

**Airport CDM DMAN Evaluation at
Brussels Airport Zaventem**

Edition Number	:	1.0
Edition Date	:	18-12-2008
Status	:	Released Issue
Intended for	:	General Public

DOCUMENT CHARACTERISTICS

TITLE		
Airport CDM DMAN Evaluation at Brussels Airport Zaventem		
EATMP Infocentre Reference:		
Document Identifier	Edition Number:	1.0
	Edition Date:	18-12-2008
Abstract		
TBD		
Keywords		
Contact Person(s)	Tel	Unit
Volker Huck	93151	DAS/ATS
Elisabeth Lagios	93390	DAP/AOE

STATUS, AUDIENCE AND ACCESSIBILITY		
Status	Intended for	Accessible via
Working Draft <input type="checkbox"/>	General Public <input checked="" type="checkbox"/>	Intranet <input type="checkbox"/>
Draft <input type="checkbox"/>	EATMP Stakeholders <input type="checkbox"/>	Extranet <input type="checkbox"/>
Proposed Issue <input type="checkbox"/>	Restricted Audience <input type="checkbox"/>	Internet (www.eurocontrol.int) <input checked="" type="checkbox"/>
Released Issue <input checked="" type="checkbox"/>	<i>Printed & electronic copies of the document can be obtained from the EATMP Infocentre (see page iii)</i>	

ELECTRONIC SOURCE		
Path:	\\HHBRUNA05\etuinstr\$\AIRPORT C D M\DMAN\AIRPORTS D M A N\Brussels	
Host System	Software	Size
Windows_NT	Microsoft Word 10.0	486 Kb

EATMP Infocentre
EUROCONTROL Headquarters
96 Rue de la Fusée
B-1130 BRUSSELS

Tel: +32 (0)2 729 51 51
Fax: +32 (0)2 729 99 84
E-mail: eatmp.infocentre@eurocontrol.int

Open on 08:00 - 15:00 UTC from Monday to Thursday, incl.

DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME AND SIGNATURE	DATE
<i>Please make sure that the EATMP Infocentre Reference is present on page ii.</i>		

DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION NUMBER	EDITION DATE	INFOCENTRE REFERENCE	REASON FOR CHANGE	PAGES AFFECTED
001	06-06-2007		Initiate document	All
002	22-06-2007		Restructure, add new ATCO feedback	All
003	30-05-2008		Quantitative results added	All
004	3-11-2008		Internal AOE & ATS adaptations	All
005-06	27-11-10-12-2008		Internal & initial DLR comments	All
007	16-12-2008		Internal comments	All
1.0	18-12-2008		Final Version	none

CONTENTS

DOCUMENT CHARACTERISTICS	ii
DOCUMENT APPROVAL.....	iii
DOCUMENT CHANGE RECORD	iv
EXECUTIVE SUMMARY.....	1
1.1 Document	3
1.2 Audience	3
1.3 Purpose	3
1.4 Background	3
1.5 Justification.....	4
1.6 References	4
2. PROBLEM, CONCEPT, BENEFITS, SCOPE & OBJECTIVES	6
2.1 Today's Traffic Bottlenecks.....	6
2.2 High Level Concept	7
2.3 Expected benefits	7
2.4 DMAN Concept at Brussels Airport.....	8
2.5 Scope of Experiment	8
2.6 Objectives.....	8
2.7 Methodology	8
3. The Brussels ATC TWR Environment.....	9
3.1 Advanced Movement System and Runway Sequencing.....	9
3.2 Tower Procedures & Collaborative Decision Making	9
3.2.1 Clearance Delivery.....	9
3.2.2 Ground Control	10
3.2.3 Runway Control.....	11
4. The Eurocontrol / DLR DMAN.....	12
4.1 Purpose & Functionality of the EUROCONTROL / DLR DMAN.....	12
4.2 Installation at the Brussels Airport CDM Environment	12
5. Qualitative Results.....	13
5.1 Feedback on EUROCONTROL / DLR DMAN.....	13

5.1.1	Prediction	13
5.1.2	Separation.....	13
5.1.3	HMI	13
6.	Quantitative Results	14
6.1	Normal Operations.....	14
6.1.1	The Traffic Situation	15
6.1.2	DMAN TTOT versus ATOT	16
6.1.3	DMAN TTOT-Error at given clearances (SU, PB, TAXI).....	17
6.1.4	DMAN TSAT versus AOBT	19
6.2	Adverse Conditions.....	19
7.	ACHIEVEMENTS, Observations, Conclusions & Recommendations	22
7.1	General Achievement	22
7.1.1	Technical Observations.....	22
	While the tool proved to be accurate and robust enough to function properly over recorded traffic files in research environment, the connection to a real ATC Flight Data Processing system (the Belgocontrol AMS), called for the development of dedicated interface whose role was two-fold:	22
7.1.2	Operational Observations.....	23
7.2	Conclusions	24
7.2.1	TTOT	24
7.2.2	TSAT	24
7.2.3	Adverse Conditions	24
7.3	Recommendations.....	24
7.3.1	Airport CDM Operation.....	24
7.3.2	DMAN Operation.....	25
7.3.3	Controller HMIs	25
7.3.4	Further DMAN surveys.....	25

EXECUTIVE SUMMARY

The main purpose of the conducted shadow mode trials was to achieve both qualitative and quantitative results and receive feedback on the functionality of EUROCONTROL/DLR DMAN in a CDM environment operating at Brussels Airport Zaventem, as well as to define operational requirements within the frame of Airport CDM concept elements. This report describes the evaluation of the trials in collaboration with Belgocontrol air traffic controllers at Brussels Airport Zaventem. The trials were conducted in June 2007 and April 2008, for periods of three days for each trial.

A common result of many DMAN simulations and studies in the past was that more accurate traffic planning replacing today's first-come-first-served principle could lead to large benefits for stakeholders in terms of capacity, environment, efficiency and safety. These expectations have led the industry to develop planning tools like DMAN, AMAN etc.

Based on these expected benefits and industry developments a **DMAN demonstrator, the EUROCONTROL/DLR DMAN**, has been developed by EUROCONTROL in cooperation with DLR in 2003. It is adaptable to any airport and can be used for simulation and live trials. It helps EUROCONTROL member states to implement DMAN functionality from 2006 onwards. The DMAN demonstrator permits technical and operational staff to become familiar with the concept. It supports ANSPs in the production of

- tailored cost/benefit reports,
- airport specific concepts of use,
- operational requirements - procurement specifications.

Industry can profit from the tool by using it as reference platform.

In parallel to the mentioned European research projects, the **Airport CDM implementation project** in EUROCONTROL has been developed from 2000 onwards, with the aim to enhance operational efficiency by improving event predictability (reference 11). Years of concept enhancements and operational experiences during implementations at airports resulted in expected benefits similar to those mentioned above. In 2006 the synergy between Airport CDM and DMAN was identified, and aligned within the Airport Operations division in EUROCONTROL with the argument that DMAN required a clear operational context and industrial harmonisation; and Airport CDM required technical enablers to perform the tasks in several concept elements with special emphasis on the pre-departure sequencing.

The basic principle of departure management is to integrate individual flight progress information into pre-departure sequencing from off-blocks to take-off. Its functionality may comprise three concept elements of Airport CDM:

- Milestone Approach
- Variable Taxi Time
- Pre-departure Sequencing

The scope of the experiment is limited to validation of the flight progress prediction TOBT and the DMAN prediction of TSAT and TTOT. Main objective of the trials is to gain feedback regarding the DMAN concept in a CDM environment.

