

**The EUROCONTROL
DMAN Prototype -
Description of DMAN in the
A-CDM context**

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Abstract		
<p>The main purpose of a Departure Manager (DMAN) is to help aerodrome control to build an optimized Departure sequence issue in accordance with departure demand and departure capacity. Within the CDM-context the focus is on the TSATs (Target Start-up Approval Times), which are derived out of the departure sequence. It is assumed that an electronic flight strip (EFS) system is in place. It maybe exceptionally possible to use DMAN with conventional paper-strips, but in any case the DMAN functionality does not include the display, progress, co-ordination and transfer of departures from one control position to the next.</p> <p>The following description is insufficient to build a DMAN planning algorithm without further consideration. The target audience are people involved in the drafting of DMAN specifications or in the procurement and implementation of a DMAN.</p>		
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Contents

DOCUMENT CHARACTERISTICS.....	1
DOCUMENT APPROVAL	3
DOCUMENT CHANGE RECORD	4
EXECUTIVE SUMMARY	7
CHAPTER 1 – Foreword to DMAN.....	8
CHAPTER 2 – DMAN functions linked to A-CDM.....	9
CHAPTER 3 – DMAN functions	10
3.1 Overview of DMAN functions.....	10
3.2 Variable Taxi Time Calculator	11
3.3 Creation of the “initial departure sequence”	12
3.3.1 CFMU-regulated flights.....	12
3.3.2 Non-regulated flights.....	12
3.3.3 Compacting the sequence (closing the un-necessary gaps).....	13
3.4 Departure-departure separation calculator.....	13
3.4.1 Wake-vortex separation.....	14
3.4.2 SID-separation	14
3.4.3 Speed-separation.....	15
3.4.4 VFR-departures	15
3.4.5 Intersection take-offs.....	15
3.5 Runway Sequence Optimizer	15
3.5.1 Sliding window method	16
CHAPTER 4 – DMAN interface to an EFS system.....	18
4.1 Clearance Delivery CD	18
4.2 Ground.....	20
4.3 RWY.....	20
4.4 Timeline representation	22
4.5 Insertion of a departure into the DMAN plan	22
4.6 Change of flight data after inclusion in the DMAN plan.....	22
4.7 Target Start-up Approval Time (TSAT).....	23
4.8 Late departures.....	23
4.9 Take off clearance / take off detection.....	23
4.10 Manual Interventions	23
4.10.1 Sequence Change	23
4.10.2 Sequence Freeze.....	25
4.10.3 Automatic Freeze.....	26
4.10.4 Runway blockage.....	26

4.10.5	Runway flow adjustment.....	27
CHAPTER 5 – DMAN adjustments for particularities		28
5.1	Creation of the Target DPI message	28
5.1.1	Background.....	Error! Bookmark not defined.
5.2	Crossing runways and other dependencies between runways	29
5.3	Arrivals on the departure runway.....	29
5.4	Runway crossings.....	30
5.5	Using further clearances to refine the planning	30
5.6	Using position information from surface surveillance systems.....	31
REFERENCES		32
GLOSSARY	Error! Bookmark not defined.	
ABBREVIATIONS		33

EXECUTIVE SUMMARY

The EUROCONTROL Departure Manager (DMAN) prototype was developed in early 2000 in collaboration with DLR, the German Aerospace Centre. A number of simulations were performed until it was decided that the DMAN falls in the area of the Airport CDM (A-CDM) project in support of the Pre-departure sequencing concept element of A-CDM. Within this scope a number of shadow mode trials (Brussels airport) and live shadow mode trial (Athens airport) have been performed, in close collaboration with Belgocontrol, HCAA, and DLR respectively.¹

The main purpose of a Departure Manager (DMAN) is to help aerodrome control to build an optimized Departure sequence issue in accordance with departure demand and departure capacity. Within the CDM-context the focus is on the TSATs (Target Start-up Approval Times), which are derived out of the departure sequence. It is assumed that an electronic flight strip (EFS) system is in place. It maybe exceptionally possible to use DMAN with conventional paper-strips, but in any case the DMAN functionality does not include the display, progress, co-ordination and transfer of departures from one control position to the next.

This document [information paper] does not specify a DMAN system to the detailed level of Operational or Technical Requirements. Rather it should be seen as providing background, and additional information, to those responsible for specifying their own DMAN requirements, or to those responsible for a DMAN procurement and implementation process.

*The description **is not** intended as a generic definition or as best practice, as no stakeholder consultation process has been followed at this stage.*

¹ The field-trials in Athens have been performed by DLR's "Controller Assistance for Departure Optimization" CADEO, a follow-on development of the EUROCONTROL / DLR DMAN prototype

CHAPTER 1 – Foreword to DMAN

EUROCONTROL defines DMAN as a planning system to improve departure flows at one or more airports by calculating the Target Take Off Time (TTOT) and Target Start Up Approval Time (TSAT) for each flight, taking multiple constraints and preferences into account.

DMAN systems have a wide range of sophistication-levels.

Departure management in the A-CDM context can take place more than 60 minutes before off block time. However, in reality a stable sequence is most likely to be achieved much later. The main purpose (but not the only one) is to have TSATs resulting in a desirable departure queue at the runway and Target Take Off Times (TTOT) that can be used by other parts of the air traffic network (CFMU, destination airport, receiving ATC-units etc)..

In the following description of the EUROCONTROL/DLR prototype, DMAN supports runway sequence optimisation and is dynamic. At a certain point in time the TSAT agreement between aerodrome ATC and airport/airline remains stable, but the DMAN system will adjust the plan in the background, taking account of actual events.

Those adjustments are displayed to relevant controller working positions to support the tactical handling of departures and may result in exceptional TSAT changes.

It is assumed, that the DMAN is not yet integrated with a surface surveillance system, so that the progress of the flight is taken from controller inputs on EFS.

Further developments are expected to take place in SESAR (Single European Sky ATM Research):

WP6: P6.8.4 Coupled AMAN-DMAN

WP5: P5.6.7 Integrated Sequence Building/Optimisation of Queues

CHAPTER 2 – DMAN functions linked to A-CDM

The following is an excerpt from the A-CDM Implementation Manual:

In most situations in air traffic management, the principle of “first come first served” is applied, and predeparture sequencing is no different. The result is that flights are often pushed back in an order that is not the best in the given ATC situation and/or which does not take into account the preferences of the aircraft operators. Collaborative predeparture sequencing allows ATC to arrange the Target Off Block Times (TOBT) obtained from the Turn-Round Process in a way that flights can depart from their stands in the optimum order.

The main objectives of Collaborative Predeparture Sequence are:

- *Enhance flexibility*
- *Improve punctuality*
- *Improve slot adherence*
- *Improve transparency*
- *Improve ground handling efficiency*
- *Improve stand and gate management*

Where collaborative predeparture sequencing is used, Aircraft Operators/Ground Handlers are able to communicate preferences to ATC who will take these into account together with other operational constraints such as Calculated Take Off Times (CTOTs), other traffic and the required take off sequence. The partners will be able to work together and with ATC to optimise the start up order even in very complicated circumstances, improving punctuality.

The optimised predeparture sequence will lead to more accurate Target Take Off Times (TTOTs). Any TTOT which falls outside the slot tolerance window will raise an alarm and so timely action can be taken to resolve the discrepancy. All partners will benefit from the improved transparency of the operational situation. For example, ground handlers will be able to position their resources e.g. push back tugs, more efficiently as they will know exactly in which order and when the flights will depart. Stand and gate management will be able to plan stands with more precision and AOs will be able to manage their flights according to their preferences and have a better overview of their aircraft movements

Optimisation of the take-off sequence is not strictly followed in pre-departure sequencing, but can be taken into account. In this case, the TTOTs are not a mere result of pre-departure sequencing until TOBT, but take account of individual departure-departure separation in accordance with local rules. More advanced concepts include AMAN/DMAN coupling. On mixed mode runways they require also reference to arrival-departure, departure-arrival and arrival-arrival separation. In order to remain concise, their discussion is omitted in this document.

