining these next-step trials:

- Although the TT concept proposed for Schiphol requires no new software or hardware, the future performance of TT can be improved with the aid of new automation tools, as exemplified by previous trials. However, big-data tooling for post-analysis should be considered to allow for optimal TT concept development.
- It is recommended to further enhance the TT concept by integrating it with the arrival management and sequencing processes.
- The assessment of the initial trial should consider the quality of the calculated CTOT and target times times by the Network Manager (NM).

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APPENDICES

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A. More Details on the SESAR TT Concept

This appendix provides more details of the TT concept as envisioned by SESAR. This appendix is supplementary to the TT overview and building blocks presented in chapter 2. The information described in this appendix is sourced from the SESAR Operational Service and Environment Document (OSED) for dynamic DCB measures [1].

A.1 Hotspot Detection and Target-Time Assignment

As suggested above, the first step of the TT process is to predict and identify hotspots. SESAR indicates that hotspots should be identified by the local DCB actor, which is in most cases the ATCO responsible for the Flow Management Position (FMP). This is because the local DCB actor is most aware of the latest staffing and other constraints affecting the operations of each ANSP. For the definition of a hotspot, the reader is referred to Table 2.1

After hotspots are identified, the local DCB actor, namely FMP, is expected to assign target times to one or more aircraft involved in the detected hotspot to resolve it. This process can be illustrated using the hypothetical example displayed in Figure A.1 and A.2. Here, using predicted occupancy counts, the FMP identifies an over demand of two aircraft at 11:10; see Figure A.1. To solve this issue, the FMP issues target time delays to two of the aircraft. These delays are assigned such that the total capacity of the sector is never exceeded; see Figure A.2.

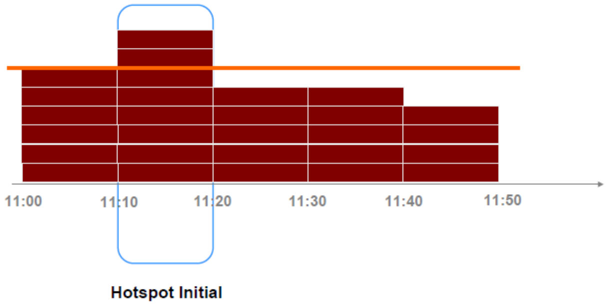

Figure A.1: Initial hotspot identification based on predicted occupancy counts [1].
In this example, the hotspot is expected between 11:10 and 11:20.

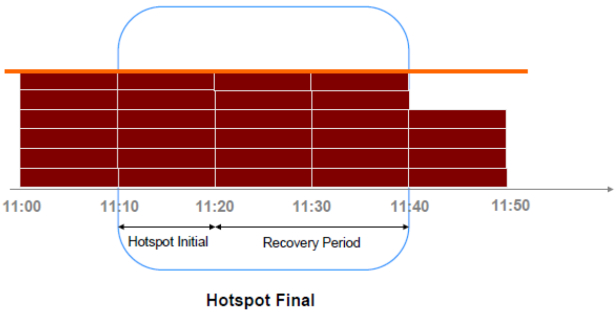

Figure A.2: The initial hotspot displayed in Figure A.1 is resolved by issuing target time delays of 10 and 20 minutes to two aircraft [1]

Once this process is completed, the FMP informs the NM of the location of the hotspot, its duration, the aircraft for which target times need to be issued, and the TT for each of these delayed aircrafts. This information is typically sent to the NM up to two hours before the so called 'cut-off' time of each flight. Here the 'cut –off' time refers to the time at which no more regulations can be imposed on a particular flight. This is often two hours prior to the scheduled take-off time.

A.2 Relationship between CTOT and TT

Once the requested TT is received by NM, and if the concerned flight is yet to take-off, then the NM reverse calculates the CTOT using the flight plan filed by the AO. This process, performed by the NM, is illustrated using the hypothetical example displayed in Figure A.3.

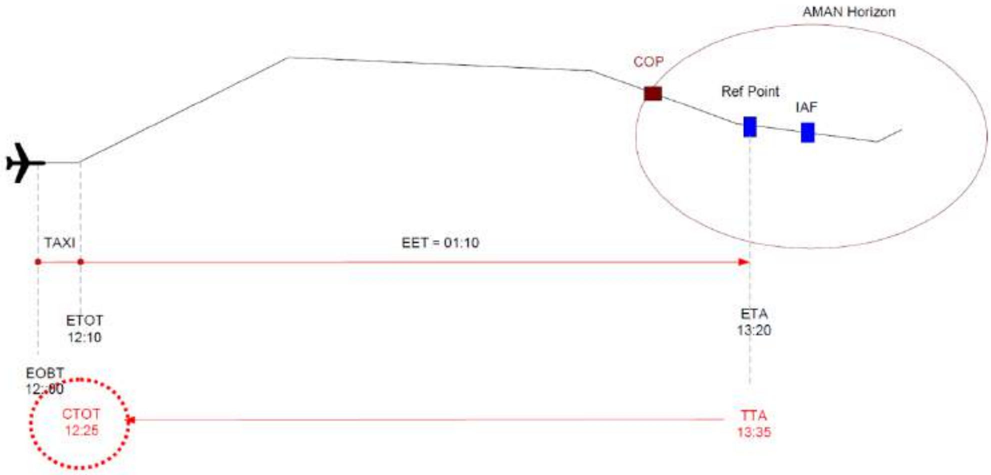

Figure A.3. The relationship between CTOT and TTA [1]. The CTOT is reverse calculated from the TTA using the Estimated Elapsed Time (EET). The EET between take-off and the TTA waypoint is determined from the flight plan. The relationship between CTOT and TT

