EPISODE 3

Single European Sky Implementation support through Validation

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This document provides the Validation Experimental Plan for Episode 3 WP3.3.5 ”Global performances at network-wide level (Macromodel)”. The goal of this Validation Exercise is to provide the main performance improvements at the ECAC wide level due to the collaborative layered planning processes defined in the SESAR ConOps.

EP3 WP3.3.5 studies how local Operational Improvements (OIs) affect the **ATM network global performances and behaviour** in terms of state (free/congested) generation/ transition, bottleneck generation, etc. The exercise covers capacity, efficiency and predictability Key Performance Areas, by delivering ECAC performance indicators in these areas.

From the wide scope of Operational Improvements introduced by SESAR Concept of Operations, EP3 WP3.3.5 focuses on those promising to deliver more benefits or having a greater impact in ECAC wide performances (capacity, efficiency and predictability). Additionally, EP3 WP3.3.5 Validation Exercise is the final step to close the loop of the WP3 validation activities. Thus, EP3 WP3.3.5 extends/analyses/refines the local conclusions of previous WP3 Validation Exercises related to the validation/ clarification of Operational Improvements/ Procedures. EP3 WP3.3.5 **integrates these local conclusions in an ECAC wide network model** and then studies the impact of the local conclusions on the global performances and behaviour, by capturing the network coupling effects.

The validation approach chosen is suitable for the first assessment at ECAC network level of the fitness for purpose of new concept functions in an early stage of maturity. EP3 WP3.3.5 validation methodology consists of a **macroscopic approach** to network modelling, based on an **innovative application** of complex system modelling to the ATM network.

The **flexible model** used allows exploring how ECAC network ATM performances can benefit from new concept elements before the detailed operational procedures are available and without requiring an intensive platform development effort. The validation technique is based on a non expensive tool allowing quick modifications and the simulation of a number of different configurations/operational functions in a short period of time. Coarse (macroscopic) level of detail keeps computational and execution time within the scope of the exercise, whereas modelling many details don’t have a significant impact on macroscopic behaviour. The main goal is to exploit the trade-off between accuracy and flexibility to be in line with the SESAR Concept lifecycle phase, focussing on capturing the performances evolution.

EP3 WP3.3.5 ”Global performances at network-wide level (Macromodel)” ultimate objective is to expand the repertoire of cost-effective validation and clarification techniques suited to the early stages of an ATM operational concept development.

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1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides the Validation Exercise Plan for EP3 WP3.3.5 “Global Performances at Network Wide Level (Macromodel)”. This experimental plan is based on a general template that has been produced collaboratively between EP3 WP2.3, the Validation Strategy and Support Tasks within EP3 WP 3, 4 & 5 (x.2.1), and complementary guidance material for E-OCVM Step 2, as provided by EP3 WP2.3 [1].

The Experimental Plan mainly covers the steps 2.1 to 2.6 of the European Operational Concept Validation Methodology (E-OCVM) [3]. It includes all information necessary to build the model network that will evaluate how local Operational Improvements (OI) affect the network global behaviour in terms of state (free/congested) generation/transition, bottleneck generation/behaviour, etc. This experimental plan is in line with EP3 WP3 Validation Strategy which covered steps 0.1 to 1.7 [5].

1.2 INTENDED AUDIENCE

The intended audience includes:

- EP3 WP3 Leader;
- EP3 WP3.2 Validation Strategy, Support and Operational Concept Refinement;
- EP3 WP3.3.1 Network Planning Expert Group;
- EP3 WP3.3.2 Business Trajectory Management and Dynamic DCB;
- EP3 WP3.3.3 Airspace Organization and Management;
- EP3 WP3.3.4 Collaborative Airport Planning;
- EP3 WP2.3 Validation Management Process;
- EP3 WP2.4.1 Performance Framework.

1.3 DOCUMENT STRUCTURE

The document is structured in four main parts:

- Section 2 details the scope, justification and objectives of the exercise together with the methodology, indicators and metrics, hypotheses and scenarios to be tested;
- Section 3 describes the activities, resources and time planning;
- Section 4 describes the data collection and analysis methodology;
- Section 5 details the exercise design.