CHAPTER 3 –DMAN functions

3.1 *Overview of DMAN functions*

This overview explains how all the DMAN functions work together. It also summarizes those sub-functions “in a nutshell”. Readers that are fully familiar with architecture and design of DMAN functionality may skip this overview..

DMAN takes each departure in its planning horizon with TOBT/EOBT within the next 90 minutes, which was discovered to be a reasonable parameter value. The value is adaptable to different needs. The TOBT is the time that the aircraft operator or the handling agent claims the aircraft will be ready for start/push. One prominent functionality of DMAN is the calculation of the expected Taxi Out Time (EXOT) for each departure. It can be broken down into the start/push phase (from pushback clearance to the “ready to taxi” status), the taxi-phase (from taxi clearance to the last position of the departure queue), the queuing phase and the line-up phase.

The EOBT/TOBT plus the EXOT is the time that DMAN assumes the flight to be ready for take off, the Estimated Take off Times (ETOTs)/Target Take off Times (TTOTs). The E/TTOTs and CTOTs (originating from CFMU) are the basis for creating an “initial departure sequence” as the next step in the DMAN process. Firstly, all flights with a CFMU restriction (and only those) are placed on the departure timeline with their exact CTOT. Then the unregulated departures are sequenced around the regulated flights, taking into account the required separation to the preceding departure. The separation-calculator is another key-function of DMAN. Now the “initial departure sequence” is established.

The next step in the DMAN process is the optimization of the initial departure sequence. The usefulness of this function has been established in simulations, but not in live-trials. It is therefore important that the function can be de-activated and the “initial departure sequence” is used. An example for optimization: Assume there is a separation of 120sec between flights that turn into the same direction (both to the left L-L or both to the right R-R) and only 60sec separation between L-R and R-L. Assume further the “initial departure sequence” renders L-L-L-R-R-R, requiring 9min from the first to the last take-off clearance in theory. If you can re-schedule those departures L-R-L-R-L-R then in theory, they only need 5min. Now, if applicable, the “optimized departure sequence” is established. Each flight has a TTOT.

The next step in the process is to calculate backwards to the TSAT. It consists simply of subtracting the value for the EXOT multiplied by an extension factor from the TTOT. The extension factor is parameterized and used to cope with uncertainty of the times in the ground progress. Ideally (extension factor =1), the so-calculated TSAT should ensure that each flight arrives at the runway exactly at the time it is needed for immediate take off, however, it is accepted as a good practice for runway optimization to always have a buffer of 3-5 aircraft at the runway in departure peaks, in order to cater for the obvious randomness in the ground progress. This can be taken into account by enlarging the extension factor or simply left to the respective aerodrome control position.

When an ATOT is received, the departure is deleted from the sequence. In theory, that should always be the first flight of the present sequence at the TTOT. Then the remainder of the sequence and the entire schedule remains unchanged. If A-SMGCS surveillance /EFS data are not available for DMAN, it may happen, that the DMAN sequence does not always

reflect the real sequence at the runway holding point. In this case the respective flight must be deleted independently of the planned number in sequence and the remaining flights will be adjusted.

If a manual is issued to an aircraft by a controller this has to be made known in the DMAN system. If it differs from the DMAN-plan it will over-write the DMAN TSAT. After the TSAT is issued the DMAN system will try to keep the TTOT for this flight stable in the plan. Departures that are not yet coordinated via the TSAT will be re-planned, if necessary, in accordance with their TOBT.

The following sections repeat the introduction and go more into detail. All steps to calculate the optimized sequence are repeated to adapt to changes. Examples for changes are:

- New departures enter the DMAN planning horizon
- Changes to TOBT, CTOT
- Given Clearances or ASAT, ATOT
- Changed ELDT/TLDT for arrivals, if mixed mode is used or the arrival runway is dependent.
- Changes to RWY or SID

3.2 Variable Taxi Time Calculator

The Variable Taxi Time calculator shall return the unimpeded taxi out time from Start/push to the arrival of the aircraft at the departure runway. In accordance with the A-CDM definition for the Estimated Taxi Out Time EXOT, the departure can be assumed to be ready for departure at that time. The EXOT will need to also take into account any queuing time.

DMAN holds models for the departure processes needed for each flight. The system will know the assigned parking positions, and if the departure needs a pushback or not. The model holds also the times the operational steps take, starting with a clearance.

For the taxi time itself the process starts with either a simple look-up table or from ASMGCS Routing function, if available. The rows and columns of the table hold the location of the aircraft and the destination runway, respectively. Opposite ends of a runway (e.g. RWY29 and RWY11) are considered as two different runways.

The location of a departing aircraft is its parking position (stand). It is acceptable to group parking positions, dependant on the complexity of the airfield and the requirement for granularity. At many airports a “natural” grouping exists via the division of parking positions into gate-areas or aprons.

Taxi times and taxi speeds can vary greatly, even if the pre-conditions are similar, hence they are difficult to predict. For a stand/runway combination with an average taxi time of 5 minutes, there will still be about 20% of the departures that need less than 3 minutes or more than 7 minutes. It is recommended to refine the ground progress time calculator only with criteria that have a clearly measurable effect.

See for example Eurocontrol internal report ASA.02.AMAN/DMAN.Del05.SUM.

EXOT timetables should be kept simple, because they will need updating for any changes on the airport layout or taxi procedure from time to time.

	A	B	C	D	E	F
1	Area	Runway	Arrival	Departure		
2	1N	25R	120	240		
3	1N	25L	300	360		
4	1N	20	240	240		
5	1NA	25R	180	180		
6	1NA	25L	240	300		
7	1NA	20	180	180		
8	1S	25R	300	300		
9	1S	25L	240	420		
10	1S	20	180	300		
11	1SA	25R	240	240		
12	1SA	25L	180	360		
13	1SA	20	120	240		
14	10	25R	180	300		
15	10	25L	360	480		
16	10	20	300	300		
17	11	25R	180	300		
18	11	25L	360	480		
19	11	20	300	300		
20	12	25R	180	300		
21	12	25L	360	480		
22	12	20	300	300		
23	13	25R	180	300		
24	13	25L	360	480		
25	13	20	300	300		
26	2N	25R	420	420		
27	2N	25L	240	480		
28	2N	20	180	360		
29	2NA	25R	360	300		
30	2NA	25L	180	360		
31	2NA	20	120	300		
32	2S	25R	360	360		
33	2S	25L	180	420		
34	2S	20	180	360		
35	3	25R	360	360		
36	3	25L	180	420		
37	3	20	180	360		
38	3A	25R	300	240		
39	3A	25L	180	300		

This is an excerpt from a DMAN EXOT/EXIT-table: Column A has the specific aprons or areas on the airfield, column B the specific runway, column C tells how much time in seconds an arrival is expected to taxi from the (most likely) exit to a position on that respective apron (EXIT), Column D the taxi time from a position on that apron to the runway head (EXOT).

3.3 Creation of the “initial departure sequence”

A departure sequence is well defined for one departure runway or for a set of dependent departure runways, for example crossing runways. In case of two or more independent departure runways there is no use to plan a sequence of events, if the events do not need synchronization. This means that in case of two independent runways two independent sequences can be built.

Therefore the initial departure sequence is the sequence of Estimated/Calculated Take off Times ETOT,/CTOT for each set of dependant departure runways.

3.3.1 CFMU-regulated flights

Firstly all regulated flights are placed in the order of their CTOTs. If one or more departures have the same CTOT, they must be sequenced with another criterion, for example the SOBT/EOBT should be taken into account (most delayed flight should go first).

Then the required departure-departure separation must be put between the regulated flights by shifting the succeeding departures of detected conflicts backwards → some flights may now be later than their CTOT, but none earlier.

3.3.2 Non-regulated flights

Next the non-regulated flights share the remainder of the departure time-line like follows: starting with the earliest E/TTOT, all flights are put in sequence with the respective separation, unless they conflict with the CTOT-flight. Then they must be placed behind. For those flights that have the exact same E/TTOT, they also need to be “randomly” sequenced

or in accordance with a “fairness-rule”, like that described for the regulated flights. Identical E/TTOTs are not uncommon, assuming the EXOT timetable entries and the TOBTs to be in integral minutes.