In this example, the local DCB actor has determined before take-off that the ETA of this flight at a 'Ref Point' along its route will result in an unwanted traffic density hotspot at 13:20. Given the predicted sector demand, it has been calculated that a delay of 15 minutes is required to solve the hotspot. Therefore, a TT of 13:35 at 'Ref Point' is conveyed to NM for this flight. Subsequently, the NM determines that the Estimated Elapsed Time (EET) to 'Ref Point' is 1 hr and 10 mins based on the flight profile and speeds specified in Eurocontrol's Enhanced Tactical Flow Management System (ETFMS). Using this EET, the NM reverse calculates the CTOT from the desired TT; CTOT = TT - EET = 12:25. This reverse calculation process using the same EET as in the ETFMS is performed so that flight crew do not need to use unrealistic speeds to achieve the TT at 'Ref Point'. After the NM calculates the CTOT, it is communicated to the AO using a Slot Allocation Message (SAM) or a Slot Revision Message (SRM); the latter is used if an earlier take-off time had been communicated to the AO prior to the issuance of the TT. SAM/SRM messages contain both the CTOT and TT information. The AO then informs the corresponding pilots of their new CTOT and TT as specified in the SAM/SRM prior to take-off.

Discussions with the Network Manager indicate that the relationship between CTOTs and TT as described by SESAR (see above) matches the practical implementation of the concept in the field when TTs are determined prior to take-off. The SESAR concept also indicates that TTs can be provided to en-route flights (e.g. long haul flights); see section A.6. *It is important to note that there is no relation between CTOT and TT when TTs are issued to a flight after take-off.*

A.3 Reconciliation of Multiple Target Time Constraints

The process described thus far has only considered the application of TTs by *one* local DCB actor. However, all local DCB actors involved in the route of an aircraft may apply target times to alleviate en route and arrival hotspots. But because multiple time constraints along a route may be inconsistent with each other, SESAR dictates that *each flight can only be assigned one TT.*

If the NM receives multiple target time constraints for a particular flight, the NM uses the principle of Most Penalizing Regulation (MPR) to determine the final TT for a flight. This implies that the target time constraint that results in the largest delay is used to define the TT for a flight. It is assumed that this TT solves all hotspots in the flight path of an aircraft. Other DCB actors will have to work with this sub-optimal TT.

Although no concrete solution to this limitation of TT is proposed by SESAR, discussions with the NM about this aspect suggests that this problem is somewhat ‘theoretical’ in nature. This is because airports are the most congested components of the European aviation network. Consequently, the TT issued by the destination ANSP is most likely to be the MPR constraint.

A.4 Target Window

In addition to a nominal value, a static Target Window (TW) is associated with all TTs. The TW can be seen as a fixed tolerance around the TT, for example between +10 minutes and -3 minutes.

SESAR indicates that the local DCB actor has to specify the desired TW when specifying the TT for a particular flight at a particular waypoint. SESAR provides no strict guidelines on how the TW should be selected. Instead, the OSED implies that the local DCB actor has to select a ‘realizable’ value for the TW based on previous experience. In previous flight trials, see Chapter 3, the adherence window of the majority of flights was monitored to determine the value of the TW that could be realized in practice given the peculiarities of the local traffic flow.

If a flight with a TT is expected to miss its TW, as per the SESAR TT concept, a revision process is initiated. The details of this revision process are described in the following section; see section A.5.

A.5 Target Time Deviation Monitoring and Revision Process

Target time adherence is a key assumption for hot spot resolution. Consequently, it is necessary to continuously re-evaluate the correct achievement of target times during the progression of a flight. This can be done using the so called Target Deviation Indicator (TDI). The TDI is the difference between the TT and the Estimated Time Over (ETO) at the same target waypoint. As per the SESAR TT concept, the TDI of all flights will be computed by the NM. The NM will then disseminate the TDI to the relevant local DCB actor and the AO’s using B2B services [1].

If the TDI becomes larger than the TW (in other words, the flight is unable to achieve the TT), then the local DCB actor may trigger a TT revision process. The local DCB actor may decide to do one of the following if the TDI falls outside the TW:

- Update the TT such that the hotspot is resolved based on the new ETO
- Cancel the TT
- Do nothing depending on the real time hot spot resolution progress

The local DCB informs the NM of decisions to update/cancel TTAs. Such instructions are also passed on directly to the flight crews via the mechanisms described in Table A.1. The revision process is also illustrated in Figure A.4. The revision process contributes to the notion that TT is a progressively refined **planning and execution** time; see Table 2.1.

