	<p>Episode 3</p> <p>D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment</p>	<p><i>Version : 1.00</i></p>
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EPISODE 3

Single European Sky Implementation support through Validation




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Episode 3
**D3.3.2-02b - Simulation Report on Business Trajectory
Management and Dynamic DCB - Annex B: Process
Simulation Experiment**

Version : 1.00

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TABLE OF CONTENTS

EXECUTIVE SUMMARY	8
INTRODUCTION	9
1.1 PURPOSE OF THE DOCUMENT	9
1.2 INTENDED AUDIENCE	9
1.3 DOCUMENT STRUCTURE	10
1.4 EXPERIMENTAL BACKGROUND AND CONTEXT	10
1.5 CONCEPT OVERVIEW	11
1.6 GLOSSARY OF TERMS	16
2 SUMMARY OF EXPERIMENT AND STRATEGY PLANNING	20
2.1 EXPECTED EXPERIMENTAL OUTCOMES, OBJECTIVES AND HYPOTHESES	20
2.1.1 <i>Description of Expected Experiment Outcomes</i>	20
2.1.2 <i>Experimental Assumptions</i>	22
2.1.3 <i>Experimental Objectives</i>	24
2.1.4 <i>Experimental Hypotheses</i>	25
2.2 CHOICE OF METHODS AND TECHNIQUES	25
2.2.1 <i>Overview of Method</i>	25
2.2.2 <i>Setting Up and Executing the Process Simulations</i>	26
2.2.3 <i>Time Planning</i>	26
2.2.4 <i>Details of the PROMAS platform</i>	27
2.3 METRICS AND MEASUREMENTS	30
2.4 VALIDATION SCENARIO SPECIFICATIONS	32
2.5 PROMAS IMPLEMENTED PROCESSES	33
2.5.1 <i>Impact of TTAs allocation on simulated sectors airspace</i>	38
2.6 TRAFFIC SAMPLES	40
2.7 ROLES	40
2.8 RESPONSIBILITIES	40
2.9 PROCEDURES	40
2.10 SIMULATION ENVIRONMENT	41
2.11 EXPERIMENTAL VARIABLES AND DESIGN	41
3 PROCESS - CONDUCT OF VALIDATION EXPERIMENT RUNS	42
3.1 EXPERIMENT PREPARATION	42
3.2 EXECUTED EXPERIMENT SCHEDULE	42
3.3 DEVIATIONS FROM THE PLANNING	44
4 PROCESS - EXPERIMENT RESULTS	45
4.1 MEASURED EXPERIMENT RESULTS	45
4.1.1 <i>Model Development View</i>	45
4.1.2 <i>Process View</i>	45
4.1.3 <i>Operational View</i>	53
4.2 CONFIDENCE IN EXPERIMENTAL RESULTS	76
4.2.1 <i>Quality of Results</i>	76
4.2.2 <i>Significance of Results</i>	77
4.3 UNEXPECTED EXPERIMENTAL RESULTS	77
5 ANALYSIS OF EXPERIMENT OUTCOMES	78
5.1 ANALYSIS OF OUTCOMES ON THE BASIS OF DETERMINED HYPOTHESES	78
5.2 ANALYSIS OF CONSEQUENCES OF OUTCOMES FOR EXPERIMENT OBJECTIVES AND ASSUMPTIONS	79
6 CONCLUSIONS AND RECOMMENDATIONS	84
6.1 FINDINGS	84
6.1.1 <i>Findings about concept clarification and operational scenarios</i>	84
6.1.2 <i>Key findings about validation techniques and the platform</i>	85
6.2 ISSUES	86



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

6.3	RECOMMENDATIONS	86
6.3.1	<i>General recommendations</i>	86
6.3.2	<i>Recommendations on supporting DODs and Operational Scenarios</i>	87
6.3.3	<i>Conclusions and Recommendations for Project Level.....</i>	87
6.4	CONCLUSIONS	87
7	REFERENCES AND APPLICABLE DOCUMENTS.....	88



LIST OF TABLES

Table 1: EP3 WP3.3.2 exercise overview	15
Table 2: Acronyms and Abbreviations	17
Table 3: Terms used for the dynamic DCB and BT management.....	19
Table 4: Time definitions used in dynamic DCB and BT management.....	19
Table 5: OI steps being addressed by EP3 WP3.3.2.	22
Table 6: The high level objectives for the Process Simulation work.....	25
Table 7: Hypotheses for the Process Simulation experiment.....	25
Table 8: EP3 WP3.3.2 Supported metrics and measurements	32
Table 9: RAMS scenarios with traffic samples extracted from PROMAS strategies.	39
Table 10: Nb of BT Negotiations.....	52
Table 11: Percentage of flights whose arrival order has been changed.....	57
Table 12: Average delay due to DCB Queue Process (min)	58
Table 13: Analyzed sectors and declared sector capacity values	61
Table 14: Analysed sectors and declared sector capacity values (STRATEGY 1)...	68
Table 15: Summary of Measured Experiment Results.....	76
Table 16: Hypotheses and outcomes	79
Table 17: Objectives addresses by the Process Simulation experiment	83

LIST OF FIGURES

Figure 1: Evolution of arrival traffic regulation processes.....	12
Figure 2: Temporal horizon of TTAs and CTAs	13
Figure 3: Process Simulation schedule of work	27
Figure 4: PROMAS platform link with RAMS	29
Figure 5: General description of PROMAS	30
Figure 6: Main processes implemented in PROMAS	33
Figure 7: PROMAS negotiation based in the medium/short term planning phase....	34
Figure 8: PROMAS negotiation based in the execution phase	35
Figure 9: Associated time to each action.....	36
Figure 10: TTA allocation	37
Figure 11: Traffic samples and RAMS Plus scenarios process generation	38
Figure 12: Schedule of work for the Process Simulation.....	43
Figure 13: BT Negotiations in Hail Validation Scenario and in Strategy FPFs.....	46
Figure 14: BT Negotiations in Hail Validation Scenario and in Strategy 1.....	46
Figure 15: BT Negotiations in Hail Validation Scenario and in Strategy 2.....	47



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

Figure 16: BT Negotiations in Snow Validation Scenario and in Strategy FPFS.	47
Figure 17: BT Negotiations in Snow Validation Scenario and in Strategy 1.	48
Figure 18: BT Negotiations in Snow Validation Scenario and in Strategy 2.	48
Figure 19: BT Negotiations in Rain Validation Scenario and in Strategy FPFS.	49
Figure 20: BT Negotiations in Rain Validation Scenario and in Strategy 1.	49
Figure 21: BT Negotiations in Rain Validation Scenario and in Strategy 2.	50
Figure 22: BT Negotiations in Wind Validation Scenario and in Strategy FPFS.	50
Figure 23: BT Negotiations in Wind Validation Scenario and in Strategy 1.	51
Figure 24: BT Negotiations in Wind Validation Scenario and in Strategy 2.	51
Figure 25: Validation Scenario specifications.	53
Figure 26: Delay distribution when applying a DCB Queue process to the same traffic sample for Validation Scenarios Hail and Snow and the three Strategies.	55
Figure 27: Delay distribution when applying a DCB Queue process to the same traffic sample for Validation Scenarios Rain and Wind and the three strategies.	56
Figure 28: <i>Hourly runway operations</i> count for RWY 33 R of Madrid Barajas airport	59
Figure 29: <i>Hourly runway operations</i> count RWY 33 R (zoom in the range of interest)	60
Figure 30: Entry Sector Operation Count (LECMCJL)	62
Figure 31- Entry Sector Operation Count (LECMCJU)	62
Figure 32: Sectors LECMCJL/U RAMS scenario capture	63
Figure 33: Entry Sector Operation Count (LEMDESN)	64
Figure 34: Sectors LEMDESN RAMS scenario capture.	65
Figure 35: Entry Sector Operation Count (LEMDREN)	65
Figure 36: Sectors LEMDREN RAMS scenario capture	66
Figure 37: <i>Hourly runway operations</i> count for RWY 33 R of Madrid Barajas airport STRATEGY 1.	67
Figure 38: <i>Hourly runway operations</i> count RWY 33 R (zoom in the range of interest) STRATEGY 1.	67
Figure 39: Entry Sector Operation Count (LECMCJL) STRATEGY 1	69
Figure 40: Entry Sector Operation Count (LECMCJU) STRATEGY 1.	69
Figure 41: Sectors LECMCJL/U RAMS scenario capture STRATEGY 1	70
Figure 42: Entry Sector Operation Count (LEMDESN) STRATEGY 1	71
Figure 43: Sectors LEMDESN RAMS scenario capture STRATEGY 1.	72
Figure 44: Entry Sector Operation Count (LEMDREN) STRATEGY 1	73
Figure 45: Sectors LEMDREN RAMS scenario capture STRATEGY 1.	74



EXECUTIVE SUMMARY

Several studies foresee a huge increase in the number of saturated airports operating at full capacity for most of the day. This emphasises the need for dynamic and adaptive processes to manage efficiently short notice events that impact on arrival capacity.

The SESAR ConOps introduces the Dynamic demand and capacity balance as one of the concept elements that are expected to have a significant impact on the way arrival traffic will be adapted to the available airport capacity both in the short term and execution phases. It is expected to provide flexible and efficient arrival congestion management through DCB/sequencing time-based measures.

The exercise EP3 WP 3.3.2 'Business Trajectory Management and Dynamic DCB' addresses the management of arrival traffic congestion situations due to a non severe capacity shortfall –mainly at large or medium size airports- in the short-term planning and execution phases from a few hours in advance up to the AMAN boundary. The exercise focuses on managing demand-capacity imbalances that require the re-planning of business trajectories by airspace users, but are below the level of severity that would trigger the UDPP process. This document (an annex to the main report) describes in detail the Process Simulation experiment.

The main objective of the Process Simulation experiment addresses the development and refinement of the processes involved in applying dynamic DCB solutions, as well as the assessment of a new validation technique by using PROMAS (Processes Management Simulator).

PROMAS simulation exercise reallocates TTAs to the flights affected by a capacity constraint to fulfil the restriction. It is assessed through 12 validation scenarios, based on the magnitude of the congestion, the accuracy of the situation and priorities defined, while integrating airspace users' business constraints and preferences

The main conclusion extracted from this exercise is the feasibility of the concept. It was possible to create an arriving queue according to the restriction. However, it was not possible to define the best priority-allocation strategy, since it is highly linked to each particular assessed validation scenario. There are also many points that have to be defined by experts, as the need to refine the processes and actors involved in a dynamic DCB process, since these could affect to the feasibility of the process. As well as the need to assess the new conditions (rerouting, level changes...) that aircrafts should follow to fit the restriction.

It is also recommended to refine the conditions that trigger UDPP process, which should be defined depending not only in the level of the severity shortfall but also in the traffic pattern

PROMAS is a new platform that has been developed in the scope of this exercise. Due to this fact, there have been a lot of simplifications that make the results only applicable at local level. Anyway, it stresses the trend of the traffic and the main problems a non severe capacity shortfall solution has to face.



INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

Two experiments were carried out under the same exercise for EP3 WP 3.3.2, which contributes to the validation activities of EP3 Work Package (WP) 3. One experiment used Process Simulation (which is the subject of this document), and the other Gaming. So, three validation documents were produced:

- a report summarising the two experiments as part of one exercise. This is the main report [1];
- a document (as an annex to the main report) that describes in detail the Gaming experiment [2];
- a document (as an annex to the main report) that describes in detail the Process Simulation experiment (this document).

The validation exercise plan [3] may provide useful further details about this experiment, if the reader requires.

The exercise combines human-in-loop gaming sessions and automatic process simulations conducted respectively by EUROCONTROL's Experimental Centre (EEC) and INECO. Those two activities address the same operational scenarios dealing with the management of arrival (mainly) and en-route (partly) demand-capacity imbalances that are predicted to occur in the short-term planning and execution phases.

1.2 INTENDED AUDIENCE

This document is intended for work package, sub-work package and exercise leaders of EP3 WP3 and EP3 WP2. Through EP3 WP2.2, it should also be of interest for EP3 WP4 and EP3 WP5 as it deals with transversal topics such as arrival congestion and business trajectory management.

In detail, the intended audience includes:

- EP3 WP2 System Consistency;
 - EP3 WP2.2 Leader (Clarification and Refinement of SESAR ConOps);
 - EP3 WP2.3 Leader (Validation Process Management);
 - EP3 WP2.4.1 Performance Framework
 - EP3 WP 2.5 Leader (Reporting and Dissemination);
- EP3 WP 3 Collaborative Planning:
 - EP3 WP 3 Leader;
 - EP3 WP 3.2.1 Leader (EP3 WP3 Validation Strategy and Support);
 - EP3 WP 3.2.2 Leader (Operational Concept Refinement);
 - EP3 WP 3.3 Leader (Collaborative Planning Processes Activities);
 - EP3 WP 3.3.1 Leader (Expert groups);
 - EP3 WP 3.4 Leader (Results and Analysis Report);
- The SESAR Joint Undertaking (SJU).



1.3 DOCUMENT STRUCTURE

The document is structured as follows:

- Section 0 introduces the scope and justification of the validation exercise (i.e., covering Gaming and Process Simulation);
- Section 2 summarises the experimental plan;
- Sections 3 and 4 describe the experiment and results;
- Section 5 provides an analysis of the outcomes of the experiment;
- Section 6 provides conclusions and recommendations;

Unless otherwise stated, each section concerns itself with Process Simulation only.

1.4 EXPERIMENTAL BACKGROUND AND CONTEXT

The document reports on the Process Simulation experiment and its contribution to the validation exercise EP3 WP3.3.2 which is done within EP3 WP3 Collaborative Planning.

The SESAR definition phase [8] identified main blocking points in the current ATM system. Among these, the EP3 WP3 validation strategy listed those that are directly related to collaborative planning and thus in the scope of EP3 WP3: Some of those blocking points are directly linked to the EP3 WP3.3.2 exercise and concern both arrival and en-route dynamic DCB measures:

- **Cooperation of all ATM actors in ATFCM processes at network level;**
- **Respect of ATFCM measures;**
- **Balanced approach between ATFCM and capacity management.**

Moreover, several prospective studies predict a huge increase in the number of saturated airports operating at full capacity for most of the day. This emphasises the need for dynamic and adaptive processes to manage efficiently short notice events that impact arrival capacity.

The SESAR ConOps introduces the following set of concept elements that will have a significant impact on the way arrival traffic will be adapted to the available airport capacity both in the short term and execution phases:

- **Queue management** will allow a significant extension of the geographical and temporal scope for arrival congestion management in the execution phase;
- **Business trajectory management** both in the short-term planning (SBT) and the execution phases (RBT);
- **Dynamic demand and capacity balancing (DCB);**
- **UDPP** (User Driven Prioritisation Process).

The combined application of these concepts should provide flexible and efficient arrival congestion management through DCB/sequencing time-based measures. These will be adapted to the magnitude of the congestion and the accuracy of the situation while integrating airspace users' business constraints and preferences.

Still a large number of high-level open issues remain that prevent stakeholders from having a clear and commonly agreed picture of the associated ATM processes. The following questions are addressed by this exercise:

- How will airspace-user business trajectory management interact with dynamic DCB and queuing?



- As ground delays will remain the safest and most efficient means to resolve significant arrival demand/capacity imbalances, which collaborative decision making processes and functions will cover this aspect of demand-capacity balancing in the short term planning phase? And, how will UDPP be triggered in this context and to which situations should it apply?
- The extension of the geographical range of an arrival queuing process in the execution phase will fundamentally shift the nature of the process from a local to a network scale. This raises many issues requiring further investigation, such as:
 - The involvement of network management actors in the process and their share of responsibilities;
 - The interface between DCB in the short term planning phase and traffic management/regulation processes in the execution phase;

The purpose of this exercise is to provide an initial contribution to concept clarification by providing some elements (mainly qualitative) to answer the above questions;

The second key objective of the exercise is to initiate the building of a validation infrastructure – including methodology, techniques and platforms – to support future validation work for SESAR network operations.

1.5 CONCEPT OVERVIEW

This exercise looked principally at the management of arrival traffic congestion in the short term planning and execution phases from a few hours in advance up to the AMAN boundary.

Referring to EP3 WP3's Detailed Operational Descriptions (DODs) and the operational scenario OS-11, three main processes can contribute to the management of arrival demand-capacity imbalances on the day of operations working at different look-ahead time horizons and level of granularity.

- DCB/UDPP processes applied to flights in planning phase and issuing TTAs;
- Dynamic DCB issuing TTAs and operating within the [2 hours, 40 minutes] timeframe, regarding the look-ahead to a detected imbalance. Dynamic DCB applies both to flights in planning and execution phases;
- AMAN operating within a look-ahead limited to 40 minutes (the exact value to be validated).

Figure 1 provides an illustration of what is the evolution from current situations.

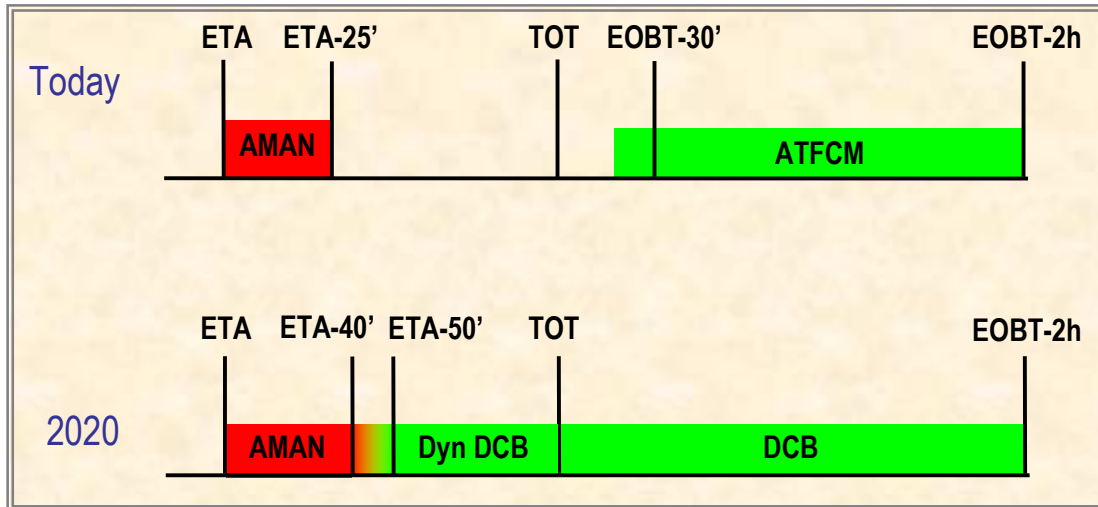


Figure 1: Evolution of arrival traffic regulation processes

The 'barrier' between planning and execution is not easy to delineate because many situations require a coordinated management of SBTs and RBTs. To simplify matters, dynamic DCB and DCB processes are, in a first validation step, merged into a unique layer. This layer/process will be collectively called 'dynamic DCB' in the rest of this document.

The dynamic DCB solution for arrivals involves an airport alerting the network of a demand capacity imbalance resulting either from a capacity shortfall or a deviation from the network/airport operations plan. The affected flights are then identified and each one is sent a TTA (target time of arrival) constraint which will indicate its delay. The airline operator then decides how to assign the delay; for example, a ground delay if the aircraft has not taken off, speed reduction or vectoring if they have already taken off or a combination of the two. The allocation of TTAs must also take into account the emission of CTAs (calculated time of arrival) by the AMAN. Figure 2 shows the interaction between the dynamic DCB queue and the AMAN queue.

The terms 'queue' and 'sequence' that appear in this report are used interchangeably with the terms 'AMAN' and 'DCB'. For example, no distinction is made between the two terms 'DCB sequence' and 'DCB queue'.

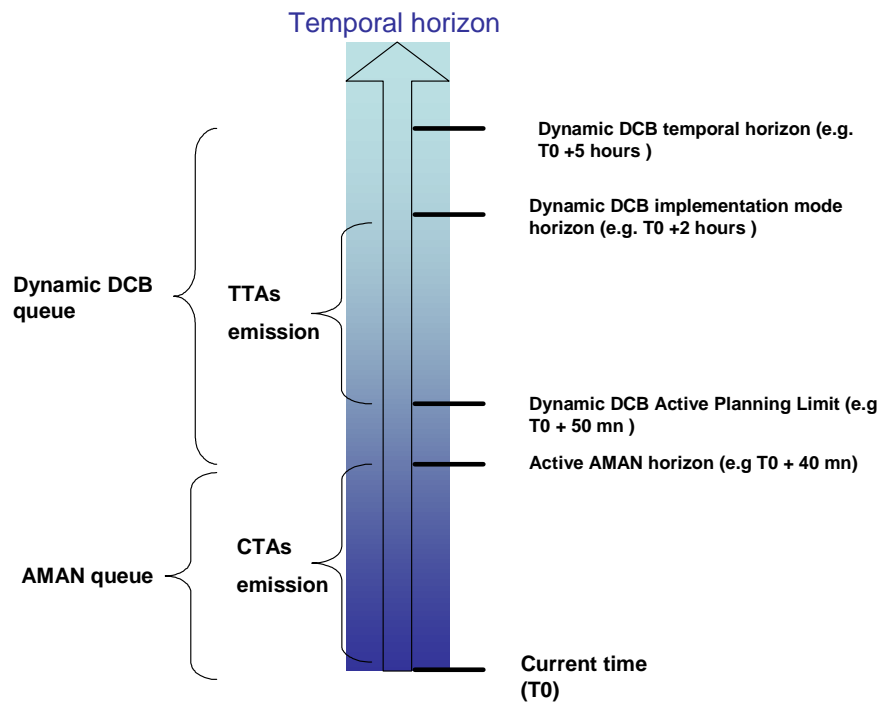


Figure 2: Temporal horizon of TTAs and CTAs

It should be highlighted that:

- This decomposition between dynamic DCB and AMAN must be viewed in terms of process, not necessary in terms of tools;
- **The parameter values in Figure 2 are given for example only.** It will be an objective of future exercises to determine appropriate values.


There are major differences between TTAs issued by the dynamic DCB process and the CTAs issued by the AMAN process:

- TTAs are much less restrictive and accurate than CTAs: [-3mins, +3mn] for TTAs and [-30s,+30s] for CTAs;
- Business trajectory adaptation in response to a TTA must not interfere with tactical separation management processes for flights in the execution phase.

Dynamic DCB solutions combined with business trajectory management are intended to enhance current operations. Currently, ATFCM provides ground regulations and gives implicitly the 'how' to resolve capacity problems. Dynamic DCB solutions extend the scope of action into the execution phase and provide constraints that the involved parties must meet; aircraft operators will decide how to meet them. The process of implementing dynamic DCB solutions will increase co-operation at local and regional levels.

There is potentially a performance conflict with a trade-off between individual area control centre (ACC) targets and network targets. There is also a question of how to ensure participation and buy-in from ACCs as these measures will constrain their options and will require effort to put in place.

The key concept elements addressed in this exercise are business trajectory management and dynamic DCB. More precisely, the exercise addresses the collaborative processes to adjust the demand to the available capacity in the short-term planning and execution phases.

	Episode 3 D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment	<i>Version : 1.00</i>
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Full UDPP process definition is out of the scope of this exercise. Therefore, the exercise focuses on managing demand-capacity imbalances that require the re-planning of business trajectories by airspace users, but are below the level of severity that would trigger the UDPP process. However, the exercise will investigate the conditions under which UDPP might be triggered.