3.3.3 Compacting the sequence (closing the un-necessary gaps)

The runway schedule will now have unnecessary gaps. Imagine the following: Flight#1 is non-regulated and violates separation-criteria to its regulated follower flight#2 by say 10 seconds. Then it needs to be scheduled behind flight#2 or even delayed further. But this may create a gap in front of flight#2. Each time this happens the regulated flights (flight#2 in the example) shall be advanced by the least of the following:

- Without violating separation minima to the new predecessor
- As much as needed to allow the succeeding non-regulated flight (flight#1 in our example) to take off at E/TTOT
- to remain inside the CFMU slot (CTOT minus 5 min through CTOT plus 10 min)

Note 1: A prominent feature of the A-CDM concept is the improved co-operation between airport and CFMU and the linking of airport to the ATM network via updated departure information. In this context there is a defined DPI-message (Departure Planning Information) for each departure. For this message the DMAN needs to provide a virtual “what-if” planning for regulated flights, as if the flight had no slot. It is used in the CFMU for the provision of “slot-improvements”.

Runway 25R					
BRT423	E145	HELEN3C		TO	29
AFR3461	CRJ1	SOPOK3C	12:23	TO	28
BMA3RE	B735	HELEN3C		TO	27
DAT41G	RJ85	SPI2D		TO	26
					25
COA61	B763	HELEN3C		TO	24
					23
BMA234	F70	HELEN3C		TO	22
					21
DAT19M	RJ85	HELEN3C		TO	20
EWG031	AT42	LNO2D		TO	19
					18
DLH5889	CRJ1	LNO2D		TO	17
					16

This could be an initial departure sequence. It is actually compacted. Note the 2 minute separation between DAT19M, BMA234 and COA61. They are due to the fact the departures depart on the same SID. The sequence results from the applicable TTOTs and the separation values.

Note 2: The DMAN prototype does not create an “initial departure sequence” based on first – come- first-served principle by default. It creates the respective optimised sequence order. If the Controller wants to see the “initial departure sequence” based on that principle, he has to change the planning strategy to first-come-first-serve(“FCFS”). The DMAN prototype supports a pre-defined set of different planning strategies and allow to specify additional ones. When the planning strategy is changed to FCFS then instead of the optimised sequence the first-come-first-serve sequence is shown.

3.4 Departure-departure separation calculator

Departure-departure separation rules may vary from country to country and also airport to airport. They typically fall into three categories:

- 1) Wake-vortex separation (WV)
- 2) SID separation (Standard Instrument Departure)
- 3) Speed category separation

To get the separation the maximum of the three (WV, SID, speed) per departure-departure pair is taken.

3.4.1 Wake-vortex separation

The Wake-vortex separation is normally dependant on the departure's ICAO classification as Heavy, Medium or Light (other categories exist in different countries). The applicable set of values for the respective airport can be easily edited into a small table.

3.4.2 SID-separation

The SID-separation is dependant on the first turn in the SID, rather than the later direction of the route. The respective number of minutes required between two flights can be kept in a table.

	Standard Instrument Departure Routes (SID)					LN
	CIV1E	CIV2Q	CIV7D	LN02C	LN02D	LN
CIV1E	LL	LL	LL	LL	LL	
CIV2Q	LL	LL	LL	LL	LL	
CIV7D	LL	LL	LL	LL	LL	
LN02C	LL	LL	LL	LL	LL	
LN02D	LL	LL	LL	LL	LL	
LN02Q	LL	LL	LL	LL	LL	
PITES3C	LL	LL	LL	LL	LL	
PITES3D	LL	LL	LL	LL	LL	
ROUSY3C	LL	LL	LL	LL	LL	
ROUSY3D	LL	LL	LL	LL	LL	
SOP0K3C	LL	LL	LL	LL	LL	
SOP0K3D	LL	LL	LL	LL	LL	
SPI2Q	LL	LL	LL	LL	LL	
SPI2C	LL	LL	LL	LL	LL	
SPI2D	LL	LL	LL	LL	LL	
CIV1C	RL	RL	RL	RL	RL	
DENUT3C	RL	RL	RL	RL	RL	
ELSIK2D	RL	RL	RL	RL	RL	
ELSIK2C	RL	RL	RL	RL	RL	
HELEN3C	RL	RL	RL	RL	RL	
KOK2C	RL	RL	RL	RL	RL	
NIK2C	RL	RL	RL	RL	RL	
NIK4Z	RL	RL	RL	RL	RL	
LN03Z	RL	RL	RL	RL	RL	
PITES3Z	RL	RL	RL	RL	RL	
ROUSY3Z	RL	RL	RL	RL	RL	
SOP0K4Z	RL	RL	RL	RL	RL	
SPI4Z	RL	RL	RL	RL	RL	
CIV7L	DSG	DSG	DSG	DSG	DSG	
ELSIK1L	DSG	DSG	DSG	DSG	DSG	
LN04L	DSG	DSG	DSG	DSG	DSG	
PITES3L	DSG	DSG	DSG	DSG	DSG	
PITES3N	DSG	DSG	DSG	DSG	DSG	
ROUSY3L	DSG	DSG	DSG	DSG	DSG	

This is part of a SID-separation table. For each pair of SIDs an entry of (LL, RR, LR, RL, DSG, or DSGX), telling whether the departures turn the same direction (LL, RR), different directions (LR, RL), are in independent different SID groups (DSG) or dependant different SID groups DSG X. DSGs apply for day-SIDs and night SIDs and DSG_Xs apply for SIDs from different runways at the same time.

	A	B
1	parameter name	value
2	RR	120
3	RL	60
4	LR	60
5	LL	120
6	DSG	0
7	DSG X	120
8		
9		

The respective separation values in seconds.

3.4.3 Speed-separation

The speed separation may apply only for SIDs that share a common path element. If that is so, common-path SIDs need to be kept in listings of respective sets. The respective separation-value can be kept in a table and only applies for departures with the same SID or the same common-path group.

3.4.4 VFR-departures

The minimum separation between IFR-departures is 60 seconds. However, there is the possibility to release a departure behind a VFR departure after it vacates the centerline extension axis. That may be before 60 seconds have expired. It is, however difficult to forecast and therefore probably not worth the effort.

Important: The departure-departure separation calculator can only be used for planning the sequence and the resulting schedule. It cannot not be used for actual separation assurance or separation violation warning!!!

3.4.5 Intersection take-offs

Intersection take-offs may need different spacing. However, the fact whether or not a departure will request/accept an intersection take off depends on various factors and is known late in the process. The application of special separation rules for DMAN planning shall only be implemented if intersection-takeoffs can be confidently forecast early. Intermediate holding points and intersection take offs can be fed into DMAN via the EFS/A-SMGCS as part of the routing function.

3.5 Runway Sequence Optimizer

Runway sequence optimization has been evaluated in various fast-time simulations. It can render 7% increase in runway throughput, dependant on the mix of traffic in terms of wake-vortex category, SID and speed.

See Eurocontrol internal ASA02.DMAN.DEL05.FEA for departure runways and ASA.02.AMAN/DMAN.DEL04.REP for mixed mode runways.

Those fast time simulations only compared random take-off sequences with fully optimized

sequences and therefore lack reality. They assume specifically that:

- there is a continuous over-demand of departures
- the ground and runway controllers only perform sequence-improvements by swapping two consecutive departures.

DMAN performs sequence-improvements

- by checking many possible permutations of the departure sequence
- departures take-off with the exact separation-spacing assumed
- the optimized runway sequence can be achieved 100%.

Up to now, the increase in runway throughput has not been proven in real time simulations or field-trials. That means that the usefulness of runway sequence optimization is not proven. If applied, it should be always possible to neutralize the optimization and plan on the “initial departure sequence”.