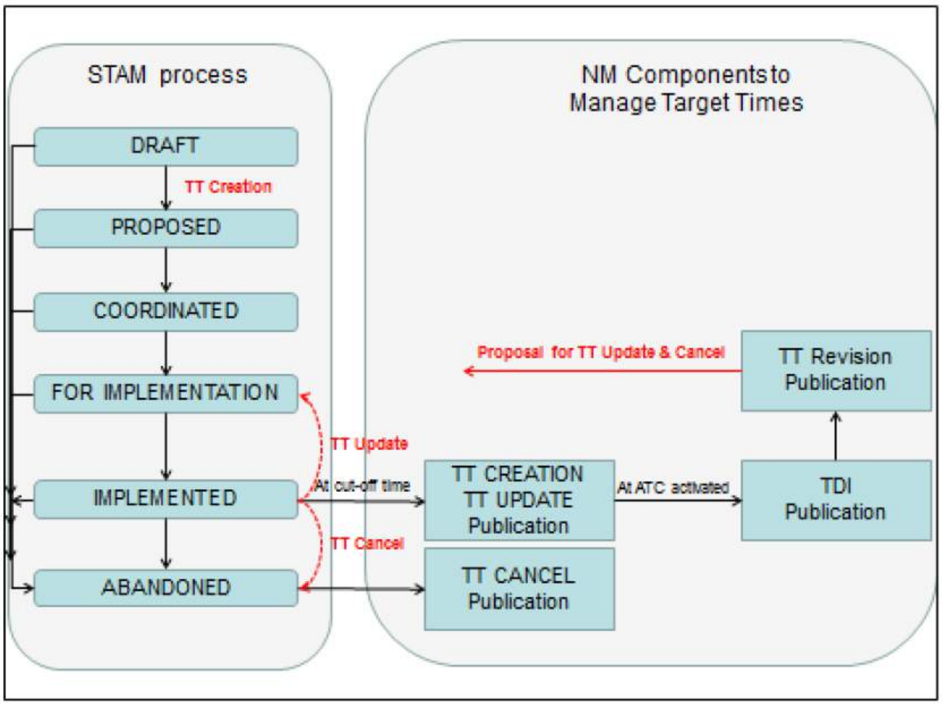

Figure A.4: Target time revision process [1]

Although the SESAR vision for TT includes the revision process described above, the NM has indicated during the interview that the revision process is not foreseen for practical implementations of the concept in the short-to-medium term. *Without a revision process, the TT concept should only be seen as an ATFCM planning tool, and as an enhancement to the CTOT process.* Nonetheless, it is imperative that ANSPs monitor TT adherence using post-ops analysis to identify the realizable TWs for their specific operation, and to identify any issues of incidental or persistent TT non adherence.

A.6 Dissemination of Target Times

Table A.1 below describes how target times are to be communicated between the various actors, at various different time periods.

Table A.1: Dissemination of Target Time Information [1]

TT Event	Addresses	Pre-departure Phase	Execution Phase
TT Creation	Pilot	FOC sends a 'TT creation' using ACARS	ATC sends a 'TT creation' using standard STAM processes
	DCB, FOC	NM sends a 'TT creation' using SAM/SRM	NM sends 'TT creation' using B2B
	ANSPs in route of a/c	NM sends a 'TT creation' using SAM/SRM	NM sends 'TT creation' using B2B
TT Update	Pilot	FOC sends a 'TT update' using ACARS	ATC sends a 'TT update' using standard STAM processes
	DCB, FOC	NM sends a 'TT update' using SAM/SRM	NM sends 'TT update' using B2B
	ANSPs in route of a/c	NM sends a 'TT update' using SAM/SRM	NM sends 'TT update' using B2B
TT Cancellation	Pilot	FOC sends a 'TT cancellation' using ACARS	ATC sends a 'TT cancellation' using standard STAM processes
	DCB, FOC	NM sends a 'TT cancellation' using SAM/SRM	NM sends 'TT cancellation' using B2B
	ANSPs in route of a/c	NM sends a 'TT cancellation' using SAM/SRM	NM sends 'TT cancellation' using B2B

As indicated previously, the original SESAR vision for TT includes modification of target times during flight execution. *However, the Network Manager has indicated that Target Time revision after take-off is too complicated for practical implementations of this concept.* Furthermore, none of the ongoing trials testing the concept make use of such a 'dynamic TTA'. Therefore, the second row and the last column of the above table is unlikely to be used in the field in the near-to-medium term time horizon.

A.7 Link between TT and AMAN/XMAN

SESAR distinguishes the relationship between TT and AMAN, and the relationship between TT and XMAN. These relationships are detailed in this section.

TT and AMAN

SESAR indicates that the TT information and the updated ETOs on TT waypoints within the AMAN horizon should be used as input data into the destination's AMAN system for calculation and updating of ATC constraints (e.g. Controlled Time of Arrival (CTA)). When a flight approaches the destination airport's AMAN horizon, the TT will be replaced/overwritten by ATC constraints (e.g. CTA), and communicated to all interested/concerned parties. *The ATC constraint is expected to be inside the TW, when feasible and not impacting the overall arrival management performance.*

TT and XMAN

The Extended AMAN (XMAN) concept consists of three distinct horizons:

- Eligibility Horizon (EH): the point from which XMAN receives data and begins processing a sequence
- Active Advisory Horizon (AAH): Once the aircraft enters the Active Advisory Horizon (AAH), and depending on the delay sharing strategy selected for Extended AMAN operations, the Extended AMAN may send advisories for concerned flights in the form of speed advice, time to leave the metering fix (TOM) or time to loose (TTL) or Controlled Time of Arrival (CTA) to upstream ANSP.
- Frozen Horizon (FH): the point at which the AMAN landing sequence is fixed and cannot be changed.