Table 1 summarises the scope of the exercise:

EP3 WP3.3.2 Business Trajectory management	
Leading organization	EUROCONTROL
Validation objectives	<p>The key concept elements addressed in this exercise are business trajectory management and dynamic DCB. More precisely, the exercise addresses the collaborative processes to adjust the demand to the available capacity in the short-term planning and execution phases. It is assumed in this exercise that the capacity has been previously optimised to the maximum extent.</p> <p>Full UDPP process definition is out of the scope of this exercise. Therefore, the exercise focuses on managing demand-capacity imbalances that require the re-planning of business trajectories by airspace users, but are below the level of severity that would trigger the UDPP process. However, the exercise will investigate the conditions under which UDPP might be triggered.</p>
Rationale	<p>Two different simulation techniques are used and tailored to cover the need of the exercise:</p> <ul style="list-style-type: none"> • Gaming human-in-the-loop exercise refining operational scenarios and providing elements to define actors' behaviour models using a model called DARTIS. The first step will be to focus on arrival congestion management through a gaming exercise, and the management of TTAs in relation to business trajectory management; • Process Simulations allowing modelling and incrementally refining the designed processes through the identification of gaps. The scope of the Gaming human-in-the-loop exercise will be extended (geographical extension and range of simulated dynamic DCB measures). At least 2D distortions of business trajectories would be addressed. The simulation of processes, relying on the PROMAS platform will assess the SESAR collaborative planning processes extending the conclusions obtained in the Gaming human-in-the-loop exercise. On the other hand, business trajectories and network entities (sectors, airports) will be simulated in a high-level way, by means of exchanging data with an external and simplistic performance model.
Expected results	<p>Results expected from this exercise are:</p> <ul style="list-style-type: none"> • Refined operational scenarios, including the following elements: <ul style="list-style-type: none"> ○ The scope of dynamic DCB (what level of congestion should it address?); ○ The roles and responsibilities of actors; ○ The method of operation (or more reasonably part of it) for dynamic DCB and business trajectory management, including an ordered sequence of actions; ○ The high level definition of system functions that support the process (queuing, network monitoring, users' interactions...); • Elements to refine actors' behaviour models, in particular related to network monitoring (network managers) and the management of dynamic DCB constraints in business trajectories (airspace users); • Initial assessment of the impact on performance (mainly efficiency) and



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

EP3 WP3.3.2 Business Trajectory management	
	<p>ATC operations.</p> <p>In addition, some outputs to the macro analytical model will be provided:</p> <ul style="list-style-type: none"> • The identified processes that have been triggered during the Gaming & Process Simulation exercises; • A set of bottlenecks and gaps within the ATM Process Model; • The actors' behaviour recorded during the Gaming sessions; • Performance assessment results.
OI steps addressed	<p>DCB-0208: Dynamic ATFCM.</p> <p>AUO-0203: Shared Business / Mission Trajectory (SBT).</p> <p>AUO-0204: Agreed Reference Business / Mission Trajectory (RBT).</p> <p>AUO-0102 User Driven Prioritisation Process (UDPP) (very partly).</p> <p>DCB-0103: SWIM enabled NOP.</p> <p>DCB-0305: Network Management Function in support of UDPP (partly).</p>
Validation Techniques	Gaming and fast-time modelling.
Supporting DOD / Operational Scenario	<p>DOD M2/3: Medium/Short Term network planning.</p> <p>DOD E4: Network management in execution phase.</p> <p>Scenario OS11: non-severe (no UDPP) Capacity shortfalls impacting arrivals in the short-term.</p> <p>Scenario OS-36: non-severe (no UDPP) Capacity shortfall impacting multi-nodes in the short-term.</p>
Geographical area – performance framework level	ECAC area

Table 1: EP3 WP3.3.2 exercise overview



1.6 GLOSSARY OF TERMS

Term	Definition
ACAP	Arrival Capacity
ACC	Area Control Centre
AO	Aircraft Operator
AMAN	Arrival MANager
ANSP	Air Navigation Service Provider
AOC	Aircraft Operator Centre
APOC	Airport Operations Centre
ASAT	Actual Start-up Approval time
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATA	AMAN Time of Arrival
AUO	Airspace User Operations
BT	Business Trajectory (whether shared SBT or reference RBT)
CAMES	Co-operative ATM Measures for a European Single Sky
CDA	Continuous Descent Approach
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit
ConOps	Concept of Operations
CTA	Calculated Time of Arrival
CUPT	Current User Preferred Business Trajectory
DARTIS	Decision Aid to Real Time Synchronisation
DCB	Demand and Capacity Balancing
DMEAN	Dynamic Management of the European Airspace Network
DOD	Detailed Operational Description
ECAC	European Civil Aviation Conference
EOBT	Estimated Off Block Time
E-OCVM	European Operational Concept Validation Methodology
EP3	Episode 3 project from the European Commission
ETA /ETO	Estimated Time At / Estimated Time Over
FAB	Functional Airspace Block
FMP	Flow Management Position
FPFS	First Planned, First Served
HMI	Human Machine Interface



Episode 3
D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

Term	Definition
IP	Implementation Package
KPA	Key Performance Area
KPI	Key Performance Indicator
LVP	Low Visibility Procedures
MTV	Medium Term Validation
NOP	Network Operation Plan
OI	Operational Improvement
OPLOG	Operational Log
OS	Operational Scenario
PROMAS	Process Management Simulator
PRR	Performance Review Report
PRU	Performance Review Unit
QTA	Queuing Time of Arrival
RBT	Reference Business Trajectory
RNM	Regional Network Manager
RTA	Required Time of Arrival
SBT	Shared Business Trajectory
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SRNM	Sub Regional Network Manager
SWIM	System Wide Information Management
TBV	To Be Validated
TMA	Terminal control Area
TOBT	Target Off Block Time
TOT	Take Off Time
TSAT	Target Start-up Approval Time
TTA	Target Time of Arrival
TTOT	Target Take Off Time
UDPP	User Driven Prioritisation Process
WP	Work Package

Table 2: Acronyms and Abbreviations

Term ¹	Definition
Airline Default Delay Absorption	This is similar to DDAS (see below) but for business trajectory calculation

¹ Note that most of these terms are specific to this exercise and are not general SESAR terms.




Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

Term ¹	Definition
Strategy (ADDAS)	on the airline side. It shall be possible to define different strategies (mixed or 'ground delay') depending on airline preferences.
Aircraft Operator (AO)	The generic term for a user of airspace, which includes commercial airlines, business jets, military and private pilots.
Current User preferred BT (CUPT)	Corresponds to the trajectory (including off block/in-block times) without any dynamic DCB constraints. (Used within DARTIS)
DCB TTA Target Location	The reference location at which the QTAs and TTAs are calculated in the dynamic DCB process. Options include the AMAN boundary, the runway or the IAF.
Default Delay Absorption Strategy by ATM (DDAS)	This is a parameter used to determine how the delay (resulting from a TTA) to be absorbed is distributed between the air and ground segments of the BT calculated/ revised by ATC (not the AOC). Two options shall be defined: <ul style="list-style-type: none"> • Ground delay: the whole delay is attributed to the ground; • Mixed delay: the delay is split between the air and ground segments of the trajectory.
Delay Threshold	The Delay Threshold is the minimum level of arrival congestion/delay beyond which the dynamic DCB process can be automatically triggered. It expresses the share of responsibility between local/network management for the management of congestion and represents an amount of delay that can be safely and smoothly managed by local/sub-regional planning processes.
Game	A simulation consists of Game Players, a game platform, i.e., DARTIS, a Game Scenario (set up by a Scenario Designer), Game Scripts, a set of playing rules, a Game Manager, and a traffic sample. The game will allow freedom of action for the Game Players.
Game Manager	The person in charge of the game.
Game Players	Humans and computer players that play a role in a game. An example of a role is an Aircraft Operator for Airline X.
Game Scenario	This is a scenario that will set the context of a game, giving the high level events that will or may occur in the game. The Game Scenario is set up by the Scenario Designer who pre-selects various DARTIS options (such as the rules by which Aircraft Operators can absorb delay) in order that these various dynamic DCB concept options can be explored for suitability and efficiency.
Game Script	A Game Script gives details of a Game Scenario. Different Game Players may have different Game Scripts (e.g., Game Players that are playing different Airline Operators may be instructed to adopt different delay absorption strategies). The Game Scripts may not necessarily be complete or accurate (this will depend on the game).
Process Simulation	A Process Simulation consists of a platform (i.e., PROMAS), a scenario (set up by a Scenario Designer), a set of Roles, Rules and Functions, and a traffic sample. The Process Simulation will allow a great number of roles and several strategies to be modelled in an easy and quick way.
PROMAS Scenario	The PROMAS Scenario, composed of a set of processes, roles, rules, strategies and actors, tries to model in a realistic way the BT management concept in some special conditions. It is set up by the Scenario Designer.
Roles and Actors (PROMAS)	Automated Roles and Actors. An example of a role is a Sub-Regional Manager (containing rules). An actor is the flight crew in the short-term planning phase (not containing rules).
Rules/Strategies	Different Roles may have different Rules, and their combination will lead to a strategy (e.g., Roles that model different Airline Operators may be

	Episode 3 D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment	<i>Version : 1.00</i>
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Term ¹	Definition
	instructed to adopt different delay absorption strategies).
Scenario Designer (DARTIS)	The person who selects specific parameter options in DARTIS to design a game for the Game Players to play.
Scenario Designer (PROMAS)	The person who models the different processes, roles, rules, strategies and actors to assess the BT management concept.

Table 3: Terms used for the dynamic DCB and BT management

Term ¹	Definition
ATA	AMAN Time of Arrival at the airport. This is the arrival time calculated by the AMAN.
CTA	Calculated Time of Arrival on the congested point. CTAs are sent to the aircraft / ATC based on ATAs calculated by the AMAN. CTAs are similar to TTAs sent by the dynamic DCB process.
ETA/ETO	Estimated Time over the congested point (airport, navigation point, sector entry). An ETA/ETO is extracted from the current user preferred trajectory.
QTA	'Queuing Time on Arrival'. This is the theoretical estimated time that an aircraft would be delayed at a (pre-defined) congested point. Thus, QTAs will be used as an indicator of likely congestion. If the level of delay is unacceptable, a dynamic DCB process could be implemented.
TTA	'Target Time of Arrival'. This is the arrival time at the dynamic 'DCB TTA Target Location' allocated to an Aircraft Operator as a result of a dynamic DCB process. A TTA is based on a QTA but not necessarily equal to it.
EOBT	Estimated Off Block Time
ETOT / TOT	Estimated Take Off Time / Take off Time
TOBT	Target Off Block Time. This is the Off Block time provided by AOs in the business trajectory and takes into account any dynamic DCB constraints (TTAs) that exist.
TTOT	Target Take Off Time. This is the take-off time due to the TTA allocation process.

Table 4: Time definitions used in dynamic DCB and BT management



2 SUMMARY OF EXPERIMENT AND STRATEGY PLANNING

2.1 EXPECTED EXPERIMENTAL OUTCOMES, OBJECTIVES AND HYPOTHESES

2.1.1 Description of Expected Experiment Outcomes

The Process Simulation experiment is focused on developing and refining the processes involved in applying dynamic DCB solutions, as well as assessing on a new validation technique by using PROMAS (Processes Management Simulator). The expected outcomes were both qualitative and quantitative.

- Qualitative results:
 - Highlight ‘incoherencies’ between the Experts’ opinions and the description of an Operational Scenario by assessing the dynamic DCB processes included in the ATM Diagram Model;
 - Detection of potential bottlenecks: indicating the actors or functions that are highly involved and the reasons of that;
 - Contribution to Concept, DODs and Operational Scenarios refinement;
- Quantitative results (by post-processing):
 - Process view:
 - Number of negotiations/data exchanged between the different actors/functions (in potential bottleneck situations);
 - Operational view:
 - Delay Distribution generated;
 - Percentage of flights that have suffered changes in their trajectory while the dynamic DCB solution is applied;
 - Peak of negotiations of departure APOCs;
 - Information to support the development of the TTA Allocation Strategy.

Performance assessment is not the main objective of the experiment, but process assessment to analyse the coherence of the ATM system in a particular scenario. Therefore, the metrics do not have to strictly comply with the metrics defined in the performance framework document produced by Episode 3 WP2 [4]. However, some other quantitative and qualitative metrics regarding with process assessment have been defined and measured.

2.1.1.1 Experimental Outcomes and Operational Improvement Steps

These outcomes are linked to the operational improvement steps that have been addressed, to some degree, by the two EP3 WP3.3.2 experiments, see Table 5. The +/- values in the Impacted KPAs’ column indicate the size of the expected impact of the operational improvement step on the KPA. The grey-coloured rows highlight the operational improvement steps related to UDPP; which were only partially addressed in the experiments.



Episode 3
D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

OI-Step	Description	IP	Impacted KPAs (expected) ²	How the OI step has been addressed in the exercise
DCB-0208	Dynamic ATFCM/DCB	IP2	CAP +++ SAF + EFF +	This OI Step is partially addressed. The exercise scope is limited to the adaptation of business trajectories to the available capacity – mainly airport arrival capacity – through the management of time constraints (TTAs) in the business trajectories. In the gaming exercise, those TTAs can be applied either at the destination airport or on en-route points. TTAs can be issued either automatically by a dynamic DCB queuing system or manually by network managers. TTAs can be applied to both SBTs and RBTs within a predefined window, which ends 40/50 min before ETA to avoid interactions with ATC tactical control.
AUO-0102	User Driven Prioritisation Process (UDPP)	IP2	EFF +++	The UDPP process is not simulated. In the Gaming, actors can simulate a 'dummy' activation/deactivation action of the UDPP process. Gaming actors' actions are recorded –without any impact on the simulation - providing some elements related to the level of severity requiring the triggering of the UDPP process and the associated roles and responsibilities.
AUO-0203	Shared Business / Mission Trajectory (SBT)	IP2	FLX + PRD + EFF +++ ENV +	AOC gaming actors are provided with 'rough' facilities for planning/ re-planning shared business trajectories taking into account any TTAs. Re-planning of SBTs is limited to time modifications in the business trajectories (no 2D/3D management).
AUO-0204	Agreed Reference Business / Mission Trajectory (RBT) through Collaborative Flight Planning	IP2	CAP + FLX + PRD +++ EFF + ENV +	AOC gaming actors are provided with 'rough' facilities for planning/re-planning reference business trajectories taking into account all TTAs. Re-planning of RBTs is limited to time modifications (i.e., no 2D/3D management).
DCB-0103	SWIM enabled NOP	IP2	PRT + PRD +++	In the simulations, the NOP contains all business trajectories, network node capacities, dynamic DCB constraints (TTAs), network monitoring indicators (as available in

² CAP – Capacity, SAF – Safety, FLX – Flexibility, PRD – Predictability, EFF – Efficiency, ENV – Environmental Sustainability, PRT – Participation. The assessment of the expected impact on the KPAs was performed by SESAR Task 2.2.4; see The European Air Traffic Management Master Plan Portal www.atmmasterplan.eu.

OI-Step	Description	IP	Impacted KPAs (expected) ²	How the OI step has been addressed in the exercise
				current operations) and overload alerts. All the NOP information evolves dynamically during the simulation and is shared by all the actors.
DCB-0305	Network Management Function in support of UDPP	IP2	FLX +++	The dynamic DCB queuing provides the default delay allocation as an initial basis for discussions/negotiations between airspace users (as previously mentioned this part is not simulated). In addition, the dynamic DCB queuing process supports individual requests from airspace users for sequence changes using a slot swapping process.

Table 5: OI steps being addressed by EP3 WP3.3.2.

The stakeholders want the results of the exercises to refine the concept description of dynamic DCB. The operational ATM stakeholders want a clearer idea of what the dynamic DCB solutions are, how they can be applied, and how they will impact their operations in the future. EP3 stakeholders (EP3 WP2, EP3 WP3) want to update the DODs and the operational scenarios as well as ensuring that the concept refinement is consistent across work packages.

2.1.2 Experimental Assumptions

There are some common assumptions between the Gaming and Process Simulation experiments, and some that are unique to one experiment or the other. The following assumptions are common to both experiments:

- The airspace around the Fiumicino (LIRF), Milan (LIML), Barajas (LEMD) and Barcelona (LEBL) airports does not include any prohibited/restricted/segregated areas. Furthermore, the sectorisation and route network are those currently (i.e., 2009) implemented operationally;
- Most anticipated/recurrent airport traffic demand-capacity imbalances are dealt with in the long and medium term planning phases through the layered planning process. Nevertheless, in order to ensure an optimal utilisation of airport resources, a margin is considered, leaving a significant proportion of low and medium severity imbalances to be managed on the day of operations when the picture of traffic and capacity is better known. Moreover, due to the reduction of troughs in the daily traffic demand at major airports; the negative impact of unanticipated capacity shortfalls is significantly increased if not treated adequately by DCB in the short-term planning phase;
- There is no centralised ATFCM slot allocation process. The DCB regulation of arrival traffic in the short-term phase (and partly in the execution phase) can be viewed as a decentralised queuing process. The main difference with the AMAN process is that dynamic DCB works at a different level of granularity, accuracy and time horizon and implies different actors and CDM processes. This is not explicitly described in the ConOps, which provides a high level description of the dynamic DCB process and the short-term planning phase. This leaves room for different interpretations;



Episode 3


D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

- In situations that require the UDPP process to be triggered, the dynamic DCB queuing process provides the default delay allocation as a basis for negotiation between airspace users and the default measure in case of no agreement. The ConOps explicitly mentions this as part of the network management function;
- The implementation of the SESAR concept will not necessarily induce a stable NOP or traffic picture in the short term planning and execution phases. The concept mentions explicitly that airspace users can refine their business trajectories until shortly before off-block time, taking into account updated information (meteorological forecast...), and that an RBT can be frequently updated during its life. Moreover, SESAR D2 [5][1] raises clear performance requirements related to the flexibility KPA;
- The required technical enabler of SWIM enabled NOP is in place;
- Functional airspace blocks (FABs) will be in place;
- In nominal conditions (UDPP not triggered), flights can only be exempted from meeting dynamic DCB solution constraints (refuse TTA) with good reason: emergency on-board, insufficient fuel to meet constraints, or through a slot swapping request;
- Dynamic DCB solutions can only be applied to flights inside the ECAC region;
- Departure airports can accommodate all requests for on-ground delays (i.e., there are no constraints on how many aircraft can be delayed on the ground and for how long);
- All aircraft in the 2020 traffic sample can implement the BT updates needed to meet their CTAs. In addition, Air and Ground are sufficiently equipped to be able to respect Target Times and to negotiate if cannot be achieved;
- Due to the flexibility required by airspace users and the unavoidable uncertainties of airport operations, the accuracy/stability of the traffic picture in the short-term planning phase will not be significantly higher in 2020 than in current operations. Therefore using current traffic records to simulate the uncertainty/instability of the traffic picture in SESAR 2020 context is acceptable.

The following assumptions are specific to the Process Simulation experiment:

- The acceptable limit of ground delay is 15 minutes;
- For a flight already airborne, it should be better not to increase the speed by more than the 10% neither decreasing the speed by more than the 3%;
- During one Process Simulation there will be only one capacity shortfall and one capacity recovery;
- The AMAN system will manage flights 40 minutes prior to landing, provided that the RBT has been published (case departure and arrival airports are very close). This parameter is called the 'AMAN Advisory Active Horizon';
- Flights can be submitted to a dynamic DCB queue management process at the latest 50 minutes before their ETA/TTA. This parameter is known as the 'DCB Queue Active Limit';
- Flights between the AMAN Advisory Active Horizon and the DCB Queue active limit will not be assigned with a TTA since they will receive a CTA in a few minutes;
- The dynamic DCB Queue Management process only provides a TTA if the flight has reached a time horizon of two hours (to be validated) before ETA.

	Episode 3 D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment	<i>Version : 1.00</i>
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2.1.3 Experimental Objectives

The following objectives are specific to the Process Simulation experiment:

ID	Objective Description
Clarification of the concept:	
O.P1	Define the system functions that are needed to support the dynamic DCB process and BT management (queuing, network monitoring, interactions between APOC and users...).
O.P2	Define the interaction of DCB process (queue) with some execution phase processes (AMAN).
O.P3	Gain a better understanding of how actors work within the dynamic DCB process and BT management, and in particular, how actors interact.
O.P4	Measure the number of information exchanges between the different involved actors and the number of triggered processes to detect the main processes and actors that could be supposed to be likely bottlenecks.
O.P5	Provide some elements about which information should be exchanged, and when, to assure a successful synchronisation between AMAN and dynamic DCB Queue processes.
Assessment of process feasibility:	
O.P6	Define an initial dynamic DCB and BT management process that covers implementing, amending and cancelling dynamic DCB solutions (queue).
O.P7	By designing three different TTA allocation algorithms: <ul style="list-style-type: none"> • To assess both the effectiveness and the delay impact on the different type of flights; • To launch specific issues to refine these strategies regarding the airborne priority subject; • To support the functional development and refinement of the best TTA allocation Strategy.
O.P8	Support the functional development of some of the functionalities that should be included in the future Network Management Function.
O.P9	Provide an assessment of the impact on BT management related to the different TTA Allocation Strategies being addressed.
O.P10	Analyse the relationship between the severity of the shortfall capacity and the delay to be managed by dynamic DCB queue measures.
O.P11	Study the timeframe when dynamic DCB queue measures can be implemented in an effective way (i.e. sudden shortfalls, anticipated shortfalls, short duration, long duration, etc.).
O.P12	Identify the incoherencies and bottlenecks of the processes described in the OS-11 what would support both the refinement of the concept and the updating of this operational scenario.
Exploration of new techniques:	
O.P13	Develop PROMAS, new process simulation tool for assessing complex systems able

ID	Objective Description
	to simulate roles, procedures...
O.P14	Demonstrate that both planning processes and SBT/RBT data can be linked by PROMAS to be used in future studies.

Table 6: The high level objectives for the Process Simulation work

2.1.4 Experimental Hypotheses

The following hypotheses are specific to the Process Simulation experiment:

ID	Hypotheses Description
H.P1	The dynamic DCB and BT Management part of the ATM Process model establishes without incoherencies or loops-without-end who is responsible for carrying out any process, which information is required for it, what information is output and to whom, and the duration of the process.
H.P2	Dynamic DCB and BT management processes will improve the management of the current DCB problems by means of implementing some planning/execution solutions. Specially, although not only, those processes triggered once a flight has taken-off until it reaches the AMAN active horizon.
H.P3	Dynamic DCB and BT management processes will allow airspace users to decide how they want to adapt their SBT/RBT to meet a constraint.
H.P4	AMAN and dynamic DCB Queue processes will be coordinated and synchronised by means of a clear procedure.
H.P5	Non-severe capacity shortfalls can be solved without UDPP. Severity can be defined as the maximum admissible delay per flight (e.g. 15 minutes of ground delay).

Table 7: Hypotheses for the Process Simulation experiment

2.2 CHOICE OF METHODS AND TECHNIQUES

2.2.1 Overview of Method

The objectives of this experiment have been achieved through a new validation technique called process simulation. It is based in a new process simulation tool that has been developed for assessing complex systems, based on discrete events able to simulate roles, procedures, etc, and also flights, sectors, etc. It can also perform simultaneously performance and process assessments. (section 2.2.4 provides a description on the processes simulation platform). Process simulations are particularly useful at revealing hidden incoherencies arising from the relations between actors involved and their responsibilities. A software platform called PROMAS has been developed and used to assess dynamic DCB measures and BT management against simulated traffic samples. Several simulations have been performed, based in the OS-11 'Non-severe capacity shortfall impacting arrivals in the short term', with each simulation consisting of a different scenario and/or a different strategy of the dynamic DCB process. PROMAS offers both qualitative and quantitative results.

These are the specific benefits to process simulations:

- A high number of actors can be included in the analysis. Regarding this experiment:
 - The different AOCs of those flights whose SBT is affected by the dynamic DCB arrival queue;



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

- The flight crew of those flights whose RBT is affected by the DCB Arrival Queue;
- The different APOCs of those airports from where some flights are going to depart and whose SBT is affected by the dynamic DCB arrival queue;
- A 24-hour traffic sample can be easily used;
- Different strategies and role behaviours can be emulated and analysed;
- By modifying and combining the implemented input variables, many simulations can be easily performed;
- Because the simulation model is absolutely automated, the objectivity of the result is guaranteed;
- Management processes, flight events, algorithms and functions live together allowing PROMAS to analyse in an automated way how some operational values impact on the ATM Process Model and vice versus.

2.2.2 Setting Up and Executing the Process Simulations

The Process Simulation work does not require experts to play roles in the simulation, but does require the following:

- **The PROMAS platform;**
- **PROMAS Scenario;** a scenario is composed by a set of rules, actors and the traffic sample, as well as the set of parameters that defines the strategy to be assessed:
 - A **set of rules;** these are necessary to define when the actors have to act, which tasks they have to execute, the time duration of each task, and which actors' properties have to be changed;
 - **Actors;** each actor has his/her own properties;
 - **A traffic sample;** there is one 2020 traffic sample. Taking into account that process analysis, concept refinement and assessment of innovative techniques are the main objectives of this experiment, the selection of the fictive constrained airport is not relevant. However, in order to model a realistic case to test the platform Madrid-Barajas airport has been chosen due to its European significance and the availability of information. The traffic sample encompassed all the traffic arriving to Madrid airport from any origin, whether starting from with the ECAC area or not. Traffic not arriving at Madrid was filtered out.
 - A **set of parameters,** needed to launch each simulation under different conditions (e.g. 10% shortfall capacity, 1 hour in advance, type of TTA Allocation Strategy...).

2.2.3 Time Planning

Figure 3 lists the main planned tasks that have been carried out in the Process Simulation work.



Technical Overview of PROMAS

PROMAS is a process management simulation platform developed in the scope of Episode 3 OS-11 by INECO. It is a new process simulation tool for assessing complex systems, based on discrete events able to simulate roles, procedures, etc, and also flights, sectors, etc. It can also perform simultaneously performance and process assessments.

Different sort of processes have been integrated into a unique platform, such as:

- ATM Diagram Model Processes (including time line) provided by EP3 WP2;
- Network Management Function provided by an Operational Scenario Description;
- Storyboards provided by Gaming and expert groups;
- 2020 forecasted traffic provided by EP3 WP2.

PROMAS is a simulation platform under development. For the present experiment, PROMAS platform has been developed with some simplifications that will be covered over the course of the time.

Functions

The main functions implemented in PROMAS in the scope of this experiment are:

- DCB solutions Processor:
 - TTA Allocation Strategy FPFS;
 - TTA Allocation Strategy 1;
 - TTA Allocation Strategy 2;
- Flight Data Processor;
- Selector of solutions.