1.4 BACKGROUND

Episode 3 is charged with beginning the validation of the operational concept expressed by SESAR Task 2.2 and consolidated in SESAR D3 [2]. The initial emphasis is on providing:

- Detail on key concept elements in SESAR (concept detailing);
- Initial operability through focussed prototyping exercises and performance assessment of those key concepts (operability and performance studies);
- Initial supporting technical needs impact assessment (technical impact);

- Analysis of the available tools and gaps for SESAR concept validation (validation tools), and;
- Reporting on the validation methodology used in assessing the concept (validation methodology assessment).

The validation process as applied in EP3 is based on version 2 of the E-OCVM [3], which describes an approach to ATM Concept validation, and is managed and coordinated by EP3 WP2.3. Validation exercises should provide evidence, preferably measured, about the ability of some aspect of the concept to deliver on some aspect of the performance targets. In order to prepare well the validation exercises, an exercise plan should be produced according to step 2 of the E-OCVM.

As described in the EP3 WP3 Validation Strategy [5], EP3 WP3 Collaborative Planning Processes will combine several techniques in a step-by-step process (see Figure 1-1) to provide not only an assessment of the feasibility of the SESAR Collaborative Planning Processes, but also an initial trend of their impact and influence on the expected level of network performances.

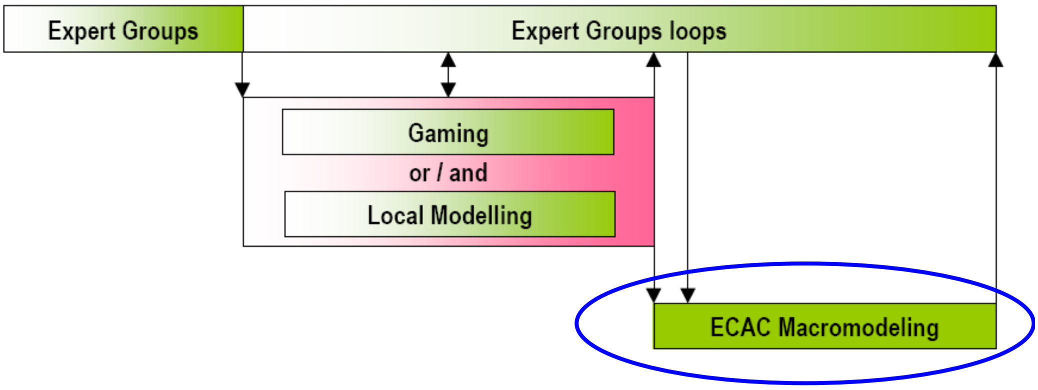

Figure 1-1 EP3 WP3 Validation Process

The exercise plan in this document describes the validation exercise EP3 WP3.3.5 “Global Performances at Network Wide Level (Macromodel)” which addresses the validation at ECAC wide level of a set of OIs related to the short-term planning and the execution phases. This exercise also closes the loop of the WP3 validation activities, and performs the extrapolation of the local results from the rest of EP3 WP3 exercises at ECAC level.

1.5 GLOSSARY OF TERMS

Term	Definition
AFUA	Advanced Flexible Use of Airspace concepts
AMAN	Arrival Manager
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
BT	Business/Mission Trajectory
CDM	Collaborative Decision Making
ConOps	SESAR Concept of Operations
CTA	Controlled Time of Arrival
CTO	Controlled Time of Over-fly
D/L	Data Link
DCB	Demand and Capacity Balancing
DMA	Dynamic Mobile Area
DOD	Detailed Operational Description document
DOW	Description of Work document
E-OCVM	European Operational Concept Validation Methodology
ECAC	European Civil Aviation Conference
EOBT	Estimated Off Block Time
EP3	Episode 3 project
ETA	Estimated Time of Arrival
ETO	Estimated Time Over
FAB	Functional Airspace Block
FUA	Flexible Use of Airspace
IP	SESAR Implementation Package
KPA	Key Performance Area
KPI	Key Performance Indicator
NOP	Network Operations Plan
OIs	Operational Improvements
RBT	Reference Business/Mission Trajectory
QTA	Queuing Time on Arrival
RTA	Required Time of Arrival
SBT	Shared Business/Mission Trajectory
SESAR	Single European Sky ATM Research programme
SWIM	System Wide Information Management
TMA	Terminal Manoeuvre Area
TTA	Target Time of Arrival

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Term	Definition
TTO	Target Time Over
UDPP	User Driven Prioritisation Process
WP	Work-Package

