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Outbound Punctuality Sequencing by Collaborative Planning

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Summary

Most significant delays in ATM are created on the ground during flight preparation before pushback and during ground operations until take-off. Significant benefits can be achieved by improving departure planning. This can be realised by bringing together different actors in ATM and by using their planning data in a flexible, efficient and transparent way. Departure planning can be optimised towards punctuality, towards acceptance of airlines' planning preferences and towards efficient use of available runway capacity.

A Departure Management tool (DMAN), the so-called Outbound Punctuality Sequencer (OPS), developed by NLR, is presented in this paper. The tool aims to support the pre-departure planning process in an interactive and co-operative way. Optimisation towards punctuality is achieved by using flight preference functions. The OPS DMAN tool is a planning-support tool based on balanced decision-making. The contributions of different constraint-related flight preferences to an optimised departure planning are made transparent to the user. This paper explains the tools and presents some preliminary evaluation and validation results.

Contents

(24 pages in total)

1 Introduction

1.1 Overview

Large hub airports have gone through a process of growth and evolution that are facing them with a variety of problems and constraints, such as runway capacity problems, runway operational deployment constraints, and taxiing and line-up queuing problems. Amongst others, these problems are urging these airports to seek for a better co-ordination between the actors involved in flight preparation.

This paper presents a departure management tool based on use of information, made available by Collaborative Decision Making (CDM). While CDM only could be made beneficial by just monitoring available planning data of different actors, a concept is presented here, that is based rather on a pro-active and synthesising planning process. This process brings together planning preferences and constraints of different actors, and will use this data to accomplish an overall optimised planning result. The idea behind the concept is that the human planning controller is superior in short-term, flexible and reactive decision making, while an algorithm can be superior in a complex, strategic and iterative optimisation process, comparing a variety of quantitative weighted preferences. An advantage of such a tool can be the neutral and traceable way of decision making that allows taking into account preferences that can provide benefits to airline operations but that in all other respects works according to objective rules.

The DMAN tool under discussion, the so-called Outbound Punctuality Sequencer (OPS), is developed by NLR for complex operations at large airports with complex gates and runway systems, making punctual departure operations a challenging problem. The tool is prepared and ready to be tested and evaluated.

This paper presents an overview of the concept of operations of OPS, its implementation and the principles of operations of the algorithm. Finally, a validation strategy is explained together with some of the preliminary results. More elaborate validation work will be undertaken in the near future.

1.2 Background

Good examples of the recognised needs for better planning and co-ordination can be found in CDM application studies, performed e.g. for the airports of Brussels, Barcelona and Stockholm Arlanda [1],[2],[3] and [4]. An important result of these studies teaches that enhanced efficiency is anticipated merely by bringing together the planning information of the different actors involved in flight preparation and departure operations of a flight. Already the knowledge of possible constraints and inconsistencies in planning could be helpful. Another important result was the conclusion that the timely availability of an estimated ready-for-pushback time, made available by the pilot to Air Traffic Control (ATC), could be helpful to establish a more efficient departure planning.

An Operational Concept for Departure Management has been developed by LFV and NLR within the context of one of the projects of the European Union 5th Framework Programme, Gate-to-Gate [5], being part of an Integrated Operational Concept (IOC) for gate-to-gate operations in a collaborative and air-ground integrated way [6]. The Gate-to-Gate IOC is developed in compliance with the Eurocontrol Strategy for 2000+ [7] and [8] and the Eurocontrol Operational Concept Document (OCD) [9]. The OPS tool will be used by NLR for a DMAN validation experiment, simulating the Stockholm Arlanda Airport, in the Gate-to-Gate project.

2 Concept of Operations

2.1 The Problem

After some years of stable, or even decreasing, air traffic demand, the demand is expected to increase continuously during the coming years. The capacity of airspace, airports and its related infrastructure has to follow this trend and the Air Navigation Service Providers (ANSP) have to improve their services. The most urgent requirements of airlines to ATM service provision can be summarised as to improve punctuality, to reduce costs and to facilitate prioritisation for flights that are critical for their operations.

A large part of the delays and also part of the inefficiency of flight operations find their deeper cause in traffic management at the airport, during the flight preparation phase before take-off. CDM papers, addressing enhanced ground and departure operations, all identify the lack of co-ordination on planning as the major cause [1], [2], [3] and [4]. A timely anticipation on a departure sequence planning is missing. In particular, at large airports with strong variations in taxiing times and with departure queuing problems, there is a need to control the off-blocks planning. What is missing is an early indication for the aircraft's readiness to go off-blocks by the pilot, which might allow a Departure Planner to issue a Departure Clearance (DCL), based on a planned Target Off-Blocks Time (TOBT).

The TOBT is in all respects a heavily constrained planning item. Each actor involved in the ATM process might have valuable reasons to impose a number of planning constraints, either as a hard constraint or as a constraint to be weighted and balanced against other interests. It is ultimately the interest of all actors to reach an outcome of departure planning, which is the result of balanced decision-making.

Traceability, performance measurements and monitoring of the decision-making process are critical issues for acceptance of one of the major changes in ATM objectives, namely to replace the objective of **expeditious** service provision by **on-time** service provision in compliance with the planning. This change is fundamental for improvement.

What is needed for a CDM integrated departure planning process at airport level, is:

- The pilot, being willing and able to provide his estimated off-blocks ready-time.
- ATC, being able to manage, to plan and to sequence departures, taking into account all planning constraints.
- The airport, to provide their services in-line with a planned estimated off-blocks time.
- A Departure Management process, which follows flow management constraints, regulating overloaded sectors as well as arrival flows to congested airports.

What seems by intuition to be promoted in the best way just by expeditious operations, is ultimately a complex optimisation process. The optimum is to bring planning constraints in balance with requirements for punctuality. Other interests, such as optimisation of separation, are in fact a subject of secondary interest. When optimising for punctuality and when the capacity falls short, optimisation for separation is a means to reach punctuality of departures by best use of available capacity.