Input Data

The inputs to PROMAS in the scope of this experiment are:

- Different sort of processes based on the ATM Diagram Model Processes, and the actors involved in them;
- Assumptions extracted from OS-11 and expert groups;
- Capacity Shortfall and Recovery conditions;
- Traffic sample (traffic files coming from RAMS Plus).

Output Data

All the events that occur during the simulation are stored in a file. PROMAS provides qualitative and quantitative results by post-processing this file.

Figure 4 shows a brief scheme of this experiment: functions implemented, inputs, outputs and relation established between the two different platforms used (RamsPlus and PROMAS).

Once the DCB Solution is elaborated and accepted by PROMAS, the outputs are an input in RamsPlus to analyse their feasibility by studying the aircrafts behaviour according to the restriction.

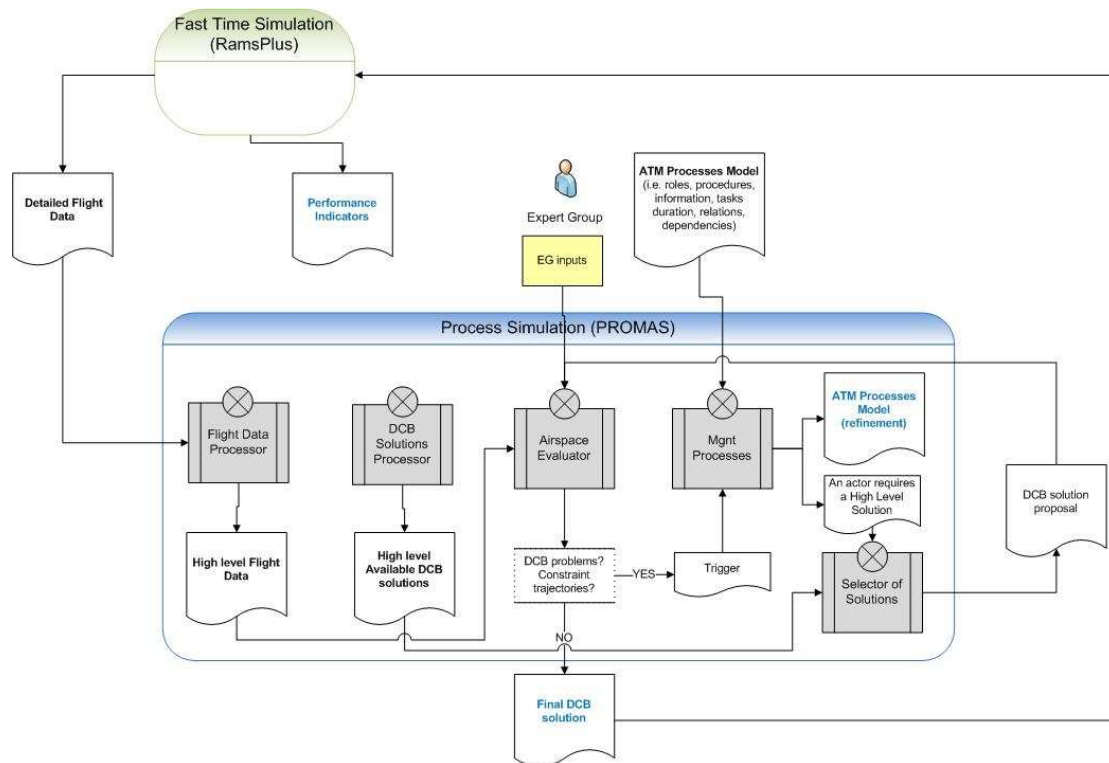


Figure 4: PROMAS platform link with RAMS

Platform

Process simulations will be implemented in PROMAS, which is a tool to represent the operation of any type of organisation or system by means of fast time simulations based on discrete events.

This software requires a set of components and procedures to build the scenario. To complete any scenario is also required to create some functions that are easily aggregated to the platform because it is highly modular and scalable.

The programme performs the role of the components in the scenario and reproduces the system operation activities by using the Logic and Execution Modules and the internal Trigger and Agenda functions (see Figure 5).

After each run, this software provides a detailed event log referring to the system operations. After processing the simulation output data, the required information is extracted to evaluate relevant outputs.

Finally, together with PROMAS, there is another existing tool that has been used in this experiment: RamsPlus. Both tools have not been integrated in a unique platform, but they have been used in a coordinated way so that each of them has been fed with data coming from the other.

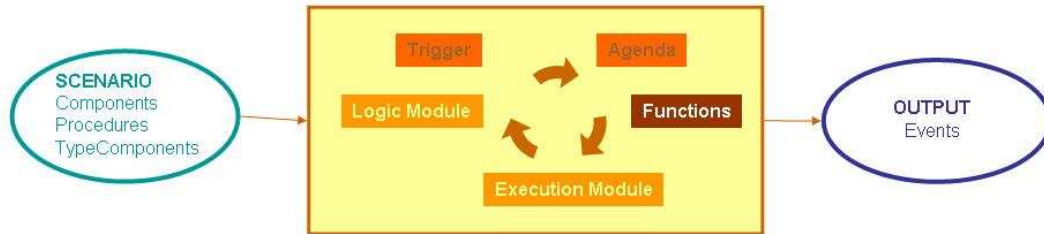


Figure 5: General description of PROMAS

PROMAS is not applicable only to complex ATM systems but it has been developed to assess any general complex organisation.

In the scope of this exercise a "performance assessment" would offer figures and conclusions based on the traditional KPIs (capacity, efficiency, etc) while a "process assessment" would offer figures and conclusions based on the number, simultaneity and redundancy of tasks that should be performed by different actors, looking for bottlenecks, incoherencies, saturating tasks, and overworked actors.

Traditionally, a fast time simulation tool is developed focused in a very specific area (e.g. RAMS Plus, TAAM, SIMMOD, etc) and uses an internal clock using seconds, where nothing occurs between two seconds. However, this Process Simulation Tool is open to any field and does not use time but processes execution times (i.e. after one process is executed comes another process); in between two consecutive processes there is nothing. These types of tools do not allow the simulation of continuum trajectories (x, y, z, t), but allow the implementation of a great detail of relations, dependencies, roles, rules, etc.

2.3 METRICS AND MEASUREMENTS

Each process simulation provides the analyst with qualitative and quantitative information, that has been used to assess the feasibility and coherency of the processes addressed and described in OS-11. These different sorts of data are described separately below.

Qualitative Data

After each simulation, PROMAS captures which processes are triggered or resumed to help meet the hypotheses listed in section 2.1.4.

Moreover, three TTA Allocation strategies have been developed to produce relevant information that could help in further studies to decide which one should be the best strategy or strategies to implement.

Quantitative Data

Some quantitative data are logged by PROMAS in an 'events' file. One of the objectives for this experiment is to demonstrate that numerical data offered by PROMAS can be processed to give useful metrics. The numerical data will be used to compare different scenarios (i.e., different strategies, active horizons, severities, prediction times, local characteristics).

The data captured by PROMAS in each simulation are:

- Who (actor) and when (time) requests a refresh of the AMAN or dynamic DCB sequence;
- For every flight involved in the dynamic DCB queue process:
 - The time at which the sequence was calculated;

- For each flight in the sequence:
 - Flight ID;
 - ETA;
 - TTA (if any);
 - Status (airborne, non-airborne);
 - BT type (SBT, RBT);
 - If non-airborne:
 - TOBT proposed by AOCs to satisfy TTA;
 - The time at which AOC negotiates TOBT with APOC;
 - The time at which APOC agrees with the proposed TOBT;
 - How much delay is absorbed and where (air or ground)?
 - If airborne:
 - Manoeuvre proposed by Flight Crew to satisfy TTA;
 - The time at which flight crew negotiates manoeuvre with ATC;
 - The time at which ATC agrees with the proposed manoeuvre;
- For every flight involved in the AMAN process:
 - The time at which the sequence was calculated;
 - For each flight in the sequence:
 - Flight ID;
 - ETA;
 - CTA (if any);
- The data captured by RAMS Plus in each simulation are:
 - ETA (Estimated Time of Arrival);
 - TOT (Take-off Time);
 - Sector Entry Operations per hour.

Table 8 below provides an overview of all the metrics and measurements used in the Process Simulation experiment.

Supported Metric / Measurement	Platform / Tool	Method or Technique
Process view PV.1: Functional process model for every TTA allocation strategy; PV.2: Number of negotiations/data exchanges performed during the Implementation of a dynamic DCB queue; PV.3: Information exchanged between AMAN and DCB queue functions.	PROMAS	Process Simulation
Operational view OV.1: Number of flights that are able to meet a proposed	PROMAS	Process Simulation

Supported Metric / Measurement	Platform / Tool	Method or Technique
TTA to recover the capacity after a shortfall; OV.2: Delay distribution generated (CAP.LOCAL.APT.PI 10: Arrival Airspace Delay); OV.3: Delay to be managed by AMAN; OV.4: Delay to be managed by a dynamic DCB queuing process; OV.5: Delay induced by AMAN on the dynamic DCB queuing process; OV.6: Affecting SBTs; OV.7: Affecting RBTs; OV.8: Percentage of flights that have suffered changes to meet the constraint with respect to the original arrival order; (FLX.ECAC.ER.PI 3); OV.9: TTA Allocation list.		
Sector entry operations per hour; Hourly Runway Operations.	RAMS	Fast-Time

Table 8: EP3 WP3.3.2 Supported metrics and measurements

2.4 VALIDATION SCENARIO SPECIFICATIONS

For the Process Simulation experiment, 12 Validation Scenarios have been defined, implemented in PROMAS and studied.

Three different strategies have been created and assessed. Strategy should be understood as the priority allocated to the aircrafts depending on their status (e.g. SBT/RBT):

- Strategy FPFs, as currently;
- Strategy 1, which gives higher priority to airborne aircrafts, provided that ground flights are not delayed more than 15 minutes (assumption A-01 from Experimental Plan);
- Strategy 2, which gives total priority to airborne flights.

For each strategy, there are four scenarios assessed with different conditions. They have been defined based on the specifications of the Experimental Plan³:

- Hail: 10% capacity shortfall. The shortfall is known and effective at 15:00 p.m., the recovery is known and effective at 17:00 p.m.;
- Snow: 30% capacity shortfall. The shortfall is known and effective at 15:00 p.m., the recovery is known and effective at 17:00 p.m.;
- Rain: 10% capacity shortfall. The shortfall is known at 14:00 p.m. and effective at 15:00 p.m., the recovery is known 16:00 p.m. and effective at 17:00 p.m.;
- Wind: 30% capacity shortfall. The shortfall is known at 14:00 p.m. and effective at 15:00 p.m., the recovery is known 16:00 p.m. and effective at 17:00 p.m.

The 12 validation scenarios results of the appliance of each strategy to each one of the four validation scenarios.

³ To be easier to name in the report, each one of the four validation scenarios has an associated name



2.5 PROMAS IMPLEMENTED PROCESSES.

Before and after initiating a DCB Queue process there are some other processes that need to be triggered and that have been modelled and implemented in the PROMAS platform in the scope of this experiment.

The next figures show the most relevant negotiations performed, the data exchanged in them, the actors involved and the outputs obtained, according to the ATM Process Model Diagrams [6].

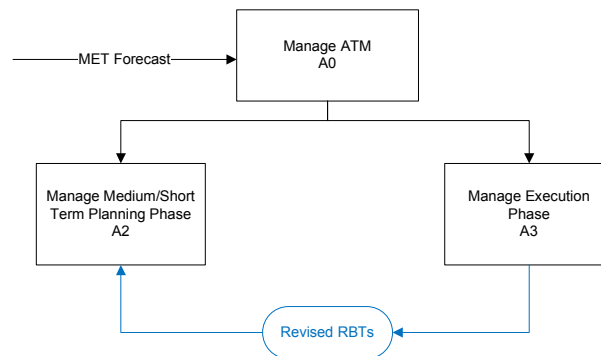


Figure 6: Main processes implemented in PROMAS

In the previous diagram, black colour refers to the actions carried out and blue colour to the obtained results. However in the next figures the colour code is: black colour refers to high-level actions, red colour refers to the lowest level actions, blue colour to the obtained results and green colour to the involved actors.

Figure 7 and Figure 8 show the low-level processes included in the main ones defined in Figure 6. All these processes have been implemented in PROMAS platform to run the process simulations. While Figure 7 shows the actions, results from those actions and involved actors in a DCB Queue process according to Manage Medium/Short Term Planning Phase, A2 process, Figure 8 shows the same applied to Manage Execution Phase, A3 process, both based on the ATM Process Model Diagrams [6].

According to the ATM Process Model Diagrams [6] there are some actions that have to be triggered once a capacity shortfall is detected in the medium/short term planning phase. These actions are triggered by the actors involved in the process and were simulated in the platform following the steps of Figure 7:

Once the APOC staff detects an imbalance between capacity and demand in the airport, it selects, refines or elaborates a DCB solution at airport level, and is coordinated with the Regional and Sub Regional Network Manager, which implement an airspace DCB solution at airport level to reach an agreement and to propose a DCB solution valid at airport and airspace level.

Once a DCB Solution is proposed, its impact in the network is assessed, if accepted by the Regional Network Manager, the DCB Solution is accepted and applied by the Sub Regional Network Manager.



Episode 3
D3.3.2-02b - Simulation Report on Business Trajectory
Management and Dynamic DCB - Annex B: Process
Simulation Experiment

Version : 1.00

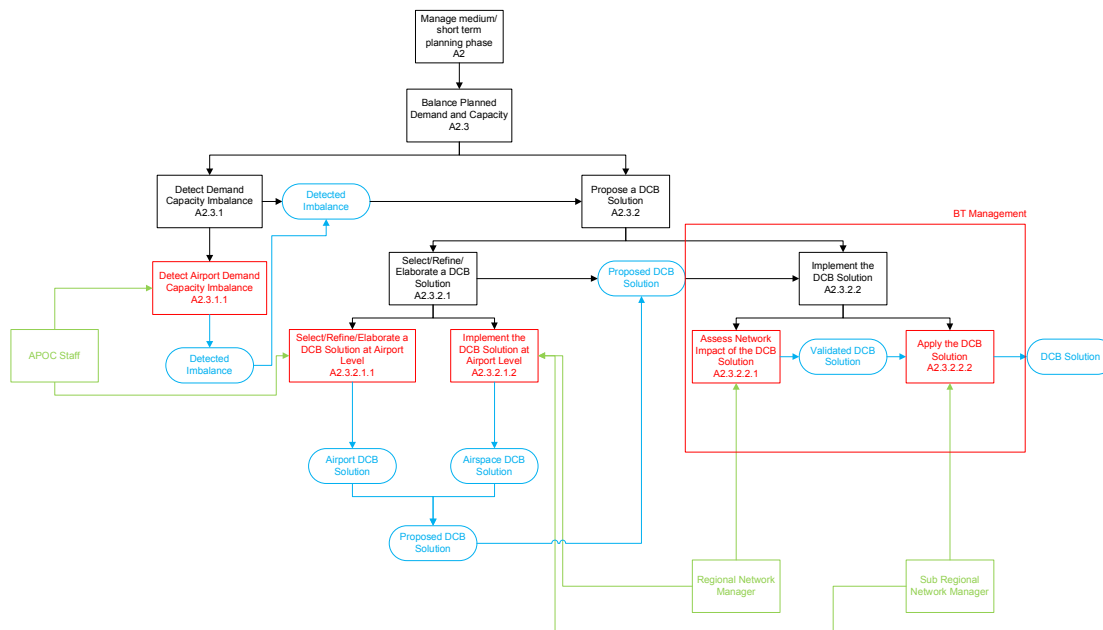


Figure 7: PROMAS negotiation based in the medium/short term planning phase

According to the ATM Process Model Diagrams [6] there are some actions that have to be triggered once a capacity shortfall is detected in the execution phase. These actions are triggered by the actors involved in the process and were simulated in the platform following the steps of Figure 8:

Once the Sub Regional Network Manager and the APOC staff assess the runway capacity load and detects an imbalance due to the runway is under load, the APOC Staff selects, refines or elaborates a Dynamic DCB solution at airport level, and is coordinated with the Regional and Network Manager, which defines an airspace DCB solution at airport level to reach an agreement and to propose a DCB solution valid at airport and airspace level.

Once a Dynamic DCB Solution is proposed, its impact in the network is assessed, if accepted by the Regional Network Manager, the DCB Solution is accepted and applied by the Sub Regional Network Manager. Afterwards, the Sub Regional Network Manager and the APOC Staff apply the Dynamic DCB Solution, optimise and implement the arrival queue by generating the new arriving traffic sequence.



Episode 3
D3.3.2-02b - Simulation Report on Business Trajectory
Management and Dynamic DCB - Annex B: Process
Simulation Experiment

Version : 1.00

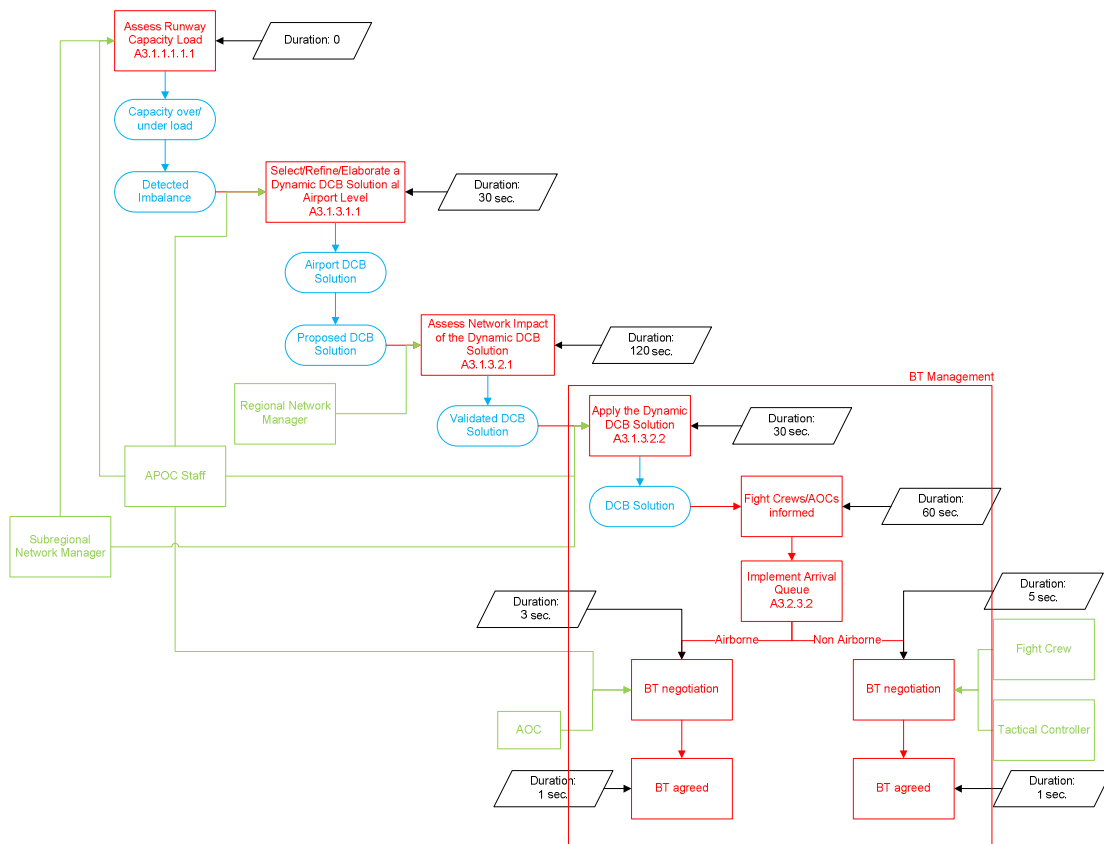


Figure 9: Associated time to each action.

PROMAS exercise is in charge of negotiations processes during medium/short term and execution phases and also proposes a DCB solution and assesses the network impact of the implementation of this solution in case of a capacity restriction. However, the implementation of the solution has not been simulated by PROMAS.

When a capacity restriction occurs, a DCB Queue process is triggered. This process is in charge of reordering the traffic sequence during the capacity shortfall period, and the different processes implemented in PROMAS to model this function are shown in the next figure:

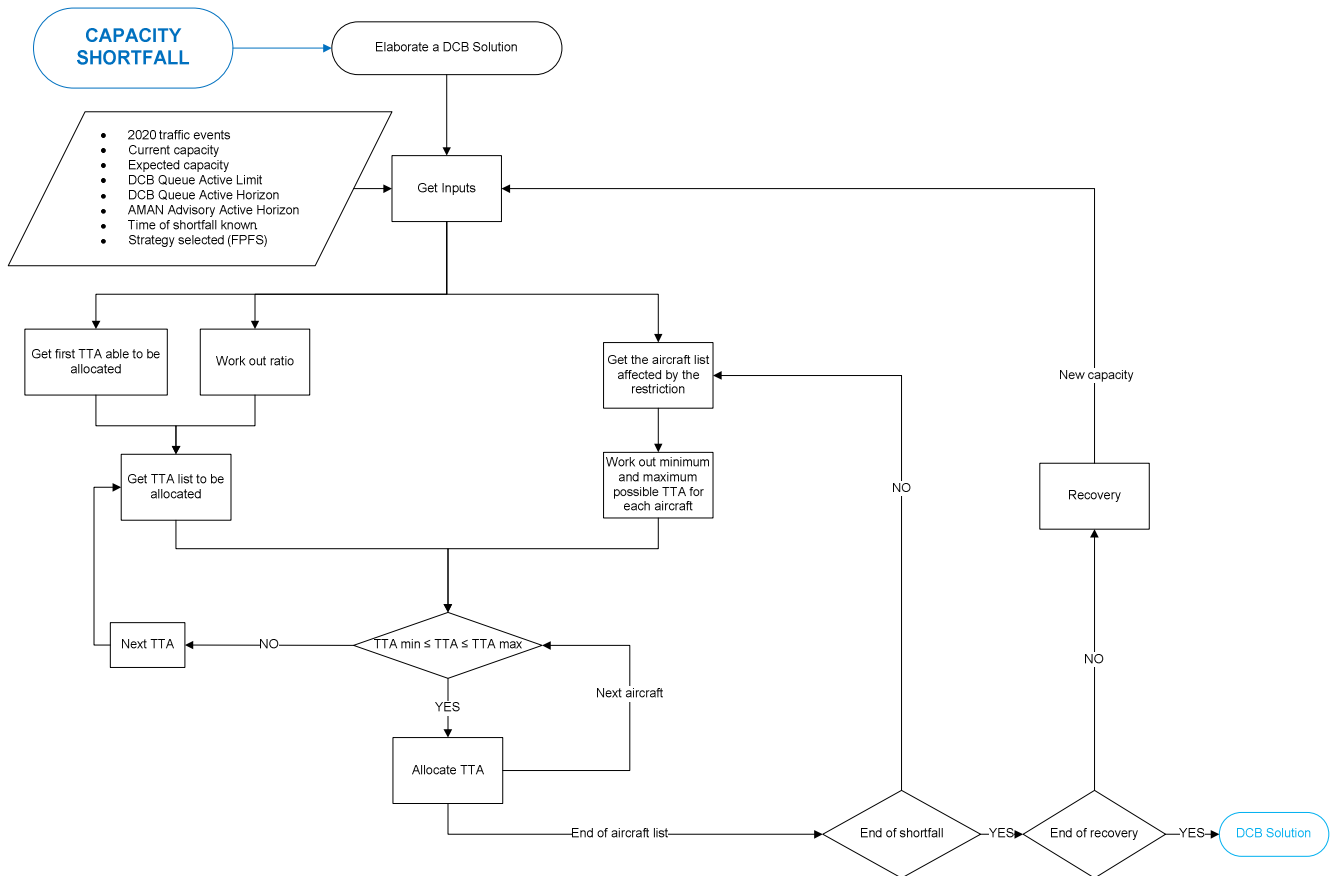


Figure 10: TTA allocation

Figure 10 shows how a DCB Queue is worked out. This process is triggered by a capacity shortfall to elaborate a DCB solution at airport level. The required information is provided by the own simulation tool and collected by the TTA allocation module. The inputs are referred to the validation scenario specifications (see section 322.4), the traffic patterns and the time frames for the implementation of the solution, e.g. AMAN Advisory Active Horizon, DCB Queue Active Limit, DCB Queue Active Horizon.

Based on the traffic pattern and the restriction, the tool tried to reallocate TTAs to the arriving aircrafts planned queue, according to the assumptions defined in the Experimental Plan [3], such as the fact that non airborne flights (when a new TTA is allocated) should not be delayed more than 15 minutes. Different aircrafts' priorities were also defined in the exercise (see section 322.4).

The way an aircraft receives a new TTA follows the next steps:

- Work out maximum and minimum possible TTAs, according to the assumptions.
- Choose the most advanced TTA within the timeframe (minimum and maximum TTA). If the aircraft is delayed more than allowed by the assumptions there are two possibilities:
 - If the aircraft has higher priority than other with a more advanced TTA, then this aircraft receives the most advanced TTA and the other is delayed.
 - If not, the aircraft keeps this TTA, even if it is more delayed than recommendations say.

There are also some rules defined:



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

- Aircraft can pass others with a different status (non-airborne to airborne and vice versa), but they cannot pass others with the same status.
- When one aircraft passes several aircraft (with less level of priority), the change is not one in the position of another, they all are delayed one position each one.