The three different XMAN horizons can be seen in the figure below:

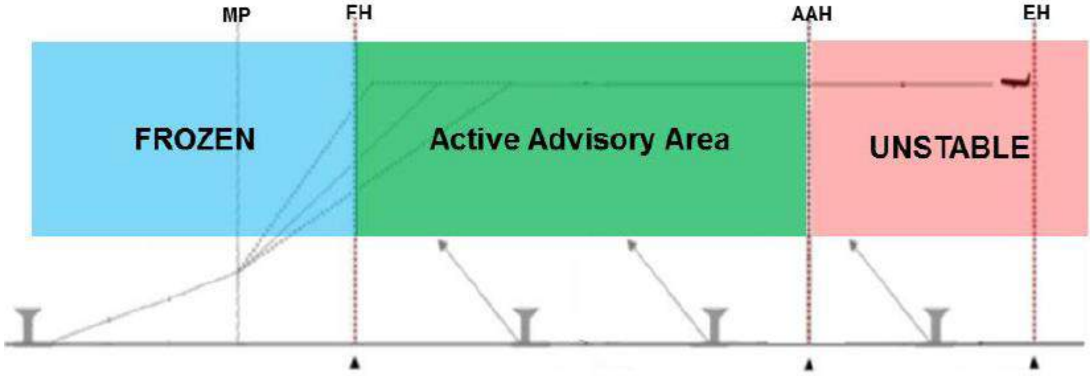

Figure A.5: XMAN time horizons [1]

In the context of TTA, it is possible that a flight passes the AAH while it has been assigned a TTA. The question is whether this will create any kind of conflict between the objectives which TTA intends to achieve and the objectives of XMAN. To understand how the TTA concept and the XMAN concept work together, it is important to look at the differences between the objectives, the domains and the granularities of the concepts.

	TTA concept	XMAN concept
Objective	Demand capacity balancing through flight plan adherence. Initially effectiveness of tactical regulations. The concept aims to prevent too many or too few aircraft in a certain sector during a certain (e.g. 20 mins) time period	Pushing-out delay absorption from TMA to extended TMA and en-route. Extended arrival management, work-load reduction in TMA and extended TMA. Descent profile optimization. The concept aims to control aircraft to take their planned position in a sequence of arriving aircraft.
Domain	Capacity Management, flight planning, planning adherence	Air Traffic Control
Time horizon	2 to 3 hours before landing.	Approx. 45 minutes before landing (in case of 200 NM planning horizon)
Granulatity, time tolerance	CTOT has -5/+10 minutes tolerance TTO/TTA tolerance is undefined, practical tolerances range from ± 3 mins to ± 5 mins	Time target at approach fix (IAF) range from 60 seconds to 30 seconds
Amount of delay absorption	Concept is based on delay absorption before take-off. Concept is not focussed on delay absorption during flight.	±5 minutes (without stack holding) for combined en-route and approach phase of flight.

Table A.1: TTA vs XMAN characteristics

As can be seen in table 1. TTA and XMAN operate in different domains and must be seen as complementary. In fact an effective AMAN / XMAN operation requires an effective of capacity management function to be in place, in order to prevent traffic overload (and subsequent stack holding). Traffic bunching with subsequent stack holding prevents descent profile optimization and must therefore be prevented as much as possible. The TTA concept is an enabler of an effective AMAN/XMAN operation.

When aircraft enter the Active Advisory Horizon they may have a TTA for a waypoint that has not yet been reached. An aircraft which has a TTA may be reduced (or increased) in speed on the basis of advisories from the AMAN from the destination airport (in case these advisories are communicated to the upstream centre, this is called an XMAN advisory). These instructions are given by the air traffic controller of the controlling Air Traffic Control unit to the pilot, and take precedence over any other instruction or objective. This also holds true for any target time that the pilot may have received with the ground delay that was issued.

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B. Interview Notes

To learn more about the practical experiences with TT, interviews were performed with TT trial experts at Skyguide, DSNA, NATS and Eurocontrol. This appendix provides the notes taken during those interviews.

B.1 Skyguide

Background

1. What is your background and role within Skyguide? And how does this fit into PJ25 (Zurich Trials)?
   - Capacity Management for Skyguide
   - Directly involved in iStream and xStream (PJ25) trials

2. What was the general aim of the TTA trial in Zurich?
   - To produce a good sequence in advance so that there is no holding before opening of airport in the morning
   - Important note: all trials only used TT from 06:00-07:00
     - This is **not a capacity constrained** time window
     - Only for sequencing and avoiding holding due to strict opening time of airport -> very different to LHR and CDG

TTA Implementation

1. Could you describe how TTA is implemented for Zurich?
   - TT is implemented to optimize arrival sequencing
   - The airlines provide Skyguide with ETO upto 5 hours before arrival for long haul. Many cases before take-off. For Short-haul it comes from the NM.
   - Skyguide compiles this information to make a sequencing
   - Skyguide uses this sequencing to determine TT for each flight
   - In iStream, only long haul flights. In xStream, all flights
   - This TT is sent to pilots via their dispatch. In most cases before take-off
   - Initially the process was very manually driven with emails. Now automated tool available
   - Pilots informed about TT and ties to adhere. They think FMS is used for this.
     - 5 minute window is aimed at for TT by skyguide. If it falls outside 5 mins, sequence will be affected.
   - Executive ATCOs not informed
     - Sequence better
     - So controller benefits from workload

2. Are you making use of AMAN/XMAN systems in Zurich? If so, is the TT integrated with the AMAN?
   - No
   - AMAN is old
   - XMAN in 2020
   - Sequence is calculated by TT tool between 6-7 am
   - No immediate plans to connect TT with AMAN/XMAN

3. What is the role of the Network Manager in the TTA implementation at Skyguide?

- NM not involved in iStream
- In xStream they are involved in the short haul flights. They calculate the CTOT based on TT supplied by Skyguide.
- NM disseminates the CTOT and TT. Updates ETFMS.