3.5.1 Sliding window method

There are several possibilities to program the optimization, given here is the “sliding window” algorithm. It looks at one set of departures at a time (first the window A, B, C, D, E) and then slides that window down the entire set of departures (A, B, C, D, E, then B, C, D, E, F, then C, D, E, F, G, then D, E, F, G, H etc). There should be a maximum position-shift, for example three. That means flight#23 in the initial departure sequence (IDS) can only have numbers between #20 and #26 in the optimized departure sequence (ODS). Otherwise certain departures (light and slow aircraft, for example) would be delayed indefinitely.

Each sliding window-run translates the entire IDS into an ODS. It starts with the first five departures (numbers A, B, C, D, E) and tries all 120 permutations of those five flights. Those 48 permutations that start with an E or end in an A are discarded, because they violate the maximum position-shift rule. For the other 78 a fictional schedule is built, that means each flight gets a fictional departure time. There are, of course, conditions: No flight will be planned to take off earlier than the ETOT and additionally for regulated flights, not earlier than five minutes before CTOT. No flight can take off earlier than the preceding departure plus required separation. Now the best of all those is the one with the lowest sum over all delays² (delay=fictional take off time minus ETOT or minus CTOT for CFMU regulated flights). Lets say it gives the sequence C, D, B, A, E. Then this defines the very first position in the overall ODS³. It is the flight C from the IDS. Now the window-of-five slides down by one position and the permutation process is applied to flights D, B, A, E, F.. From the full 120 permutations again those ones are discarded which have ODS numbers that differ more than 3 from the IDS-number. The winning permutation now defines ODS-number 2 and the window slides further down by one unit. This process is repeated until the end of the planning horizon.

One full translation of the IDS into an ODS takes a modern computer just a tiny fraction of a second, of course.

² In the DMAN prototype this depends on the chosen planning strategy and also the optimisation criteria expressed by weighed objective functions.

³ How many flights are taken into each window and how many flights are taken out of the optimized window into the complete ODS is configurable in the DMAN prototype and is part of a planning strategy.

						23
						22
	BRT423	E145	HELEN3C		TO	21
						20
	COA61	B763	HELEN3C		TO	19
	DAT41G	RJ85	SPI2D		TO	18
	BMA3RE	B735	HELEN3C		TO	17
	DLH5889	CRJ1	LNO2D		TO	16
	BMA234	F70	HELEN3C		TO	15
	AFR3461	CRJ1	SOPOK3C	12:23	TO	14
	DAT19M	RJ85	HELEN3C		TO	13
	EWG031	AT42	LNO2D		TO	12

The same set of aircraft like shown in the picture for the initial departure sequence. Here the “expensive” SID separations for the HELEN3C departures are avoided by swapping DLH5889 and AFR3461 between DAT19M, BMA234 and BMA3RE. Note also that COA61 is positioned before BRT423. They do have the same SID, but the Embraer needs 2 minutes WV-separation anyway behind the B767.

3.5.2

Note 1: The CFMU slot compliance can not be guaranteed, neither in the IDS nor in the ODS. Simply assume 10 departures with the same CTOT and an average 90 seconds separation. The described algorithm keeps guard of regulated flights simply by having them close to CTOT in the IDS and the maximum position shift in the ODS.

Note 2: It has been shown that CPU- and memory requirements for this task are easily met by standard PC hardware (see Eurocontrol internal ASA02.DMAN.DEL05.FEA for departure runways and ASA.02.AMAN/DMAN.DEL04.REP for mixed mode runways).

Note 3: The sliding window-method can obviously be generalized to a wider/smaller window-size than five and also to another slide-value. Slide-value in the description is one, but the method could employ also slide-values of two or three, that means each time a window-evaluation is done, not only one but two or three flights are fixed and the window slide accordingly by two or three positions down. The parameters window-size and slide-value influence the optimization-performance and the CPU/memory requirements of the computer.

Note 4: The evaluation-criterion described is the total delay of all flights in consideration. One can also introduce airline preferences for prioritization, treat aircraft already taxiing differently etc. There is no problem on the data-processing side to do so. The way to implement this is a weighted sum over the desired criteria, expressed in certain cost-units. The resulting ODS would be in accordance to certain pre-defined and agreed operational criteria.

Note 5: For the CFMU E-DPI and T-DPI messages the DMAN needs to provide a virtual “what-if” planning for regulated flights, as if the flight had no slot. It is used in the CFMU for the provision of “slot-improvements” until the CTOT is frozen (at a certain time parameter after T-DPIs is issued). For more information see DPI implementation guide (Ref).

CHAPTER 4 –DMAN interface to an EFS system

Many major European airports have, or are on the verge of, replacing paper-strips with Electronic Flight Strips (EFS). These systems display relevant flight data to several controller working positions (CWP), that can be pre-set to a controller-role (one or more of Clearance delivery, Ground and Tower Control). Relevant times when working with DMAN are the TOBT, the TSAT and the TTOT. EFS-systems may also feature a “time-line” which displays the departures in accordance with the take-off schedule.

4.1 Clearance Delivery CD

A possible realization for “Clearance Delivery Position” by the EUROCONTROL DMAN Prototype where departures have been activated, they are fully blue.

Note: Sometimes the actual start-up is delayed by a couple of minutes due to controller workload, late crew re-action and/or late ground-service (tow-truck). In order to cater for such delay, a buffering-function can be activated in CADEO. It adds an adjustable percentage to the EXOT when back-calculating from the TTOT to the TSAT. If the percentage is set to 0%, the TSAT for unconstrained flights would be equal to the EOBT.

CLD
EXTERNAL VIEW
[Icons]

ACID	TYPE	STAND	DEST	RWY	SID	EOBT	TOBT	TSAT	CTOT	NXT	CL	CWP
OAL163	B734	B03	LGTS	03L		05:00					ESU	
AEE510A	A320	A32	LGTS	03L		05:00					ESU	
AZA7JE	A321	B42	LIRF	03L		04:55					ESU	
OAL902	A320	A38	LGTS	03L		04:55					ESU	
OAL329	B733	A03	LCLK	03L		04:50					ESU	
AEE600	A320	A01	EGSS	03L		05:40					ESU	
BLE438P	MD83	A45	EDLV	03L		06:30					ESU	
OAL381	AT72	B53	LROP	03L		04:35					ESU	
AEE30HR	A320	A36	LGIR	03L		04:30					ESU	
AEE330	A320	B15	LGSA	03L		04:30					ESU	
AFR2333	A320	B05	LFPG	03L		05:05					ESU	
DLH2FL	A306	B09	EDDF	03L		04:05		04:05		25	ESU	
AEE27HI	RJ1H	B51	LGHI	03L		04:15					ESU	
OAL271	B734	B36	EGKK	03L		05:00					ESU	
OAL650	AT72	B62	LGMK	03L		04:00		04:03		23	ESU	
AEE90LK	A321	A35	LCLK	03L		04:00		04:02		22	ESU	
AEE25MT	RJ1H	A30	LGMT	03L		04:00		04:00		20	ESU	
SWR1843	A321	A07	LSZH	03L		04:40					ESU	
OAL760	AT43	B57	LGHI	03L		03:50		03:50		10	ESU	
OAL530	B734	B32	LGSA	03L		03:50		03:51		11	ESU	
OAL550	AT43	B66	LGSR	03L		03:45		03:45		5	ESU	
OAL500	B734	B38	LGIR	03L		03:39		03:46				RWY
OAL570	B734	B40	LGMT	03L		03:35		03:40				RWY
OAL770	AT43	B58	LGLM	03L		03:29		03:39				RWY
OAL750	DH8A	B52	LGSM	03L		03:35		03:37				RWY
OAL730	AT72	B55	LGKO	03L		03:35		03:36				RWY
OAL600	B734		LGKR	03L		03:28		03:38				RWY
AEN957	DH8A	F08I	LGKV	03L		03:36		03:44				RWY

Cancel
03:40:59
Confirm

Voice on

OAL500

Destination : LGIR

SID :

Runway : 03L

Squawk :

Initial level : FL060

Message :

Information :

TOBT :

Slot : ;

* TSAT : 03:46

* TTOT : 03:56

03:39:43: given clearance esu

03:39:43: eobt 03:45 changed to 03:39

03:15:00: tobt changed to

00:45:10: stand changed to B38

Above latest development by DLR CADEO applied during Athens trials

4.2 Ground

A possible realization of the GND position HMI. The planning info is contained in columns 6,7 and 8: TOBT, TTOT and time-to-go to the next clearance.