2.5.1 Impact of TTAs allocation on simulated sectors airspace

Once PROMAS has been executed, a further test based on RAMS Fast Time simulator has been carried out by SICTA to assess the impact of BT modification on Spanish sectors.

This evaluation occurred through the observation of 'Sector Entry Operations per hour' and 'Hourly Runway Operations' metrics.

RAMS scenarios and traffic samples generation

In order to analyse the PROMAS outputs, different stages were necessary.

A generated traffic sample feeds PROMAS simulation. This traffic sample process generation was one of the most important stages, as shown in Figure 11.

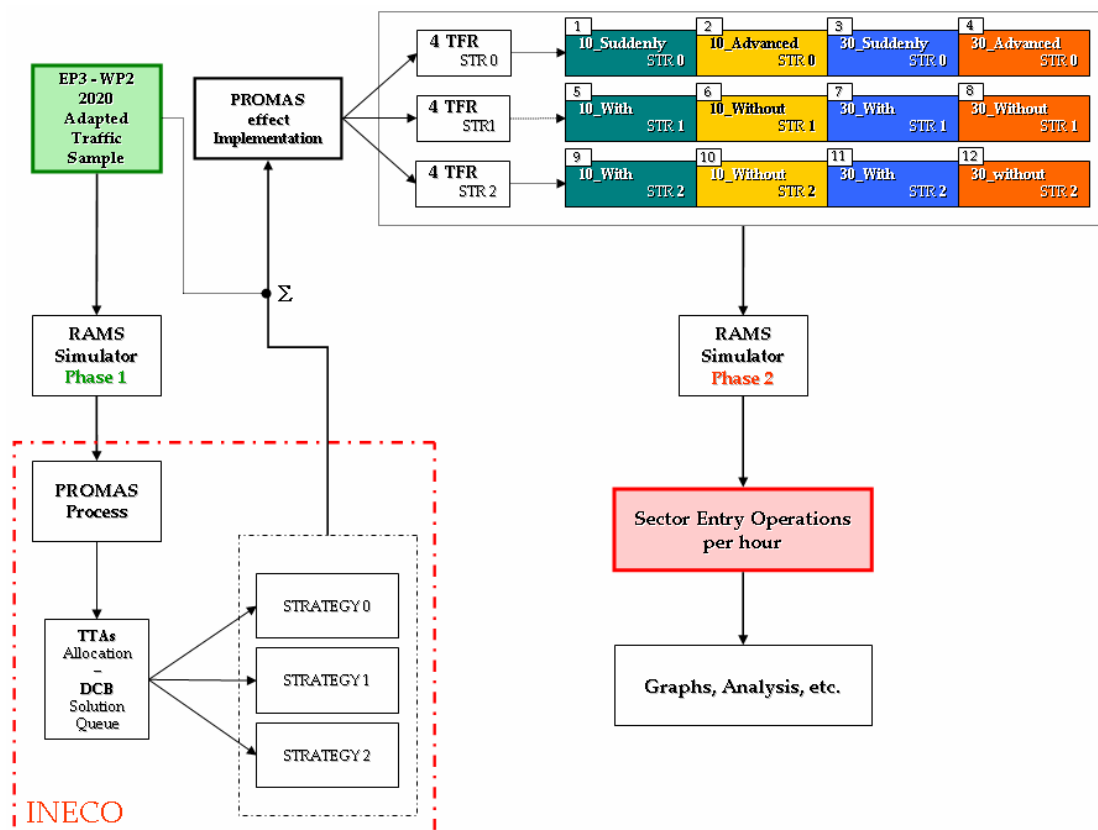


Figure 11: Traffic samples and RAMS Plus scenarios process generation

Observing Figure 11, we can note the following points:

- The first phase starts from the consideration of the 2020 traffic sample supplied by WP2 of Episode 3, which was adapted and used in the FTS-RAMS+ Baseline scenario (RAMS phase 1) in order to provide some 'log files' containing information on flight profiles:
 - Callsign;



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

- Origin APT (Airport);
- Departure time;
- Arrival time;
- Flight time;
- Used IAF Name;
- IAF Time;
- Cruise Time;
- End Of Cruise Time;
- Aircraft type;
- Aircraft capability.
- The RAMS file outputs 'flight.out.1' (suitably adapted) were employed as input data in the PROMAS process;
- PROMAS process has produced 3 different strategies taking into account the sending of TTAs (*and, eventually CTAs values calculated by AMAN and not taken into account in the RAMS+ analysis*) and applying of the DCB solution Queue;
- Each PROMAS STRATEGY means a different way to reorder aircrafts and each of them has 4 different arrivals order lists, from which 4 different RAMS+ scenarios were modelled;
- 4 traffic samples per each PROMAS strategy (12 different traffic samples) together with the baseline scenario were created and simulated through RAMS Plus Simulator (see Table 9) with dedicated runs (RAMS phase 2);
- In order to analyse the output, the 'Sector Entry Operations per hour ' and 'Hourly Runway Operations' values were extracted through ATM Analyser (RAMS tool);
- At the later stage, the results from previous point were compared with the initial Baseline scenario which was employed as input in the starting block of whole process shown in the Figure 9;
- A lot of graphs were extracted for all airspace Spanish sectors with following codes:
 - LEMDxxx (e.g.: LEMDAPN, LEMDDEN, ... and so on);
 - LExxxxx (e.g.: LEBLX5W, LECBCCC, and so on);
- Graphs containing results on '*Hourly Runway Operations*' were extracted only for Runway 33 RIGHT of Madrid Barajas airport, because the PROMAS process concerns the arrival aircraft flow just to runway 33R.

PROMAS STRATEGIES	RAMS SCENARIOS				
	Scenario 0 BASELINE	Scenario 1	Scenario 2	Scenario 3	Scenario 4
FPFS	TRA01	TRA02	TRA03	TRA04	
	<i>10_Suddenly</i>	<i>10_Advanced</i>	<i>30_Suddenly</i>	<i>30_Advanced</i>	
	Scenario 5	Scenario 6	Scenario 7	Scenario 8	
STRATEGY 1	TRA05	TRA06	TRA07	TRA08	
	<i>10_With</i>	<i>10_Without</i>	<i>30_With</i>	<i>30_Without</i>	
	Scenario 9	Scenario 10	Scenario 11	Scenario 12	
STRATEGY 2	TRA09	TRA10	TRA11	TRA12	
	<i>10_With</i>	<i>10_Without</i>	<i>30_With</i>	<i>30_Without</i>	

Table 9: RAMS scenarios with traffic samples extracted from PROMAS strategies



2.6 TRAFFIC SAMPLES

Process Simulations used the 2020 traffic sample supplied by EP3 WP2. It will be adapted as necessary to support the validation objectives.

2.7 ROLES

Actors involved in implementing dynamic DCB solutions include:

- Sub-Regional Network managers for the FABs handling the constrained airport's main arrival flows;
- The Regional Network Manager, with a view of the entire ECAC area;
- The APOC of the constrained airport;
- APOCs of the departure airports affected by the constraint (no human actor in the gaming);
- Several airlines (AOC and flight crew) who will be involved in implementing the dynamic DCB solutions;
- ATC:
 - Gaming: one generic ATC role (when TTA is allocated to airborne flights, simplistic negotiation with the flight crew to agree the way of achieving it);
 - Process Simulations: specific ATC roles; ATS Supervisor (TWR), Executive Controller (Arrival TMA) and Executive Controller (ACC).

2.8 RESPONSIBILITIES

The PROMAS experiment allocates responsibilities to the actors according to the ATM Diagram Model.

2.9 PROCEDURES

The Process Simulation experiment explores the process for implementing dynamic DCB solutions (i.e. DCB Queue by applying different TTA Allocation Strategies), how dynamic DCB interacts with the AMAN process, and how many and when the BT negotiations take place to meet the delivered TTA.

The APOC identifies the need to alter runway capacity (either a reduction or increase back up to the declared capacity). Once it is input into the NOP, the dynamic DCB process is triggered and a DCB queue is applied (see OS-11). A DCB Queue is delivered based on a TTA Allocation Strategy. Then the BT negotiations between APOC, AOC, ATCs, Flight Crew are carried out. The AOCs then update the relevant BTs in the NOP where the impact of the changes can be assessed.

Several remarks can be made about the designed DCB processes and validation scenarios:

- The trigger of the process is an alteration of airport capacity. It must be emphasised that the designed dynamic DCB processes aim to apply to any situation of demand capacity imbalances detected with short notice. Episode 3 validation scenarios focused on capacity alteration events only because it was a convenient way to generate imbalances using current traffic samples;
- The DCB measures employed only time-based traffic management measures (sequencing techniques). Other measures, such as re-routing or flight level changes, are not considered in these experiments.



On the Process Simulation side the APOC identifies the need to alter runway capacity (either a reduction or increase back up to the declared capacity), either immediately or in the very close future. They activate the restriction and, according to the ATM Diagram Model, all the required events before the DCB Queue solution are triggered. Target Time of Arrival (TTA's) are then calculated and sent to the relevant actors involved in the processes and the new TTAs are negotiated between the actors involved and finally accepted.

2.10 SIMULATION ENVIRONMENT

The PROMAS environment encompasses the whole traffic arriving to Madrid airport from any origin, whether starting from with the ECAC area or not. Traffic that is not arriving at Madrid is filtered out of the traffic sample.

2.11 EXPERIMENTAL VARIABLES AND DESIGN

The independent variables chosen for the process simulation experiment are:

- TTA Allocation Strategy:
 - FPFS (First Planned, First Served);
 - Strategy 1: flights-in-air have more priority than flights-on-ground;
 - Strategy 2: flights-in-air have absolute priority;
- Level of the severity of the shortfall capacity (during 3 hours):
 - 10%;
 - 30%;
- The time in advance when the capacity shortfall is known:
 - Suddenly;
 - 1 hour in advance.

The dependent variable is the arrival delay as measured by the PROMAS platform.



3 PROCESS - CONDUCT OF VALIDATION EXPERIMENT RUNS

3.1 EXPERIMENT PREPARATION

The main activities to perform the Process Simulation experiment based on the OS-11 [7] are organised in three phases:

- Phase 1: Preparatory activities, sub-divided in the following tasks:
 - Definition of the experiment: by a deep analysis of the OS-11, identifying the simulation scenarios to be modelled by PROMAS, identifying the main variables to be controlled and the metrics to be measured, as well as stating the hypothesis that should be tested;
 - PROMAS Development: to finish the interim PROMAS development and to tune up and prepare the platform capabilities in order to be able of modelling the defined simulation scenarios;
 - Adaptation of the Traffic for the Simulation;
 - While the appropriate 2020 traffic sample to be injected in PROMAS was delivered by SICTA, some pre-scenarios were run with a real traffic sample to test the platform;
 - When the traffic sample was ready, the files were adapted to the properly data format and introduced in the scenario model and in PROMAS simulator as inputs;
 - Modelling of Scenarios. This includes:
 - Definition of the general program structure and its programming;
 - Definition of each strategy and its programming;
 - Coordination with Gaming assumptions;
 - Pre-execution of each strategy in a stand alone platform to perform a preliminary verification;
 - Implementation of the different strategy functions in the platform;
 - Definition and implementation in PROMAS of the relevant part of negotiation processes, according to ATM Process Model Diagrams [6];
- Phase 2: Execution activities, including:
 - Simulation Execution for each validation scenario. Once they have been correctly modelled, each scenario is run, and the final results obtained;
- Phase 3: Post-Experiment Activities, which include:
 - Output data post-processing to obtain the selected metrics;
 - Analysis of processes simulation results;
 - Analysis of performance simulation results;
 - State the conclusions, issues, key findings and recommendations.

3.2 EXECUTED EXPERIMENT SCHEDULE

Figure 12 lists the main tasks planned to be carried out in the Process Simulation experiment.



3.3 DEVIATIONS FROM THE PLANNING

During the conduct of the experiment one independent design variable from Experimental Plan for Business Trajectory Management [3] has been modified:

Based on the analysis of the traffic sample received from the FTS, it has been considered as appropriate the replacement of 30% instead of the initial 20% shortfall capacity study, and also the duration of the restriction has been reduced to two hours instead of three, since the results obtained by using the 20% shortfall capacity were similar to 10% shortfall capacity and had short effect in the recovery process. Also with 10%, and even 20% shortfall capacity the delay was assumed by the less saturated hours.

To get a better understanding of the results the flight status has been simplified: it is considered that SBT status corresponds to a non airborne flight, and RBT status to airborne flights.



4 PROCESS - EXPERIMENT RESULTS

4.1 MEASURED EXPERIMENT RESULTS

4.1.1 Model Development View

One of the benefits due to the usage of Process Simulations techniques for validating purposes is the possibility of obtaining results by the mere fact of developing the model.

That is the case while developing the DCB Queue processes and specifically the TTA Allocation Strategies in which some of the defined requirements could be useful for future studies. For that reason, even knowing that these can not be assumed as standard and commonly agreed results, they have been included in this chapter.

4.1.1.1 Information exchanged between AMAN and DCB queue functions

The information exchanged between AMAN and DCB queue functions has been defined in this experiment as:

- The delay that AMAN process generates in DCB Queue process in case the capacity shortfall is suddenly known. AMAN has to send the following information to the DCB Queue process:
 - The mounted up delay of the aircrafts within the AMAN range (40 minutes in advance);
 - The ratio time to be applied between arrivals;
 - Which aircrafts are already managed by the AMAN with an allocated TTA, and which is the last aircraft managed by the AMAN to clearly identify which aircrafts should not be 'disturbed' by the DCB Queue process;
- The new arrival queue developed by the DCB Queue process: DCB Queue should send to AMAN the managed aircrafts with their new TTA.

Next, the process and operational results of the process simulation experiment are discussed separately.

4.1.2 Process View

The results included in this section regards to the feasibility of the processes implemented in the process simulation. Both qualitative and quantitative outputs are used to draw up conclusions concerning processes.

4.1.2.1 Number of negotiations/data exchanged during the Implementation of a DCB queue

The next figures show, in 10-minute intervals, the number of BTs negotiated during the capacity restriction.

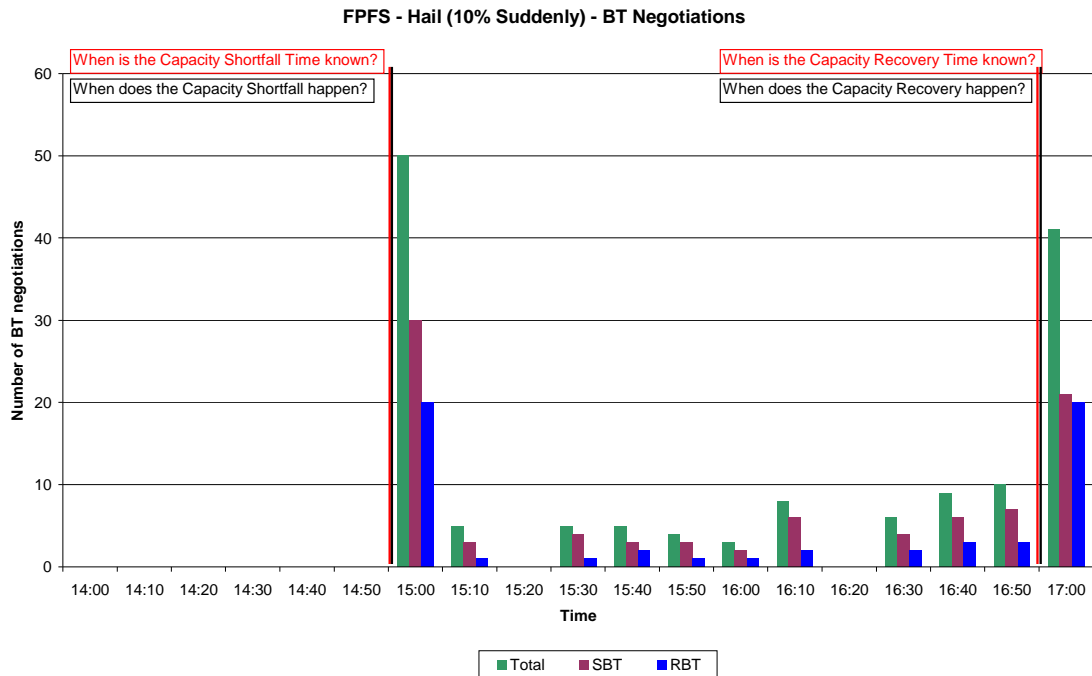


Figure 13: BT Negotiations in Hail Validation Scenario and in Strategy FPFS.

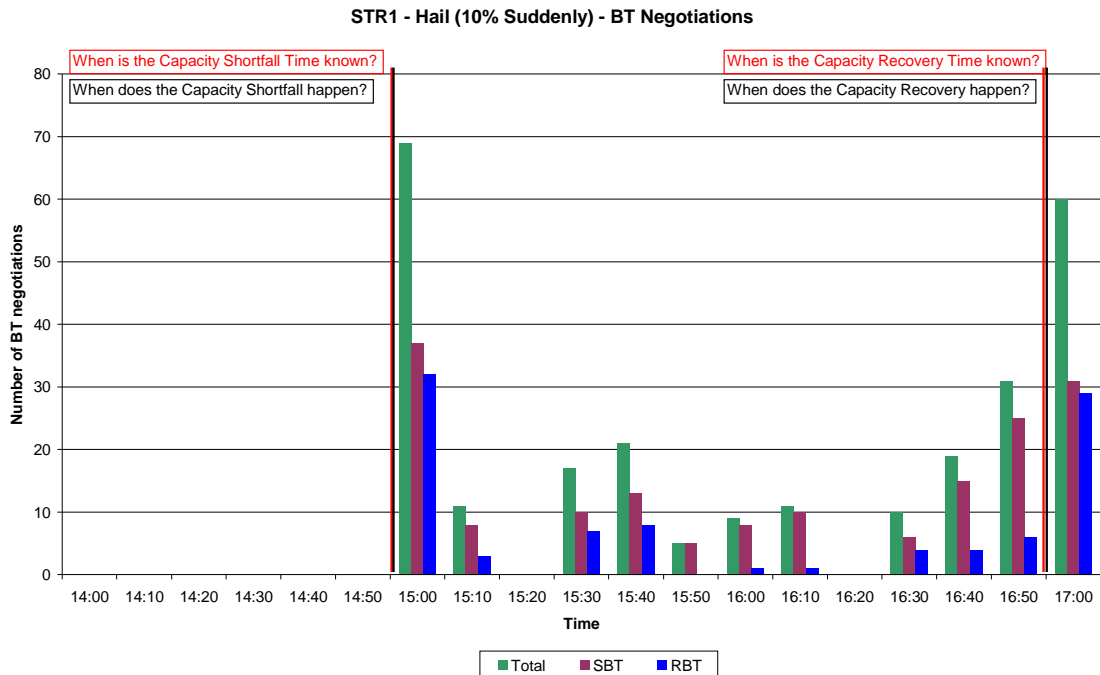


Figure 14: BT Negotiations in Hail Validation Scenario and in Strategy 1.

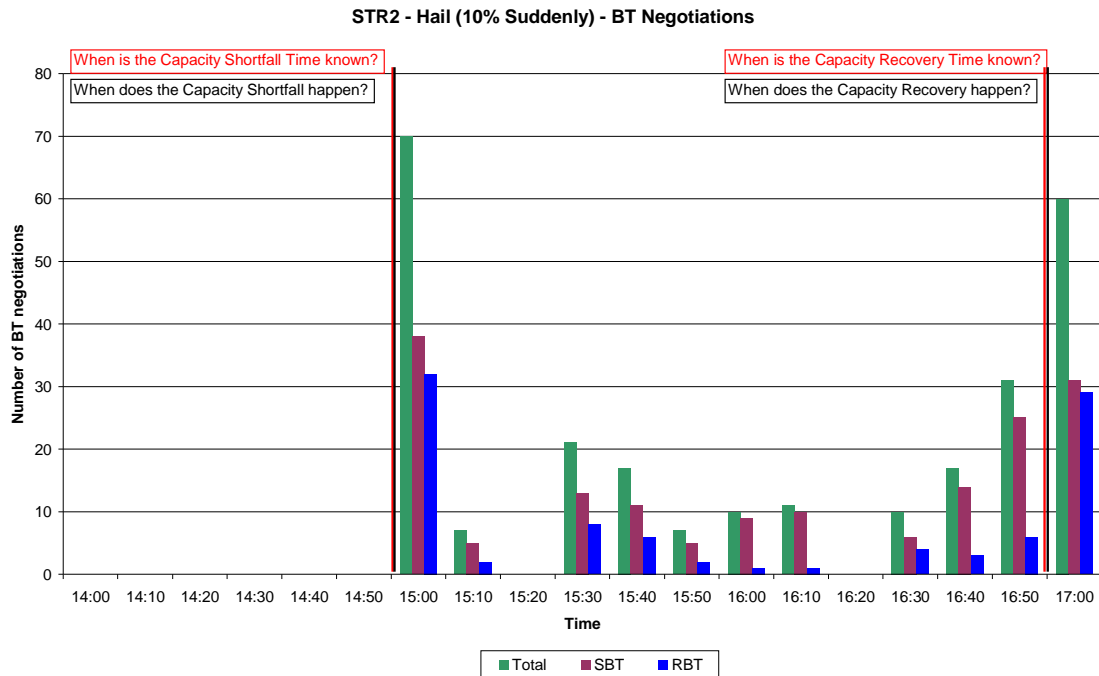


Figure 15: BT Negotiations in Hail Validation Scenario and in Strategy 2.

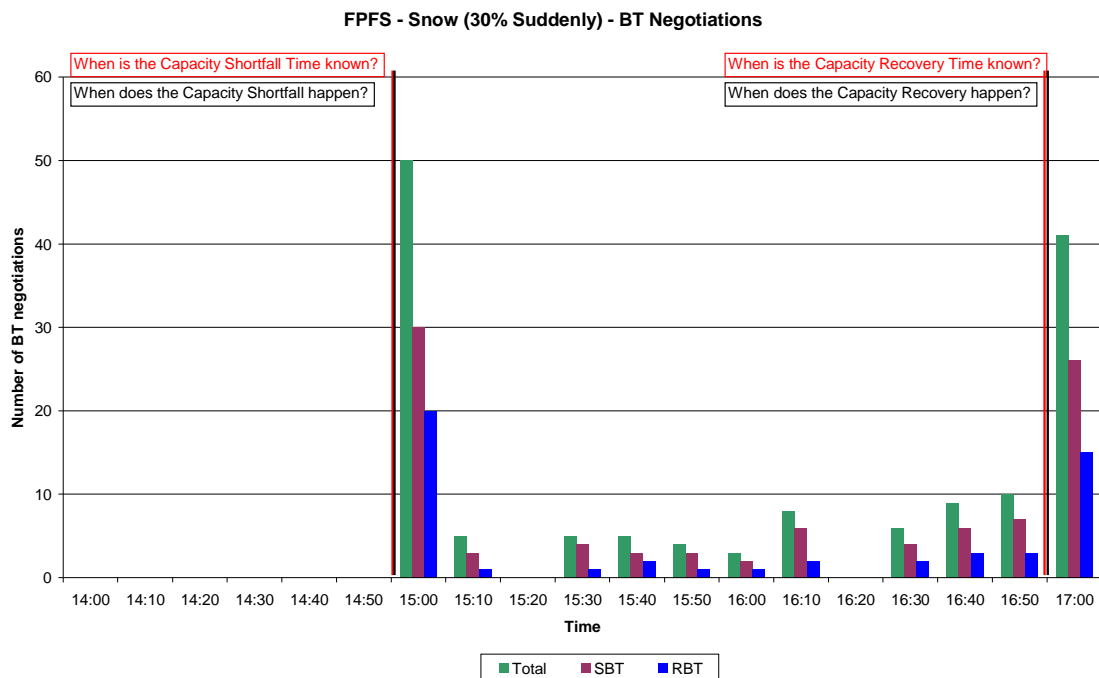


Figure 16: BT Negotiations in Snow Validation Scenario and in Strategy FPFS.