4. What is the role of the FMP in the TTA implementation at Skyguide?
   - Determine sequence for arrival based on airline ETOs, and then assign TTA to each flight

5. Did Skyguide make use of any specific tools regarding the TT trials? If so, what was the effect of the tooling on the results?
   - Initially communication with airlines and sequence

6. How accurate were the ETOs that were extracted from the CHMI tool? And how accurate were the ETOs that the airlines provide? Did accuracy resulted in problems generating the arrival sequence?
   - The data from long haul flights was very accurate
   - Data from NM was very inaccurate

7. How did the SWISS company tool influence the arrival sequence? Did SWISS use this tooling for TT swapping?
   - Yes used for TT swapping. Only Swiss slots could be used for swapping.
   - Based on connecting passengers
   - Both istream and xstream

8. Who determines if a flight gets a TT and how is it calculated and distributed?
   - FMP of skyguide. Email is sent to AOs via automated tool. All AOs can see full sequence and TTs

9. What waypoint is used as the TTA fix? Is the same waypoint used as the TTA fix for all flights?
   - Standard inbound waypoints

10. How are TTAs communicated to airspace users and to upstream ATC? Is this done by Skyguide or by NM?
    - By email to AOs
    - No communication with upstream ATC

11. Are TTAs updated before and during flight? If so, how are the updates communicated?
    - Only static TTA
    - No revision in flight. This is too complex.

TTA Results and Trials

1. Are pilots and airlines willing to adhere to their TTA? What is their incentive to do so?
   - Yes. They don't like holding. They can adjust their plan before take-off in most cases, so they are happy.

2. What were the important KPA/KPIs for Zurich?
   - Reduction of holding -> very important given
   - Efficiency of flight profile

3. Has TTA reduced the occurrence of traffic bunching, and improved the predictability of traffic? Were there other KPAs that showed promising results?

- 70% predictability -+4 mins -> max 5 min deviation of TT

4. Are there any other benefits of the TTA concept?
   - Main benefit is reduced holding.

5. What are the pitfalls of this concept based on your experience? (Does this concept reduce the amount of flexibility available to the ATCO?)
   - Communication to AO is crucial. They need to be made aware of the benefits. They need to provide ETOs
   - Make them aware and adhere
   - Best informed – best served

6. Which part of the concept works as anticipated, and which parts do not work as anticipated?
   - iStream worked so well that it is now part of the operations in the mornings.
   - But data from NM really inaccurate. This needs to be improved for it be really effective for short haul flights
   - More coordination needed with adjacent centres when concept is expanded
   - It is likely that the results are good because this is a standalone trial without other ANSPs using TT

B.2 DSNA

Background

3. What is your background and role within in DSNA? And how does this fit into PJ25 (Paris Trials)?
   - ATCO in Paris
   - Works on SESAR projects about flow management
   - Not involved in Fairstream (1st TTA trial)
     - Very few flights
   - Involved in iStream (2nd TTA trial) in 2014-2015
     - Large scale demo
     - Technical issues with NM
     - Worked on CONOPS for iStream
     - Integration with AMAN and XMAN
   - xStream (started Sep-Oct 2018), main ATFCM expert
     - Better concept and tool than iStream
     - Project leader of xStream
     - Both Orly and CDG
     - Integration with AMAN and XMAN

4. What was the general aim of the TTA trials in Paris?
   - Improve CTOT with TT
   - Better sharing of goal between FMP, FOC and pilot
   - Optimize arrivals into Orly and CDG
   - Mainly involving Air France (since this the main airline in Paris)

TTA Implementation

12. Could you describe how TTA is implemented for CDG?
    - Capacity at TMA is ok, but can be improved with TT
        - Goal is to improve the predictability of flights to improve the sequencing of flight s using AMAN
    - New AMAN Tool
        - Display timeline to runway, given ATFCM delay and planned runway arrival rate
        - Determine underfeeding/overfeeding
        - Optimize runway usage
        - Mandatory cherry picking
            - Select which flights to regulate with TT
        - Electronically send TT for the selected flights to the NM
        - NM converts TT to CTOT
        - TTA selected to match real capacity with demand in TMA
            - Regulation using CASA were not satisfactory for DCB
        - TT tool used to improve runway throughput
        - ORLY trials two weeks ago (beginning January 2019)
            - Better feeding of runway
            - Initial results indicates 10-15% reduction of delay

13. Could you please generally describe the iAMAN system?
    - It is a TT tool for iStream and xStream trials to compute TTAs for (the selected) flights
    - Sequence arrivals to match capacity in TMA

14. What is the role of the Network Manager in the TTA implementation at DSNA?
    - TTs sent to NM by tool (waypoint and corresponding time)
    - NM Generate CTOT
    - NM distributes TT and CTOT using SAM to AO
    - Marc does not know if AO sends both CTOT and TT to pilot. He thinks most AO will only inform pilots about CTOT
        - Air France not to follow TT when airborne. Only CTOT is sent to pilot. TT following is too complex for pilot once airborne and maybe bad for safety