2.2 Proposed Solution

The proposed solution is to implement a Departure Manager tool (DMAN), i.e. OPS, that enables ATC to make a synthesis of planning constraints of all actors affecting flight planning and being involved in the departure process. Essentially, the DMAN can work within the present context of operations, on the condition of three operational changes:

- The pilot must issue timely (e.g. 15 min. before off-blocks) his planned and estimated off-blocks ready-time, the so-called First Off-Blocks Time (FOBT), he waits for a call for pushback at the planned Target Off-blocks Time (TOBT). The DCL is given, including TOBT, assigned runway (RWY), departure route (SID) and Target Take-Off Time (TTOT). (See also [10], chapter 3.)
- The controllers must provide ATC services for ground movement operations **on-time** rather than **expeditious**.
- Accurate departure planning must be facilitated, possibly by re-organising certain tasks of ATC in the context of pre-departure flight planning. Following this new procedure, the Departure Planner fulfils a controller function, communicating with the pilot, possibly also with the Airline Operations Centre (AOC), and with the Central Flow Management Unit (CFMU).

The operations of the DMAN are dependent only on a few planned timing data items, some actual data, and some background planning data. The background data concerns:

- Knowledge of estimated taxiing times between gates and runway holding point, including pushback time, line-up time, and possibly extended with a planned time period e.g. for de-icing,
- Knowledge of applicable runway departure and arrival wake vortex separation standards,
- Knowledge of applicable SID separation standards.

The DMAN derives an optimised departure planning from planning constraints and flight preferences. Flight plan inputs are expected from AOC, but received via CFMU. As long as the flight plan information received from CFMU does not include ground movement planning, this information has to be added. It would be preferable, however, if AOC would be able to pass its own preferred or estimated ground movement planning, including runway and SID, to CFMU and ATC. With sufficient information provision on the planning of applicable runway configurations, AOC will be able to provide early (less than 1 hour before departure) a detailed and reliable flight planning.

Based on a layered and convergent departure planning process, slot assignments (less than 3 hours before departure) can be based on an early available flight plan, while departure sequencing can be managed manually and monitored by ATC from roughly 45 minutes before pushback. Re-planning and re-iteration of sequence planning may occur until pushback. The pilot comes in the loop shortly before pushback, and the departure sequence is not updated any more automatically, once the DCL is issued. The Departure Planner transfers the flight to the pushback service and thereafter ground movement control will take over the communication with the pilot. It is the objective now to guide the aircraft to the holding point for an on-time take-off, i.e. as planned. Nevertheless, it is anticipated that it is natural to expect planning deviations. In that case, the planning has to be updated in compliance with actual operations, and manual updates of the departure sequence planning are permitted. Also Ground Movement Controllers are able to accomplish planning updates as required. The OPS tool plays no role in planning updates after pushback, however the tool has to react on delays that affect the pre-departure planning.

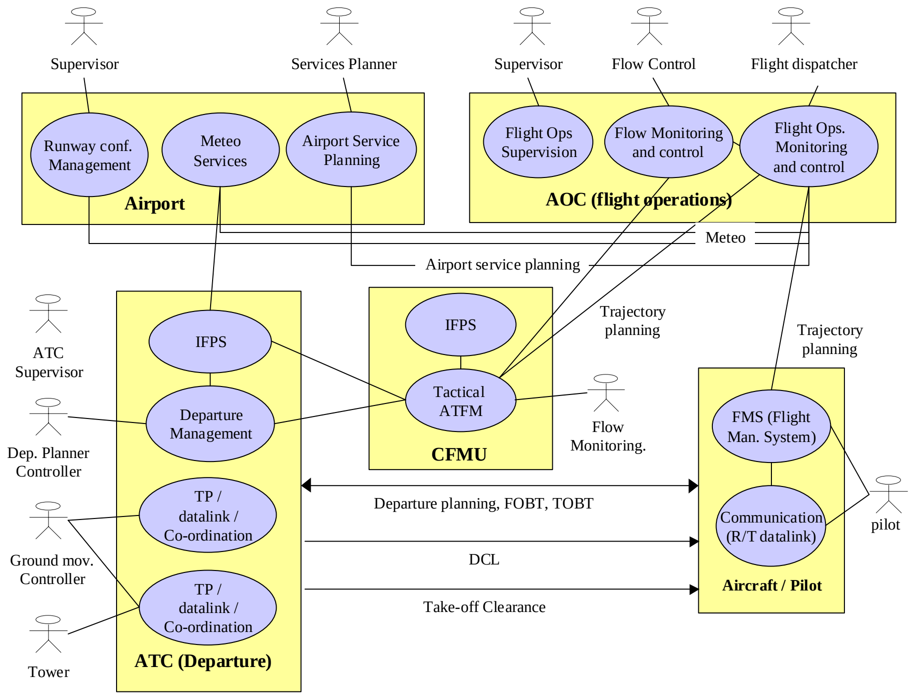

Figure 1 - Overview of Context of Operations of an OPS DMAN Tool

An overview of the operational context is presented in Figure 1 and a simplified scheme of the interactive and convergent layered planning process is illustrated in Figure 2.