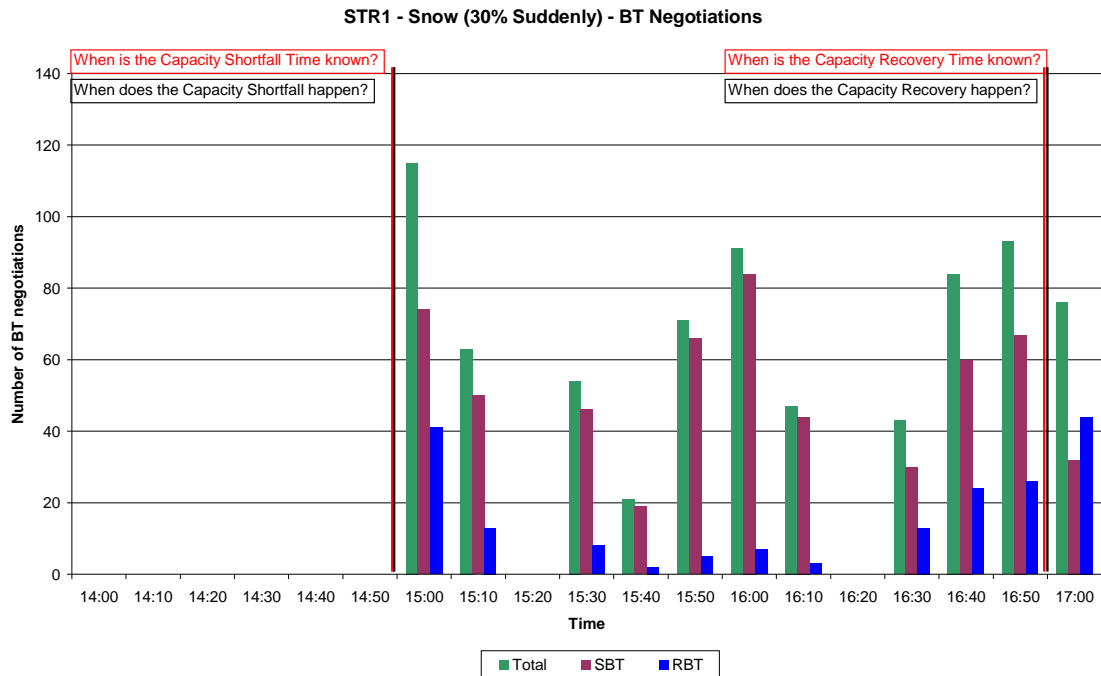


Figure 17: BT Negotiations in Snow Validation Scenario and in Strategy 1.

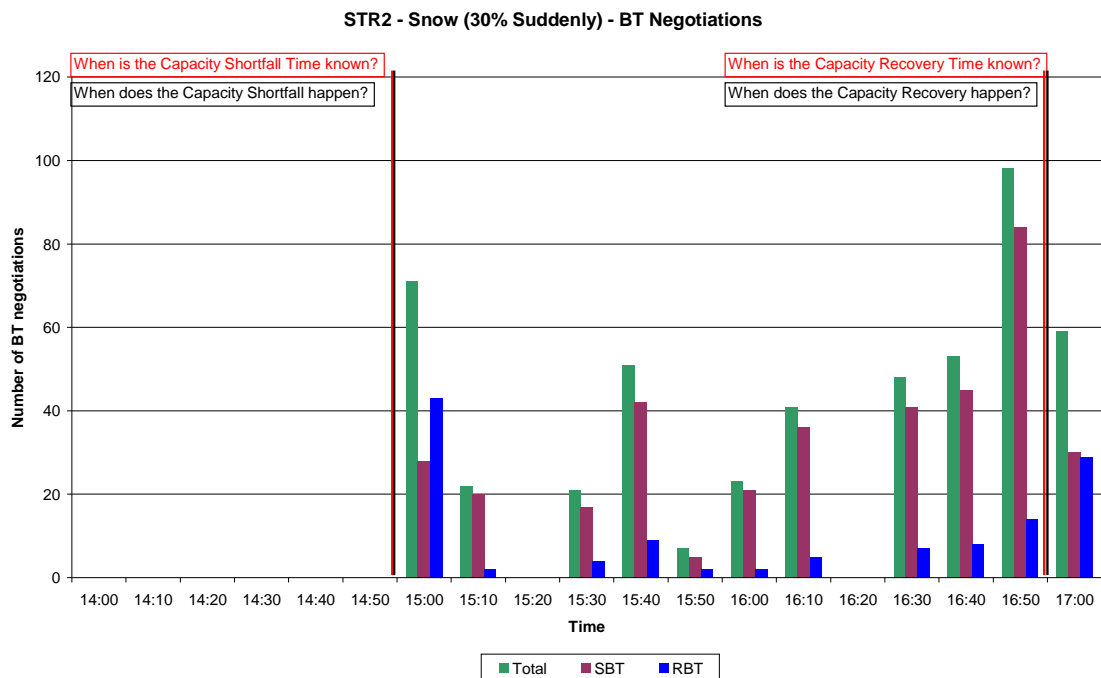


Figure 18: BT Negotiations in Snow Validation Scenario and in Strategy 2.

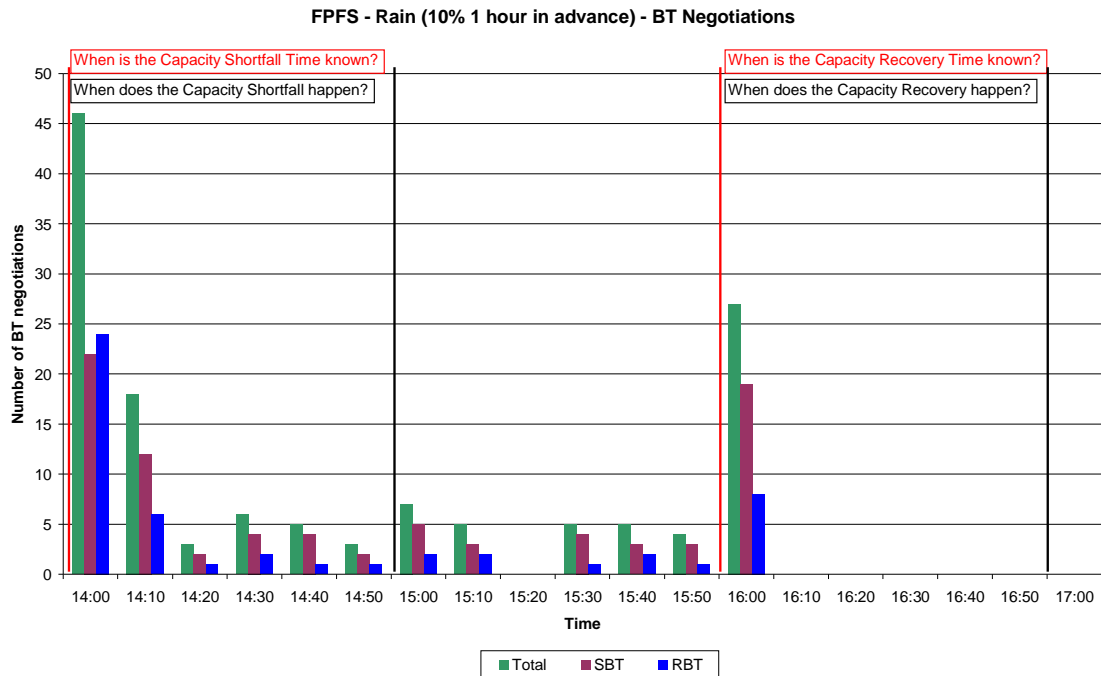


Figure 19: BT Negotiations in Rain Validation Scenario and in Strategy FPFS.

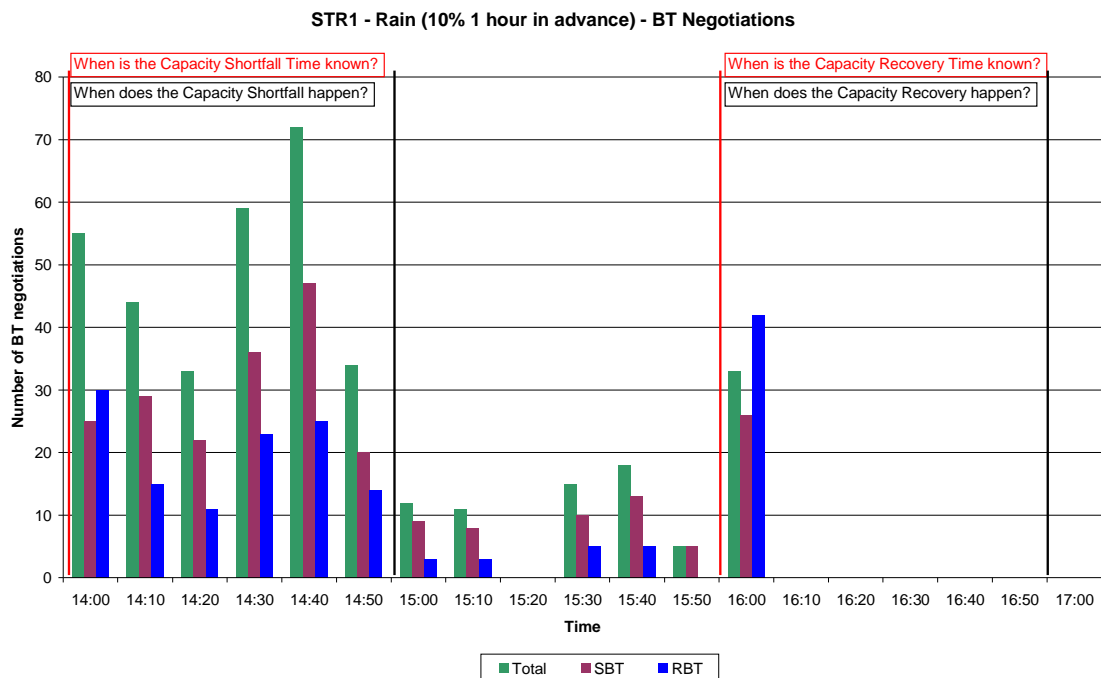


Figure 20: BT Negotiations in Rain Validation Scenario and in Strategy 1.

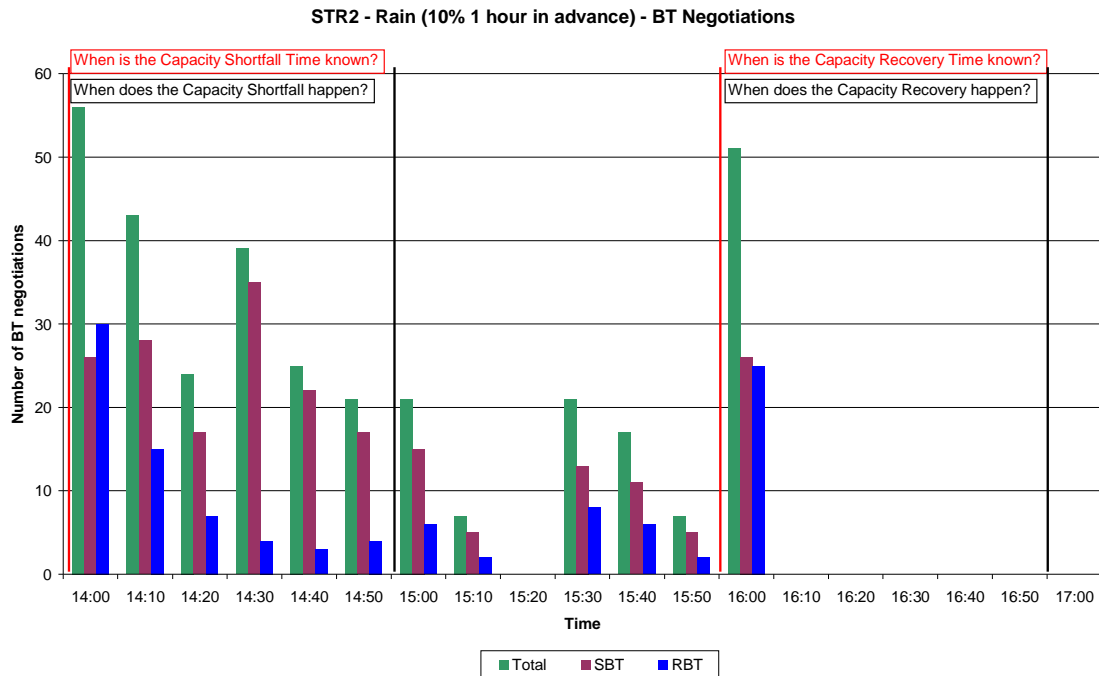


Figure 21: BT Negotiations in Rain Validation Scenario and in Strategy 2.

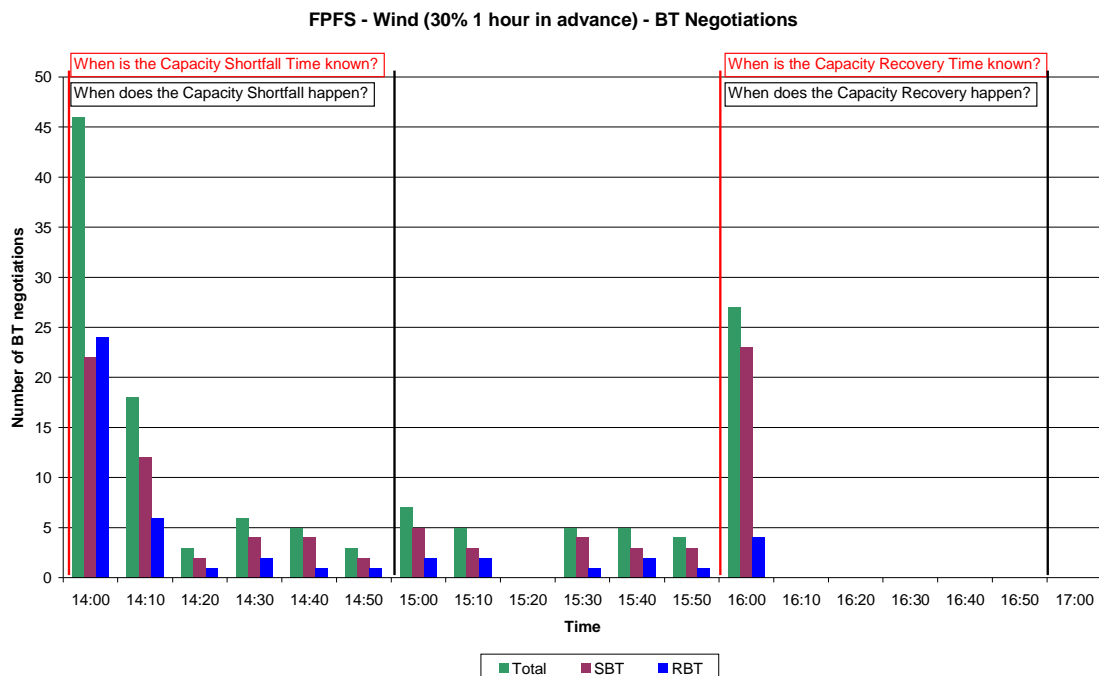


Figure 22: BT Negotiations in Wind Validation Scenario and in Strategy FPFS.



STR1 - Wind (30% 1 hour in advance) - BT Negotiations

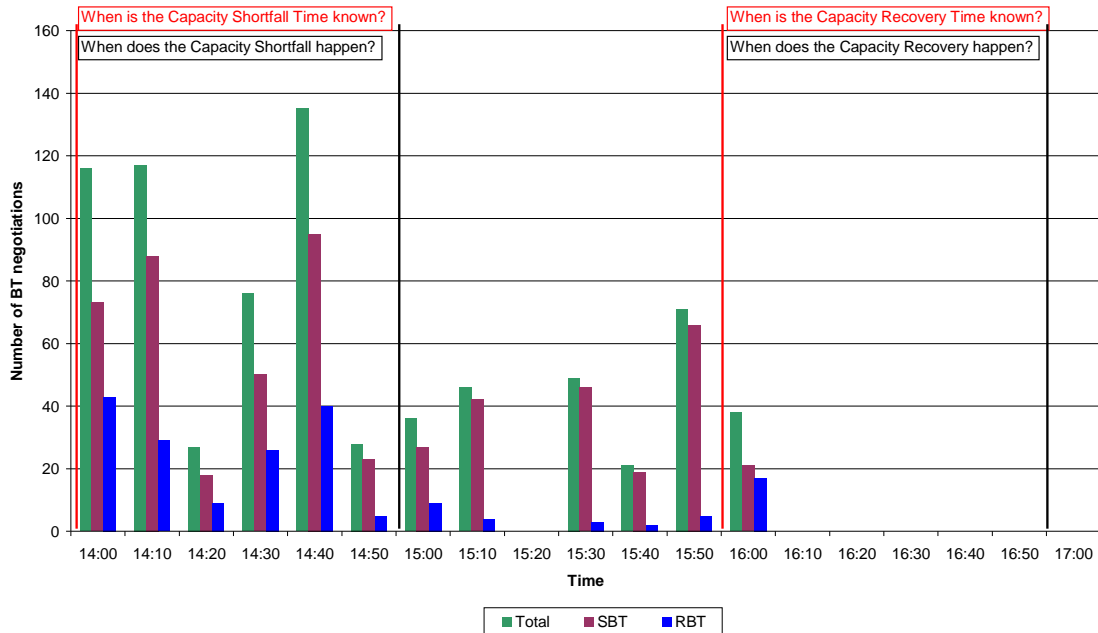


Figure 23: BT Negotiations in Wind Validation Scenario and in Strategy 1.

STR2 - Wind (30% 1 hour in advance) - BT Negotiations

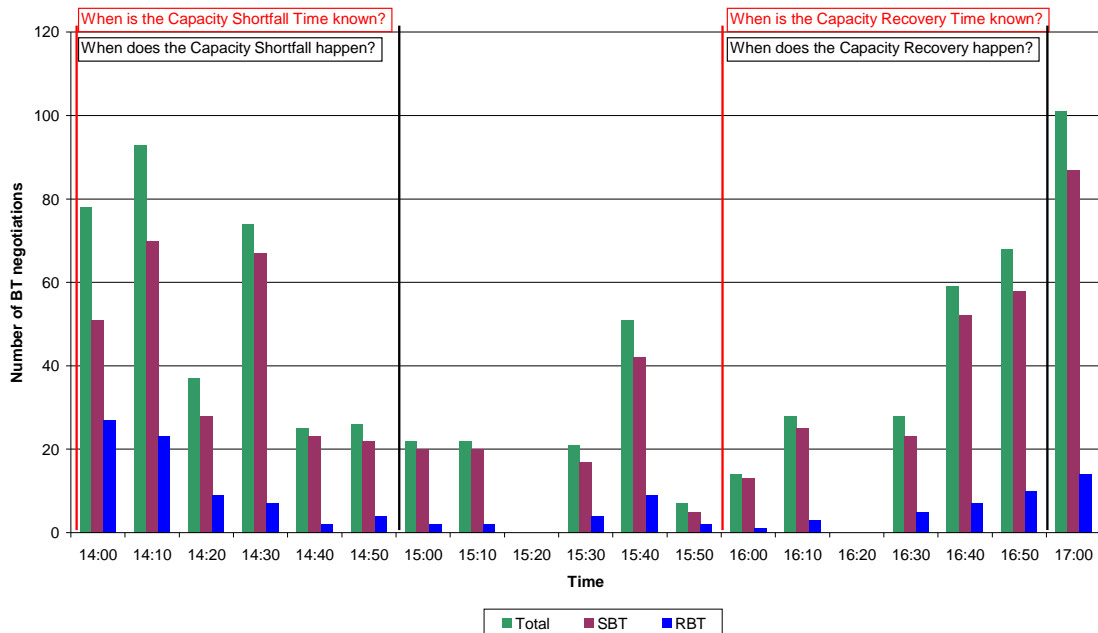


Figure 24: BT Negotiations in Wind Validation Scenario and in Strategy 2.

After analysing these figures, some conclusions can be drawn up:

- Suddenly versus 1 hour in advance:
 - Although expected it should be noted that the peak of BT negotiations is lower when the capacity shortfall is known 1 hour in advance. The reason is that the first set of flights arriving later than Capacity Shortfall Time as well as within the DCB Queue range is lower;
 - Expected too, the number of BT modifications due to the DCB Queue process is lower when the capacity shortfall is suddenly known. So, this figure would indicate that 'Suddenly' scenarios could be preferred by AUs. However it should be noted that in such scenarios the AMAN would change the BT of those flights that 'escaped' from the DCB Queue Active Limit to meet the constrained capacity;
- 10% versus 30%:
 - The number of affected BTs, when the Capacity Shortfall Time happens, does not depend on the severity of the shortfall;
- FPFS versus Str1 versus Str2:
 - While the restriction is active, there are new BTs negotiations every time a new flight reaches the DCB Queue Active Horizon:
 - In case of Strategy FPFS, there is only one TTA per flight so it is necessary only one BT negotiation;
 - In case of Strategies 1 and 2, many flights receives more than one TTA, so the number of BTs negotiation is quite higher in comparison with strategy FPFS. That is because each flight reaching the DCB Queue Active Horizon triggers the TTA Allocation process, and taking into account the corresponding priority, it may be likely required to re-allocate a lot of flights;
- In all the Validation Scenarios the global number of BTs negotiations for a RBT-status flight is lower than for a SBT-status flight. This may be due to the local characteristics of the assessed scenario, so it is recommended to perform further studies in airports where there is a high percentage of arriving flights whose flight duration is higher than the DCB Queue Active Horizon.

		Hail & Snow (Suddenly)	Rain & Wind (1 hour in advance)
Maximum number of BT negotiations, within a ten minutes window, involving one APOC in one departure airport (LEPA - Palma de Mallorca).	FPFS	6	5
	STR1	13	15
	STR2	12	15

Table 10: Nb of BT Negotiations

For the assessed scenarios, LEPA-LEMD is a meaningful city-pair and with flight duration lowers than 2 hours. This is why LEPA APOC appears as the most impacted APOC by the capacity shortfall. This result should be read considering the characteristics of Madrid traffic, but it would be relevant to assess in further studies the impact of such negotiations on the APOC. His/her workload should be established and defined as a maximum number of BT negotiations per a period of time (e.g. 10 minutes).

4.1.3 Operational View

4.1.3.1 Measured Experiment Results with PROMAS

The three strategies sequences arriving flights by allocating them different levels of priority based on their status (i.e. SBT/RBT) what results in a different delay distribution.

The twelve Validation Scenarios have been defined based on the specifications of the Experimental Plan [3]⁴:

Scenario	STRATEGY FPFS				STRATEGY 1				STRATEGY 2			
	Hail	Snow	Rain	Wind	Hail	Snow	Rain	Wind	Hail	Snow	Rain	Wind
10% Capacity Shortfall ⁵	X		X		X		X		X		X	
30% Capacity Shortfall ⁶		X		X		X		X		X		X
Shortfall suddenly known ⁷	X	X			X	X			X	X		
Shortfall known in advance ⁸			X	X			X	X			X	X

Figure 25: Validation Scenario specifications.

The figures below show, for each Scenario applying each one of the three strategies, the delay distribution generated when applying a DCB Queue process to the same traffic sample.

The graphs only show the aircrafts managed by the DCB Queue (does not represent the aircrafts managed by the AMAN) and should be read as follows:

- In the x-axis: each bar represents a single aircraft and its associated delay, there is no associated timescale along this axis. Only delayed aircrafts (those that receive TTAs) are shown in these graphics. Validation Scenarios in which there are more bars mean that there are more aircrafts affected by the restriction.
- In the y-axis: the generated delay per aircraft, in minutes, allocated by the PROMAS simulation.


⁴ To be easier to name in the report, the twelve validation scenarios have an associated name. It means that each validation scenario has its own specifications, and these specifications are associated to a validation scenario name.

⁵ Nominal Demand: 42 a/c, 10% capacity shortfall: 36 a/c.

⁶ Nominal Demand: 42 a/c, 30% capacity shortfall: 29 a/c.

⁷ The shortfall is known and effective at 15:00 p.m., The recovery is known and effective at 17:00 p.m.

⁸ The shortfall is known at 14:00 p.m. and effective at 15:00 p.m., the recovery is known 16:00 p.m. and effective at 17:00 p.m.

	Episode 3 D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment	<i>Version : 1.00</i>
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The colour code is: green bars refer to the shortfall period while blue ones represent the aircrafts affected during the recovery period⁹.

Aircraft depicted in the graphs are ordered by their original ETA. Once they have received a new TTA, this TTA is considered as the baseline arrival time in the recovery period to allocate a recovery TTA.

⁹ 'Recovery period' refers to the time needed after the shortfall period until the traffic sequence is not already affected by the restriction (flights can keep their original ETA).



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00



Figure 26: Delay distribution when applying a DCB Queue process to the same traffic sample for Validation Scenarios Hail and Snow and the three Strategies.



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00



Figure 27: Delay distribution when applying a DCB Queue process to the same traffic sample for Validation Scenarios Rain and Wind and the three strategies.



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

By comparing the four Scenarios:

- As expected, in cases of 10% shortfall capacity (Scenarios Hail and Rain) recovery period is shorter than in cases of 30% shortfall capacity (Scenarios Snow and Wind) because of the shortfall severity;
- Likewise, in cases of 30% shortfall capacity out of nominal capacity (Snow and Wind Scenarios) the peak delays are higher than in cases of 10% shortfall capacity out of nominal capacity (Hail and Rain Validation) because of the shortfall severity.

Based on the previous figures there are some facts that have to be highlighted in strategy FPFS:

- In all the scenarios there are a percentage of flights with delays exceeding the recommendations in assumptions A-01 and A-02 from the Experimental Plan [3] (FPFS 56% - STR1 69% - STR2 70%).

Based on the previous figures there are some facts that have to be highlighted in strategy 1:

- Ground flights are not delayed more than 15 minutes (assumption A-01 from Experimental Plan [3]), but this assumption causes high delays in airborne flights (even higher than 80 minutes).

By comparing Strategies 1 and FPFS:

- Although the total delay does not vary significantly by using one or other strategy, under Strategy1 many individual flight delays are extremely higher in comparison with FPFS.