In three days of cooperation with Belgocontrol clearance delivery and ground controllers we provided instructions, let them operate the system in shadow mode with live traffic via the radio frequency, and held evaluation discussions. Much feedback on the EUROCONTROL/DLR DMAN, the DMAN concept, and the comparison with the AMS Belgocontrol system was derived, which are the basis for this report.

The DMAN concepts between AMS and the EUROCONTROL version differ in many ways, although they both predict sequencing on the runway and off-blocks. Brussels airport does not require efficient runway sequencing proposals by DMAN due to unsaturated traffic. The AMS DMAN basically functions as initial traffic sequencer.

In the contrary the EUROCONTROL/DLR DMAN has been developed to fit saturated runways producing more accurate take-off predictions. A significant Airport CDM derived requirement on DMAN is to develop more stable pre-departure sequence at a time parameter defined locally, to be used effectively by airport operators and ground handling agents.

INTRODUCTION

1.1 Document

This report describes the evaluation with Belgocontrol air traffic controllers at Brussels Airport Zaventem. It was conducted in June 2007 and April 2008, for periods of three days for each trial. The shadow mode trial evaluation focuses on the qualitative evaluation of the Airport CDM concept, by using the EUROCONTROL/DLR DMAN in the tower environment.

1.2 Audience

Possible audiences of the document are EUROCONTROL, Belgocontrol, the Airport CDM community, Research & Development units of industry partners, aeronautical industry, and others who are interested in the first results with the EUROCONTROL/DLR DMAN.

1.3 Purpose

The main purpose of the conducted trial is to achieve both qualitative and quantitative feedback on functionality of DMAN linked to the CDM platform as operating at Brussels Airport Zaventem.

1.4 Background

Since the nineties many research projects funded by the European Commission have investigated different types of departure management (DMAN) concepts in different airport environments. Example projects are AFAS (4th framework, reference 6), Gate-to-Gate (5th framework, reference 4 and 5), Leonardo (5th framework, reference 8), NUP2+ (reference 7) and others.

A common result of many DMAN simulations and studies was that more accurate traffic planning replacing today's first-come-first-served principle could lead to large benefits for stakeholders in terms of capacity, environment, efficiency and safety. These expectations have led the industry to develop planning tools like DMAN, AMAN etc.

The EUROCONTROL **DMAN project** has studied extensively the problem of managing departures at major European airports based on statistics and operational analysis (reference 1 and 2). After collecting requirements from the main stakeholders (airlines, airports, ATC), conducting comprehensive traffic observations, an analysis and several fast time simulations, the necessary elements of system supported departure management have been determined.

Based on these expected benefits and industry developments a **DMAN demonstrator** has been developed by EUROCONTROL in cooperation with DLR in 2003. It is adaptable to any airport and can be used for simulation and live trials. It helps Eurocontrol member states to implement DMAN functionality from 2008 onwards. The DMAN demonstrator permits technical and operational staff to become familiar with the concept. It supports ANSPs in the production of

- tailored cost/benefit reports,
- airport specific concepts of use,
- operational requirements - procurement specifications.

Industry can profit from the tool by using it as reference platform.

In parallel to the mentioned European research projects, the **Airport CDM implementation project** in EUROCONTROL has been developed from 2000 onwards, with the aim to enhance operational efficiency by improving event predictability (reference 11). Years of concept enhancements and operational experiences during implementations at airports resulted in expected benefits similar to those mentioned above. In 2006 the synergy between Airport CDM and DMAN was identified, and aligned within the Airport Operations division in EUROCONTROL with the argument that DMAN required a clear operational context and harmonised requirements for industry, and Airport CDM required technical enablers to perform the tasks in several concept elements.

Evaluation of DMAN within the Airport CDM concept has taken place in various experiments. First however, a Cost Benefit Analysis was developed to make the business case (reference 1). Fast and Real Time Simulations have been conducted during various projects (reference 3 and 4). Also an operational Concept has been derived (reference 9). In 2008 this concept is updated in the Generic Operational Concept for DMAN integration in Airport CDM and A-SMGCS (reference 10). More detail on Airport CDM can be found on the website (reference 12) and in the Airport CDM Implementation Manual (reference 11).

1.5 Justification

This document aims to support Airport Operators or ANSP's who consider implementation of Airport CDM with some form of departure sequencing, by providing results and conclusions based on shadow mode experiments at Brussels Airport.

DMAN within an Airport CDM environment is expected to contribute to operational efficiency through pre-departure sequencing and potentially increase runway throughput as a result of this efficiency.

Sequencing at the runway enables more accurate predictions, which are contributing to more accurate traffic predictions for TMA and ACC sectors. However an important benefit is also expected for the European network, which shall utilise more efficiently the available slots, and moreover is expected to reduce the amount of flow restrictions in the future due to more accurate traffic predictions.

1.6 References

1. Departure Manager Feasibility Report, version 1-0, EATM ASA02.DMAN.DEL05.FEA, November 1999.
2. Airport Traffic Data Analysis, version 1-0, EATMP ASA.02.AMAN/DMAN.DEL05.SDY, October 2002
3. Gate-to-Gate WP1 ,Fast Time Simulation Results, Eurocontrol, October 2006
4. Gate-to-Gate WP1 RTS 1 Simulation Report, version 2-0, LFV/Eurocontrol/Think Research, October 2006
5. Gate-To-Gate Operational Concept Description (D1.1.2) Flow and Departure Management version 2.0 – LFV/NLR/Thales-ATM/EUROCONTROL, Stockholm, 30 June 2004

6. AFAS RTS Test Report for Pre-Departure and Departure Phases – NLR, Amsterdam, February 2004
7. NUP2+ Arlanda DMAN Validation Exercise Report – LFV, Stockholm, November 2007
8. Leonardo Operational Concept v1-0 – NLR, Amsterdam, 2004
9. DMAN Operational Concept, V. Huck, T. Blajeva, September 2006
10. Generic Operational Concept for DMAN integration in Airport CDM and A-SMGCS, version 0-3, EUROCONTROL, October 2008
11. Airport CDM Implementation Manual – EUROCONTROL, Brussels, November 2008
12. Eurocontrol Airport CDM website www.euro-cdm.org
13. European Operational Concept Validation Methodology (E-OCVM) version 2.0 – EUROCONTROL 2004

2. PROBLEM, CONCEPT, BENEFITS, SCOPE & OBJECTIVES

This chapter contains the general problem description for departure management in today's traffic situation. Further it explores a high level operational concept, which is then applied to Brussels Airport. The expected benefits, scope of the experiment and results, as well as the objectives as described in regard to reference 5.

2.1 Today's Traffic Bottlenecks

Nowadays the departures are mostly processed in a first-come-first-served (FCFS) manner according to start up by the pilot requested time. The predominant FCFS working method without pre-planning at the clearance delivery position may result in the following disadvantages:

- Consecutive departures that require the maximum wake vortex separation. If a "Heavy" aircraft has reached the holding position first, it will depart first, although a "Light" is next in the queue and this will require the maximum separation. DMAN tries to avoid the occurrences of such "expensive" separations where runway capacity is lost.
- Consecutive departures that follow on the same SID. Again, same SID departures will require bigger separation, than consecutive flights on different SIDs. DMAN tries to avoid the occurrences of such "expensive" separations where runway capacity is lost.

In dense traffic it is beyond human capabilities to quickly reckon the shortest applicable separations based on at least 4 constraints:

- Wake vortex;
- SIDs;
- Ground progress of the flights, i.e. the motion of the a/c on the manoeuvring area;
- Runway occupancy caused by the arrivals in mixed mode operations.

This challenging task is performed by the DMAN algorithm, provided the tool is fed with accurate data of the status of every flight in the sequence. If the controller deviates from the calculated sequence without notifying DMAN, the tool will still bring benefits, since:

- DMAN tends to spread departures to the same departure fix
- It tends to cluster departures with the same wake vortex category

The above supports the reduction of departure separations.