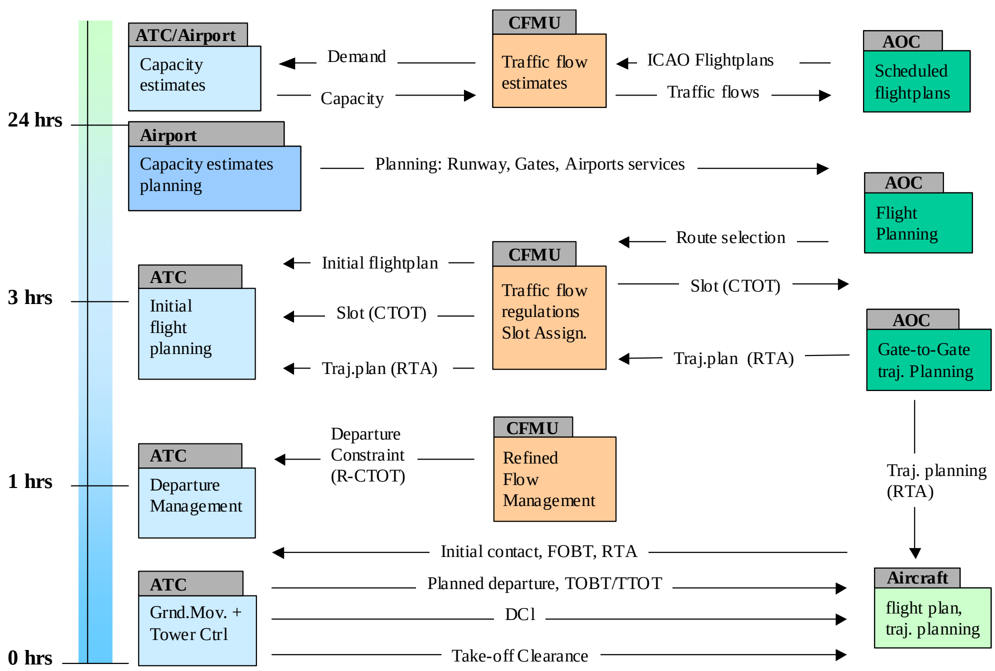

Figure 2 - CDM and Departure Management, Simplified Stakeholders' Interaction Scheme

Two other aspects, affecting departure sequence planning, need to be mentioned:

- The DMAN is designed to support multiple runways in mixed-mode operations. However, the strategy to distribute departures over runways is often airport-specific, and based either on gate assignment or on flight destinations. The runway assignment is assumed to occur before initial sequencing and runway assignment changes are accomplished manually.
- The DMAN is designed as a highly interactive tool. Flights can be swapped and frozen manually, while they can be de-frozen manually again. A good reason is that not all knowledge is subject to automatic sequencing, e.g. congestion on an apron is not part of the optimisation process at present.

2.3 Potential Benefits

The following benefits are expected from use of OPS in a context of CDM operations:

- Enhanced punctuality by better planning and more predictability,
- Improved use of available capacity, by being more efficient in deployment of available runway capacity, in particular for mixed-mode operations,
- A better quality-of-service by better anticipation of late changes and delay announcements,
- Tactical controller workload reduction by limiting the number of simultaneously moving aircraft,
- Emission reductions by limiting queuing at the holding point, and
- Economical benefits by accurately planned ground movement operations.

3 Implementation of a DMAN for Strategic Planning

3.1 Requirements for OPS and Implementation

A departure sequencing is determined that make the best use of available capacity in a punctual way, meaning that flights can be scheduled as close as possible to their preferred departure time. Preference functions express punctuality and will guide the sequencing process. Although separation plays a secondary role compared to punctuality in the scheduling process, it nevertheless has an important influence. (See also [11] and [12].)

Preference functions play a key role in OPS. They represent the timing constraints of multiple ATM stakeholders: CFMU, airline, pilot, airport, and ATC. Preference functions are not assigned to specific flights but to all flights that appear in the planning. Therefore, no individual flight is favoured above the other, and the equity principle holds. For each flight a combined preference function is composed from constraint-related preference functions, determined by one specific constraint of one flight each, i.e. the flight's CTOT, R-CTOT (Refined CTOT) and FTD (First Time of Departure), delivered by different stakeholders. (The R-CTOT allows refined constraints

to cope with congestion at destination airports and the FTD is derived from the FOBT, submitted by the airline [13].)
The importance of constraint-related preference functions differs depending on the weight given to each type of constraint. Therefore, a weight is assigned to each separate preference function modelling its importance. The preference function of each individual flight is built from these preference functions by a weighted sum that is normalised again to values between 0 and 1.

Figure 3 shows an example of a preference function, in which the preference of ATC is expressed when an arbitrary flight should depart at a time relative to its CTOT.

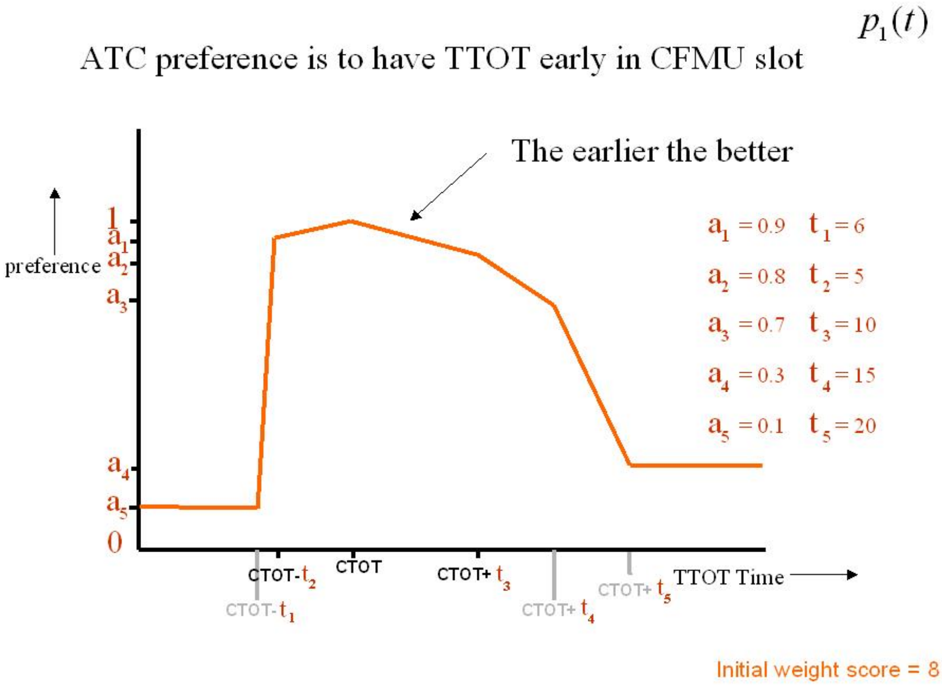

Figure 3 - Example Preference Function for ATC, based on CTOT

In each departure schedule, a TTOT is assigned to each individual flight. For each computed TTOT, the combined function assigns a score for that flight. Each flight in a sequence contributes to the final score by taking the total sum of scores of flights divided by the number of flights, i.e. the average score of flights. The optimisation algorithm computes the optimal solution for any set of preference functions and weights.