Based on the previous figures there are some facts that have to be highlighted in strategy 2:

- Even though the strategy 2 gives absolute priority to airborne flights, the number of airborne flights delayed more than the recommendations are similar to the number provided by the other strategies (assumption A-02 from Experimental Plan [3]). That unexpected result is because the severity of the shortfall capacity induces quickly a delay higher than 216 seconds (i.e. 3% out of 2 hours);
- As expected, this strategy causes higher delays in non airborne flights than the others one.

By comparing the three strategies:

- In strategy 1 the highest delays are associated to airborne flights, whereas in strategy 2 the highest delays corresponds to non airborne flights;
- In strategy 2 the maximum individual flight delays are higher than when applying any of the other two strategies.

Table 11 shows the percentage of flights (from the whole managed aircrafts during the simulation of the validation scenario) that have suffered changes to meet the constraint with respect to their original arrival sequence¹⁰; (FLX.ECAC.ER.PI 3). Loss row refers to shortfall capacity period, and Gain row refers to capacity recovery period.

	STRATEGY 0				STRATEGY 1				STRATEGY 2			
	Hail	Snow	Rain	Wind	Hail	Snow	Rain	Wind	Hail	Snow	Rain	Wind
Loss	0	0	0	0	69	96,2	66,3	96,6	76	96,2	80,2	93
Gain	0	0	0	0	70	82,6	96,7	100	95	91,4	80	93,3

Table 11: Percentage of flights whose arrival order has been changed.

¹⁰ During the recovery period, results are based on the initial arrival order, even if they have been already modified during the shortfall period.

Delay Distribution generated (CAP.LOCAL.APT.PI 10: Arrival Airspace Delay):

	STRATEGY 0				STRATEGY 1				STRATEGY 2			
	Hail	Snow	Rain	Wind	Hail	Snow	Rain	Wind	Hail	Snow	Rain	Wind
Loss	9,9	34,1	12,9	25,5	9,8	36,5	9,8	29,9	9,8	36,5	10,3	29,4

Table 12: Average delay due to DCB Queue Process (min)

The average delay shown in Table 12 does not depend on the strategy as expected. Despite of the fact that the individual flight delays are differently shared in between affected fights, the total delay does not significantly change as no 'arrival window' is missed.

4.1.3.2 Measured Experiment Results with RAMS

In this section there is a slight difference in the graphs nomenclature:

- Validation Scenario Hail is called 10_suddenly or 10_without;
- Validation Scenario Snow is called 30_suddenly or 30_without;
- Validation Scenario Rain is called 10_ advanced or 10_with;
- Validation Scenario Wind is called 30_ advanced or 30_with.

➤ **Strategy FPFS**

In this section the measured *Hourly Runway Operation* and Sector *Entry* values through extracted for the PROMAS STRATEGY – FPFS are reported.

HOURLY RUNWAY OPERATIONS

Based on the graphs reported in this section there are some facts that have to be highlighted regarding STRATEGY FPFS:

- The strategy PROMAS - FPFS affect only some of the time slots of the whole simulation day;
- Only for the slots of time between 15:00 and 22:00 for which the trend seems quite irregular, a different order of arrival was found;
- The irregular trend found is consistent with what has been reported in section 6.1.1 concerning the evaluation of delays caused by the new arrival time distribution.



FPFS STRATEGY - LEMD RUNWAY 33R
Hourly Runway Operations

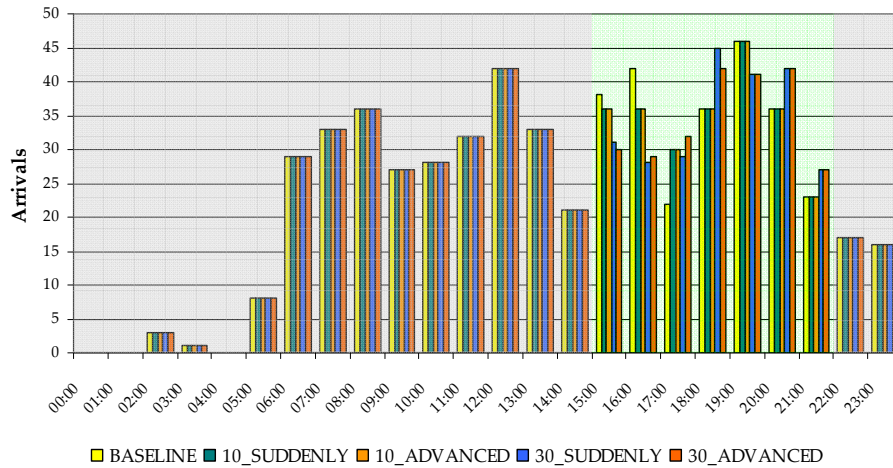
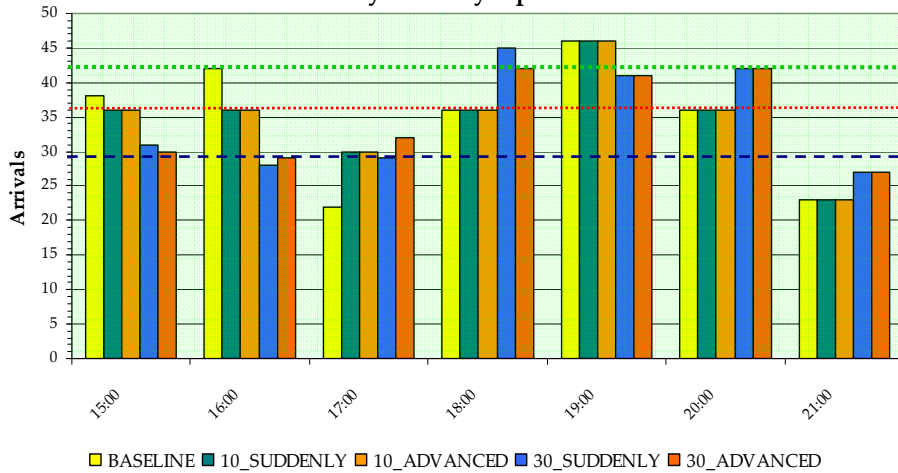


Figure 28: Hourly runway operations count for RWY 33 R of Madrid Barajas airport

- The most visible changes due to the allocation of new TTA values fall in the period of approximately 7 hours on 24 (From 15:00 To 22:00);
- There weren't found differences between the results obtained for scenarios Hail and Rain even if these are different from the results obtained for the FPFS, Snow and Wind scenarios;
- In the first two hours of the period of interest (from 15:00 to 18:00) the aircraft arrivals flow tends to decrease in a non-uniform mode, this is due to the new TTA values allocation;
- The decrease in the number of arrivals verified in the first 2 time bands of the interested period, causes consequently an increase in the number of arrivals in immediately following time bands.(17:00 - 18:00). This period should coincide with the phase of recovery;
- Looking at the graph in Figure 28, it is noted that this strategy has introduced a series of delays such as to gradually reduce the number of arrivals in the first hours of interested period, in order to balance the traffic demand with available capacity (DCB) and in later stage to increase the arrivals in the following slots of time (18:00 to 22:00);
- The results obtained for the slots of time included in the period from 18:00 to 20:00 do not appear to be positive because although the new value of TTA, the traffic demand value exceeds, even if a bit, the declared capacity value.



FPFS STRATEGY - LEMD RUNWAY 33R
Hourly Runway Operations



Nominal Capacity
 Airport shortfall Capacity 10 %
 Airport shortfall Capacity 30 %

Figure 29: Hourly runway operations count RWY 33 R (zoom in the range of interest)

SECTOR ENTRY OPERATIONS PER HOUR

Applying STRATEGY FPFS the obtained values of the traffic demand about some sectors, in terms of *Entry Sector Operations* are lower than the values of declared sector capacity.

For this reason will be shown afterwards the graphs of the only sectors highlighted in yellow (see Table 9) for which the obtained results appear to be interesting in order to assess the outcomes of the applied strategy.

About the values shown in red, they indicate those sectors for which the resulting traffic demand values, already in the baseline scenario, appear to be well beyond of the declared capacity values shown in table and the results are inconsistent and not useful to carry out this study. Therefore, the graphs of these sectors are not reported in this section.

Analysed sector with relative declared sector capacity values were reported in the following tables:



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

SECTOR	CAPACITY		SECTOR	CAPACITY	
LEBLX5W	Not available	Other Spanish Sector	LEMDAPN	39	TMA
LECBCCC	43		LEMDDEN	49	
LECBDDN	42		LEMDDWN	49	
LECBDDS	42		LEMDENN	45	
LECBLGL	34		LEMDESN	45	
LECBLGU	35		LEMDREN	43	
LECBMMI	43		LEMDRWN	43	
LECBP1I	36		LEMDWNN	47	
LECBPP2	42		LEMDWSN	47	
LECBVVI	40				
LECBXAL	42				
LECLTMW	36				
LECLVLC	Not available				
LECMCJL	37				
LECMCJU	43				
LECMPAL	32				
LECMPAU	40				
LECMTER	40				
LECMZGZ	40				
LECPDWX	34				
LECPGOX	38				
LECPIXX	32				
LECPL1W	30				
LECPL2W	30				
LECPMXX	35				

Table 13: Analyzed sectors and declared sector capacity values



Madrid TMA LECMCJL - (From 14h00 To 21h00)

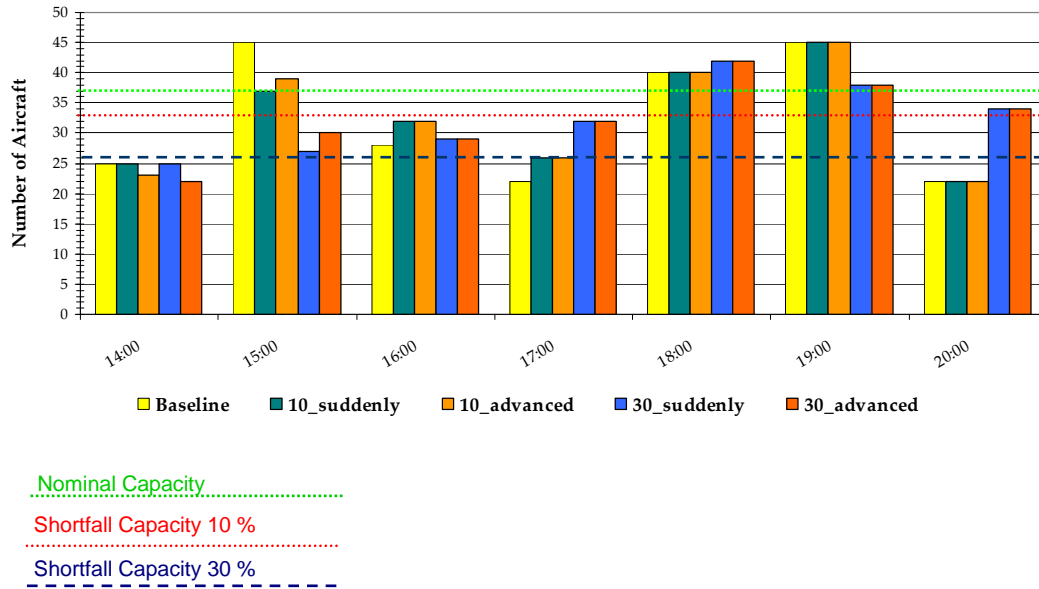


Figure 30: Entry Sector Operation Count (LECMCJL)

Madrid TMA LECMCJU - (From 14h00 To 21h00)

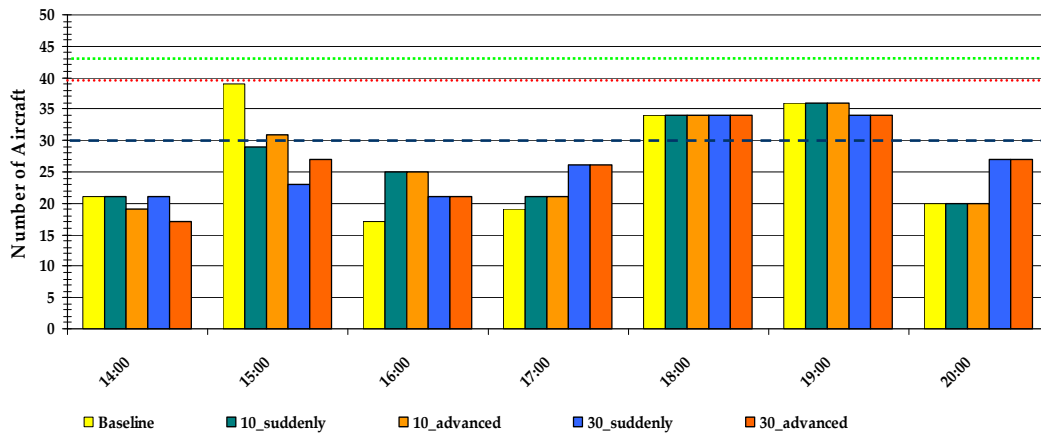


Figure 31- Entry Sector Operation Count (LECMCJU)



Based on the graphs reported in this section there are some issues that have to be highlighted regarding STRATEGY FPFS:

- The graphs in Figure 30 and Figure 31 represent the only slots of time of the simulation day in which changes occurred between the various, applied sub-strategies under STRATEGY 0 – FPFS (From 14:00 To 21:00);
- The Figure 32. represents a graphic capture of the simulated airspace taken from a RAMS scenario to identify the location of the area and determine whether it falls within of the sub-region illustrated in section 2.3 of the Experimental Plan;
- The obtained results for the sector **LECMCJL** show that the values of traffic demand are very high, also in the baseline scenario;
- From obtained results for both sectors we can notice that the arrivals flow is not very uniform. This seems clear within the time period from 14:00 and 16:00 where there is a significant decrease in the value of the entry sector movements. This is due to the fact that once the capacity shortfall is happened and the new value of TTA is sent, the crossing times of involved sectors are modified in order to balance demand and capacity;
- The following slots of time from 16:00 to 18:00 are characterized by small increments compared to the baseline, this is due to the start of recovery phase at 17:00 and to the introduced delays by strategy;

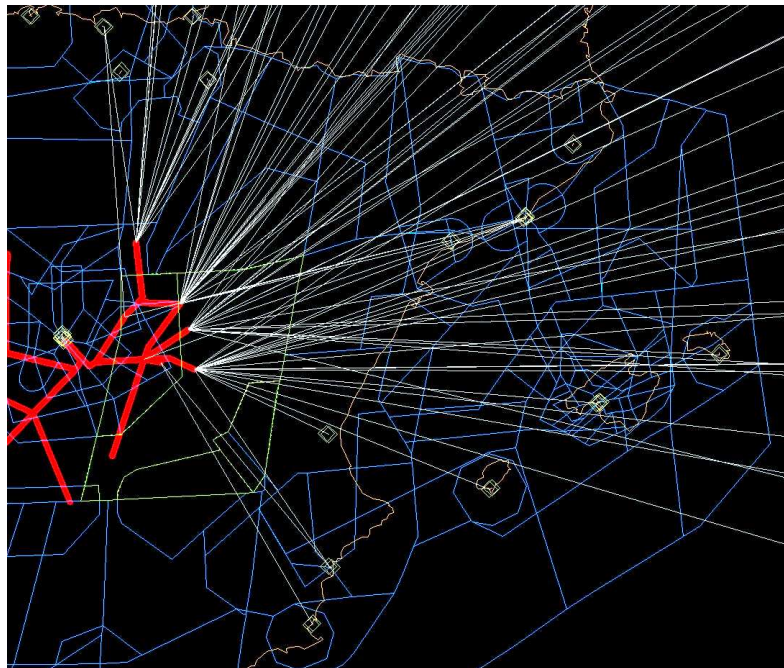


Figure 32: Sectors LECMCJL/U RAMS scenario capture

- The results (**LECMCJL**) show some peak values in some slots of time due to the introduction of the delays after re-planning in time through the allocation of the new TTA values. The values of these peaks appear to be higher than the declared capacity values regarding the validation scenarios **Hail** and **Rain** within the period from 19:00 to 20:00;



- As far as the **LECMCJU** sector, the results show a valid efficiency for all applied strategy except for slots of time from 18:00 to 20:00 in which the obtained values from scenarios **Snow** and **Wind** are greater than the value indicating the 30% capacity shortfall (line midnight blue);

Madrid TMA LEMDESN - (From 14h00 To 21h00)

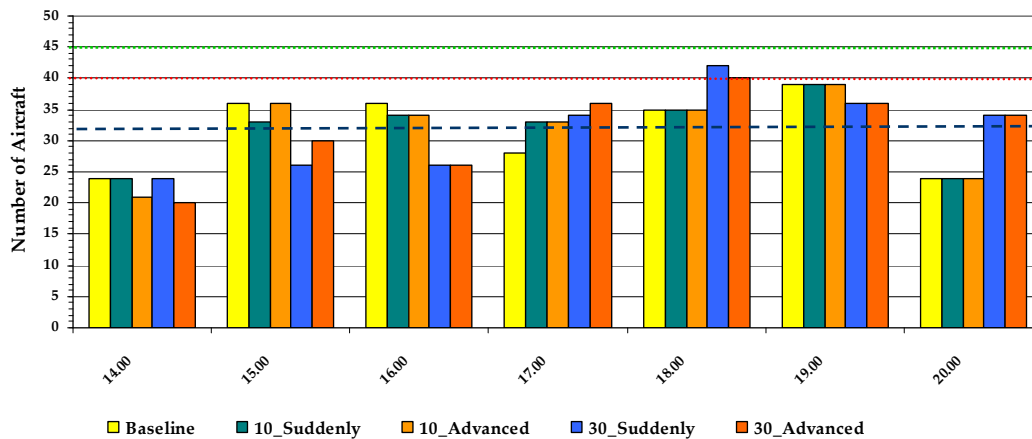


Figure 33: Entry Sector Operation Count (LEMDESN)

- Looking at the graph in
- Figure 33 we note that for the sector **LEMDESN**, the validation scenarios **Hail** and **Rain** are very efficient because the values of the resulting traffic demand for each time slot are always compliant with the both limits of the nominal capacity that its value to 10% (40 ac. /h);
- Also as far as **Snow** and **Wind** validation scenarios, the obtained results are positive even if in the slots of time from 17:00 to 20:00 the traffic demand values are higher than the limit to 30% capacity shortfall. This result shouldn't be negative since in these slots of time there are the effects due to recovery phase.

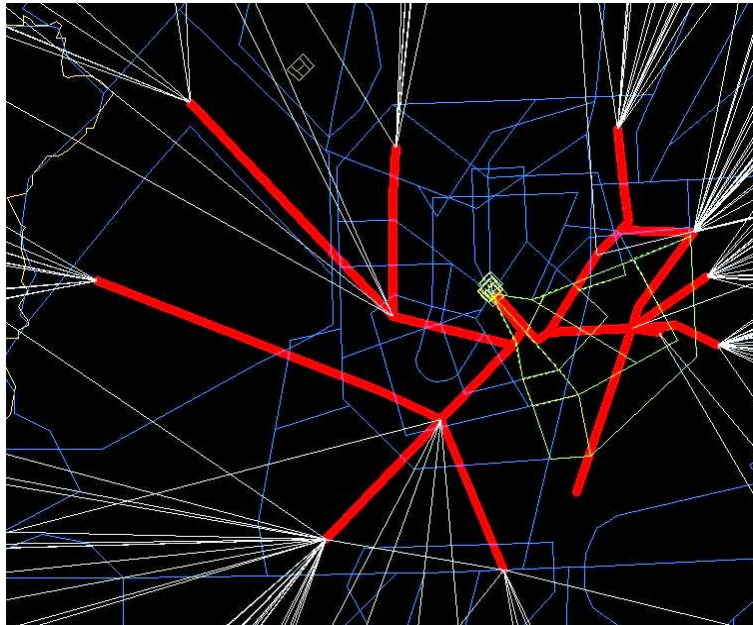


Figure 34: Sectors LEMDESN RAMS scenario capture

Madrid TMA LEMDREN - (From 14h00 To 21h00)

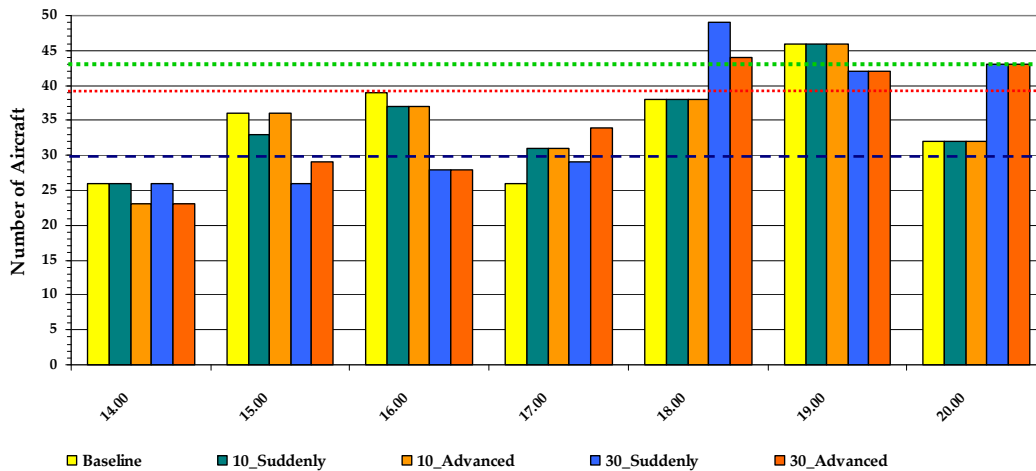


Figure 35: Entry Sector Operation Count (LEMDREN)

- The results obtained for the LEMDREN sector are substantially similar to those obtained for the LEMDESN sector except for the highest peak values seen in some time slots. Looking at the graph will note that the results obtained for scenarios **Hail** and **Rain** are very similar and respectful of imposed limit value of capacity during the slots of time within the period of interest. Naturally even in this case, the delays introduced in the early stages of capacity shortfall produce a substantial increase in the



number of movements in the sector during the slots of time from 18:00 to 21:00. In particular, between 18:00 and 20:00 slots of time there is also the overcoming of the declared capacity values;

- Finally there is a maximum peak of 49 aircraft in the sector during the time slot between 18:00 and 19:00 which greatly exceeds the maximum allowed capacity value (43). Of course, the 49 aircraft represents a traffic demand value and it is mainly due to the different renegotiation of the TTA value.

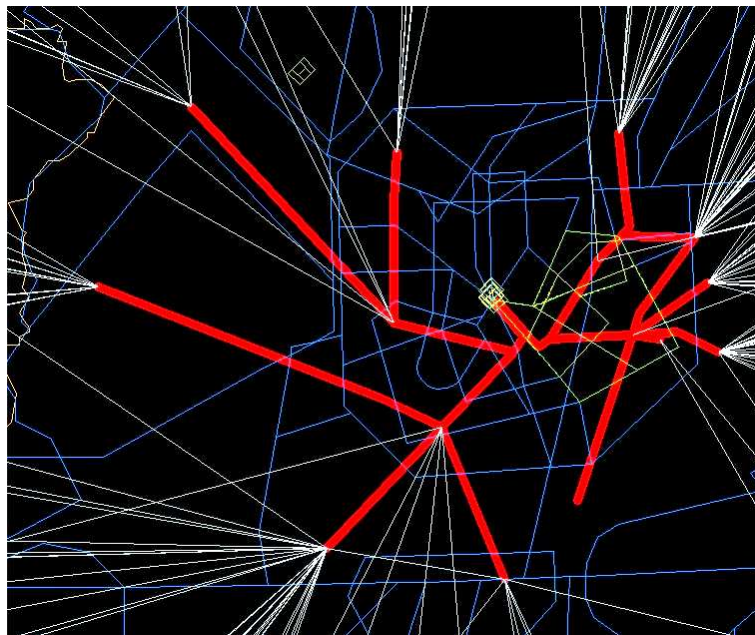


Figure 36: Sectors LEMDREN RAMS scenario capture

➤ STRATEGY 1

In this section the measured values of *Sector Entry Operations per hour* through RAMS simulation runs regarding the PROMASS STRATEGY 1 are reported.

HOURLY RUNWAY OPERATIONS

Based on the graphs reported in this section there are some facts that have to be highlighted regarding STRATEGY 1

- The PROMASS STRATEGY 1 affect only some of the time slots of the whole simulation day;
- Only for the slots of time between 14:00 and 20:00 a different order of arrival was found;
- During the first hours of the period shown in the figures (Figure 37 and Figure 38 – green background) between 14:00 and 17:00, the trend seems to show a gradual decrease of the number of arrivals;
- From 17:00 to 18:00 the results of the four simulated scenarios (**Rain**, **Rainout**; **Wind** and **Windout**) show an increases compared with results for the baseline scenario, this is especially true for the scenarios **Rain** and **30_Wiht**;



- In the period between 18:00 and 20:00 there is a reduction of the values except for the results obtained for scenario **Wind**, for which there was a very high peak value (50) and **Rain** scenario for which 37 was obtained;
- In particular from 19:00 to 20:00 the resulting values appear to be steady and coincident with the values of baseline, excepted for the high values of 52 for scenario Rainout and the 67 for scenario Windout.