2 EXERCISE SCOPE AND JUSTIFICATION

2.1 STAKEHOLDERS AND THEIR EXPECTATIONS

The table below shows all the stakeholders of the exercise and their main expectations:

Stakeholder	Involvement	Why it matters to stakeholder	Expectations
European Commission	Funding part of the exercise as part of the project budget.	Identification of substantial and sustainable improvements in ATM processes through an initial validation of the SESAR Operational Concept.	Expected improvement of the operational capacity, efficiency and predictability of the air transport system.
SESAR JU	Technical Auditor.	Usage of the output of this exercise for initial operability and performance assessments of the SESAR concept. Exploration of innovative cost-effective validation methods and to provide lessons learnt to the SJU work programme.	Expected increment of the air transport system operational capacity, efficiency and predictability.
Research and development centres	Represented by ISDEFE and EUROCONTROL as exercise members.	Analysis of the impact of the local processes and airspace solutions on performance at the ECAC wide level.	Identification of the network effects and the network resiliency.
ANSPs	Represented by AENA as exercise member.	Identification of how local operations and DCB measures impact on network global stability and throughput.	Expected increase in capacity, efficiency and predictability.
Airport operators	Represented by AENA as exercise member.	Identification of how local airport operations impact on network global stability and throughput.	Expected increase in capacity, efficiency and predictability.
EP3 WP3.3.1: Network Expert Group	Episode 3 Expert Group.	Refinement of EP3 WP3.3.5 assumptions and validation scenarios.	N/A
EP3 WP3.3.2: Business Trajectory Management and Dynamic DCB	Episode 3 Exercise.	Analysis of the impact of local processes and airspace solutions at the ECAC wide level.	No decrease of capacity due to DCB constraint management. Increase of the network performance.
EP3 WP3.3.3: Airspace Organization and Management	Episode 3 Exercise.	Analysis of the impact of capacity management processes taking into consideration Airspace Management / Flexible Use of Airspace (ASM/FUA) at the ECAC wide level.	Expected increase in capacity.
EP3 WP3.3.4: Collaborative Airport Planning.	Episode 3 Exercise.	Analysis of the impact of collaborative approach to airport management at the ECAC wide level.	Expected increase in predictability.
EP3 WP2.4.1: Performance Framework	Episode 3 Work package.	Delivery of ECAC Key Performance Indicators and assessment of the influence of local performances in global performances.	Expected increase in capacity, efficiency and predictability.

Table 2-1 Stakeholder expectations

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2.2 DESCRIPTION OF ATM CONCEPT BEING ADDRESSED;

2.2.1 Introduction

EP3 WP3.3.5 validation exercise explores the impact on the ATM performances, at ECAC wide level, of the application during the **short-term planning and the execution phases** (see §2.5 Validation Scenario) of some of the **Operational Improvements** (OIs) proposed by SESAR Target Concept [2]. The exercise also extrapolates at ECAC wide level some local results obtained by previous exercises of Episode 3 addressing the same or other sets of OIs.

The aim is to obtain a first assessment of how local OIs affect the ATM network global performances and behaviour. The exercise addresses the coupling effects derived from the simultaneous implementation, at diverse areas of the network, of a specific Operational Improvement, as well as the synergies and trade-offs related to sets of OIs.

As a foreword, it must be emphasized that ATM involves a complex and interrelated set of technologies, so are OIs highly interrelated between them. The implementation of a specific OI or set of OIs can not be performed in isolation. Though, for the validation or clarification of a certain OI, the focus is on the operational perspective. Therefore, all the OIs technically linked with the specific OI of interest are assumed to be implemented, but they are not simulated.

The focus is on **Implementation Package 2**, from 2013 to 2020.

2.2.2 Addressed Operational Improvements

EP3 WP3.3.5 focuses on those OIs promising to deliver more benefits or having a greater impact at ECAC wide level. Specifically, the OI steps **addressed** are:

- DCB-0103 SWIM enabled NOP;

  The NOP is a 4 dimensional **dynamic**, rolling picture that provides a relational image of the state of the ATM environment for past, present and future. The plan includes the trajectories shared into the system, the capacity being offered, the actual and forecast MET conditions, resource availability, etc. While a user will only need to see the part of the picture he is concerned with together with its broader implications in order to carry out an action on and with the plan, the applications themselves always use the totality of the information available in the SWIM environment. **SWIM enabled NOP** integrates all stakeholders into the ATM system by providing the necessary level of data availability to meet the goal of **informed decision making** and **proactive planning** based on known scenarios and real-time information on unexpected events available and spread through the system.