15. Did DSNA make use of any specific tools regarding the TT trials?
    - Yes -> AMAN tool (see answer to question 1)
    - Thales designed the tool since they make the AMAN for DSNA
        - Tool is still a prototype
            - Has some robustness issues
            - Tool robustness has improved from iStream to xStream

16. Does DSNA determine which flights get a TTA, or is this task done by the NM? Is there a difference between the exercises?
    - DSNA decides
    - 1st hotspot is detected
    - A few flights are selected for TTA (cherry picking)

- Delay of +5 to 10 mins is assigned to each cherry picked aircraft
- Aim is to only issue TTA to only a few aircraft to solve the predicted hotspot

17. What waypoint is used as the TTA fix? Is the same waypoint used as the TTA fix for all flights?
    - First waypoint of STAR is used as the TT fix for all aircraft

18. How are TTAs communicated to airspace users and to upstream ATC? Is this done by DSNA or by NM?
    - SAM and SRM messages by NM

19. Are TTAs updated before and during flight? (How are the updates communicated?)
    - No
    - Marc thinks that no stakeholder is ready for this
    - This is because the predictability of the sequence is only good 20-30 mins before entry into airspace of Paris
    - Upstream ACC not fond of TTA, or Dynamic TTA
    - But, AMAN sequence is updated based on up to date info of airborne flights

20. How does TTA work together with iAMAN during the second trial? (Does TTA affect the AMAN/XMAN planning?)
    - Yes. The goal is to use the TTA to facilitate and optimize the AMAN planning

TTA Results and Trials

7. Are pilots willing to adhere to their TTA? What is their incentive to do so?
    - The goal of TTA is to improve the arrival sequence in the planning (pre-tactical) stage
    - But in practice Flights can get late
        - Weather
    - Also CTOT has a window
        - -5 +10
        - Air France tries for -5
    - Because of window and weather, TTA cannot always be complied with
    - But, when aircraft are airborne, new estimates are used to optimize AMAN sequence

8. What were the important KPA/KPIs for CDG?
    - Capacity
    - ATFCM delay
    - Regulation rate

9. Has TTA reduced the occurrence of traffic bunching, and improved the predictability of traffic? Were there other KPAs that showed promising results?
    - Yes, reduced traffic bunching
    - Improved predictability

10. Are there any other benefits of the TTA concept?
    - Reduced ATFCM delay by 10-15%

- No impact on safety
- Still working on further improving the tool and the benefits

11. What are the pitfalls of this concept based on your experience? (Does this concept reduce the amount of flexibility available to the ATCO?)
    - It works when you are alone, i.e., the only ANSP using TTA
    - When you have five TTAs from different ANSPs impacting each flight, it will only work the ANSP that issued the Most Penalizing Regulation (MPR)
    - Eurocontrol reconciliation may not line up with the planning for ANSPs with less penalizing regulations
        - ORLY is MPR in the trials
        - So no effect in their trials of other ANSPs

12. Which part of the concept works as anticipated, and which parts do not work as anticipated?
    - Works best with hotspots
    - Needs to have FMPs that are trained well to use tool
    - More trials needed to answer this question

13. What was the main difference between the results of the two trials?
    - Better tool in xStream

14. Do you think that the trials acquired enough data?
    - Every one saw benefit -> capacity improvement visible
    - More data needed

15. What would be a general recommendation to any other airport that is trying to set up a TT trial?
    - Quality of tool has to be very high-> easy to use, robust, training

10. What future improvements can be made to the TTA system?
    - Currently only European flights
    - In future, TTA should be given to long-haul and airborne flights (i.e., updates)
    - Improve info sharing between ANSPs to improve predictability
        - Goal is to get to a 10-30s predictability for airborne flights
    - Currently EFPL data used as input for TTA tool
    - In future, live data from ADS-B could be used to improve prediction of airborne flights

B.3 NATS

Background

5. What is your background and role within in NATS?
    - FMP – airspace capacity management
    - Manager (Airspace Capacity Management) ACM planning
    - Gets involved in trials and new procedures

6. What is the SESAR project in which LHR trials are being performed?
   - PJ 24 – Work package 6
   - Purpose: test LHR digitalized DCB tool
     - Tool computes a TTA to realize planned landing rate
     - TTA is back calculated from CTOT

7. What is your involvement with the TTA trials?
   - Manages involvement of his team in TTA trial
   - NATS support team – LHR operational efficiency cell (LOEC)
   - Trial on March 18th

TTA Implementation

21. Could you describe how TTA is implemented for LHR? (Are there any differences from the SESAR description of TTA?)
    - No differences according to him, but in actuality:
      - Conversation revealed that he sees it only as a ATFCM planning aid, *not* an ATC tool that is to be used during the operation
      - The CTOT is calculated for the LHR stacks to reduce time in stacks and realize the desired landing rate
      - This means that for European flights, only CTOT. No live update of TTA during flight
      - TTA issued in flight only for long haul flights from outside Europe since these flights don't have a CTOT. This is done via the FOC, not via the ATCO.
      - ATCO only aware that there are regulations, but not the TTA for each flight
      - Pilot only told about CTOT and not explicitly about TTA, although TTA is technically mentioned in slot message
      - Benefit is that the CTOT is calculated in such a way that the TTA at the stacks will result in a lower stack holds and more likely result in the desired landing rate at LHR
      - So in essence TTA is used at LHR to make 'life better' for the AMAN! – it is a sort of 'pre-sequencer' -> this is my interpretation not his.