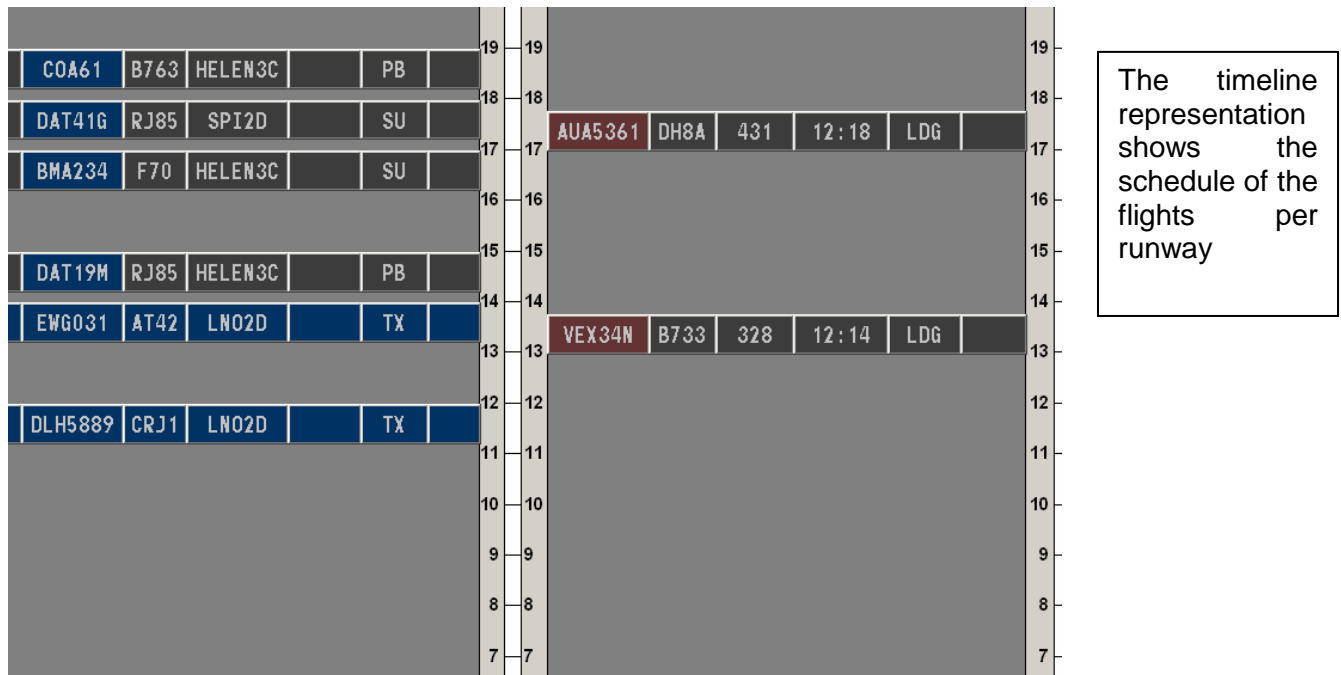
BRT423	E145	906	25R	B1	12:01	12:22		ENR	
DAT41G	RJ85	327	25R	B1	12:01	12:18		ENR	
BMA234	F70	207	25R	B1	12:01	12:17		ENR	
COA61	B763	237L	25R	B1	12:01	12:19		ENR	
DAT19M	RJ85	229R	25R	B1	12:01	12:15		ENR	
EWG031	AT42	432	25R	B1	12:01	12:14	1	SU	
AFR3461	CRJ1	421	25R	B1	12:01	12:21	8	SU	
DLH5889	CRJ1	422	25R	B1	12:01	12:12	-1	SU	

A possible realization of the GND position. The planning info is contained in columns 6,7 and 8: Activation time, TTOT and time-to-go to the next clearance.

4.3 RWY

The Runway or TWR position with arrivals and departures. Flights controlled from the shown position fully coloured, arrivals brown and departures blue. The planning info is contained in columns 7,8 and 9 for the departures: CTOT, TTOT and time-to-go to the next clearance.

4.4 Timeline representation



4.5 Insertion of a departure into the DMAN plan

A useful planning horizon for DMAN is 90 minutes. The CFMU-regulated flights shall all have received their initial CFMU-slot 120 minutes before EOBT. Those flow-measures typically result in co-ordination efforts between aircraft operators and CFMU to improve the slot. At 90 minutes lead-time the available information (the EOBT, CTOT and TOBT) can be considered useful for DMAN planning. However, many aircraft in the range of the planning horizon will not even have landed yet. Each flight will undergo several changes in the optimized sequence before arriving at a more tactical planning horizon of approximately 30 minutes ahead. There is no point really to split the plan into two sections (strategic / tactical), even if the use of the DMAN plan (the DMAN timeline) will be very different with 80 minutes to-go or 15 minutes to go. It is generally accepted that the DMAN-plan is dynamic, in order to stay in synchronization with the actual real-time events. It is clear that the degree of commitment to the plan will increase when approaching the tactical phase (funnel of commitment).

4.6 Change of flight data after inclusion in the DMAN plan

There are many ways that flight data changes. A CFMU-slot maybe issued, revised, cancelled. A TOBT may change the previous EOBT or be updated for other reasons. Flights may be cancelled, new IFR flight plans received. All these changes will result in changes of the DMAN plan for the respective flights and all other departures scheduled later. The result is a quasi-continuously changing/driftting time-line in the pre-tactical horizon (lead-times of 45 minutes or more). This part of the plan is not more than a matching of the presently available departure demand and the departure-status of the airport (already built-in delays, runway configuration, runway flow etc). It is not recommended to use the DMAN plan for the co-ordination of commitments (like for example the issuance of a TSAT) at that early stage.

4.7 Target Start-up Approval Time (TSAT)

The main change in terms of plan-commitment is the issuance of the TSAT. As earlier described, the DMAN has TSAT-proposals for all planned flights. They shall be executed or manually changed by aerodrome control at the latest at start/push request of the departure.

Now what happens inside the DMAN?

The departure must be considered from now on with a different level of commitment. It is recommended to treat the flight equal to a flight with a CFMU-slot. That means the EXOT is added to the TSAT and the result is the TTOT. In the resulting re-calculation of the IDS first all CFMU-slotted flights **AND** all confirmed TSATs populate the timeline. Then those are separated according to rules and thereafter the “free” flights will take the remainder of the timeline.

Note: If an update on TOBT is received after the controller’s TSAT issue, the flight shall be re-sequenced according to the new TOBT and the resulting TSAT will be issued.

4.8 Late departures

The general philosophy to treat late departures is to postpone them once or twice and thereafter delete them from the DMAN-plan. They shall be returned to the departure flight plan storage with an “expired” instead of the TOBT. They can, of course, always be re-activated with a new TOBT, but they shall not block space in the DMAN plan.

Note: Controllers should determine the local implementation of late flights and the suspension strategy.

Now what happens inside the DMAN?

Regular checks have to be performed, for example once a minute. Flights that did not receive start/push clearance until 5 minutes after TSAT, shall be prompted for controller action. The controller could decide to do nothing (the flights remains unchanged in the plan), to postpone it by adding 10 minutes to the TSAT or to delete it from the DMAN planning (“expired” overwrites TOBT).

Note: There is an alert defined in A-CDM: CDM11 --> TOBT / TSAT not respected.

Note: The actual start up approval (ASAT) can be given in advance of TSAT. In this case the TSAT shall be set accordingly.

4.9 Take off clearance / take off detection

The planning for one particular departure ends with its takeoff. All data are still within DMAN to ensure the separation of following departures. The sequence number one goes to the next flight planned for take off by the DMAN plan.