  EP3 WP3.3.5 exercise assumes a fully operative **SWIM environment** enabling **NOP common real-time situational awareness** in the ECAC area. The OI is addressed by reproducing an environment where network operations are managed, optimised and synchronised as expected and un-expected events and risks unfold. Departures across the whole ECAC area are aligned with actual network conditions; taking into account constraints such as capacity and demand balancing and target time of arrival at capacity constraint airports.

- DCB-0208 Dynamic ATFCM using RBT (TS-0103 Controlled Time of Arrival (CTA) through use of datalink and TS-0106 Multiple Controlled times of Over-fly (CTOs) through use of data link);

  Dynamic ATFCM management (DCB-0208) takes benefit of the 4D trajectories to allow supporting the queue management and the achievement of the CTA/ CTOs. TS-0103 and TS-0106 OIs allow achieving CTA and CTOs through use of datalink and with enhanced accuracy to optimize arrival sequence and queue management.

These two OIs are highly technically linked with DCB-0208, and therefore assumed as implemented.

EP3 WP3.3.5 exercise studies how the stability of the demand and capacity situation is influenced by the ability of the individual flights to **comply with CTAs and CTOs with the required performances**. The **uncertainty** associated with flight duration and times over/ time of arrival is **reduced to a minimum**, and thus dynamic ATFCM scope of measures is enlarged with the use of CTA/CTOs for DCB purposes.

- DCB-0305 Network Management Function In Support of UDPP;

A delay management function is implemented at ATFCM network level to assist airspace users in the **UDPP process**. In case of severe capacity shortfall, SESAR Target Concept foresees that airspace users made their prioritisation according to the UDPP process. The Network management Function assesses the impact of the UDPP proposal on network stability or calls a CDM process to agree an alternative solution in order to minimise the impact of the users' proposal on the network stability.

In the absence of any capacity shortfall, trajectories are handled on a first come first served basis. In case of severe capacity shortfall affecting departures, departure flights can be prioritised according to pre-defined rules/ criteria. The criteria for building the **departure queue** (either first come first served or prioritisation) is needed **in case of disruptions of the network and at congested airports**. When time permits, airspace users are allowed to trade slots based on agreements and rules that are transparent to the other actors but that respect **sets of rules** agreed by all parties (**UDPP**). **EP3 WP3.3.5** reproduces the situation leading to the triggering of the UDPP process for departures in various nodes of the ECAC network, and studies the impact of different **prioritisation criteria** (see §2.5 Validation Scenario) in network performances, capturing any adverse network wide effects that their application may develop.

Additionally, EP3 WP3.3.5 exercise is the final step to close the loop of the EP3 WP3 validation activities. Thus, EP3 WP3.3.5 extends/analyses/refines the local conclusions of previous WP3 Validation Exercises related to the validation/ clarification of certain Operational Improvements/ Procedures. Thus, EP3 WP3.3.5 validation exercise, by integrating certain results, is **assuming the implementation** of the OIs addressed by the related previous WP3 validation exercise to obtain these results.

The integration and the extension to ECAC wide level of **all** the results and conclusions of WP3 validation exercises, is out of the scope of EP3 WP3.3.5 validation exercise. Thus, EP3 WP3.3.5 explores the technique and methodology for global integration of local validation results by focussing on **some** of the local results obtained by previous WP3 validation exercises. Besides, the analysis of which results of previous WP3 exercises are suitable to be integrated by EP3 WP3.3.5 could not be completed until those previous WP3 exercises have completed their respective conduction phases. The final record of validation results from previous WP3 exercises being further processed by EP3 WP3.3.5 will be included in EP3 WP3.3.5 Report.