In addition, within an Airport CDM environment, DMAN receives more accurate departure time predictions based on which more efficient departure planning can take place (from off blocks). Then DMAN as decision support tool provides the pre-departure sequence to the clearance delivery position.

2.2 High Level Concept

The basic principle of departure management is to integrate individual flight progress information into pre-departure sequencing for off-blocks and take-off. It combines three concept elements of Airport CDM:

- Milestone Approach
- Variable Taxi Time
- Pre-departure Sequencing

Key element in the Airport CDM concept, and hence in pre-departure sequencing, is the prediction by the Aircraft Operator or Ground Handler of the target off-block time (TOBT). With this prediction the DMAN calculates a sequence that reflects the flight progress in the inbound flight or turn-round phase. Using the variable taxi time DMAN also calculates the target take-off time (TTOT) and the target start-up approval time (TSAT).

The more advanced concept for DMAN integration in Airport CDM and A-SMGCS is described in reference 10. Here, A-SMGCS can be used for feeding back actual events recordings such as actual off-blocks time and actual take-off time. However, for simplicity this feed back of information was not applied in this experiment at Brussels Airport. Important reference to this operational concept is the Airport CDM implementation manual (reference 11).

2.3 Expected benefits

Based on years of operational validation on several European airports it was concluded that active flight sequencing on off-block or take-off events, derived on accurate off-block predictions by the Aircraft Operator and/or Ground Handler, could lead to the following specific benefits:

- Increase of environmental benefits:
 - Reduced fuel emissions (global warming)
 - Reduced noise (residents around airport)
- Increased operational efficiency benefits:
 - Improve predictability of in- and off-block times (Airport Operators, Ground Handlers)
 - Reduced taxi times (Aircraft Operator)
 - Reduced fuel consumption (Aircraft Operator)
 - Stabilised traffic flows (ATC)
- Increased Safety
 - Less workload (ATC)
 - Less stress and chaotic turn-round process (Ground Handler, Aircraft Operator)
- Enhancement of ATM network by
 - Increased number of utilized slots (CFMU, ATC)
 - Reduced number of overall assigned slots (CFMU, Aircraft Operator)

2.4 DMAN Concept at Brussels Airport

At Brussels Airport already a DMAN operating as traffic sequencer was installed, integrated into the AMS system. This **AMS DMAN** output will be used as point of reference for traffic sequencing, in order to verify results with the **EUROCONTROL/DLR DMAN**. In chapter 5 and 6 these results are presented.

In the prediction of the system off-block time, or TSAT, a margin is taken into account to buffer for cheating by airlines. As described above, the AMS DMAN already contains this buffer, however this buffer is maybe too large.

Important difference with AMS DMAN is that AMS DMAN can not hold aircraft long at the gate, although delay should be absorbed at the Clearance Delivery position. The EUROCONTROL/DLR DMAN enables longer delay at the gate, depending on the runway sequence situation. The EUROCONTROL/DLR DMAN application is tailored to fit saturated runways, while in the actual situation at Brussels airport, the runways are not saturated.

Once TSAT is updated manually, it is important to have the DMAN algorithm to anticipate a new runway planning, as this manual override can influence the situation at the runway threshold significantly. However, for Brussels airport this is not an important issue due to its sufficient average capacity on the runways.

2.5 Scope of Experiment

The scope of the experiment is limited to validation of the flight progress prediction TOBT and the DMAN prediction of TSAT and TTOT.

2.6 Objectives

Main objective of the trials is to gain feedback regarding the DMAN concept operating in a CDM environment and derive operational requirements. This feedback can be divided into high level open questions which can be later elaborated:

1. How is the representation of flight data in DMAN?
2. How is the prediction of TSAT and TTOT in DMAN?

It is not the purpose of this trial to validate the display interface, however all comments are welcome.

2.7 Methodology

The work in this project has been performed in compliance with the European Operational Concept Validation Methodology (reference 13).

3. THE BRUSSELS ATC TWR ENVIRONMENT

This chapter describes the context of the evaluation of the EUROCONTROL/DLR DMAN. Objective is to gain as much information on the present day of operation at the airport, and how the EUROCONTROL/DLR DMAN is positioned relatively to the operations.

Already today the main working positions in the control tower each have tasks that are influenced by the new Airport CDM process which is applied since January 2005 (reference 1). The relevant task information is described in section 3.2. It is useful to take into account how the in-house developed AMS system works in relation to existing procedures, in order to compare the interaction with EUROCONTROL/DLR DMAN. This is described in section 3.1. Finally, feedback on the EUROCONTROL/DLR DMAN is placed into context of the current way of working at Brussels Airport, and observations as well as recommendations by the participants in the trials are taken into account. This is described in section 5.1

3.1 Advanced Movement System and Runway Sequencing

Belgocontrol developed in-house an Airport Movement System (AMS) which consists of Advanced Surveillance, Movement Guidance and Control System (A-SMGCS) which is still in pre-operational trials, operational Electronic Flight Strips (EFS), and an operational Departure Manager (DMAN). Variable taxi times are used to calculate Managed Take-Off Times (MTOT) on the runway and System Off-Block Times (SOBT) at the gate.

An application by Park Air for A-SMGCS is still operational in the tower. It will be replaced by the AMS application in the near future.

The current AMS DMAN computes an SOBT and MTOT based on the CDM process with resulting TOBT, with the objective to derive sequences for off-blocks and runway. In daily practice the first sequence is made by Delivery, based on Airline TOBT and manual TSAT input by ATC. The second sequence is then made by the Ground Controller based on pushback request and taxi progress. The latter is clearly a tactical process, reactive on the Airline requests. The runway sequence is therefore modified based on the Delivery by Ground Control.

3.2 Tower Procedures & Collaborative Decision Making

Belgocontrol has three main tower positions:

1. Clearance Delivery
2. Ground Control
3. Runway Control

Below, per position the current working procedures are described.

3.2.1 Clearance Delivery

At Clearance Delivery En-Route Clearance and Start-Up Clearance are given separately, before handover to Ground Control takes place. CDM procedures are implemented and

TSAT is the main driver for the distributed off-block sequencing by the AMS Departure Manager.

Planning

The TSAT is derived manually after an automated advice of the off-block time is proposed via the SOBT. The SOBT is back-calculated after projecting the TOBT onto MTOT via the taxi time from gate to runway. TOBT updates are issued by airlines to the CDM platform at an early or at a later stage (via datalink, email or radio). . This TOBT represents the target readiness of the aircraft, and triggers AMS DMAN to schedule the flight and derive a SOBT. All flights are ideally scheduled by AMS DMAN to be early in their CFMU slot (CTOT-5 minutes, if available). The AMS DMAN sequences flights on the runway, shifts in time, and then derives the feasible SOBT.

The AMS DMAN is however mainly used by controllers for its off-block prediction SOBT, since the Ground Controller and Runway Controller later on tactically decide on the actual sequence optimization for the runway. For this reason the manual TSAT is often earlier than SOBT, as this SOBT is a very cautious prediction of the off-block time, whereas controllers prefer to have the aircraft pushed as soon as possible. This situation generates a lot of discussion in Belgocontrol, about the real benefit of the advisory by DMAN.

As the runway sequence proposal is not actively used by controllers, it is the explanation for the fact that the manual TSAT does not trigger an update for the runway sequence proposal. It is simply not needed.

Clearances

The En-Route clearance is formally separated from the Start-up clearance, to avoid abuse by airlines who aim to get an earlier pushback time. However this En-Route clearance is for almost 50% of the airlines requested via a Datalink procedure. In the nominal case this clearance request is made when the aircraft is ready for pushback. Hence, the En-Route clearance is directly linked with the Start-Up Clearance.