Performance issues are important here, because the OPS tool has to be integrated into a real-time operational environment. OPS must guarantee operational performance in all situations. The OPS tool has been tested with exceptionally heavy scenarios (for Stockholm Arlanda), i.e. 30% more traffic than usual. The prototype is tested using real-life scenarios.

Although the optimisation algorithm finds the optimal solution given any set of preference functions (including their weights), the problem of finding the optimal set, that will support departure planning at a given airport, is a problem for the users. It should be noted that the set of preference functions and their scaling might vary depending on the airport and the preferred mode of airport deployment. The potential to vary the shape of the preference functions may stimulate the search for the most satisfying set, given the balancing principle that lay behind the weight and scaling values. These weight and scaling values are restricted to the interval of 0 and 1. The advantage of this range is that there is a common understanding of the interpretation of preference values in this range, and this makes comparison between computed schedules and judgement of computed schedules a lot easier for stakeholders and technicians. Furthermore, it is possible to show statistics of a schedule, which represents the quality of a plan, for which a special purpose Human Machine Interface (HMI) is designed.
Note that departure planning takes places at the runway and not at the gate. This means that taxi-times and line-up queuing times will determine the off-block times of aircraft derived from the calculated sequence on the runway. Taxi and line-up times are estimates. The more accurate these estimates are, the more accurate the departure planning at the gate will be. The estimates include a minimum line-up queuing time, because some minimum threshold holding time is necessary in order not to risk to loose runway capacity by unforeseen deviations from the planning.

3.2 Human Machine Interface

The Departure Planner monitors the planning on a time-proportional sliding window, displaying flightplan information (strips) of one or more runways selected for departures and/or mixed-mode operations. In case of mixed-mode use, the departures can only be planned in a non-conflicting way with scheduled arrivals, with a preference for alternate scheduling, and starting by default from such a scheme. Each flightplan data block will be linked to a time bar with a pointer that points to the Target Take-Off Time (TTOT). A newly assigned TTOT will be represented by a new position of the TTOT-pointer and the related TTOT-assignment value will be determined either by a newly calculated departure sequence order, or by a manually forced position and sequence order. The sliding block on the time bar represents the required minimal separation to the preceding flight, taking into account the weight categories of both aircraft.

The displayed sequence of flightplan data blocks will change only by confirmation of the Departure Planner that re-organisation of the departure scheduling is accepted. The controller is able to change the automatically determined sequence order at any time as deemed necessary. In principle, no intervention is necessary to accomplish the sequencing, the only required human intervention is to issue the DCL and to transfer the flight.

The Departure Display window (DEPARDIS) is illustrated in Figure 4. (See [10], Chapter 6.) The design of this interoperable time-proportional sliding window is similar to the one for previously prototyped arrival managers; see for example DADI-2 as a reference [14]. The controller can move and can change the selection of a displayed time window.

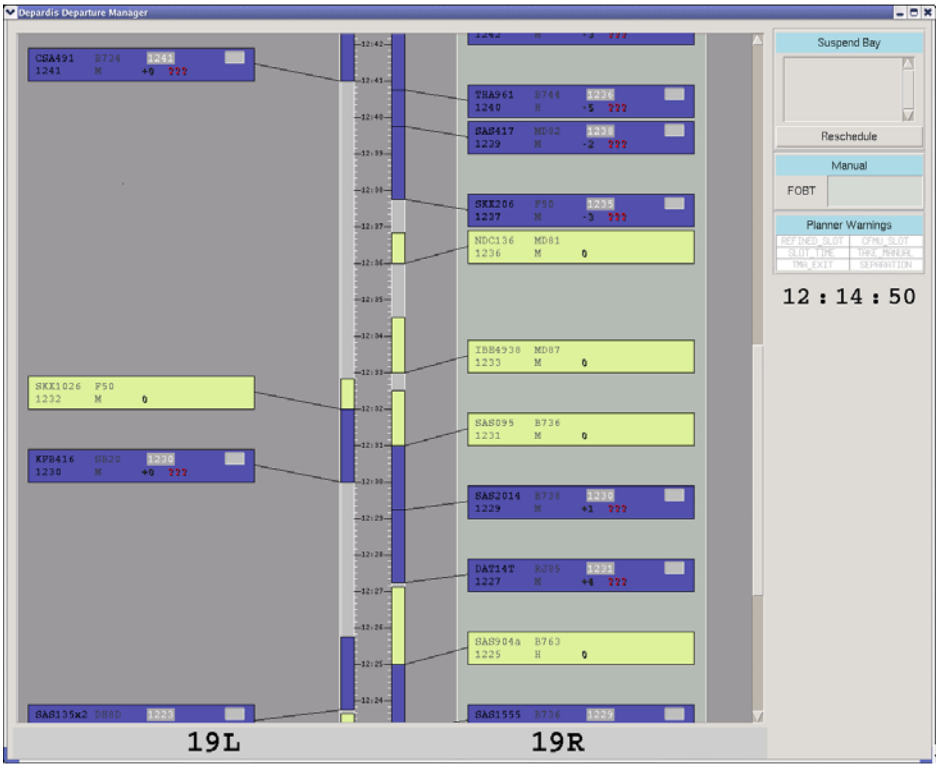

Figure 4 – The HMI of the Departure Display Window

All time-related control activities can be exercised within the departure display window, while the controller is able, in addition, to swap a flight to the other time bar and to re-assign in this way its runway assignment. The DCL, together with a transfer of control to pushback services, takes place by clicking on a DCL status field in the label. Other planning, control and co-ordination activities will take place in separate transaction windows. The transfer of control terminates the automatic sequencing process as well as the planning activities of the Departure Planner.