It may have the position number one in the ODS, but in some cases it may not. The deletion can be executed at the entry of take-off clearance given or the SSR-detection (or both), depending on availability and reliability of these inputs.

4.10 Manual Interventions

4.10.1 Sequence Change

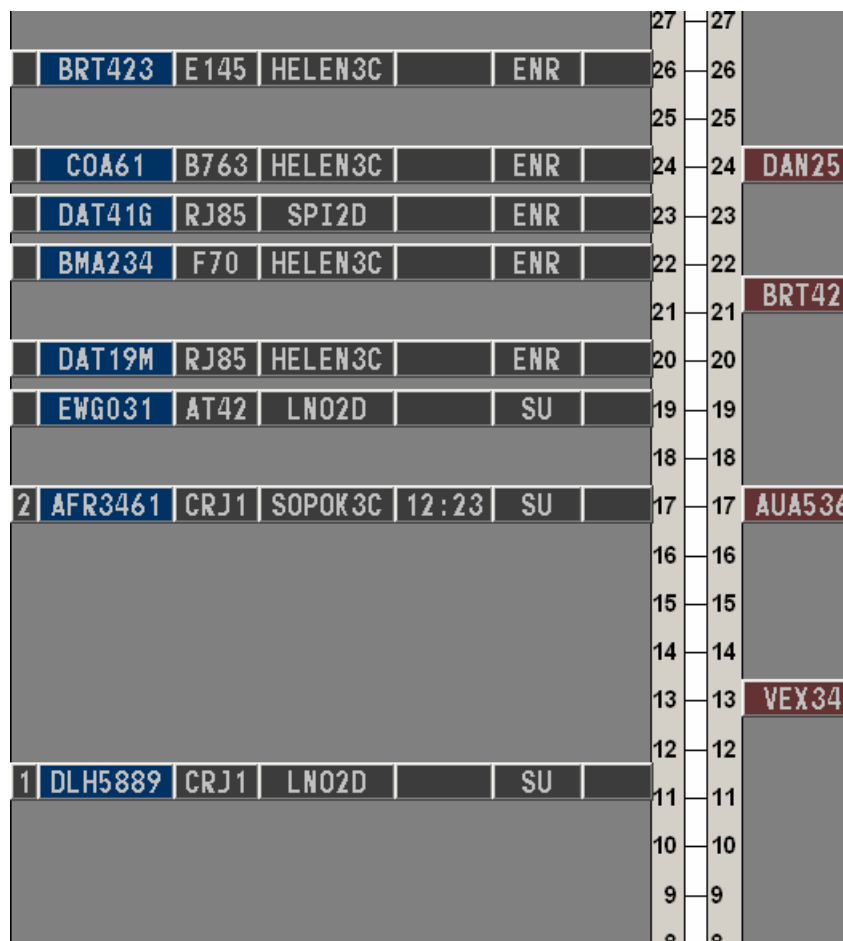
Manual intervention with the planned sequence is an important operational requirement for DMAN. The implementation is more difficult than expected on “first sight”. The main problem

is that the “manual change” needs to be protected from further re-planning by the DMAN function.

It is therefore strongly recommended to combine manual interventions with sequence freeze. The sequence can be frozen automatically after AOBT and can be frozen earlier via manual intervention. Manual sequence changes shall be restricted to that frozen part of the sequence.

If manual interventions take place in the non-frozen part of the departure sequence, they need to be clearly defined and the controller needs to understand the possible consequences.

The general idea is as follows: The responsible controller for the planning wants a different runway sequence of flights than the one displayed by DMAN on the timeline. He then selects the flight (with the mouse-pointer and a right-click-and-hold) and drags the flight to another position in the queue, between two consecutive flights and then releases the flight (by releasing the right mouse button), in short words “drag & drop”.



Manual sequencing:
The slotted AFR461 (CTOT 12:23) leaves a gap in front, because it was forced into the sequence as #2 by the controller

Now what happens inside the DMAN?

There are many possibilities to implement manual sequencing. Only some are mentioned here:

1st possibility: An ODS has to be computed which “forces” the drag & drop flight to have the sequence number of the latter flight of those two consecutive flights. (It has to be squeezed in-between two flights of the earlier sequence) and the following flights have to be delayed if necessary. But the manual intervention has to be kept safe against further changes by the DMAN-planner.

Warning: Assume, for example, a flight is manually put on sequence number #10 and later

this flight is delayed by 15 minutes. The result is that all flights with sequence numbers higher than #10 may also be delayed. There will probably be a large gap between #9 and #10 for no apparent reason.

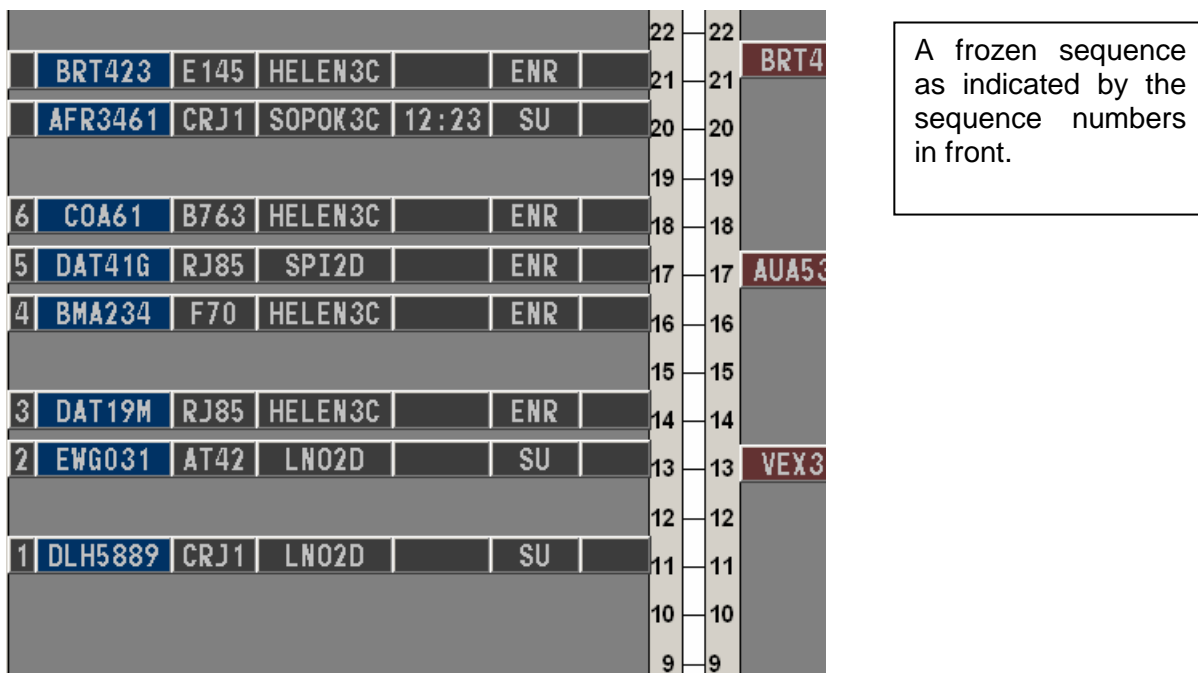
2nd possibility: the flight is treated as a CFMU-regulated flight. As mentioned before that means the flight is put into the timeline with the slotted flights before the free flights. The flight is still subject to adjustment with unknown extent.

3rd possibility: The flight gets a totally fixed TTOT and all the others are planned around that flight → when delays occur before the flight, they will one by one “jump” over the fixed flight to become sequenced after.

Conclusion: To avoid the mentioned problems, it is preferable to combine manual interventions with sequence freeze.

4.10.2 Sequence Freeze

A part of the sequence is frozen if the DMAN planner does not change it anymore. It is still subject to manual sequence change. It is theoretically possible to freeze the sequence of let's say five flights that are planned for some time in the future and treat them as a block that shall not be touched by the planning algorithm, but that is unusual. By all means, the frozen sequence shall start with at the beginning of the sequence, it means with the next take off until some position further down the timeline.



A frozen sequence as indicated by the sequence numbers in front.