In non-nominal cases aircraft request early their Runway and SID. They will receive the information, but then be put in standby mode, to provide them with clearances when they are ready. This is sometimes confusing since it is often unclear when the aircraft is really ready after standby is activated.

Clearance Delivery will hand over the aircraft after issuing the Start-Up Clearance to the aircraft on ASAT (Actual Start-Up Approval Time), if correctly applied this ASAT is close to TSAT. Many pilots however are not aware of TSAT or the meaning of it.

3.2.2 Ground Control

The Ground controller will not get a flight handed over before Clearance Delivery has issued the start-up clearance. This is to avoid unnecessary flights in the Ground Controller overview, and once handed over the flight is normally ready for Push back request.

The ground controller will issue the Pushback clearances according to aircraft request and platform (apron) situation. From the moment the pushback is approved the aircraft will be pushing and starting its engines for several minutes. Once ready for taxi the Ground controller will issue the taxi clearance and guide it towards the runway.

From that moment the Ground Controller will actively deliver all aircraft in the most feasible sequence to the runway, in direct coordination with the Runway Controller sitting beside him in the tower. Although the Runway Controller will have the final decision, it is the Ground Controller who actually prepares the sequence for optimized runway use. It does not take the earlier AMS DMAN proposed sequence in account, since the Actual Start-Up Clearance is also no longer related to the proposed SOBT. In the tactical phase the pre-tactical proposed sequence is abandoned.

The Ground Controller actively separates traffic by use of Electronic Flight Strips, representing the actual traffic situation on the platform. No datalink procedure is applied by the Ground controller, however recently there have been live trials at Brussels Airport with datalink clearances in the D-Taxi project (Eurocontrol).

Once approaching the Runway Threshold, the Ground Controller hands over the flight to the Runway Controller. If active runways are crossed this handing over back and forth may occur between Ground and Tower Controller, based on taxi route and required runway entry.

When a runway configuration change occurs this is ideally done at Clearance Delivery for new flights to depart. However, in some cases due to e.g. arrival traffic on the current departure runway, a configuration change requires taxiing traffic to manually get a new runway and SID assigned.

3.2.3 Runway Control

The Runway Controller is responsible for all the traffic around the runway, and he issues Take-Off, Line-up, and Runway Crossing Clearances when needed. It should be noted that with Airport CDM the traffic is already organized much earlier than before and therefore there is less "tactical sequence" at the runway.

The Runway Controller can have different manners of making the actual runway sequence. Some controllers use the prepared sequence by the Ground Controller and let all aircraft onto the runway via one entry. Other Runway Controllers use multiple entries for last minute changes to the sequence, based on departure routes and aircraft categories.

Runway Control applies no datalink application, but communicates only by voice. The runway sequence coming from AMS DMAN is not actively applied.

4. THE EUROCONTROL / DLR DMAN

4.1 Purpose & Functionality of the EUROCONTROL / DLR DMAN

The EUROCONTROL/DLR DMAN is result of a co-operation between EUROCONTROL and German Aerospace Center DLR. It was designed to conduct:

- Fast time simulations for Benefit assessment
- Real time simulations for evaluation of the DMAN Concept
- Shadow Mode trials for Demonstration.
- Active shadow mode trials for Operational Evaluation*

Brussels was the first airport chosen for shadow mode trials. The conditions were ideal for testing because it could be compared to an operational DMAN, the Brussels AMS. No active shadow mode trials took place in Brussels. "Active" means the aerodrome controllers consider advisories on TSAT or take off sequence.

* Such trials are planned for Athens and Lisbon.with un updated version of DMAN

The EUROCONTROL / DLR DMAN supports optimization of the runway sequence. That means it will minimize the total amount of separation needed for a given set of departures e.g heavy aircraft with a rule of departing in sequence to save on expensive wake vortex separation or to alternate left and right turn departures to spare the 2 minute separation needed between departures with SIDs on same direction.

The EUROCONTROL/ DLR DMAN will adapt the predicted take off time even after the departure has received start up clearance (the Brussels AMS freezes all the planned times after start up for the sake of plan-stability). When a number of departures take off considerably later than their predicted take off time (result of a rejected take off or an unexpected arrival on the same runway), all consecutive departures may be delayed by the respective amount of time lost.

The EUROCONTROL/ DLR DMAN allows input of runway blockage, for example for runway inspections and snow clearance.

The EUROCONTROLI / DLR DMAN is not designed for operational use! It has to be stopped and reset for runway configuration changes. It is not robust enough for operational standards. Its advantages are the easy transportability and the possibility to adapt quickly to special conditions and trial requests.

4.2 Installation at the Brussels Airport CDM Environment

The EUROCONTROL / DLR DMAN was tested in passive shadow mode trials in the Brussels airport CDM environment. "Passive" means the aerodrome controllers did not effect

any advisories on TSAT or take off sequence. However, the system received the start-up, pushback, taxi and take off clearances when input by EBBR aerodrome control into the AMS.

This “automatic” flight progress can be suppressed. Then there has to be a controller/trial operator in order to progress the flights. This feature allows “hands-on” demonstrations of the DMAN concept.

The following chapters report the feedback received from two Brussels controllers who participated to the trials (Qualitative results) and the evaluation of the log files that were taken during the runs (Quantitative results).

5. QUALITATIVE RESULTS

5.1 Feedback on EUROCONTROL / DLR DMAN

This section provides feedback on the Eurocontrol / DLR DMAN in two sections:

- Prediction
- HMI

5.1.1 Prediction

In a brief comparison between the TSATs generated by the EUROCONTROL / DLR DMAN, and the SOBT generation by AMS DMAN, the parameters appeared to be stable in their deviation of 1-3 minutes.

The runway sequences of both DMAN are not compared in a large extend. Statistical analysis must be applied to enable conclusions on that topic. See next chapter.

5.1.2 Separation

Separation values are presented correctly, however the 757 has special treatment in the runway sequence, as its vortex is considered to be larger than the other aircraft. For this reason, the 757 has large separation between its trailer and leader

5.1.3 HMI

Although the EUROCONTROL/DLR DMAN HMI as an application is not under evaluation, since it is a prototype, several comments were reflected on its characteristics.

Flight Information

On the Clearance Delivery position it is of importance to visualize all information in the Departure/En-Route Clearance message, since this is information a controller wishes to read once calling the pilot. The HMI provides this.

Time representation

The taxi time and the EOBT on the displays of Ground and Tower Controller are important parameters to add to the displays, since they judge if flights are late and might be suspended by CFMU at the limit EOBT + 40 minutes. If flights are late the controller can open a priority for these flights, or send them back to the gate. Controller will obey this limit due to regulation with CFMU. However the suspension parameter becomes of less importance when the airport is linked to the network and CFMU receives updated information on departures through DPI (Departure Planning Information).

Time representation is a personal preference of controllers, however more accentuation of modified/updated times can trigger the controller to attract his attention. TTOT is never used by controllers, however again this is due to the airport situation and unsaturated runways. In fact, TTOT can be replaced by the system prediction, SOBT.

TSAT should also be in the main displays, as this is the trigger for assigning Start-up Clearance. Now it is the minor text box below, unable to compare one flight with others. TSAT also cannot be changed manually, which means less flexibility for the Clearance Delivery Controller. This is a more important topic to consider, as controllers always demand flexibility of a system.