There are some non-nominal options for ground movement controllers available e.g. to transfer the flight back to the planner. Flights that are significantly delayed or that are cancelled, can be re-scheduled or removed from the planning via a suspend bay.

Finally, an extra window is available to monitor the actual performance of the departure scheduling process. Depending on traffic demand and runway availability, each flight may score a punctuality optimisation value that can reach up to 100%. This window can be monitored by the departure controller or a supervisor.

Once, the flight is transferred to Ground Movement Control and later to the Tower, they will have access both to the planned departure sequence, displayed as a sequenced time table, and both will be able to change the planning in compliance with actual traffic conditions. The displayed planning information can be considered as complementary to flight status information, displayed on a plan view display with plots and labels.

3.3 The principle of the Optimisation Algorithm

A major aspect of the algorithm is that it stays close to the way controllers solve their scheduling problems. The controllers as well as the algorithm will focus on punctuality and use of the runway. In busy periods the focus lies by nature on optimised use of the runway, while in case of less traffic there is more room for punctuality. Not only the business is relevant but also the separation constraints will influence the way to use the runway. For instance, in case of bad weather conditions, separation has to be extended, which decreases runway capacity and therefore automatically will shift the focus to more efficient use of the runway. OPS supports the controller in finding optimised schedules in terms of punctuality ***and*** runway deployment. This is an improvement compared to departure optimisers that only focus on optimised use of the runway.

The general approach for parameterised preference functions allows:

- flexibility, i.e., for each airport a different set of preference functions and weights for any group of stakeholders can be applied,
- on-line validation of departure planning effectiveness,
- on-line adjustment of the shape of individual preference functions, and
- easy adjustment of the set of preference functions.

Figure 5 presents the HMI for changing the preference functions for stakeholders.

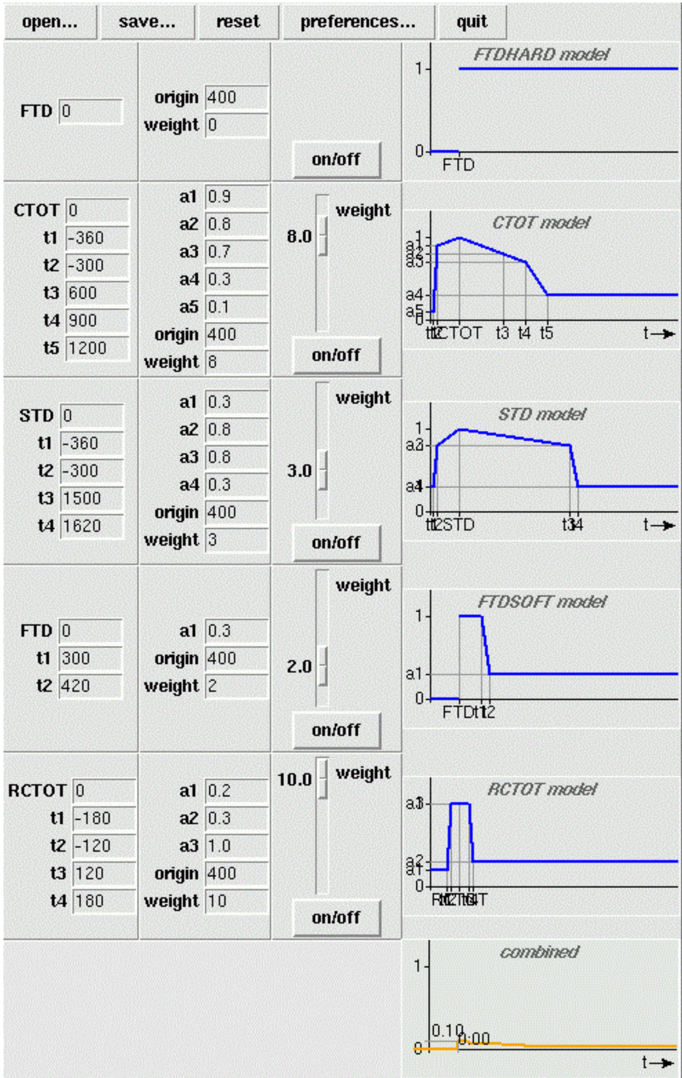

Figure 5 - Preference Functions displayed for Real-time Performance Evaluation

A real advantage during the development of OPS was that due to the fast and elegant nature of the algorithm, it could be implemented as an off-line scheduling application in Microsoft Excel. Small but relevant cases of seven flights, each with a separate preference function, can be solved using this Excel analysis-tool that corresponds one-to-one to a solution of OPS. It is a tool therefore that plays an essential role in the validation process. Using the offline-analysis implementation of the algorithm, solutions of OPS can be verified and can be traced.

The algorithm starts optimisation from an initial ordering based on STD or CTOT. The algorithm finds the optimal sequence according to the set of preference functions and their weight for any number of flights obeying the separation constraints. In order to do this, the algorithm calculates for each permutation of the selected number of flights the optimal position of the flights in time according to the preference functions, resulting in different scores for each permutation.