Flights can be frozen in their position number or in their take off time.

If they are **frozen in their position number** (for example flights A, B, C, D, E are frozen in this particular order) but still kept floating in time, the consequences are:

- Advantage: The timing of events at the runway, for example several late reactions on the take off clearance, will be reflected even in the frozen part.
- Disadvantage: If one flight in the frozen section is subject to delay (assume for example 10 minutes for a problem on flight deck), then all the other flights sequenced behind will also be delayed 10 minutes, Computers do not do what you want from them, they do what you told them to do.

If they are **frozen in time**, the consequences are:

Advantage: If one flight in the frozen section is subject to delay (assume for example 10

minutes for a problem on flight deck), it will be just ten minutes later on the time line. It will create a gap at the position it was before the change, and it will not be properly separated at the position after the change.

Disadvantage: The timing of events at the runway will not be reflected. A delayed flight may not have proper separation after it is put back on the timeline to the respective delayed position.

4.10.3 Automatic Freeze

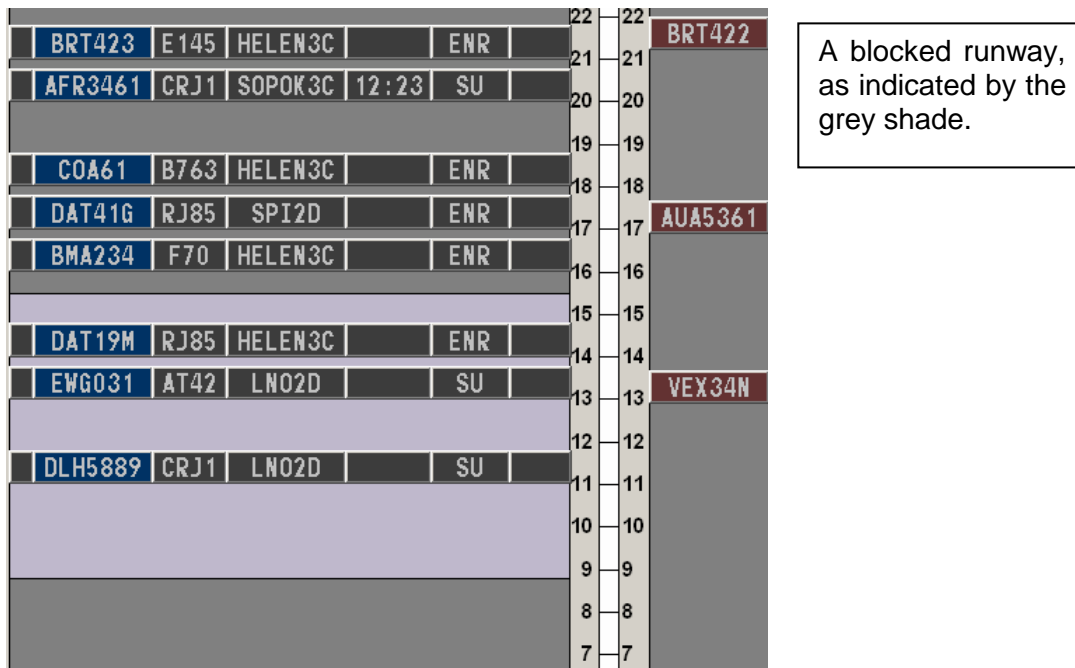
It is generally accepted that DMAN sequence changes must be more and more limited as closer you come to the tactical phase (funnel of commitment). Possibilities are to:

- Freeze all flights after a certain event (AOBT)
- Freeze all flights with a given time to elapse before take off.

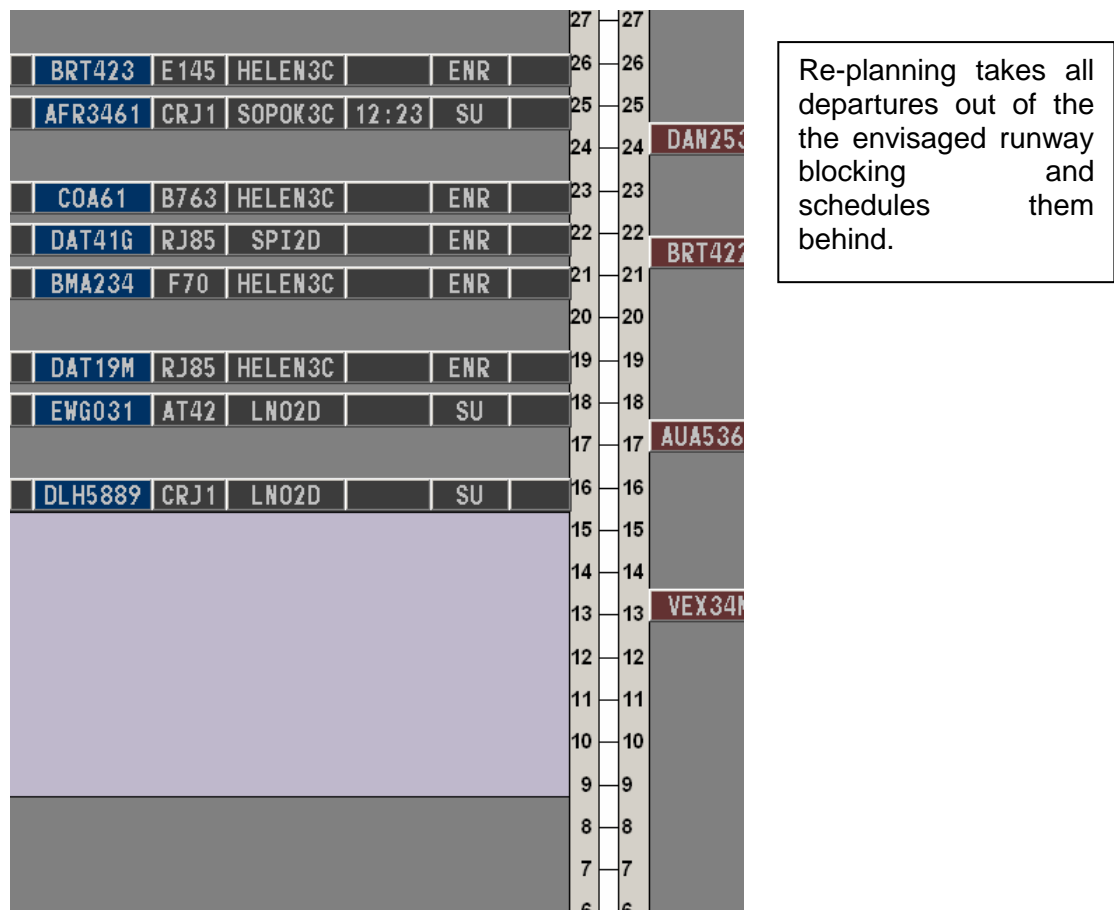
Flights can be frozen in their position number or on a certain take off time. See discussion in the previous chapter.

Note: not implemented in the DMAN prototype⁴.

4.10.4 Runway blockage



⁴ Sequence freeze after crossing a so called „virtual gate“ is implemented within CADEO. For this functionality position data are required.



The insertion of a runway blockage, for example for runway inspection or snow-removal shall have two options:

- Start after take off of a selected departure and have a certain duration
- Be defined by start and end-time

4.10.5 Runway flow adjustment

Situations may arise that will reduce the runway throughput, mostly due to adverse weather conditions, including but not limited to very low visibility. The RWY-controller or supervisor must have a simple means to slow the traffic. It is an operational requirement for DMAN that the controller can set a certain flow rate to adjust the runway throughput. The DMAN planner, however works on specific separations between flights (rather than for example with a fixed time of 90 seconds to meet a flow rate of 40 departures per hour).

Remember that separation in DMAN is originating from rules concerning the consecutive flights. They could depend on wake-vortex category, SID, aircraft speed and other local rules. If DMAN assumes a fixed value of, for example 90 seconds then sequence optimization is not possible.

One way to overcome the problem is an adjustable minimum separation, which is defaulted for example to 60 seconds and can be raised in accordance with the desired flow rate.