The EUROCONTROL/DLR DMAN issues timing information for each departure and each clearance (start, push, taxi, line-up, take-off) in “minutes-to-go”. For unconstrained flights in low traffic demand this time-tag simply results from the TOBT plus the estimated duration of progress, sometimes referred to as left bound flights. In high traffic demand departures are typically constrained by their predecessors in the runway sequence and the time-tag represents a “time-to-loose” advisory, sometimes referred to as right bound flights. The HMI does not make a difference between the two. The difference can, however, be deducted from the departures position in the time-line display.

EUROCONTROL/DLR DMAN makes no visual difference between left bound flights and right bound flights. This is unusual to the Ground and Runway Controllers.

Handling of Flight Strips

Handing over the flight backwards from the Runway Controller position is only possible via Clearance Delivery, but not via Ground. This is uneasy, however not a major issue. It should be there for cases an aircraft breaks of its take-off, and must be re-sequenced or when the aircraft has to return to the gate.

6. QUANTITATIVE RESULTS

The first section describes normal conditions on the airport. In the second section adverse weather conditions influenced the performance of the CDM concept.

6.1 Normal Operations

The quantitative results concentrate on the

- Target Take-Off Time (TTOT) and the
- Target Start Up Approval Time (TSAT)

DMAN was running in passive shadow mode operation, which means there was no feedback from the decision support feature of DMAN to the actual operations. The results presented originate from Brussels airport EBBR 7th April 2008 from 1400UTC until 1700UTC. The EUROCONTROL/DLR DMAN sequence optimizer was neutralized, which means the first-come-first-serve procedure with a general separation of 80s between two consecutive departures and 45s between an arrival behind a departure and a departure behind an arrival was applied in the algorithm. The sequence is not optimized due to FCFS, but the calculation of TTOTs and TSATs was done based on the FCFS sequence.

First the traffic situation at the airport is presented in section 5.1.1. Then focus is put on the take-off time prediction, in sections 5.1.2 and 5.1.3. In section 5.1.4 the off-block TSAT predictions are compared to the actual off-block times.

6.1.1 The Traffic Situation

The following graphic originates from evaluations of German Aerospace Center (DLR):

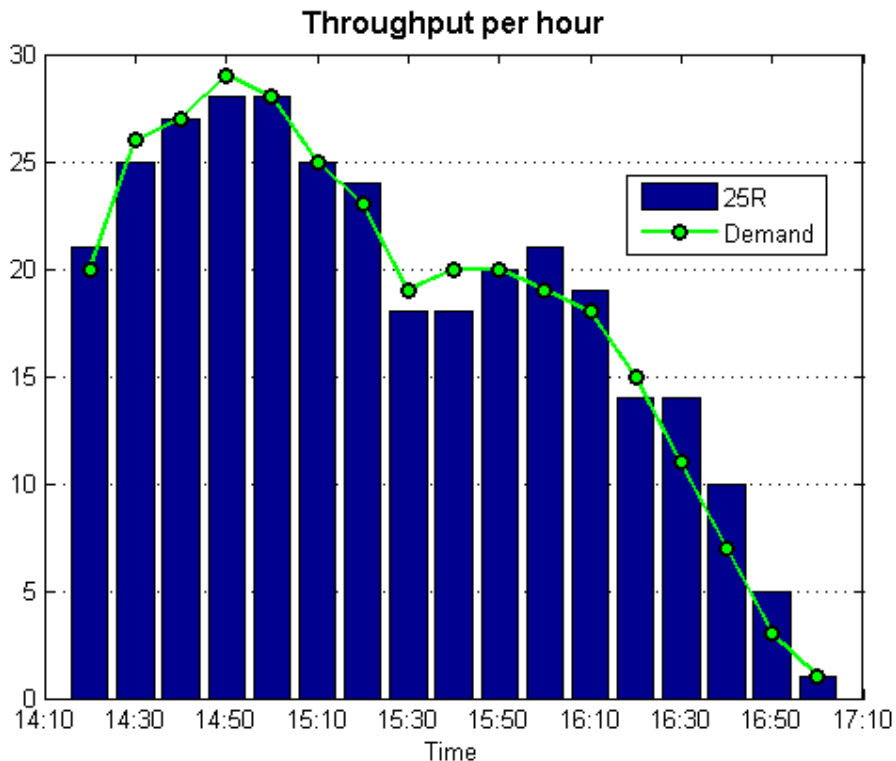


Figure 1: number of departures on runway 25R

This graphic compares the departure throughput with the traffic demand. Each vertical bar represents the throughput value for one hour, starting from the time mentioned underneath the bar. It can be seen that the departure runway capacity was sufficient during the time period. However, a queue of 5-7 departures waiting for take-off at the runway was observed several times.

6.1.2 DMAN TTOT versus ATOT

Figure 2 depicts the average offset of the DMAN target take-off time (TTOT) and the actual take-off time (ATOT). It reads like follows:

The horizontal axis reaches from 40 minutes before ATOT on the left until the moment of ATOT on the right for each individual departure.

The vertical axis depicts the difference between TTOT and ATOT reaching from 20min “late” on the bottom to 20min “early” on the top, averaged over the entire period from 1400UTC to 1700UTC.

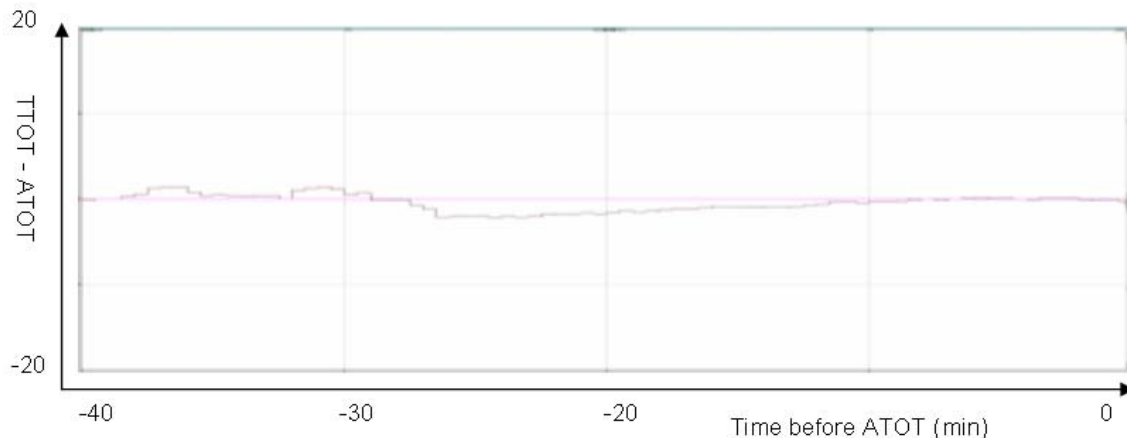


Figure 2: TTOT evolution versus ATOT

This diagram shows that the airport model for DMAN was appropriate. The taxi time-table and also the separation between departures has on average matching the real-world, otherwise a bigger off-set would be visible in the graphic. This diagram **does not** mean that the predicted TTOT was close to the ATOT.