Thereafter, the permutation with the highest score can be found resulting in a sequence of flights assigned to positions in time for which the separation constraints hold [15]. In [16] the algorithm has been proved to be mathematically valid for any number of flights. However, in order to be feasible in real-time, the sequence of flights is not solved by the algorithm as a whole but is divided into a number of smaller subsets of flights, for which the algorithm is applied without weakening the quality of the departure sequence. An initial sequence is derived which acts as a first smart guess of the final sequence. By using subsets of the initial sequence for which the algorithm will calculate the optimal positions, only a restricted set of permutations of the planned flights will be checked. In real-time implementation the algorithm uses sequences of 4 to 7 flights. The initial sequence is important for fast convergence in finding an optimal or near-optimal solution. Generally, the initial order, based on the ordering of STD and CTOT times of flights, will lead to quite good results.

Events, such as a CTOT received from CFMU, an FOBT provided by the pilot, closing or opening of a runway etc., influence OPS immediately. OPS will calculate a new schedule based on the new data derived from an event. This event-driven approach allows e.g. the dynamic adjustment of the separation table and thus reacting in this way on changing weather conditions.

4 Validation of OPS

The evaluation and validation plan of the OPS DMAN tool has been prepared in two complementary ways. On one side a real-time validation experiment is being prepared at present and is planned to take place in March 2005, on the other side a fast-time validation experiment has been completed recently.

The real-time experiment has the objectives:

- To validate the potential to plan and control high volumes of departing air traffic using OPS,
- To demonstrate effective use of available runway capacity,
- To demonstrate the benefits of **on-time** planning and control service provision, and the potential for increased punctuality of departure operations, and
- To achieve controller acceptance.

This real-time experiment will comprise simulations, using a configuration of two parallel mixed-mode runways at Stockholm Arlanda Airport, and including ground-movement operations and operations in the TMA. The simulation experiment will be performed with seven controllers and nine pseudo-pilots. One Departure Planner will accomplish a departure planning with support of OPS and the actual performance of the simulated departure operations will allow measuring the benefits of use of OPS, compared with the performance in equivalent baseline simulations without support of a departure management process.

The fast-time simulation experiment had the objectives:

- To validate the performance of OPS over a large traffic sample, under varying conditions with respect to the performance of the algorithm as well as the computing performance of the implementation,
- To perform a validation test on quantitative benefits with respect to line-up delays and departure punctuality as a result of departure sequencing with support of OPS.

The fast-time experiment had a limited scope. The size of the experiment was limited to one sample of real-life air traffic of the busiest day at Arlanda Airport on the 22nd of May 2003, running with one runway configuration (19R for departures, 26 for arrivals). The scope of the experiment was limited as well. One day of air traffic (404 departures, 404 arrivals) was simulated using a TAAM model (Total Airspace and Airport Modeller), and using real-life Actual Off-Blocks Times (AOBT) as “planned” departure times.

The first simulation run, simulating the baseline scenario, could reproduce fairly well the ground movement operations and line-up queuing of real-life operations, except for some excessive delays that happened in real-life for unknown reasons.

In the next step, the 404 departures over 24 hours were re-sequenced by the OPS DMAN, determining optimised off-blocks departure times in slot windows of: [–5, +10] min. (the assumed CTOT window). It was assumed further that flights were able to depart within their slot and could realise their planned TOBTs. Running the TAAM fast-time simulation again with an adapted departure planning allowed the experiment to analyse the effect of accurate departure planning on actual departure operations.

It should be noted that the re-sequencing by OPS was processed as one off-line run without iteration and without re-planning. The assessment exercise was limited therefore to assess only part of the available functionality, i.e. optimising with respect to ground movement operations. The fast-time experiment is illustrated by Figure 6.

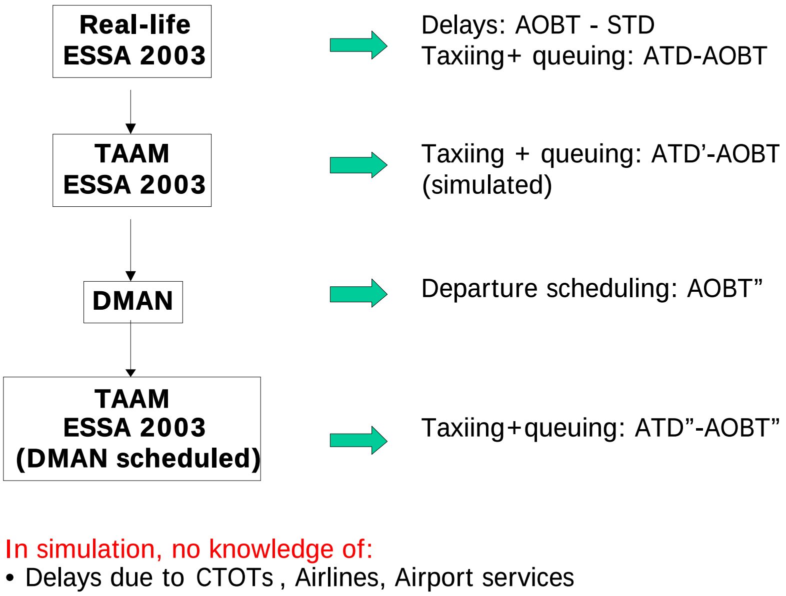

Figure 6 - Fast-Time Simulation Process to assess Performance of the OPS DMAN Tool

Execution of the fast-time experiment, and comparing the results of the two runs, provided the following results:

- The sequencing of the 404 departing flights demonstrated correct functioning of the OPS DMAN tool over a period of 24 hours, including low and high traffic densities. The result shows ~25% of the flights to be re-planned within their assumed slot-time, aiming to realise a more efficient and more punctual departure (See Figure 7).
- The sequencing of the departures, running in a normally configured mode, was completed within two minutes on a present-day standard PC (1.6Ghz). This gives good confidence for good real-time behaviour under normal operational conditions, calculating roughly 45 minutes of traffic or less.
- Optimised planning shows the potential to benefit the punctuality (see figures below). A better departure schedule can be reached by better planning of TOBTs.
- Comparing line-up delays over the day, with and without departure sequencing, demonstrates a reduction of line-up delays (see figures below).