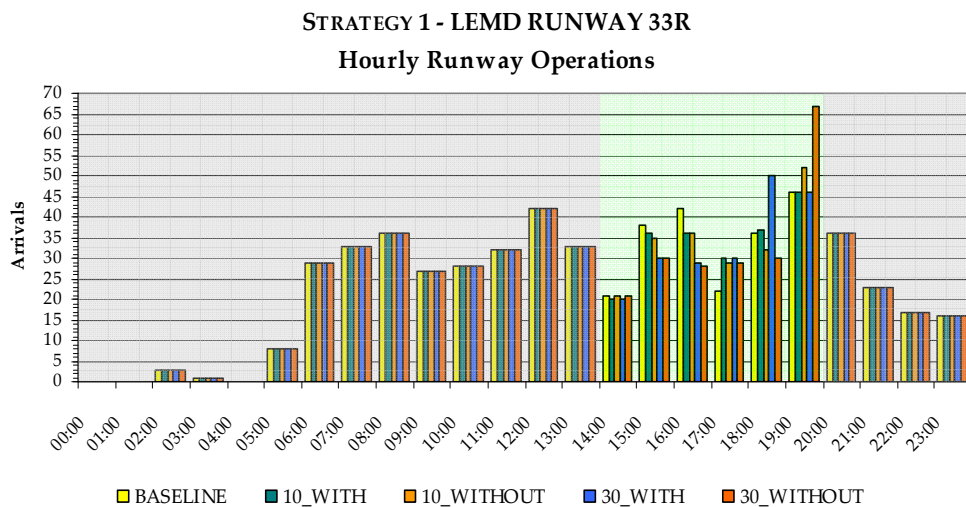


Figure 37: Hourly runway operations count for RWY 33 R of Madrid Barajas airport STRATEGY 1

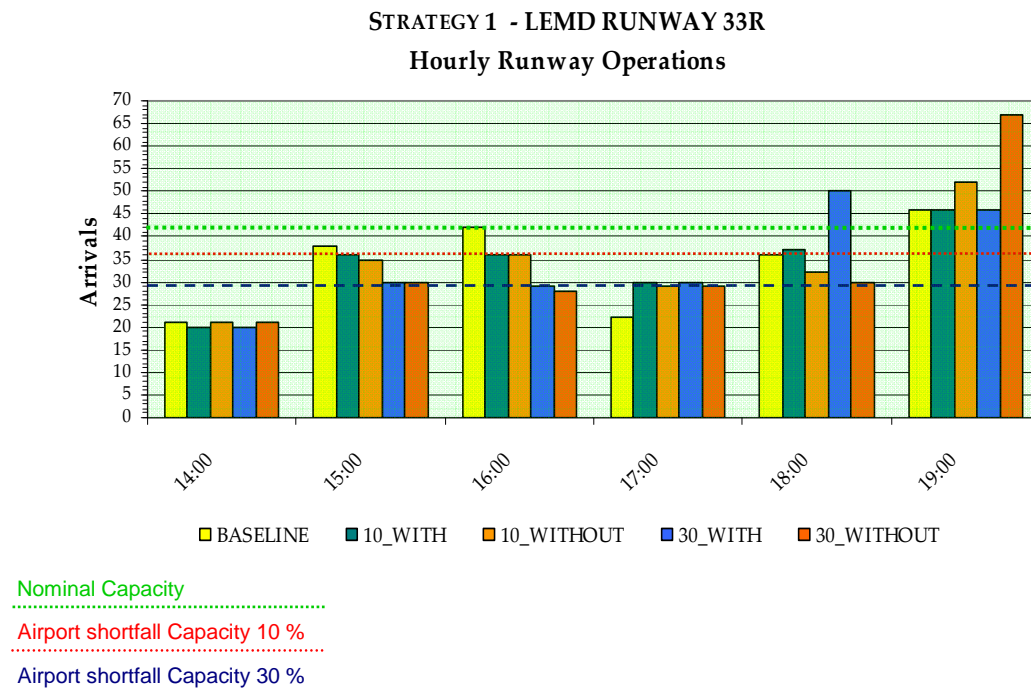


Figure 38: Hourly runway operations count RWY 33 R (zoom in the range of interest) STRATEGY 1



SECTOR ENTRY OPERATIONS PER HOUR

Analysed sector with relative declared sector capacity values were reported in the following table:

SECTOR	CAPACITY		SECTOR	CAPACITY	
LEBLX5W	Not available	Other Spanish Sector	LEMDAPN	39	TMA
LECBCCC	43		LEMDDEN	49	
LECBDDN	42		LEMDDWN	49	
LECBDDS	42		LEMDENN	45	
LECBLGL	34		LEMDESN	45	
LECBLGU	35		LEMDREN	43	
LECBMMI	43		LEMDRWN	43	
LECBP1I	36		LEMDWNN	47	
LECBPP2	42		LEMDWSN	47	
LECBVVI	40				
LECBXAL	42				
LECLTMW	36				
LECLVVLC	Not available				
LECMCJL	37				
LECMCJU	43				
LECMPAL	32				
LECMPAU	40				
LECMTER	40				
LECMZGZ	40				
LECPDWX	34				
LECPGOX	38				
LECPIXX	32				
LECPL1W	30				
LECPL2W	30				
LECPMXX	35				

Table 14: Analysed sectors and declared sector capacity values (STRATEGY 1)

Applying STRATEGY 1 the obtained values of the traffic demand about some sectors, in terms of *Entry Sector Operations* are lower than the values of declared sector capacity.

For this reason will be shown afterwards the graphs of the only sectors highlighted in yellow (see Table 14) for which the obtained results appear to be interesting in order to assess the outcomes of the applied strategy.



About the values shown in red, they indicate those sectors for which the resulting traffic demand values, already in the baseline scenario, appear to be well beyond the declared capacity values shown in the table and the results are inconsistent and not useful to carry out this study. Therefore, the graphs of these sectors are not reported in this section.

Madrid TMA_LECMCJL - (From 14h00 To 20h00)

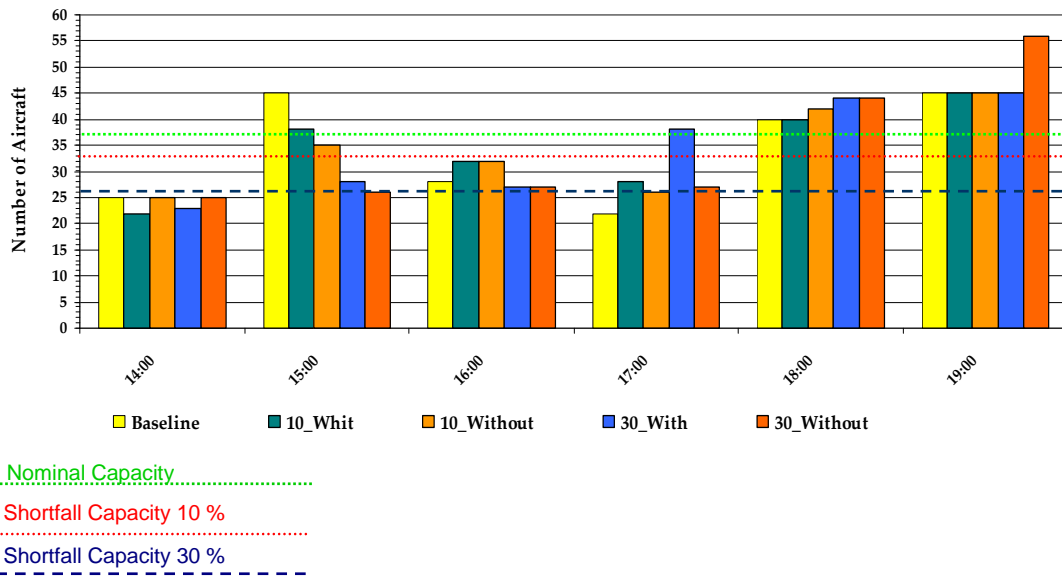


Figure 39: Entry Sector Operation Count (LECMCJL) STRATEGY 1

Madrid TMA_LECMCJU - (From 14h00 to 20h00)

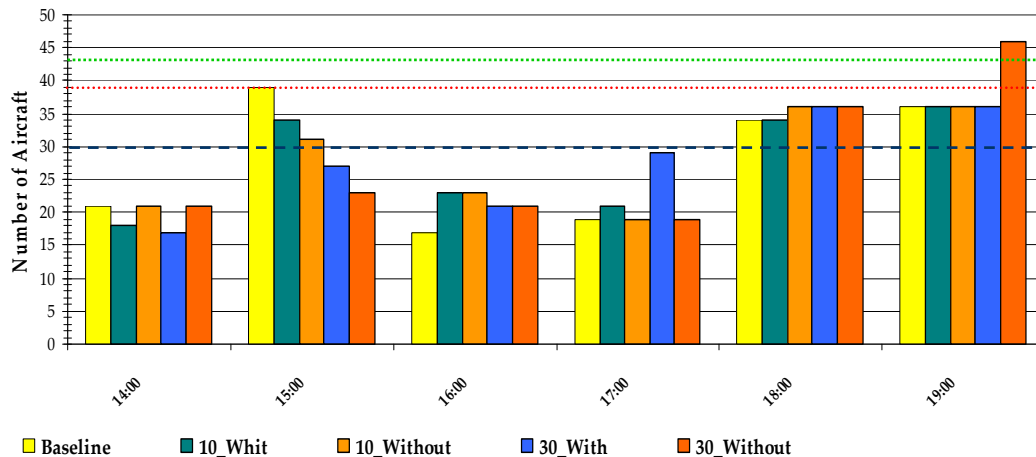


Figure 40: Entry Sector Operation Count (LECMCJU) STRATEGY 1



Based on the graphs reported in this section there are some facts that have to be highlighted regarding STRATEGY 1

- The graphs in Figure 39 and Figure 40 represent the only slots of time of the simulation day in which changes occurred between the various, applied sub-strategies under STRATEGY 1 (From 14:00 To 20:00);
- Figure 41 represents a graphic capture of the simulated airspace taken from a RAMS scenario to identify the location of the area and determine whether it falls within of the sub-region illustrated in section 2.3 of the experimental plan;
- The obtained results for both sector **LECMCJL** and **LECMCJU** show that the values of traffic demand is very high, also in the baseline scenario specially in the slot time from 15:00 to 16:00;
- From obtained results for both sectors we can notice that the arrivals flow is uniform in the first hour of interested period. Within the time period from 15:00 and 16:00 there is a significant decrease in the value of the entry sector movements. This is due to the fact that once the capacity shortfall is happened and the new value of TTA is sent, the sector pierce times are modified in order to balance demand and capacity;
- In the next slots of time from 16:00 to 18:00 the obtained values are characterised by increments compared to the baseline, this is due to the start of recovery phase at 17:00 and to the introduced delays by strategy;

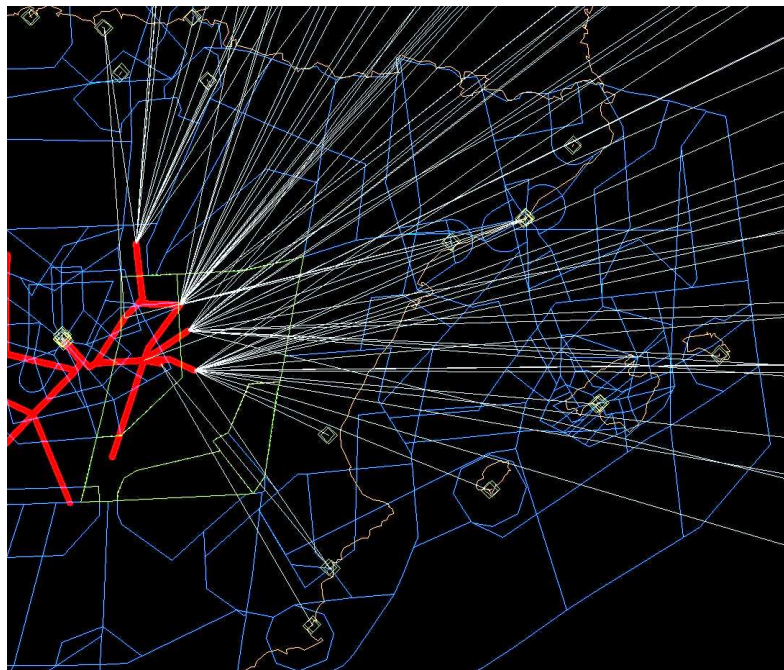


Figure 41: Sectors LECMCJL/U RAMS scenario capture STRATEGY 1

- The results (**LECMCJL**) show some peak values in some slots of time due to the introduction of the delays after re-planning in time through the allocation of the new TTA values. The values of these peaks appear to be higher than the declared capacity values regarding the all **strategies** and respective RAMS scenarios within the period from 18:00 to 20:00;



- As far as the **LECMCJU** sector, the results show a valid efficiency for all applied strategy except for slots of time from 19:00 to 20:00 in which the obtained values (46) from scenario **Windout** are greater than the value indicating the 30% capacity shortfall (line midnight blue) and declared sector capacity value (43);

Madrid TMA_LEMDES~~N~~ - (From 14h00 to 20h00)

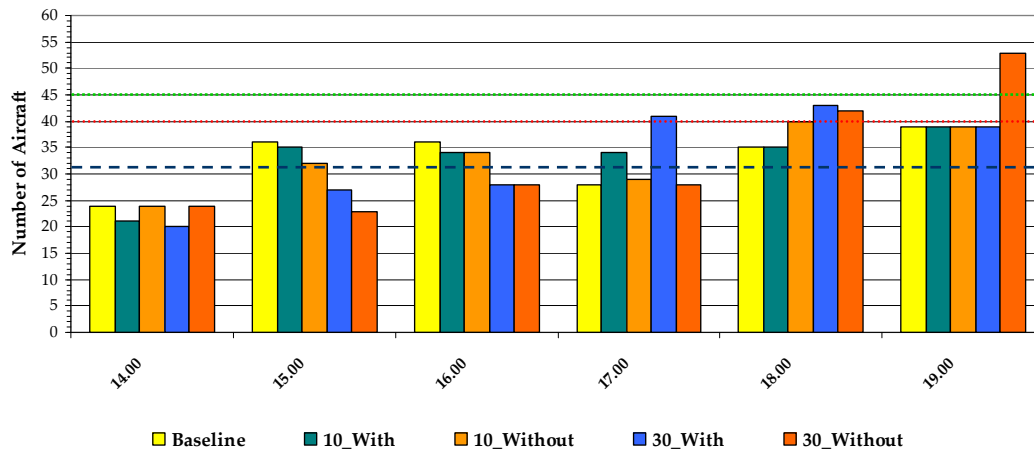


Figure 42: Entry Sector Operation Count (LEMDES~~N~~) STRATEGY 1

- Looking at the graph in Figure 42 we note that for the sector **LEMDES~~N~~**, the strategies **Rain** and **Rainout** are very efficient because the values of the resulting traffic demand for each time slot are always lower of the both limits of the nominal capacity that its value to 10% (40 ac. /h);
- Also as far as **Wind** and **Windout** strategies, the obtained results are positive;
- The results show a peak value (53) in the slots of time from 19:00 to 20:00 for scenario **Windout** . It is very higher than the declared sector capacity (45).



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

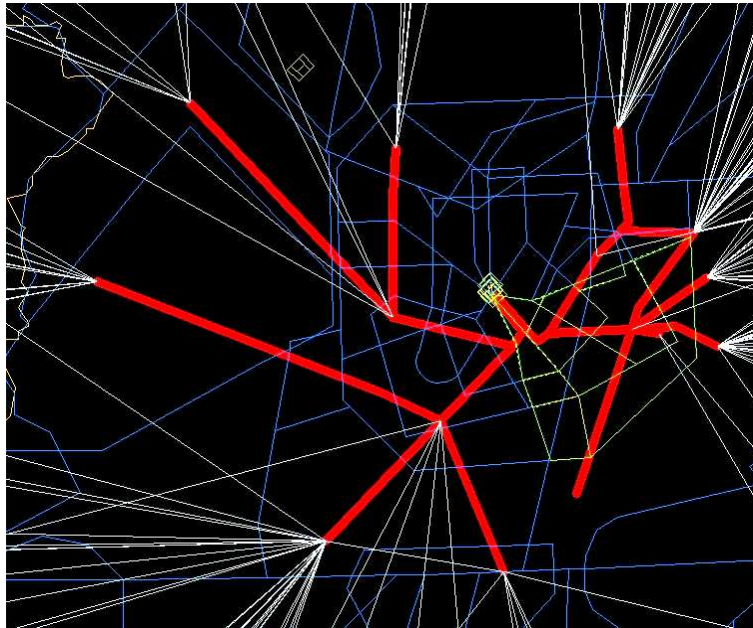


Figure 43: Sectors LEMDESN RAMS scenario capture STRATEGY 1



Madrid TMA_LEMDREN - (From 14h00 To 20h00)

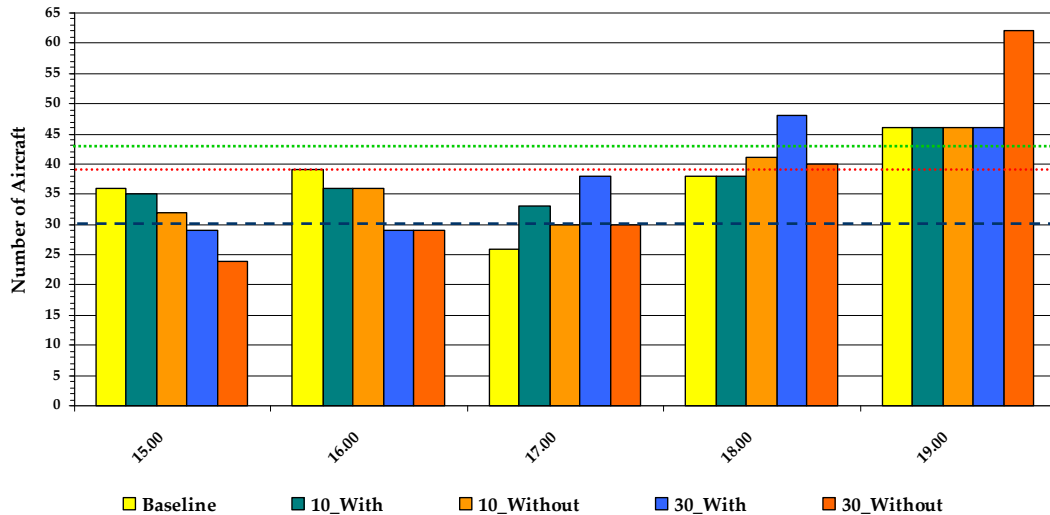


Figure 44: Entry Sector Operation Count (LEMDREN) STRATEGY 1

- The results obtained for the sector **LEMDREN** are substantially similar to those obtained for the sector **LEMDES** except following points:
 - From 15:00 to 16:00 and 16:00 to 17:00 the obtained values show a gradually decrease for all applied strategies;
 - Within the period from 17:00 to 20:00 the obtained values increase again to reach new peaks located in the slots of time between 18:00 and 20:00;
 - Both strategies Wind and Windout present peak values (48 and 62) much greater than declared sector capacity value (green line). This result shouldn't be very worrying as it represents a value of traffic demand, which appears to be very high due to the effects of the used strategies in order to balance capacity and demand.

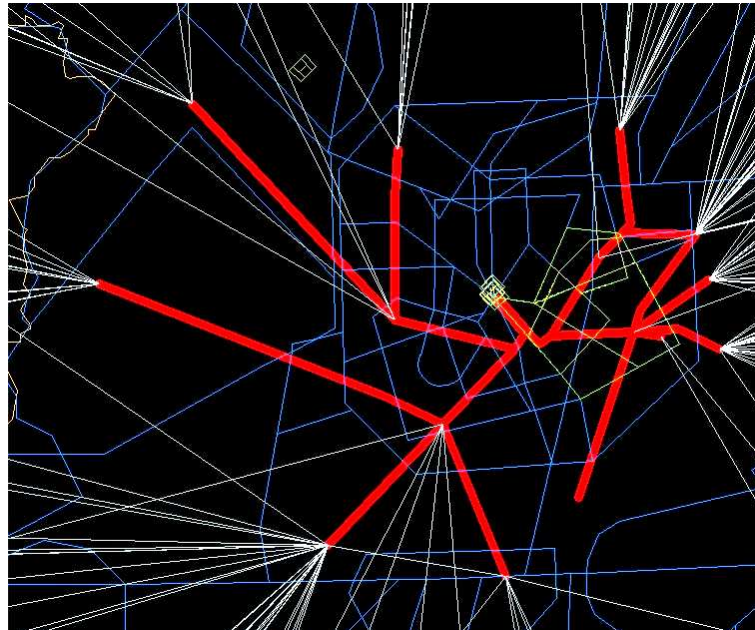


Figure 45: Sectors LEMDREN RAMS scenario capture STRATEGY 1


ID	Result	Measurement / Metric	Objective / Hypothesis
Dynamic DCB Concept			
R.P1	DCB Queue process smoothes the traffic to be managed by AMAN in all the three strategies.	Number of flights per hour. Information exchanged between AMAN and DCB queue functions. Delay to be managed by AMAN	Results relate to hypotheses H2 and H4.
Results on Validation Scenarios			
R.P2	Validation Scenarios in which restriction is known in advance presents the highest aircrafts delays later.	Delay Distribution generated	Result relates to hypotheses H2, H3 and H5.
R.P3	Flights affected by both shortfall and recovery period receive, at least, two TTAs, one during the capacity shortfall and other during the recovery period, trying to adjust the traffic demand to the airspace capacity.	Number of negotiations/data exchanges performed during the Implementation of a DCB queue.	Result relates to hypotheses H1, H2 and H3.
R.P4	In Validation Scenarios in which peak-off delay is higher, the average delay is smaller.	Delay Distribution generated.	Result relates to hypothesis H5.



Episode 3
D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

ID	Result	Measurement / Metric	Objective / Hypothesis
R.P5	Depending on the strategy, non airborne flights can absorb their delay on ground according to recommendations (not delayed more than 15 minutes). However, the number of flights that fit this statement varies depending on the strategy.	Percentage of flights that have suffered SBT changes.	Result relates to hypotheses H2 and H3.
Results on Strategies			
R.P6	Each strategy provides a different traffic sequence (modifies flights arrival order).	Delay Distribution generated	Result relates to hypotheses H2, H3 and H5.
R.P7	In strategy 1 non airborne flights are not delayed more than 15 minutes but this output causes higher delays in airborne flights. Only applicable at local level since this is the result of	Delay Distribution generated	Result relates to hypotheses H2 and H3.
R.P8	In strategy 2 airborne flights are not delayed more than the recommendations but this output causes higher delays in non airborne flights. Only applicable at local level since this is the result of	Delay Distribution generated	Result relates to hypotheses H2, H3 and H5.
Results on delays			
R.P9	Each strategy generates a different delay distribution depending on the aircraft status.	Delay Distribution generated	Result relates to hypotheses H2, H3 and H5
R10	Peak-off delays exceed delays recommendations in every validation scenario (15 minutes for non-airborne flights and no more than 3% of remaining time of flight).	Delay Distribution generated. Number of flights that are able to meet a proposed TTA to recover the capacity after a shortfall.	Result relates to hypotheses H2, H3 and H5.
R.P11	Recovery period lasts approximately the same in all the three strategies.	Delay Distribution generated.	Result relates to hypotheses H2, H3 and H5.
R.P12	The highest aircrafts delays exceed delays recommendations.	Delay Distribution generated. Number of flights that are able to meet a proposed TTA to recover the capacity after a shortfall.	Result relates to hypotheses H2, H3 and H5.
R.P13	Information exchanged between AMAN and DCB queue functions is mainly the mounted up delay generated and the new arriving traffic sequence.	Information exchanged between AMAN and DCB queue functions.	Result relates to hypothesis H4.

	Episode 3 D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment	<i>Version : 1.00</i>
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ID	Result	Measurement / Metric	Objective / Hypothesis
R.P14	When the capacity is recovered, most of the flights are not able to reach their original ETA. Only applicable at local level since this is the result of	Delay to be managed by DCB queue process.	Result relates to hypothesis H5.
R.P15	72% of traffic sample used in this exercise are non airborne flights when managed by DCB Queue ¹¹ . This traffic makes the results only applicable at local level and in the specific validation scenarios of the exercise.	Affecting SBTs, Affecting RBTs.	Result relates to hypothesis H5.

Table 15: Summary of Measured Experiment Results.

4.2 CONFIDENCE IN EXPERIMENTAL RESULTS

4.2.1 Quality of Results

4.2.1.1 Qualitative Results

The qualitative results are referred to the behaviour, and therefore the feasibility, of the processes of the ATM diagram model related to the Dynamic DCB Solution in case of non-severe capacity shortfall, and it takes into account the opinions of the experts (e.g. durations of some processes, rough definition of the prioritisation strategies, acceptable speeds, assumptions). Although conclusions in these processes were reached, due to the restrictions, hypothesis and assumptions they are not applicable but a local level. And taking into account the low maturity of the SESAR concept, the implemented processes and algorithms should also be further refined from an operational point of view.

Thanks to the high flexibility of the PROMAS models, it would be possible to incorporate more detailed parameters in order to refine the models and remove some assumptions.