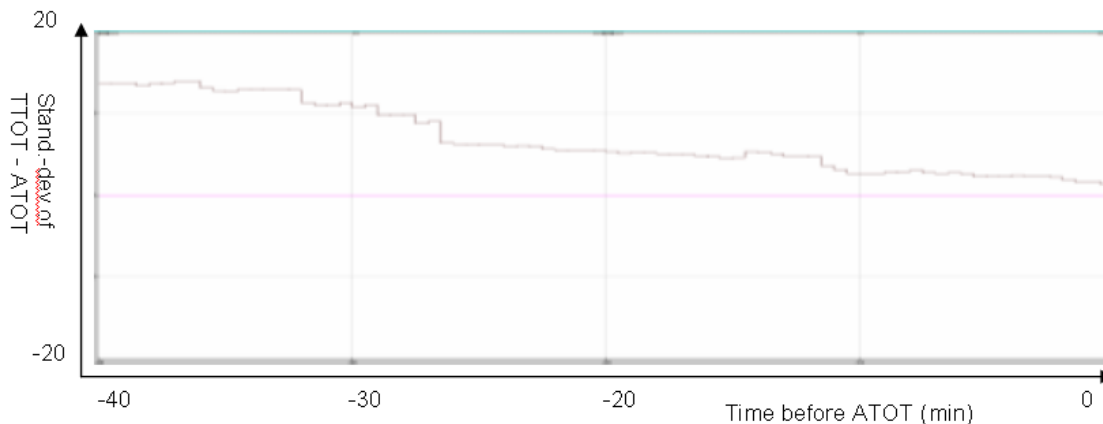


Figure 3: standard deviation of TTOT evolution versus ATOT

Figure 3 shows the standard deviation of the TTOT from the ATOT. One can see that the standard deviation is below five minutes for a time-horizon of up to 27 minutes. For time horizons between 25 und 40 minutes the standard deviation increases to approximately 10-12 minutes.

6.1.3 DMAN TTOT-Error at given clearances (SU, PB, TAXI)

The following 3 graphics originate from evaluations of German Aerospace Center (DLR):

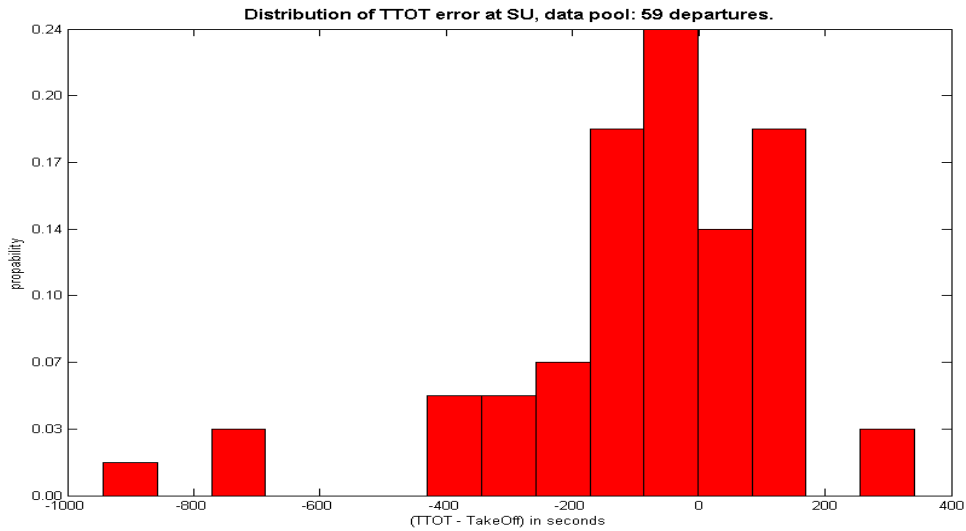


Figure 4: error of TTOT at the moment of Start-up clearance

Figure 4 shows the distribution of TTOT-errors at start up. The heights of the columns show the fraction of the entire sample of 59 departures. Within a range of ± 3 minutes the majority of the TTOT approximates the ATOT. For example, the highest column, reading 0.24, represents 24% of the departures.

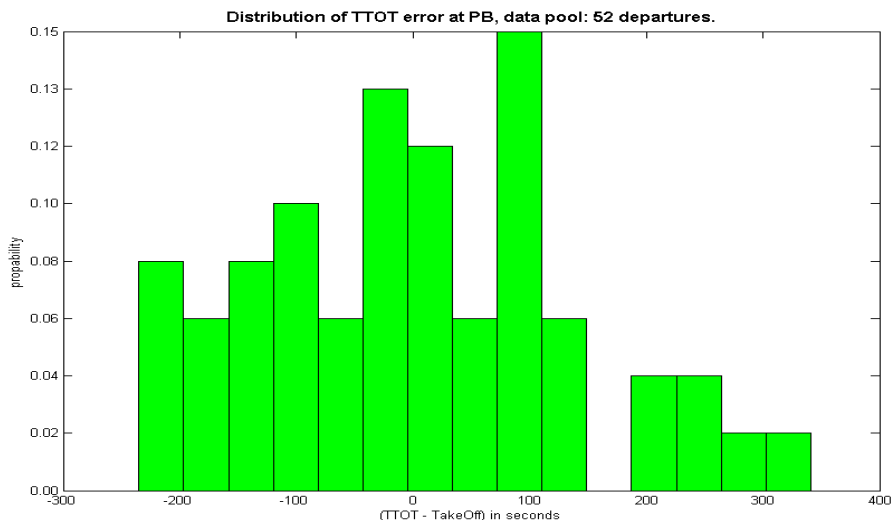


Figure 5: error of TTOT at the moment of Pushback clearance

Figure 5 above shows the distribution of TTOT-errors at push back. The heights of the columns show the fraction of the entire sample of 52 departures. Within a range of ± 3 minutes the majority of the TTOT approximates the ATOT. For example, the highest column, reading 0.15, represents 15% of the departures.

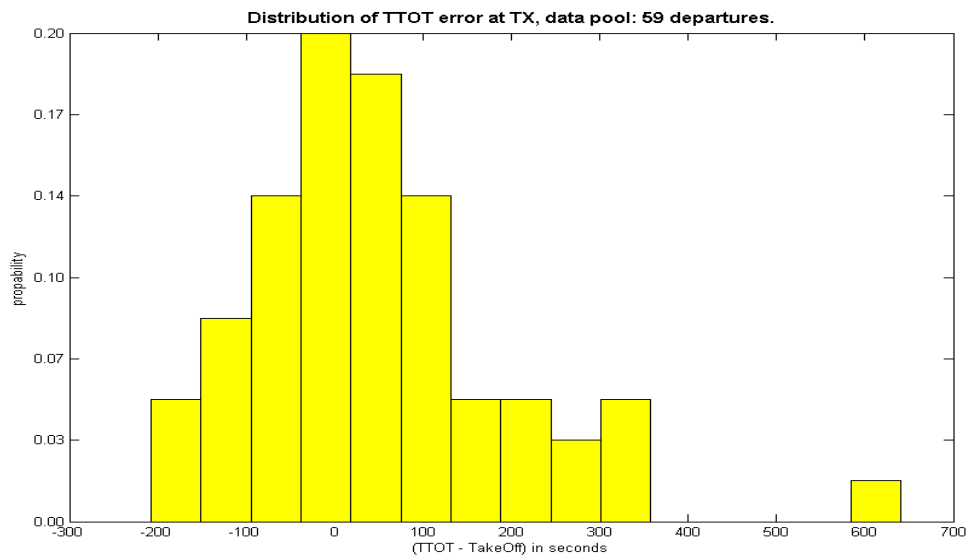


Figure 6: error of TTOT at the moment of Taxi clearance

Figure 6 shows the distribution of TTOT-errors at taxi clearance. The heights of the columns show the fraction of the entire sample of 59 departures. Within a range of ± 2 minutes the majority of the TTOT approximates the ATOT. For example, the highest column, reading 0.20, represents 20% of the departures.

6.1.4 DMAN TSAT versus AOBT

Figure 7 shows the standard deviation of the TSAT from the Actual OBT from 40 minutes before AOBT (left) to the AOBT (right). Both, the AMS in blue and the EUROCONTROL/DLR DMAN in black show a similar pattern until about 13 minutes before AOBT. Thereafter the AMS system shows better performance. The explanation is that the Ground Controller followed the AMS-system which is in actual operation rather than the DMAN system which is on passive trial. The DMAN TSAT was not visible to Ground Control during trial.