Note: not implemented in the DMAN prototype⁵.

⁵ But within CADEO.

CHAPTER 5 –DMAN adjustments for particularities

5.1 *Creation of the DPI messages**

5.1.1 Background

DPI stands for “Departure Planning Information”. There are five defined messages sent from CDM-airports to the CFMU for the refinement of network planning:

- E-DPI (early): First DPI message that is sent from the CDM Airport to the CFMU (ETFMS) notifying the ETOT based on Variable Taxi Time (VTT).
- T-DPI-t (target): This DPI message is sent from the CDM Airport to the CFMU (ETFMS) notifying the Target Take Off Time (TTOT) based on Target Off block Time (TOBT) + VTT
- T-DPI-s (sequenced): This DPI message is sent from the CDM Airport to the CFMU (ETFMS) notifying the Target Take Off Time (TTOT) based on ATC Target Start Up Approval time (TSAT) +VTT
- A-DPI (ATC): DPI message sent by the CDM Airport to the CFMU (ETFMS) notifying the TTOT after Actual Off block Time (AOBT) +VTT
- C-DPI (cancel): This message informs the CFMU that all DPI information sent is cancelled (no longer valid).

* Not implemented in the DMAN prototype.

5.1.2 Virtual Calculations by DMAN

The TTOTs of the DPIs will be taken into account (among other things by ETFMS) to calculate the CTOT.

The CFMU needs to know in this respect the earliest reasonable take off time for each flight. This can be achieved by DMAN calculating a “what-if” sequence (IDS or ODS) as if this specific departure had no CFMU-slot. This “what-if” sequence needs to be produced for each regulated flight and it needs updating with each TOBT value. The result of the what-if is an earliest possible TTOT based upon TSAT+VTT and this can be provided via T-DPI-s messages of this one flight It is also called “shadow Pre-departure sequence” and is required for slot adaptations until the CTOT is frozen (see DPI Implementation Guide).

A simpler solution: DMAN holds always two different plans:

- The real plan as discussed above, with regulated flights treated in accordance with their CTOT
- A virtual T-DPI plan, in which no departure has a CFMU-slot.

5.2 Crossing runways and other dependencies between runways

A set of runways are dependent, if take off and landing clearances cannot be given on one runway with such operation in progress on the other. As a matter of principle, they have to be treated by DMAN as one single resource, literally treated as one runway-set. However, they should be displayed on different timelines, with each operation reflected by two entries: One on its respective runway and another one (as a ghost) on the other.

At first it seems very possible to generalize respective separation rules for a set of dependent runways, but they vary from airport to airport, country to country and other situations. Therefore generalised separation rules would be very complex. It is rather recommended to define and implement them for each specific situation.

Further, departures for two dependent runways will physically queue at different positions. That means it is overall questionable whether one sequence for both runways shall be developed. The consequence would be that the plans for the different runways also depend on each other and inherit the other's dynamics.

Remember that DMAN shall not be used for actual operational separation. It is therefore possible to implement a rule that does not perfectly match the respective separation rule but is simpler. That way at least the impact on each runway's throughput (as affected by the dependent runway) is reflected upon.

It is also possible to plan two dependent runways *independently* and address the impact on runway throughput via runway flow adjustments. See above.

5.3 Arrivals on the departure runway

Arrivals on the departure runway simply block the runway for departures. Rules must exist that define the duration and the position of the blockage. As mentioned earlier, DMAN shall not be used for actual operational separation and therefore the match between the exact rules and the position of the blockage does not need to be exact. Quality of departure planning of course will increase with reliable TLDTs.

If there is a considerable amount of arrivals on the departure runway, like in true 50/50 mixed mode operations, it is important that arrival information exists for the entire planning horizon of DMAN. Otherwise the DMAN plan will become false after the point that arrivals are not anymore taken into account.

					20	20
COA61	B763	HELEN3C		ENR	19	19
AFR3461	CRJ1	SOPOK3C	12:23	SU	18	18
BRT423	E145	HELEN3C		ENR	17	17
AUA5361	DH8A	431	12:18	LDG	16	16
BMA234	F70	HELEN3C		ENR	15	15
DLH5889	CRJ1	LNO2D		SU	14	14
DAT19M	RJ85	HELEN3C		ENR	13	13
VEX34N	B733	328	12:14	LDG	12	12
EWG031	AT42	LNO2D		SU	11	11
					10	10
DAT41G	RJ85	SPI2D		ENR	9	9
					8	8
					7	7

Arrivals on the departure runway force all departures out of their way, respecting pre-set separation values between ARR -> DEP and DEP -> ARR.

5.4 Runway crossings

Note: not implemented in the DMAN prototype.

Aircraft crossing the departure runway have normally lower priority than the take off and landing operations. That means they can be ignored in the DMAN-planning. However, departures that have to cross an active runway on their way to the departure runway suffer taxi-out delays. They can be reflected in the EXOT calculation.

5.5 Using further clearances to refine the planning

The A-CDM implementation manual defines only

- Start-up approved (milestone 14)
- Off-block (milestone 15)
- Take off (milestone 16)

In some EFS systems there are more events between milestone 14 and 16 that can be traced via the respective controller inputs. They can contain

- Start-up approved,
- Pushback approved,
- Taxi clearance received,
- Line-up clearance received and
- Take off clearance received.

Those clearances can be used to refine the DMAN plan.

What happens in DMAN in that case:

The expected time periods from one event to the next have to be known to DMAN, or in other words the timetable for the progress of the departures have to hold assumptions for that time-period.

If, for example the period between pushback approval and taxi clearance received is

predicted to last 200 seconds, but the input of “taxi-clearance” is registered already 130 seconds after pushback approval, the TTOT may advance by 70 seconds, dependant on the traffic planned in front of that respective departure.

5.6 Using position information from surface surveillance systems

Further refinement of the short term DMAN plan can be expected from airport surface surveillance systems. It is obvious that such systems, specifically with reliable target identification can be used to monitor the taxi-progress of departures against the present plan. However, ideal ways of doing this have not been defined.

One simple start is to define a point on a taxiway to the departure runway (or several points on all taxiways leading to the departure runway) and trigger the freeze-function for all flights detected to pass that point (those points).

Research and development in this area is pursued.

Find out more by following keywords like

Advanced Surface Movement Guidance and Control Systems (A-SMGCS) and
European airport Movement Management by A-SMGCS (EMMA).

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ABBREVIATIONS

ACC	Area Control Centre
A-CDM	Airport Collaborative Decision Making
A-DPI	ATC Departure Planning Information message
AFAS	Aircraft in the Future ATM System
AIBT	Actual In-Block Time
ALDT	Actual Landing Time
AMAN	Arrival Manager
AO	Aircraft Operator
AOBT	Actual Off-Block Time
AP	Airports Unit
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATOT	Actual Take Off Time
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit
CND	Cooperative Network Design
COE	Centre of Expertise
CTOT	Calculated Take Off Time (CFMU)
DMAN	Departure Manager
DPI	Departure Planning Information
ECAC	European Civil Aviation Conference
E-DPI	Early Departure Planning Information message
EET	Estimated Elapsed Time
EFS	Electronic Flight Strip
EIBT	Estimated In-Block Time
ELDT	Estimated Landing Time
EOBT	Estimated Off-Block Time
EXIT	Estimated Taxi-in Time
EXOT	Estimated Taxi-Out Time
FDPS	Flight Data Processing Systems
FIR	Flight Information Region
FUM	Flight Update Message
GH	Ground Handler

IFR	Instrument Flight Rules
MDI	Minimum Departure Interval
NEAN	Update Program Phase 2+
RWY	Runway
SID	Standard Instrument Departure
SMAN	Surface Management
T-DPI-t	Target Departure Planning Information message Status "target"
T-DPI-s	Target Departure Planning Information message Status 'sequenced'
TMA	Terminal Manoeuvring Area
TOBT	Target Off-Block Time
TSAT	Target Start-Up Approval Time
TTOT	Target Take Off Time
VFR	Visual Flight Rules
VTT	Variable Taxi Time