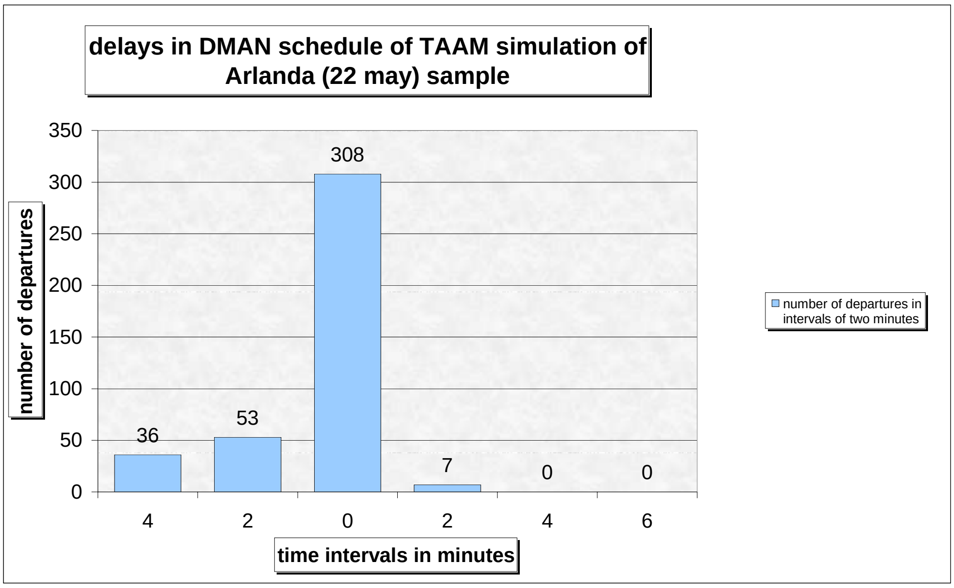

Figure 7 - Distribution of TOBTs, Re-scheduled by OPS DMAN Tool

These results will be illustrated by some figures. It should be noted that results are obtained under reproducible, fairly ideal conditions.

Figure 8 represents the improvement of punctuality over the day, by comparing the punctuality without and with re-scheduling the departures. The ATDs of both simulation runs are compared, taking into account ideal scheduled departure times, derived from the original real-life off-blocks times.

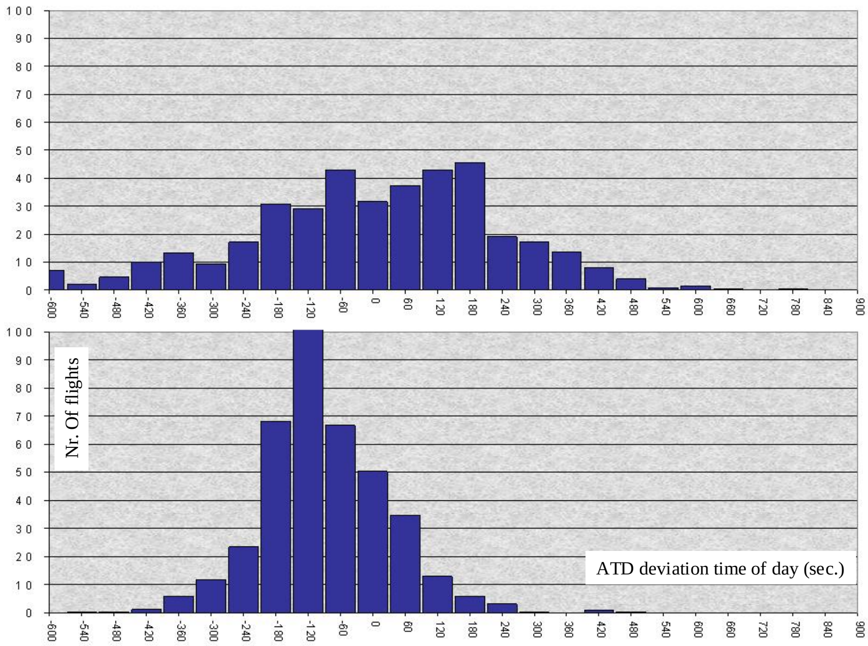

Figure 8 - Punctuality of Actual Departure Times (ATDs), without and with Re-scheduling Departures

The improved punctuality was reached by a reduction of line-up delays. Figure 9 shows line-up delays over the day, realised without and with departure sequencing. The result is a very effective reduction of these delays. The number of flights with significant line-up delays dropped down from 164 flights to 13 flights.

The total taxiing times over the day were investigated also in order to assess whether any adverse effects might have occurred during ground movement operations, e.g. gate or taxiing delays. This was not the case. The total taxiing time showed reductions that are comparable with the reduction of the line-up delays.