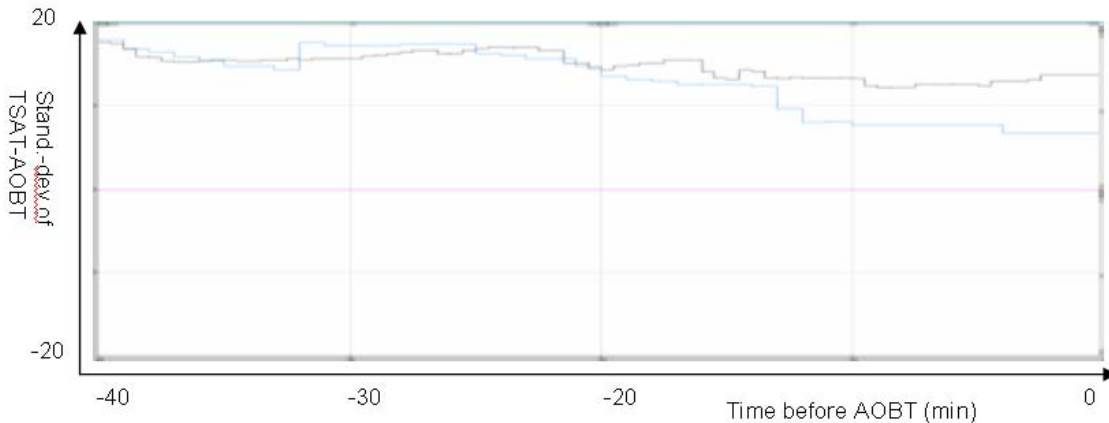


Figure 7: Standard deviation between TSAT and AOBT for AMS DMAN (blue) and EUROCONTROL/DLR DMAN (black)

6.2 Adverse Conditions

On Thursday 14th February 2008 Brussels airport suffered adverse conditions. Visibility between 200 and 500 meters resulted in operations below CAT I and de-icing procedures were in effect during the entire trial period from 0600UTC until 1000UTC. The following graphics are identical in analysis and scale with the graphics shown for the 7th April.

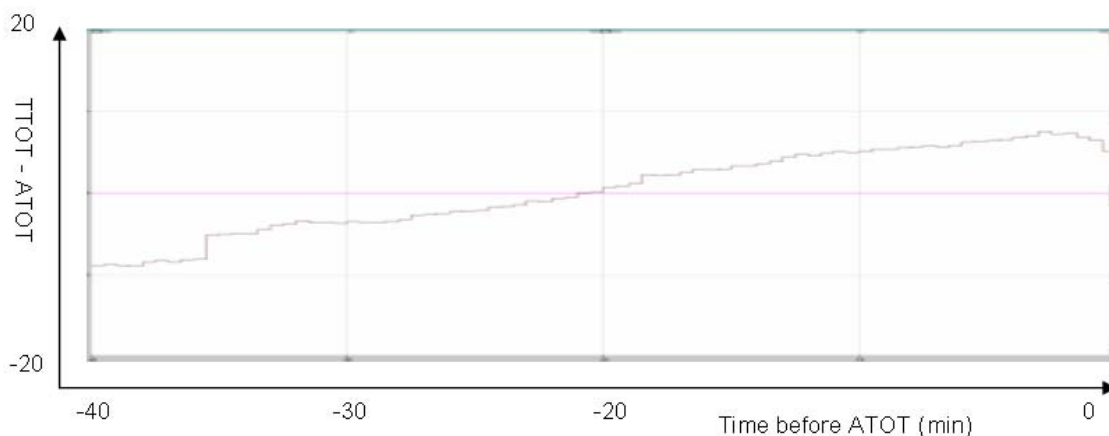


Figure 8: TTOT error evolution versus ATOT

Figure 8 shows the average TTOT-error with respect to the lead-time before ATOT from left (40 minutes lead-time) to the right (ATOT). The diagram clearly shows that the taxitime-table and the assumption for separation were inappropriate for the adverse weather conditions. It can be concluded that an adjustment for special conditions is needed.

The same pattern shows in the standard deviation diagram in Figure 9. A standard deviation between TTOT and ATOT of 10-15 minutes can be observed during the entire period.

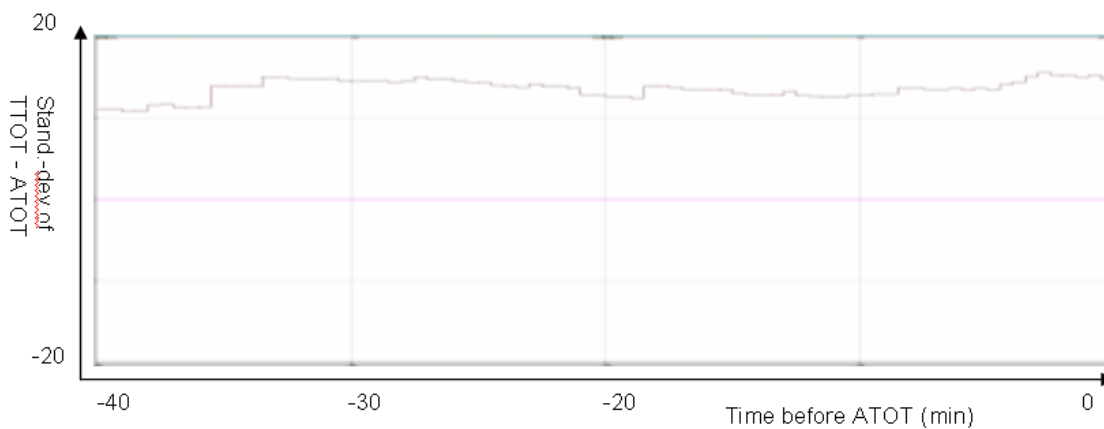


Figure 9: Standard Deviation of TTOT from ATOT in adverse conditions

The following diagram in Figure 10 shows the standard deviation of the TSAT from the AOBT. It appears to be in acceptable limits for DMAN (black) and is planned too early by AMS (blue), specifically in the pre-tactical phase from 40-20 minutes before AOBT. The reason is that the AMS TSAT defaults to the TOBT until the Clearance Delivery Controller revises the TSAT in accordance with the situation.

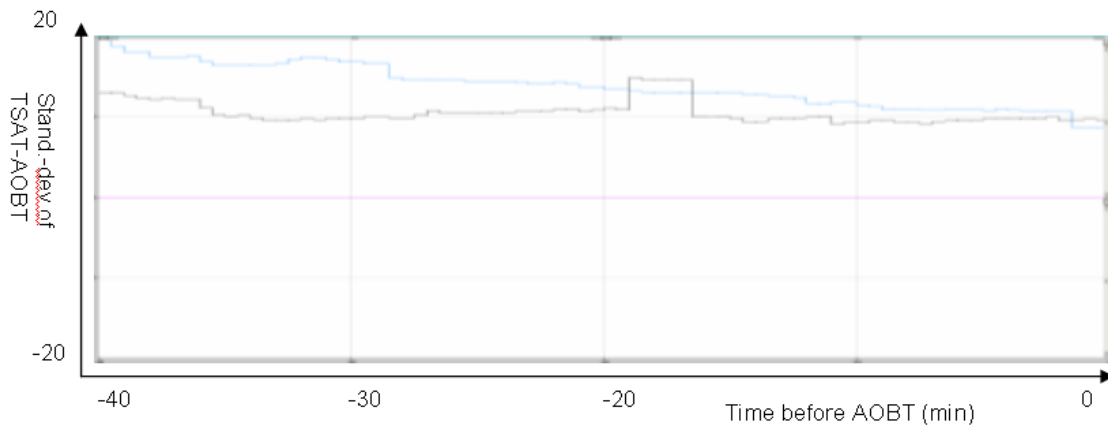


Figure 10: Standard deviation of TSAT from the AOBT AMS (blue) and DMAN (black)

7. ACHIEVEMENTS, OBSERVATIONS, CONCLUSIONS & RECOMMENDATIONS

7.1 General Achievement

For a first time during the Brussels trials the EUROCONTROL/DLR DMAN tool (Previous version) moved from the sterile environment of the research lab and has been exposed to real airport operations. This radical change entailed numerous challenges of both, technical and operational nature, which have been successfully managed by the joint effort of EUROCONTROL, DLR (the factual developer of the tool) and the host Belgocontrol. Thankfully to the lessons learned, future field trials (now started at Athens and Lisbon with an advanced DMAN from DLR) will be performed with considerably less effort and expenses.