The OIs addressed by previous WP3 exercises linked to validation results initially planned to be integrated into EP3 WP3.3.5 are (see 2.7 Links to other Validation Exercises):

EP3	Reference	Details
WP3.3.2	DCB-0208	Dynamic ATFCM using RBT
	AUO-0203	Shared Business / Mission Trajectory (SBT)

EP3	Reference	Details
	AUO-0204	Agreed Reference Business / Mission Trajectory (RBT) through Collaborative Flight Planning
	DCB-0103	SWIM enabled NOP
WP3.3.3	AOM-0202	Enhanced Real-time Civil-Military Coordination of Airspace Utilisation
	AUO-0204	Agreed Reference Business / Mission Trajectory (RBT) through Collaborative Flight Planning
	AOM-0205	Modular Temporary Airspace Structures and Reserved Areas
	AOM-0206	Flexible Military Airspace Structures
WP3.3.4	AO-0501	Improved Operations in Adverse Conditions through Airport Collaborative Decision Making
	AO-0601	Improved Turn-Round Process through Collaborative Decision Making
	DCB-0206	Coordinated Network Management Operations Extended Within Day of Operation
	SDM-0101	Network Performance Assessment

Table 2-2 OIs Addressed by Previous WP3 Exercises

2.2.3 Key Performance Areas

EP3 WP3.3.5 exercise provides simultaneous values for Performance Indicators related to the following **Key Performance Areas** (KPA):

- Capacity. This KPA indicates how the system is able to cope with the air traffic demand. EP3 WP3.3.5 exercise evaluates the improvement of network throughput due to collaborative planning reflected in the NOP, taking into account the airspace and airport capacity as a function of traffic demand patterns.
- Efficiency. It shows the capability of the system to provide trajectories as close as possible to the Shared Business Trajectories (SBTs). EP3 WP3.3.5 exercise provides the ATM global efficiency improvement due to planning and information sharing, by evaluating the suitability of the ATM system to provide an agreed and stable demand and capacity situation, ensuring timely and flexible allocation of special airspace activities.
- Predictability. Predictability assesses the system ability to control deviations from the Reference Business Trajectories (RBTs) and to share this information amongst all users. EP3 WP3.3.5 exercise shows the knock-on effects, in form of reactionary delays, produced when the capacity constrains are published and known in the system.

The Key Performance Areas covered in EP3 WP3.3.5 validation exercise and their relations with the OIs addressed by EP3 WP3.3.5 are:

OI	How it is addressed	Main KPA impacted	Expected benefits
DCB-0103 SWIM enabled NOP	Departures across the whole ECAC area are aligned with actual network conditions; taking into account constraints such as capacity and demand balancing and target time of arrival at	Predictability	More predictable and consistent ATM system. Reduction of stacking and adaptability of the departure and ground delay management to better match the network DCB situation. The improvement in predictability brings together other benefits: - Better recovering after a capacity

OI	How it is addressed	Main KPA impacted	Expected benefits
	capacity constraint airports.		shortfall; - The reduction of stacking carries on reduced emissions and costs per flight; - Matching the DCB situation helps smoothing out peaks, and smoother traffic reduces controllers' workload.
DCB-0208 Dynamic ATFCM using RBT	The uncertainty associated with flight duration and times over/ time of arrival is reduced to a minimum, and thus dynamic ATFCM scope of measures is enlarged with the use of CTA/CTOs for DCB purposes.	Capacity / Efficiency	Enhancement of resources, ANSPs can work close to the limits of the system, as they have the assurance that exceeding of limits will be prevented. Capacity buffers can be reduced. Dynamic DCB allows unpredictable events to be better managed due to the introduction of more flexible means to manage both ground and airborne delays.
DCB-0305 Network Management Function In Support of UDPP	Triggering conditions of UDPP are reproduced and the impact of different possible outcomes (prioritisation criteria) in network performances is studied, capturing any adverse network wide effects that their application may develop.	Efficiency / Predictability	Previous assessment of the network impact of the prioritisation resulting from the UDPP process avoids the appearance of unforeseen network effects associated with the implementation of the UDPP outcome. The network management function helps refining UDPP results in order to implement the strategy that minimise knock-on effect (reactionary delays).

Table 2-3 Expected Benefits per KPA

2.2.4 Detailed Operational Descriptions and Concept Maturity

In line with the OIs which are addressed by EP3 WP3.3.5 exercise, the following sections of the EP3 SESAR Detailed Operational Descriptions (DODs) ([6], [7], [8] and [9]) are concerned:

- DOD M2/3 [7] A2.3.2.2.2 Apply the DCB Solution;
- DOD E4 [9] A3.1.3.2.2 Apply the Dynamic DCB Solution;
- DOD E4 A3.1.1.1.2 Assess Airspace Capacity Load;
- DOD M2/3 A2.3.2.2.1 Assess Network Impact of the DCB Solution;
- DOD E4 A3.1.3.2.1 Assess Network Impact of the Dynamic DCB Solution;
- DOD M2/3 A2.3.1.2 Detect Airspace Demand Capacity Imbalance;
- DOD M2/3 A2.1.2.2 Optimise SBT;
- DOD M2/3 A2.3.2.1.3 Select/refine/Elaborate a DCB solution at Network Level;

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- DOD E4 A3.1.3.1.3 Select/refine/Elaborate a dynamic DCB solution at Network level.