22. What is the role of the Network Manager in the TTA implementation at NATS?
    - TT decided locally based on predicted count at the stack
    - NATS sends TTA to NM via tool (using internet)
    - NM will issue CTOT slot based on TTA to AU using SAM and SRM

23. Does NATS determine which flights get a TTA, or is this task done by the NM?
    - NATS tool decides
    - NATS FMP maintains oversight of process

24. How is the TTA value determined for each flight? (Is there a close relationship with CTOT for the same flight?)
    - Predicted traffic situation
    - Predicted landing rate
    - If predicted demand > predicted landing rate, then TTA issued for all aircraft in this period

- Departing flights from Europe will be given a CTOT
- Long-haul flights will be give TTA when airborne based on best information available (via FOC)

25. What waypoint is used as the TTA fix? Is the same waypoint used as the TTA fix for all flights?
    - For LHR it is the holding fixes
    - LHR has 4 holding stacks, and TT fix is the hold the airline filed to
    - Target holding time (e.g. reduce it to 10 min)

26. How are TTAs communicated to airspace users and to upstream ATC? Is this done by NATS or by NM?
    - Singapore trial -> direct to FOC o
    - Normal European PJ 24 -> via NM, which in turn uses SAM and SRM messages with CTOT and TTA creation/update/cancelation

27. Are TTAs updated before and during flight? (How are the updates communicated?)
    - Mostly before departure using CTOT.
    - It is theoretically possible in flight – he is not sure how this will work for Europe
    - Separate trial with Singapore airlines. They claim to be able to do +15 -7 mins in flight via FOC

28. How does TTA work together with AMAN/XMAN? (Does TTA affect the AMAN/XMAN planning?)
    - TTA goes as input for AMAN planning
    - ÁMAN fine tunes
    - No real interference because TTA used to improve arrival at Stack
    - TTA is for ATFCM -> only for planning
    - AMAN is for ATC

TTA Results and Trials

16. I understand that there are two trials at LHR. What are the differences between the two trials?
    - Old Trials
        - Long haul -> United airlines -> inconclusive
        - '52 trial' at LHR -> every aircraft got regulation (-5 +10) -> aircraft arrived more on time at stack This showed capacity can be increased from 45 to 52
        - Current actual window (without TT) = +-15. With TT = -5 +10. This
    - Future (18th of March)
        - End to end testing with NM
        - Concern over ability of NM to process messages
        - 400 messages a minute can be sent by NATS system
        - 50 messages can be processed by NM
        - Testing of TTA Tool
            - DCB 2
        - All aircraft will be given TTA
        - ATCO supervisors are told about trial
        - ATCOs only know about regulation, not about specific aircraft and continue to operate normally
        - Pilots do not know TTA, only know about CTOT

17. Are pilots willing to adhere to their TTA? What is their incentive to do so?
    - Pilots have to be briefed about it. Communication of the goal of the TTA concept is key to acceptance.
    - Adherence to TTAs can be analysed similar to TBS
        - Will take action on airlines that are repeat offenders – sanctions
    - TBS needs pilots to work at correct speeds
        - Post ops analysis is currently done to determine airline compliance

18. Has TTA reduced the occurrence of traffic bunching, and improved the predictability of traffic?
    - Previous trial showed improvement in predictability

19. Has TTA improved the workload of ATCOs in previous trial?
    - Unsure, perhaps improvement to some small degree

20. Are there any other benefits of the TTA concept?
    - Reduced holding time -> Less fuel burn -> beneficial for airline and ANSP targets

21. What are the pitfalls of this concept based on your experience? (Does this concept reduce the amount of flexibility available to the ATCO?)
    - If you have multiple airports operating in the same TMA, giving TTA may cause the traffic to become more complex -> this will affect ATCO and capacity negatively
    - Works fine now. But stand congestion for departures when implemented throughout Europe
    - Not interesting concept if trials reveal ATCO capacity increases

22. Which part of the concept works as anticipated, and which parts do not work as anticipated?
    - No surprises
    - Quite positive
    - This makes goals common between ANSP, airport and AU (currently goals are different and not known to each other).

B.4 Eurocontrol

Background

8. What is your background and role within Eurocontrol? And what was your specific role in PJ25?

    - Network Manager Directorate -> ATFCM
    - Strategic evolution of services -> operational and technical evolution of services
        - Airports and en route ATFCM measures
    - R&D (SESAR)
    - PJ24 -> Demo LHR, BCN, Palma
    - PJ25 -> Zurich, Paris CDG Orly, and Lyon
        - Paris is TMA

- Also is in discussion with FRA. Similar and Zurich
- Difference between Paris and Zurich -> Zurich is protect against too early flights
- UDPP -> user driven priority process -> SESAR ATM
    - Swapping within an airline of CTOTs.
        - KLM is doing this. Mitigate influences of late incoming flights

9. What was the general aim of the trials within PJ25?
    a. When ATFM constraint, local actor is in the best position to prioritize the available capacity to the demand

TTA Implementation

29. What is the role of the Network Manager in the TTA implementation in PJ25?
    a. Created B2B service
    b. Paris -> look at quadrant around airport at metering fixes. When constraint, they look at metring fixes. They choose what flow/order of flights should go through the metring fixes in the pre-tactical phase. They provide this order to NM using B2B. NM issues slots based on the slots, and then CTOTs, and TT is also in the SAM and SRM.
        i. 2 hours before SAM is issued
        ii. Optimization process -> airline delays flight more than 15 mins. NM tries to fill hole
        iii. SRM is issued
    c. Zurich ->no capacity constraint. Stop from arriving too early.
        i. Long haul flights have to hold before airport opens. Aim is to reduce holds. NM has no juristrication. Skyguide do the TT for long haul at the IAF.
        ii. Local domestic flights. NM gives CTOT to short haul flights to prevent interact with long haul arrivals.