7.1.1 Technical Observations

While the tool proved to be accurate and robust enough to function properly over recorded traffic files in research environment, the connection to a real ATC Flight Data Processing system (the Belgocontrol AMS), called for the development of dedicated interface whose role was two-fold:

- To collect the necessary Airport CDM and flight plan data elements, originating from the AMS and translate the data flow to understandable by DMAN format.
- To protect the AMS from any output generated by the DMAN tool, so that no interference with a real ATC FDPS to be guaranteed.

The interface development was performed by DLR in close cooperation with Belgocontrol and managed by the EUROCONTROL project manager;

Some of the major technical lessons that will enable to significantly shorten the time needed to set up the DMAN systems at other airports are as follows:

- Definition of a minimum set of data elements that the FDPS system has to pass to the DMAN tool, so that the flight can enter the DMAN planning;
- Ascertain the crucial role of synchronization of time between the local FDPS, the interface and the DMAN tool;
- Establish the minimum performance characteristics of the computers, utilized for the DMAN installation. Since the look-ahead time is always associated with the amount of information of each flight in the time span, it is crucial to afford sufficient processor power. Else, undesired effects like late update of the status of the flight, 'freezing' the planning, time out of synchronization may occur.

7.1.2 Operational Observations

While the flights in a recorded traffic sample always start-up, push-back and commence taxi in time down to the second, at a real airport ideal punctual operations are rather a luxury. Brussels International airport is a well-organized airport with history in Airport CDM, nevertheless there are variations in the way each flight progresses. The EUROCONTROL/DLR DMAN tool underwent several modifications to achieve:

- The desired flexibility, to be able to absorb exception cases (like military aircraft that do not fly a specific SID. The SID is used as a parameter to determine the best sequence);
- To integrate the exceptions into the planning; by simply ignoring the exception flights would distort the DMAN optimization, since obviously certain flights would not be included in the sequencing;

Some of the valuable lessons learned are as follows:

- DMAN should provide a stable pre-departure sequence if it is to be followed by the controller and to be distributed to airport partners. Frequent changes of the proposed sequence are difficult to comply with.
- Even if only in embryo, there is a need for an “arrivals” module in the DMAN planning, like installed in the EUROCONTROL/DLR DMAN. This is essential when the runway is used in mixed mode, or dependant runway operations..
- DMAN planning should be adjusted to changes, at least to a certain extent. The real events on taxi-out will always differ from the planned timing. The EUROCONTROL/DLR DMAN reflects all those changes, whereby the AMS ignores all them when they come about after TSAT is issued. The best design will be an intelligent compromise between the two.
- The advisory provided to the controller should be brought to a minimalistic representation, since today controllers already have too many screens to look at. The major elements considered useful are the number in the sequence and the suggested TSAT (Target Start Approval Time). Even better will be the integration of DMAN information into existing EFS systems.
- It is crucial to make controllers understand that the DMAN advisory is not compulsory and they can deviate from the suggested sequence if need be. The flexibility of the EUROCONTROL/DLR DMAN tool allows detecting the difference and replanning accordingly.

In three days of cooperation with Belgocontrol clearance delivery and ground controllers we provided instructions, let them operate the system in a shadow mode with live traffic via the radio frequency, and held evaluation discussions. Much feedback on the EUROCONTROL/DLR DMAN, the DMAN concept, and the comparison with the AMS system was derived, which are the basis for this report.

The DMAN concepts between AMS and the EUROCONTROL version differ in many ways, although they both predict sequencing on the runway and off-blocks. As Brussels airport

does not require efficient runway sequencing proposals by DMAN due to unsaturated traffic on average statistics, the AMS DMAN basically functions as initial traffic sequencer based on the CDM status of aircraft.

7.2 Conclusions

In general many aircraft operators did not provide accurate updates of TOBT, and hence, TSAT accuracy could never be of high quality in advance. Airport CDM is not functioning as it is meant to be according to the concept, which is a major disturbance for accurate DMAN evaluation at Brussels Airport.

7.2.1 TTOT

It can be derived that predictions of TTOT are becoming more accurate when closer to the actual take-off time. A clear moment in time where the standard deviation of the TTOT prediction versus ATOT is reduced is at the taxi clearance. Apparently any prediction before the moment an aircraft taxis out is subject to minor or bigger expected or unexpected disturbances.

7.2.2 TSAT

EUROCONTROL/DLR DMAN may appear more accurate than the AMS in predicting TSAT due to less margins used in off block predictions with respect to the AOBT of flights. AMS DMAN mostly equals TSAT to the TOBT which is equal to EOBT, except when derived from some airlines which actively input TOBT. AMS TSAT is therefore often not accurate, which results in manual corrections of the clearance delivery controller.

7.2.3 Adverse Conditions

During adverse conditions it becomes clear that the biggest deviation of TTOT is caused by departures that take-off unexpectedly early, rather than delayed flights. This is caused by the fact that DMAN can correct delayed flight predictions at all times, with small steps, however an early flight cannot. Hence the last correction of such flight remains in the statistics, causing a huge deviation for DMAN predictions under adverse conditions. This effect is visible for both the EUROCONTROL/DLR DMAN and the AMS DMAN.

7.3 Recommendations

7.3.1 Airport CDM Operation

Most important recommendation for further DMAN research is to enhance the Airport CDM implementation at Brussels airport. Most urgent action is the collaborative use by Aircraft Operators and Ground Handlers of the TOBT as their starting point for accurate TSAT sequencing. DMAN can operate as an enabler for the sequencing process.

It is of importance that the performance of the TOBT among Aircraft Operators is measured and transparently distributed amongst operators for post analysis. More accuracy should

lead to better service by the ANSP, especially at the clearance delivery position in providing Start up and Departure Clearance according to an optimized sequence.

7.3.2 DMAN Operation

Once there is an accurate TOBT prediction achieved at the airport, DMAN should provide pre-departure sequence with more accurate TSATs and with relevant stability with the purpose to distribute these times, and TTOT's, to the airport partners. Buffers on TSAT should only be set based on TOBT prediction performances by Aircraft Operators, in order to correct poor prediction behavior.

7.3.3 Controller HMIs

For the EUROCONTROL/DLR DMAN some feedback with respect to the HMI can be considered.

The representation of the information can be improved, since some was missing, whereas others could be removed from the working position HMI, depending on the position.

Horizon sequencing may be an interesting option for saturated airports however this is currently not needed at Brussels airport.

7.3.4 Further DMAN surveys

As a number of DMANs are operated on large airports in Europe today, it may be useful to do a survey into their specific operational concepts, while bringing them in the context of the airport lay-out and traffic characteristics.

Evaluation of different separation values by different ANSP organizations can contribute to more standardized way of handling different aircraft types, as different ANSPs apply different values on different airports in Europe today.