The DODs sections addressed by previous WP3 exercises to obtain the results initially planned to be integrated in EP3 WP3.3.5 also have an indirect link with EP3 WP3.3.5 scope ([17], [18] and [19]).

Relevant to the concept maturity, it can be quoted the current level of maturity[1] of the different concepts addressed directly or indirectly (through integration of previous WP3 exercises results)[2]:

- Collaborative Decision Making (CDM) during planning: V5 status [19];
- Collaborative Airport Planning and Airport Operations Center: V2 status [19];
- Demand and Capacity Balancing: V3 status [19];
- Network Management and Design: V3 status [19];
- Business Trajectory management: V1 status [17];
- Dynamic DCB: V1 status [17];
- Queue management: V1 status [17];
- UDPP: V1 status [17].

Finally, it must be highlighted the links identified between EP3 WP3.3.5 and the **SESAR JU´s Work Packages/Projects**. The main SESAR projects related with EP3 WP3.3.5 "Global Performances at Network-wide level" are SESAR SWP B.5 "Performance Analysis of ATM Target Concept" and SESAR WP3.12 “Validation Tool Types and Techniques Analysis”.

The main aspects of SESAR SWP B.5 addressed by EP3 WP3.3.5 are:

- Integration of the performance results obtained in the different Operational, Technical and Transversal Threads and the performing of specific validation activities aiming at providing an overall performance assessment of the concept at the SESAR Area level;
- Develop a macroscopic SESAR Performance Model using Complex Networks Theory;
- Obtain metrics/indicators related to operational KPA at network SESAR level.

The **added value** and inputs that EP3 WP3.3.5 provides to these SESAR JU projects can be summarised as follows:

- First attempt to use a Macromodel to extend the validation results and conclusions obtained at local level to the ECAC-Network level;
- The EP3 WP3.3.5 ATM macromodel delivers non-linear coupling network effects, providing results of space-time structure and behaviour of the ECAC wide network;
- Development of a SESAR Performance Model modular and easy to customize in order to implement new features;
- Expansion of the repertoire of cost-effective validation techniques suited to the early stages of SESAR concept validation.

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[1] According to E-OCVM Concept Lifecycle Model [3].

[2] The levels of maturity of the different concepts are gathered from EP3 WP3.3.2, WP3.3.3 and WP3.3.4 Experimental Plans. These sources have taken into account previous projects to perform the assessment.

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2.3 EXERCISE OBJECTIVES

EP3 WP3.3.5 exercise analyses the performances of the ATM network at the ECAC wide level associated with the implementation of OIs and set of OIs.

The **high level objectives** of EP3 WP 3.3.5 exercise are the following:

- Objective 1: Characterise the **macroscopic behaviour** of the ATM Network at ECAC level, studying how global imbalances are linked to local occurrences and how local instabilities diffuse across the network.
- Objective 2: Study how **local OIs impact ECAC wide** performances and behaviour.
- Objective 3: **Extend/Analyse/Refine** the conclusions obtained at local level in previous WP3 exercises to the network ECAC level.
- Objective 4: Expand the repertoire of **cost-effective validation and clarification techniques** suited to the early stages of ATM operational concept development.

More in detail:

Objective 1.-

The ATM network presents non-linear coupling of local dynamics, queuing generation and congestion propagation phenomena. The network works as diffuser of instabilities, and can either absorb or expand the causes of a local occurrence. Examples are the reactionary delays associated with the knock-on effect of earlier incidents, where the initial cause is no longer identifiable.

There is not a deterministic way of characterising how a local occurrence diffuses across the network. The objective of EP3 WP3.3.5 in this sense is to be able to capture the complex and unpredictable cause-effects related to how individual actions may propagate and generate effects on other parts of the system. The question to be solved is: What is the impact of local perturbations in the overall system?