30. Is this role acceptable for future trials? And what do you expect if more and more airports decide to make use of this concept? What will change in the work/role of the NM?
    a. NM help local actors as much as they can
    b. Continue to be customize help based on local goal
        i. But if constraints are en route, flexibility is reduced.
        ii. Interactions between airports are in en route. Unlikely that TT will be placed en route for flight. Most TT will be for arrival. So interactions unlikely
        iii. 32 airports in PCP

31. Is there a certain concept of TT that is the best from NM perspective?
    a. No best concept for NM
    b. Very flexible
        i. Every airport is different. So no one size fits all solution.
    c. TMA and airport better integrated is the ultimate goal
        i. Request from TMA operator and airport operator must be consistent

32. Does the NM require some extra/additional tooling to include the TT concept in its working process?
    a. Many new tools -> B2B services for connecting with local actors

   b. Changes to backend to update the slot list so that target time and fix name is included in SAM in SRM
   c. Infrastructure ready for use. Can be optimized in future.

33. Do you foresee any other tooling for other stakeholders?
    a. Yes all the ANSPs have their tools based on the goal
       i. PARIS is using XMAN
       ii. Zurich is using iStream tool
       iii. London DCB tool (heavy investment)
       iv. Spainish -> AIMA tool

34. Who, ideally, determines if a flight gets a TT and how is it calculated and distributed?
    a. Normally local actor does this
    b. But NM can do this. It is only a slight change. In some sense, this is already happening with CTOT.

35. How are TTAs communicated to airspace users and to upstream ATC?
    a. SAM and SRM

36. Are TTAs updated before and during flight? If so, how are the updates communicated?
    a. No updates.
    b. Too difficult for flight crew
    c. The rest of the plan will be updated around the problems that occur

TTA Results and Trials

23. Are pilots and airlines willing to adhere to their TTA? What is their incentive to do so?
    a. There is no requirements on pilots to strictly adhere to TT
    b. Only must take off within CTOT window
    c. No penalty on pilots. Stick as much as possible
    d. Try to avoid directs if early
    e. If take-off really late, then forget the TT. Fly at flight plan speed

24. What about airlines that do not listen to TT and disrupt the system?
    a. Embarrass airline in trade bodies that systematically don’t listen
    b. Show good behaviour and bad behaviour

25. What is the role of the ATCOs?
    a. In between ACC ATCOs not aware of TT. They should be aware that such a thing exists, and that pilots may be controlling their speed for this purpose.
    b. Inform them during the trial that traffic may be behaving strangely because of TT.

26. What were the important KPA/KPIs for Eurocontrol?
    a. Check if operational objective for each local actor
       i. Paris: reduction in route extension
    b. Per flight: conformance on take-off time, time at fix, flying time comparison with flight plan. Compare all these with the situation without TT

27. Has TTA reduced the occurrence of traffic bunching, and improved the predictability of traffic? Were there other KPAs that showed promising results?

a. Promising concept
b. Compliance of airline is key
c. Better use of resources
d. In the past when congestion, regulation is put. Regulation requested is more than needed. Local actor does not trust the regulation.
e. Goal of TT is to not waste available capacity. If there is more confidence in regulations, there will be less regulations, and more honest reporting of TT.

28. What are the pitfalls of this concept based on your experience? (Does this concept reduce the amount of flexibility available to the ATCO?)
    a. Trial in Spain: 1 Easyjet instructed to follow TT. He took-off too early. He was really slow to attain TT. He was overtaken by every other aircraft. And then he had to go to hold, even though TT in place. This was in 2014. No strange cases like this since.
    b. NM is always trying to provide what the local actor wants. If airport is not getting their wishes, it is because other things in the network take priority, like weather.
    c. The MPR shouldn't negatively affect the goals of airports too much because it is mainly an arrival regulations for all airports. So there should be no interaction between different regulations from different airports, unless weather etc. Planning can be updated before take-off.
    d. Interactions between airports only in en route. ANSPs are generally not issuing TTs in en route, only for arrival management. So there should be no interactions between airports.

29. Do you think that more trials should take place? If so, which concept should be tested?
    a. Interaction between airports to be tested in PJ 24 – mid March to Mid June.

30. What would be a general recommendation to any other airport that is trying to set up a TT trial?
    a. Very good communication between ANSP and airlines on what TT is, and what it aims to do?
    b. Airline should pass on TT to flight crew
    c. Training needed for flight crews

Schiphol TTA Concept

1. Presently at LVNL, the FMP determines the inbound rate, and this is conveyed to NM to determine the CTOTs. Can this process also be used for TTA computation?
    a. Yes, no problem. NM can compute TT at FIR boundary for LVNL based on requested inbound rate. This is only a slight change to today.

NLR

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