4.2.1.2 Quantitative Results

PROMAS and RamsPlus have produced some quantitative results, which allow performing a detailed performance analysis of the merits of different TTA allocation strategies. However, a clearer definition of the SESAR performance objectives should be addressed in future studies to find the optimum TTA allocation strategy. In the scope of the exercise it was not possible to define the best priority-allocation strategy, since it is highly linked to each particular assessed validation scenario. Therefore, it is recommended to assess other different geographical regions because results suggest that flight duration is a sensitive parameter, as well as assessing different DCB Queue horizons.

The results should be considered as local due to the characteristics of Madrid airport traffic demand and could be used as a first step for future analysis.

¹¹ Taking into account ETOT, ETA and the time when the aircraft is managed by the DCB processes.



4.2.2 Significance of Results

4.2.2.1 Qualitative Results

Statistical analysis was not performed on the qualitative results.

However, the use of PROMAS is considered to be successful, because it has been possible to assess 12 large scenarios by implementing part of the ATM Diagram Model as well as integrating it with massive operational parameters (e.g. flight events, airports, ...) and ad-hoc algorithms.

4.2.2.2 Quantitative Results

Statistical analysis was not performed on the quantitative results.

However, the quantitative results obtained by executing twelve different scenarios using the same traffic sample allowed performing a comparative (i.e. different shortfall severity, constraint prediction level and TTA Allocation Strategy) assessment that is considered an enough first step towards the Concept Refinement since it provides the trends of the behaviour of each validation scenario.

4.3 UNEXPECTED EXPERIMENTAL RESULTS

- In case of Strategies 1 and 2, many flights receive more than one TTA. That is because each flight reaching the DCB Queue Active Horizon triggers the TTA Allocation process, and taking into account the corresponding priority, it may be likely required to re-allocate many of the flights;
- Even though the strategy 2 gives absolute preference to airborne flights the number of airborne flights delayed more than 3% of the remaining flying time are similar than one applying any of the other two strategies (assumption A-02 from Experimental Plan [3]). That non-expected result is because the severity of the shortfall capacity induces quickly a delay higher than 216 seconds (i.e. 3% out of 2 hours).



5 ANALYSIS OF EXPERIMENT OUTCOMES


5.1 ANALYSIS OF OUTCOMES ON THE BASIS OF DETERMINED HYPOTHESES

Table 16 below lists the hypotheses from the Process Simulation. It also states the outcomes along with supporting reasons for each.

The possible outcomes are:

- Accept – the results from the gaming support the hypothesis;
- Accept (partial) – the results support the hypothesis to some extent however there is some limitation to be taken into account;
- Open – the results do not provide sufficient evidence to accept or reject the hypothesis so further study is required;
- Reject – the evidence is contrary to the hypothesis.

ID	Hypotheses	Outcome
H.P1	The Dynamic DCB and BT Management part of the ATM Process model establishes without incoherencies or loops-without-end who is responsible for carrying out any process, which information is required for it, what information is output and to whom, and the duration of the process.	Accept (partial)
	<p>During the development of the PROMAS model based on the ATM Process Model, some issues were detected:</p> <ul style="list-style-type: none"> • There are processes involving more than one actor and these processes should be further detailed until reaching processes with only one actor involved. Otherwise it is not possible to assess the absence of loops-without-end; • There is not any priority level assigned to each actor-process, what would allow to know which task should be left in stand by when one actor is supposed to execute two different tasks simultaneously. <p>Excepting these issues, in general, the ATM Process Model provided enough information to model the dynamic DCB processes to meet the experiment objectives.</p>	
H.P2	Dynamic DCB and BT management processes will improve the management of the current DCB problems, by means of implementing some planning/execution solutions. Specially, although not only, those processes triggered once a flight has taken-off until it reaches the AMAN active horizon.	Accept (partial)
	<p>The possibility of adapting the BT of flights already taken off would help TMA controllers by a better smoothing the incoming traffic when a shortfall happens. However, this operational improvement leads to a more complex management of DCB problems due to the new flight Crew - Controller negotiations.</p> <p>In addition, it is not clear which are the pursued objectives to solve the DCB problem; the best strategy would be one or other depending on what kind of benefit is expected: best fuel consumption (strategy 2), best ETA adherence and therefore less impact on flight rotation and less probability on losing a connecting flight (FPFS), less impact on the congestion of neighbour airports but penalising fuel consumption (strategy 1).</p>	
H.P3	Dynamic DCB and BT management processes will allow airspace users to	Accept

	Episode 3 D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment	<i>Version : 1.00</i>
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ID	Hypotheses	Outcome
	<p>decide how they want to adapt their SBT/RBT to meet a constraint.</p> <p>The processes implemented in the PROMAS platform include the negotiations processes among the involved actors to decide how to reach the allocated delays. However, the 3D adaptation has not been simulated.</p> <p>Results show that a very high number of TTAs can be allocated impacting only one airport. It should be assessed if the corresponding APOC would be able (e.g. in terms of workload) of rearranging its departure queue on time as well as allowing SBT negotiations with the different AOCs.</p>	(partial)
H.P4	<p>AMAN and DCB Queue processes will be coordinated and synchronised by means of a clear procedure.</p> <p>The coordination and synchronisation procedure should assure that the DCB Queue function receives, at least, the following information from AMAN Function:</p> <ul style="list-style-type: none"> • The latest TTA allocated by AMAN based on the number of aircrafts under AMAN range and the new arrival ratio caused by the shortfall; • The geographical coordinates to where TTA is calculated; • The new arrival ratio; and • The TTA allocation strategy preferred by the specific APOC (only if SESAR would decide to let open this possibility). 	Accept
H.P5	<p>Non-severe capacity shortfalls can be solved without UDPP. Severity can be defined as the maximum admissible delay per flight (e.g. 15 minutes of ground delay).</p> <p>Without a clear definition of a 'Non-severe capacity shortfall' characteristics four level of severities have been assessed:</p> <ul style="list-style-type: none"> • 10% airport capacity shortfall foreseen one hour in-advance; • 30% airport capacity shortfall foreseen one hour in advance; • Suddenly and unexpected 10% airport capacity shortfall; • Suddenly and unexpected 10% airport capacity shortfall. <p>Considering that the maximum admissible delay per flight is 15 minutes if on ground and 3% out of the remaining flight duration if airborne, for this local assessment this hypothesis can not be accepted.</p> <p>It should be further studied the definition of what is a non-severe capacity shortfall, to clarify the objectives to be met by the TTA allocation strategy to be developed.</p>	Open

Table 16: Hypotheses and outcomes

5.2 ANALYSIS OF CONSEQUENCES OF OUTCOMES FOR EXPERIMENT OBJECTIVES AND ASSUMPTIONS

Table 17 lists the objectives of the Process Simulation experiment, and describes to what extent they were met during the experiments.



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

ID	Objective Description
Clarification of the Concept	
O.P1	<p>Define the system functions that are needed to support the DCB process and BT management (queuing, network monitoring, interactions between APOC and users...);</p> <p>Through the implementation of the different TTA Allocation Strategies the need of developing several internal system functions has arisen. It is not still clear if some of the following functions will be external to users or internal and transparent for them. In further studies, once the concept is mature and the final strategy is decided, more required functionalities could be detected.</p> <ul style="list-style-type: none"> • Automated detection of a flight entering in the DCB Queue Horizon; • Automated capturing of every flight characteristics that are relevant for the TTA allocation strategy (e.g. remaining fuel, preferred level cruise, updated ETA, etc); • Get the first TTA that can be allocated; • Work out the new arrival ratio according to the constrained airspace capacity; • Make a list with the aircraft affected by the restriction distinguishing between SBT/RBTs; • Work out the minimum and maximum possible TTA for each aircraft attending the delay limits incorporated to the priority strategy; • Allocate the TTAs to the aircrafts according to the strategy; • During the shortfall, check whether the capacity is recovered or not; • Once the airspace capacity is recovered, detect whether the situation is stable and the initial planned situation is recovered.
O.P2	<p>Define the interaction of DCB process (queue) with some Execution phase processes (AMAN).</p> <p>The exchanged information between DCB Queue processes and AMAN has been defined during the development of the TTA Allocation Strategies. See H.P4.</p> <p>However, further studies should define more precisely when this information has to be exchanged, the processes and the involved actors in these processes.</p> <p>It has been detected a possible incoherence as experts did not reach an agreement in the definition of the required time for negotiations for the implementation of the DCB Solution. If this 'negotiation time' was higher than 10 minutes, this fact would result in the incoherence of the interim AMAN Advisory Active Horizon and the DCB Queue Active Limit, which should be accordingly modified.</p>
O.P3	<p>Gain a better understanding of how actors work within the dynamic DCB process and BT management, and in particular, how actors interact.</p> <p>Considering the obtained results, the most complex instants when the intervention and interaction of the involved actors are highly demanded are:</p> <ul style="list-style-type: none"> • When the capacity shortfall time is know (even though this shortfall is known one hour in advance); • When the capacity recovery time is know (even though this recovery is known one hour in advance). <p>PROMAS has implemented a first draft of how actors could interact in a DCB Queue process (according to ATM Process Model [6]). However, special attention should be</p>



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

ID	Objective Description
	paid in the above explained times, in which the interaction between actors should be deeply addressed in further studies to get a high level definition of the relationship among them.
O.P4	<p>Measure the number of information exchanged between the different involved actors and the number of triggered processes to detect the main</p> <p>This objective has been reached in the experiment.</p> <p>The duration of the processes could cause a bottleneck, since the required time in the negotiations and to reach an agreement could be higher than the available time in between AMAN horizon and DCB Queue Active Limit.</p> <p>In addition, as it is stated in O.P3 the most complex instants are when the capacity shortfall or recovery time are known. At these instants the required intervention of some APOCs to re-arrange and negotiate the departure queue can be a bottleneck.</p> <p>However, these results are highly linked to the experts' opinions, who allocated times to each task.</p>
O.P5	<p>Provide some elements about which information should be exchanged, and when, to assure a successful synchronisation between AMAN and DCB Queue processes.</p> <p>The exchanged information between DCB Queue processes with AMAN has been defined during the development of the TTA Allocation Strategies. See H.P4</p> <p>This information should be exchanged as soon as the shortfall or recovery is foreseen, considering both the time required by the different negotiations till achieving an agreement between all involved actors in how to meet the allocated TTAs and the gap in between AMAN Active Horizon and DCB Queue Active Limit. Further studies should help to define the optimum 'AMAN & DCB' Queue Active 'Horizon & Limit'.</p>
Assessment of process feasibility	
O.P6	<p>Define an initial dynamic DCB and BT management process that covers implementing, amending and cancelling dynamic DCB solutions (queue);</p> <p>A simplified dynamic DCB and BT Management process has been defined (hypotheses H1 and H2) covering only the implementation of a DCB solution and can be used as a first approach to the concept. However the 3D adaptation (i.e. x,y,z : rerouting, FL changes, vectoring) of the final agreement would need a further study by using FTS or RTS techniques.</p>
O.P7	<p>By designing three different TTA allocation algorithms:</p> <ul style="list-style-type: none"> To assess both the effectiveness and the delay impact on the different type of flights. <p>Depending on the strategy the distribution of delays amongst the AUs is very different. See H.P5.</p> <ul style="list-style-type: none"> To launch specific issues to refine these strategies regarding the airborne priority subject. <p>Strategies have been developed considering different airborne priorities. The relation between the DCB Queue Active Horizon and the flight time durations of flights arriving to the affected airport is extremely important to design a specific airborne priority that does not collapse the collateral departing airports. So, it should be decided in further discussions if there will be only one or several TTA Allocation Strategy that could be applied in any ECAC airport when a shortfall happens.</p> <p>In addition, any priority different from FPFS will derive in that one flight can receive</p>



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

ID	Objective Description
	<p>along its flight many different TTAs. To minimise this non-recommendable nuisance it should be studied the convenience in waiting a specific period of time to deliver the TTA proposal until is assured that, even with priority, it will be definitive.</p> <p>To support the functional development and refinement of the best TTA allocation Strategy.</p> <p>To develop the different TTA allocation strategies in PROMAS, some functionalities that should be included in the future to support the DCB Queue process are suggested:</p> <ul style="list-style-type: none"> • The implementation of a 3D simulation function that will be able to simulate the adaptation to the TTA in the airport/airspace; • Take into account the delayed aircrafts depending on the airline, airport of origin, etc, to allocate priorities depending on the most affected. <p>This function should be considered as a mere starting point for further studies.</p>
O.P8	<p>Support the functional development of some of the functionalities that should be included in the future Network Management Function.</p> <p>Considering the close relationship between the traffic demand of the constrained airport, the severity of the capacity shortfall and the effectiveness of the TTA Allocation Strategy, the Network Management Function should incorporate a function that selects/defines the appropriated ad-hoc TTA Allocation Strategy.</p>
O.P9	<p>Provide an assessment of the impact on BT management related to the different TTA Allocation Strategies being addressed.</p> <p>Taking into account the results, it is clearly demonstrated that the number of negotiations and changes in Business trajectory (i.e. BT management) is very different depending on the TTA Allocation strategy. So, this BT Management complexity due to the TTA Allocation Strategy could be one of the parameters that should be minimised when the definitive TTA Allocation Strategy were developed. In addition see O.P7.b.</p>
O.P10	<p>Analyse the relationship between the severity of the shortfall capacity and the delay to be managed by DCB queue measures.</p> <p>A capacity shortfall of 30% induces roughly x4 delay increase than capacity shortfall of 10%, However this result is strongly linked to the characteristics of the scenario.</p>
O.P11	<p>Study the timeframe when DCB queue measures can be implemented in an effective way (i.e. sudden shortfalls, anticipated shortfalls, short duration, long duration, etc.).</p> <p>The timeframe when DCB queue measures can be implemented in an effective way depends strongly on the validation scenario and the assumptions from the Experimental Plan. See H.P5.</p> <p>Most of the results are strongly linked to the geographical scenario so the conclusions should only be applied at a local level.</p>
O.P12	<p>Identify the incoherencies and bottlenecks of the processes described in the OS-11.</p> <p>It should be assessed in further studies the 10 minutes gap between the AMAN Horizon and the DCB queue limit. Some Expert opinions indicate that 10 minutes is a little short to achieve an agreement between all involved actors in how to 4D meet the TTA list, and it was proved during the development of the validation exercises that this time could be extended due to the required negotiations in the processes.</p> <p>The APOC versus AOC negotiations just when the first set of TTAs is delivered can be especially relevant in those 'highly linked collateral' airports whose typical flight</p>

ID	Objective Description
	<p>durations is less than the DCB Queue Active Horizon.</p> <p>The Controller versus Flight Crew negotiations just when the first set of TTAs is delivered can be especially relevant in those sectors that are used by a great amount of flights arriving to the constrained airport and are located around a 'DCB Queue Active Horizon' time from the constrained airport. Therefore, it could be further studied the possibility of allocating different DCB Queue Active Horizons for each ECAC airport to select the preferred sectors where negotiating the best way of adapting to the new TTA.</p>
O.P13	<p>Suggest some modifications that could be used for both refining the concept and updating OS-11.</p> <ul style="list-style-type: none"> • Increase the gap in between the AMAN Active Horizon and the DCB Queue Active Limit to avoid that AMAN delivers a CTA to a specific flight when this flight is still negotiating the best way of meeting the TTA previously delivered by DCB Queue; • Due to the close relation between the characteristics of the traffic demand (e.g. flight duration) and the behaviour of the resulting delay distribution after applying each strategy, it should be assessed the ability of allocating to each airport a different and dynamic TTA Allocation Strategy, DCB Queue Active Horizon, conditions to trigger UDPP; • Clarify what to do when a flight receive several TTAs: whether send it or not more than once, and what is the temporary limit in which this TTA is definitive.
Exploration of new techniques	
O.P14	<p>Demonstrate that both planning processes and SBT/RBT data can be linked by PROMAS to be used in future studies.</p> <p>The use of PROMAS has been successful, because it has been possible to assess 12 large scenarios by implementing part of the ATM Diagram Model as well as integrating it with massive operational parameters (e.g. flight events, airports ...) and ad-hoc algorithms.</p>

Table 17: Objectives addresses by the Process Simulation experiment



6 CONCLUSIONS AND RECOMMENDATIONS

The whole exercise was defined as an initial building block in support to the SESAR validation programme rather than as self-contained validation activity providing definitive answers to a set of validation questions. Therefore all findings, recommendations and conclusions mentioned in this paragraph must be taken very cautiously and would require further investigations to be validated.

6.1 FINDINGS

The main outcomes of the experiment can be split in two distinct categories:

- Outcomes related the concept and the evaluation of the operational scenario addressed by the experiment;
- Conclusions about the validation techniques and platforms used in the experiment.

These two aspects are developed in the two following paragraphs.

6.1.1 Findings about concept clarification and operational scenarios

The conclusions are structured around the main themes addressed by the exercise as developed hereafter.

6.1.1.1 TTA Allocation strategies

This topic was not an initial objective of the experiment. However as the topic was addressed by the PROMAS simulation and discussed by experts during the Gaming sessions, some conclusions can be drawn that have to be taken very cautiously due to the low maturity of the sequencing models implemented in both platforms.

The peak of BT negotiations is lower when the capacity shortfall is known 1 hour in advance.;

The number of affected BTs, just when the Capacity Shortfall Time happens, does not depend on the severity of the shortfall.

While the restriction is active, there are new BTs negotiations every time a new flight reaches the DCB Queue Active Horizon:

- In case of Strategy FPFS, there is only one TTA per flight so it is necessary only one BT negotiation;
- In case of Strategies 1 and 2, many flights receive more than one TTA.

In all the Validation Scenarios the global number of BTs negotiations for a RBT-status flight is lower than for a SBT-status flight. This result could be different in airports where there is a high percentage of arriving flights whose flight duration is higher than the DCB Queue Active Horizon.

For the assessed scenarios, LEPA-LEMD is a meaningful city-pair and with flight duration lowers than 2 hours. This is why LEPA APOC appears as the most impacted APOC by the capacity shortfall (13 BT negotiations in 10 minutes).

Even in scenarios where the capacity shortfall was only a 10% there is a relevant percentage of flights with delays exceeding the recommendations (3% of the remaining flight duration for in-air flights and 15 minutes for on-ground flights) (FPFS 56% - STR1 69% - STR2 70%).



In strategy 1 on-ground flights are not delayed more than 15 minutes but it causes high delays in airborne flights (even higher than 80 minutes). This result is due to the fact that Strategy 1 gives higher priority to non-airborne aircrafts, which means that airborne aircrafts are delayed in favour of the non-airborne ones. Airborne aircrafts sum up delays that can reach even 80 minutes for the most delayed aircraft and in the highest severity capacity shortfall scenario.

Even though the strategy 2 gives absolute priority to airborne flights, the number of airborne flights delayed more than the recommendations are similar to the number provided by the other strategies;

Depending on the applied strategy the individual flight delays are differently shared in between affected flights, but the total delay does not significantly change because none "arrival window" is missed.

6.1.2 Key findings about validation techniques and the platform

6.1.2.1 Process Simulation Technique

The Process Simulation validation technique was used in the scope of this exercise to study different TTA allocation strategies and their impact on the negotiation of business trajectories.

From a general point of view, this technique can be viewed as an advanced model-based technique focusing on the interaction between processes. The simulation runs quite fast once the model has been created, and also the value of certain parameters can be easily changed in a fast and easily way.

It is obviously complementary to the Gaming technique as it enables the generation of quantitative elements in support of concept clarification and possibly, at a later stage, operability assessment. However, this technique is limited and can not provide support to the Gaming sessions on line. For any future ATM assessment, the ideal way of using PROMAS platform to complement Gaming would be after Gaming analyses are concluded. Then, PROMAS would implement the detailed storyboards (i.e. sub-processes, actors, process-durations, protocol of de-blocking prioritization to be used in case an actor can not perform a process because is performing another one) and agreed assumptions coming from Gaming as well as would apply the assessment to larger scenarios.

6.1.2.2 Process Simulation Platform

The PROMAS platform was used in the context of the exercise to implement the process simulation validation technique. The experiment demonstrated the ability of PROMAS to perform the modelling of a large range of ATM processes in a very short time frame.

This platform provides qualitative and quantitative results, in the scope of this exercise it could be stressed:

- Qualitative results:
 - Highlight incoherencies;
 - Detection of bottlenecks;
 - Contribution to the concept, DODs and Operational Scenarios refinement.
- Quantitative results (by post-processing):
 - Process view:
 - Number of negotiations/data exchanges;
 - Operational view:
 - Number of flights able to complete certain tasks;
 - Delay distribution generated;



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

- Percentage of flights that have suffered changes when running the processes;
- Others, depending on the definition of the exercise.

The simulation runs quite fast once the model has been created. However, the development of the model implies a great effort, since it is required to learn the PROMAS language and to define the scenarios in an accuracy level to obtain an optimum model.

This platform has been developed in the scope of this exercise and it has not yet achieved a high level of maturity at this stage, although the main characteristics have already been established. In addition, qualitative results are obtained by post-processing which requires an extra effort apart from the development of the scenario.

It is a promising platform to be used, and particularly in the context of rapid prototyping activities.

6.2 ISSUES

Some issues or point of interests are identified as follows.

Validation Technique Issue: For any future ATM assessment, the ideal way of using PROMAS platform to complement Gaming would be after Gaming analyses are concluded. Then, PROMAS would implement the detailed storyboards (i.e. sub-processes, actors, process-durations, protocol of de-blocking prioritization to be used in case an actor can not perform a process because is performing another one) and agreed assumptions coming from Gaming as well as would apply the assessment to larger scenarios.

In this exercise, this process has not been possible due to planning constraints. However, by attending to Gaming exercises, the risk of performing exercises under very different conditions has been mitigated, and the storyboards are mainly coming from the ATM Processes Diagram Model and some inputs coming from OS-11, expert groups and FTS outputs.

Operational feasibility: It should be assessed if the corresponding APOC would be able (e.g. in terms of workload) of rearranging its departure queue on time as well as allowing SBT negotiations with the different AOCs.

The 3D adaptation (i.e. x,y,z : rerouting, FL changes, vectoring) of the final agreement would need a further study by using FTS or RTS techniques.

BT negotiations between Flight Crew and Controllers to adapt the RBT when the delay is high, could be problematic if Flight Crew argues lack of remaining fuel.

Concept Clarifications: It should be further established the way of identifying what is a severe and what is a non-severe capacity shortfall.

It is required to set the concrete objectives to be achieved by the TTA allocation strategy. It is fundamental to success in its development.

6.3 RECOMMENDATIONS

6.3.1 General recommendations

ATM Diagram Model: The ATM Diagram model would be improved by including the following parameters (i.e. process-durations, protocol of de-blocking prioritization to be used in case an actor can not perform a task because is performing another one).

Wider scope: Results are strongly linked to the traffic sample. The assessment of new traffic samples on different types of airports could give results applicable at a global level.



6.3.2 Recommendations on supporting DODs and Operational Scenarios

Concept Clarifications: The gap in between AMAN Active Horizon and DCB Queue Active Limit should be higher than 10 minutes.

It should allow to apply different ad-hoc TTA Allocation Strategy in any ECAC airport when a shortfall happens and a DCB Queue process is activated.

Any TTA Allocation Strategy based on a priority different of FPFS will derive in that one flight can receive along its flight many different TTAs. To minimise this non-recommendable nuisance it should be waited a specific period of time before delivering the TTA proposal until is assured that, even with priority, it will be definitive.

Each ECAC airport should be allowed to allocate different ad-hoc DCB Queue Active Horizons in order to strategically select the preferred sectors where negotiating the best way of adapting to the new TTA.

It should be allowed the ability of allocating to each airport a different ad-hoc TTA Allocation Strategy, DCB Queue Active Horizon and conditions to trigger UDPP.

6.3.3 Conclusions and Recommendations for Project Level

None

6.4 CONCLUSIONS

10 minutes gap in between DCB Queue Active limit and AMAN Active Horizon are not enough.

Ad hoc DCB Queue Active Horizon, DCB Queue Active Limit, AMAN Active Horizon and TTA Allocation Strategy should be dynamically assigned depending on the severity of the capacity shortfall (i.e. how much, when, until when), the characteristics of the most updated "Planned Traffic Demand" and the target delay or whatever objectives.

The most complex period of time, from the point of view of Dynamic DCB Queue and BT Management processes, are the 10 minutes after knowing when the capacity shortfall is known.

PROMAS has created an integrated model where management processes, flight events, operational parameters, algorithms and functions live together allowing PROMAS to analyse in an automated way how some operational values impact on the ATM Process Model and vice versus.

Process Simulation can be viewed as an advanced model-based technique. The PROMAS platform showed its ability to model a large range of ATM processes.



Episode 3

D3.3.2-02b - Simulation Report on Business Trajectory Management and Dynamic DCB - Annex B: Process Simulation Experiment

Version : 1.00

7 REFERENCES AND APPLICABLE DOCUMENTS

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Episode 3

**D3.3.2-02b - Simulation Report on Business Trajectory
Management and Dynamic DCB - Annex B: Process
Simulation Experiment**

Version : 1.00

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