Objective 2.-

Local OIs applied to solve local imbalances can effectively smooth the congestion at subregional level, but also cause a propagation of the problem across the network. The objective is to capture non-linearities associated with the network, and thus to validate SESAR local Operational Improvements at a network-wide level, studying the impact of local modifications applied to solve specific imbalances on global performances.

It is not the objective of EP3 WP3.3.5 to perform an accurate tracking of roots and effects, but to provide qualitative and quantitative results of the **impact of local OIs** on ECAC global and macroscopic performance. The impact of local operational procedures transcends their operational level of implementation, since local areas are **in the context of a highly interconnected network**. The validation of an OI is not complete without the validation of its associated network effects. Furthermore, for the implementation of an OI various strategies can be adopted, each one of them having different impact on the network. EP3 WP3.3.5 has the purpose of characterising the network impact for each OI addressed, as well as to exploring possible trade-offs and synergies that may arise.

Objective 3.-

Similarly to objective 2, the aim is to assess the consequences of placing in the network context the validation results and conclusions obtained at a local level by previous WP3 exercises.

EP3 WP3.3.5 aim is to study the ECAC ATM network from a macroscopic point of view. In this way, EP3 WP3.3.5 and local validation exercises, with thorough level of detail, complement each other. One of EP3 WP3.3.5 objectives is to provide a network

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context where **local conclusions can be inserted** to obtain the coupled global impact. Furthermore, according to the representativeness associated with each local validation exercise, these local conclusions can be extended over the network, in order to obtain network wide validation of the implementation of local OIs.

EP3 WP3.3.5 macromodel should allow the simultaneous integration of the results and conclusions of different local validation exercises addressing different OIs. Thus, EP3 WP3.3.5 objective is to serve as **integration** mean from local performances and operational results to global performances and behaviour, capturing the **local influences into the ECAC wide performances**.

Objective 4.-

The maturity of the concept being validated determines to a great extent the most suitable tools and techniques. The selection of the validation tool and/or methodology is very relevant. Commonly applied tools designed for today's operational procedures are limited in their use, lacking the required flexibility to validate new concept elements.

The objective is to develop a new cost-effective validation tool for concepts in an early stage of development, able to:

- Give feedback about the concept fitness-for-purpose;
- While identifying inconsistencies, feasibility blocking points, influence relations, unforeseen or negative side-effects, etc.;

The aim is to dispose of an innovative tool suitable for the first assessment of the fitness for purpose of **new concept functions** in an early stage of maturity, allowing **quick modifications** and the simulation of a number of different configurations/operational functions in a short period of time. Both computational and execution times should be kept to a minimum. The main goal is not to obtain highly accurate ECAC performances, but to exploit the trade-off between **accuracy and flexibility** to be in line with the SESAR Concept lifecycle phase (V0-V1) [3], focussing on capturing the performances evolution.

2.4 CHOICE OF INDICATORS AND METRICS

According to the EP3 WP3 Validation Strategy [5], the main objective of the EP3 WP3.3.5 exercises is to extend the conclusions obtained at local level and to integrate the different aspects of the SESAR Planning Processes. In particular, this exercise studies the following questions:

- How local unexpected events and uncertainty affect the dynamics of the whole network?
- How local rules affect the behaviour of the network?

The results obtained are Key Performance Indicators (KPIs) at ECAC level related to the Key Performance Areas (KPA) capacity, efficiency and predictability.

Due to the stochastic components and the inherent complexity of the system, the KPIs values are obtained by means of a statistical approach, by running a number of Montecarlo simulations (see §4 Analysis Specification).

Table 2-4 shows the performance indicators provided by EP3 WP3.3.5. They have been selected from the EP3 WP2.4.1 Performance Framework [4]. In order to identify and select the specific measures to be taken, both top-down and bottom-up breakdowns have been performed, leading to the final set of indicators in line with both EP3 WP3.3.5 objectives and pragmatic considerations.