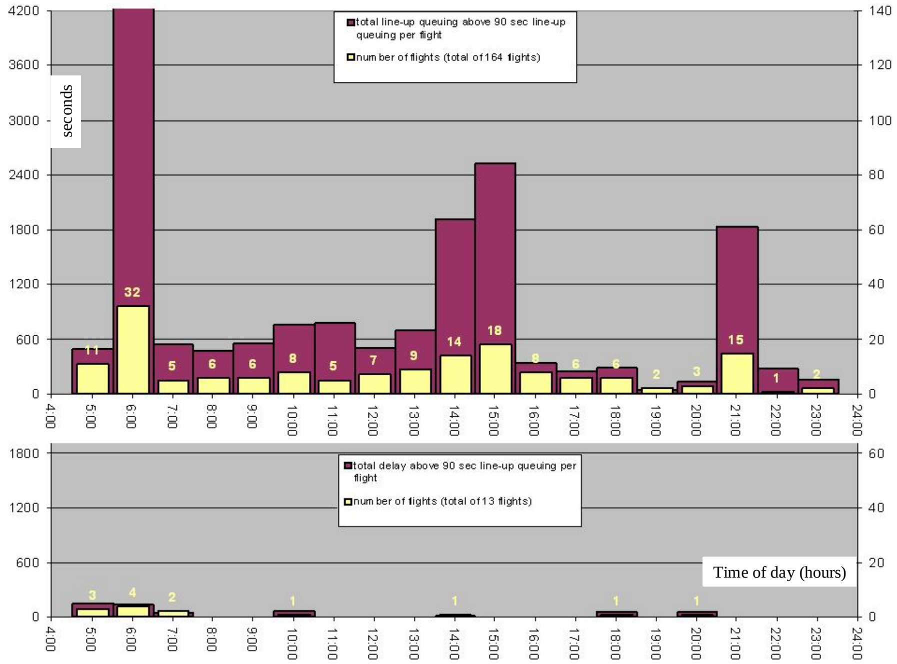

Figure 9 - Distribution of Line-up delays over the Day, without and with Re-scheduling Departures

The slot window determined the freedom to re-schedule departures and the potential to assess benefits. The table below summarises the results:

Tabel 1- Summary of Results of Fast-time Experiment

Measured:	Without Re-seqencing.	With Re-seqenc. by OPS
Number of departures over 24 hours at Arlanda	404	404
Nr. Of delayed flights, relative to “STD”	218	75
Total delay time, relative to “STD” in seconds	40078	6318

Measured:	Without Re-seqencing.	With Re-seqenc. by OPS
Total deviating time (pos. and neq.), relative to “STD” in s.	79441	296751
Avg. delay time, relative to “STD” in seconds	184	84
Number of flights with signi-ficant line-up delay (> 90 s.)	164	13
Total taxiing time in seconds	221287	237761
Total line-up delay time in seconds (> 90 s.)	18310	8453
Avg. line-up delay time in seconds (> 90 s.)	112	650

The figures derived by fast-time simulation are appropriate to be used for a Cost-Benefit Analysis (CBA). The benefits are achieved over one busy day at Arlanda, and these figures have to be extrapolated for future use. In addition, also costs have to be considered. The costs concern some extra costs on planning effort and co-ordination against benefits by reduced complexity during ground movement operations. No really significant investments are foreseen.

It is difficult to draw definite conclusions on this small experiment. The present results are based on one traffic sample at one airport only. More elaborate simulations and more research are required for more precise and reliable quantitative results. Nevertheless, the indications are positive.

5 Conclusions and Recommendations

The DMAN concept, described in this paper, provides support to a planning process accomplished before the aircraft goes off-blocks. The DMAN supports the controller in bringing together constraints and preferences on departure planning. The aim is to satisfy stakeholders’ preferences and to reach punctuality. Optimisation depends on how to find an optimum and how to express the appreciation of a sub-optimal solution for a constrained departure sequence. This is realised by the OPS DMAN tool that uses preference functions for each preference aspect of each flight, and this allows the user to monitor the decision making and to analyse the critical factors that contribute to the outcome of the sequencing process. On-line monitoring facilities will support the required transparency of this process.

By changing the operational objective of ATC to **on-time** operations instead of expeditious operations, ATC will support a realisation as close as possible to the planned departure planning. Nevertheless, it can realistically be expected that for all kinds of reasons, a Ground Movement Controller or a Tower Controller will have to deviate from the planning. Better adherence to the planning can be achieved by fine-tuning the parameterisation of OPS, thereby improving predictability.

The present implementation of OPS is built and prepared to be used in a real-time simulation environment. Nevertheless, it is possible to consider a near-term transition to operational deployment as feasible and realistic. The implementation of OPS has a couple of advantages that are unusual for advanced ATM improvements:

- Implementation affects pre-departure planning, there is no direct safety critical effect on actual operations. If any effects on safety are expected, they are positive due to the shorter duration of ground movement operations.
- Implementation requirements concerning processing and communication technology are within the scope of standard Common Off-The-Shelve (COTS) technologies.
- Implementation has a very loosely coupled link with other parts of ATM supporting systems. Almost independent or stand-alone operations are possible as long as the required planning data is exchanged.

Definitely, one important pre-condition is to get agreement on the way to operate the airport, to apply CDM and to agree amongst the ATM stakeholders on the appropriate parameter values that control the performance of OPS. The algorithm as well as its implementation is neutral towards what should be considered as the proper balance of decision-making. However, the parameterisation is not neutral and is determined by a set of values that is kept separated from the implementation. A proper fine-tuning of an acceptable set of parameter values can be evaluated by use of the off-line analysis tool and/or by fast-time simulations.

The summarising conclusion is that operational implementation is feasible and realistic. Implementation can be realised without major investments and may provide significant benefits to the Airport as well as to the Airlines.

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Abbreviations

ANSP	Aeronautical Navigation Service Provider
AOBT	Actual Off-Blocks Time
AOC	Airlines Operations Centre
ATD	Actual Time of Departure
CBA	Cost-Benefit Analysis
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit
CTOT	Calculated Take-Off Time (CFMU)
DCL	Departure Clearance
DMAN	Departure manager
FOBT	First Off-Blocks Time (Airline)
FTD	First Time of Departure (derived from FOBT)
HMI	Human Machine Interface
IOC	Integrated Operational Concept
LFV	Luftfartsverket, Sweden
NLR	National Aerospace Laboratory of the Netherlands, NLR
OCD	Operational Concept Document
OPS	Outbound Punctuality Sequencer
R-CTOT	Refined CTOT
RTA	Requested Time of Arrival (Airline)
RTD	Requested Time of Departure (Airline)
SID	Standard Instrument Departure
STD	Scheduled Time of Departure (Airline)
TAAM	Total Airspace and Airport Modeller (Preston Aviation Solutions, Melbourne)
TOBT	Target Off-Blocks Time (ATC)
TTOT	Target Take-Off Time (ATC)