KPA	Performance Indicator (PI) ID	PI Name (unit)	PI Definition
Capacity	CAP.ECAC.PI 2	Daily number of IFR flights in Europe	Daily number of IFR flights that can be accommodated in Europe.
	CAP.ECAC.PI 3	Hourly throughput overloads	Hourly throughput overloads, number of occurrences of capacity (hourly throughput) overloads by overload level per sector/airport/ point. This indicator would identify the bottlenecks and the congested nodes in the network model.
Efficiency All these indicators are focused on time efficiency. Fuel consumption is out of the scope of this exercise.	EFF.ECAC.PI 1	Percent of flight departure on time	
	EFF.ECAC.PI 2	Average departure delay per flight (min)	
	EFF.ECAC.PI 3	Percent of flights with normal flight duration	
	EFF.ECAC.PI 4	Average extra flight duration (min)	
Predictability	PRED.ECAC.PI 1	Percentage of delayed flights	Percentage of flights delayed at arrival more than 3 minutes.
	PRED.ECAC.PI 2	Average of delayed flights	Average delay of flights suffering delay of more than 3 minutes.
	PRED.ECAC.PI 6	Total delay due to disruption (min)	This indicator provides the delay caused by an unexpected event in a local area within the network.
	PRED.ECAC.PI 7	Number of reactionary delay (min)	2020 traffic scenario doesn't provide links between flights and aircraft. Thus, this indicator analyses the effect of reactionary delays using linear dependence between input and output flows in airports.

Table 2-4 Metrics and Indicators

Additionally [21], the following measures or indicators are explored:

- Theoretical demand limit of the network. This indicator is obtained through a theoretical simulation scenario (see 2.5.7 Simulation Scenarios), and represents the maximum daily number of IFR flights that can be accommodated in the ECAC area in order to have a free (non-congested) state in the network (i.e. without bottlenecks diverging with time[3]).
- Hourly throughput under-loads (capacity room) by under-load level per airport.

[3] A bottleneck is a node of the network where there is a demand and capacity (DC) imbalance which generates a departing queue at the node. The DC imbalance can be connected to the departure capacity of the bottleneck node or to the arrival capacity of the destination nodes. If the queue increases with time indefinably, this means that the network is not able, for whatever reason, to absorb the DC imbalance at the bottleneck.

2.5 VALIDATION SCENARIO

The **macroscopic approach** and the ECAC wide operational context of EP3 WP3.3.5 exercise don't have equivalence in terms of EP3 Operational Scenario. In general, EP3 Operational Scenarios contain very detailed information that is not relevant for EP3 WP3.3.5 exercise, but in some cases operational scenario is the basis for the definition of the macroscopic rules. EP3 WP3.3.5 Validation Scenario, which is described here below, takes into account inputs from the following Operational Scenarios:

- OS-11 Non-Severe (No UDPP) Capacity Shortfalls impacting Arrivals in the Short-Term [10];
- OS-19 Severe (UDPP) Capacity Shortfalls impacting Departures in the Short-Term [11];
- OS-26 Non-Severe (No UDPP) Capacity Shortfalls impacting Departures in the Short-Term [12];
- OS-36 Non-severe (No UDPP) capacity shortfalls impacting multiple nodes of the network in the short-term [13].

Main input from these set of Operational Scenarios are the cooperative DCB mechanisms that can be put in place to solve local imbalances facing European airports and en-route sectors, in 2020 on the day of operations (that is to say during the short-term planning phase and execution phase). This catalogue of DCB solutions has served as input for the design of EP3 WP3.3.5 Validation Scenario.

Additionally, EP3 WP3.3.5 exercise integrates local conclusions of previous WP3 Validation Exercises that are based on EP3 Operational Scenarios. Thus, EP3 WP3.3.5 validation exercise, by integrating certain results, is assuming the operation according to the Operational Scenarios addressed by the related previous WP3 validation exercise to obtain these results.

The **Operational Scenarios** addressed by previous WP3 exercises **linked to validation results** initially planned **to be integrated** into EP3 WP3.3.5 are:

- OS-11 Non-Severe (No UDPP) Capacity Shortfalls impacting Arrivals in the Short-Term [10] (WP 3.3.2);
- OS-34 Military Collaboration during Medium/Short Term Planning [14] (WP 3.3.3);
- OS-16 Turn-round management [15] (WP 3.3.4);
- OS-18 Airport Operational Plan Lifecycle for Medium-Short-Execution Phases [16] (WP 3.3.4);
- OS-19 Severe Capacity Shortfalls impacting Departures in the Short-Term [11] (WP 3.3.4).

2.5.1 Operational Context

The operational context of EP3 WP3.3.5 Validation Scenario is:

- ECAC wide;
- Mixed picture (**short-term planning phase**):
  - o some flights are in the planning phase (SBTs);
  - o and some flights are already in execution (RBTs).

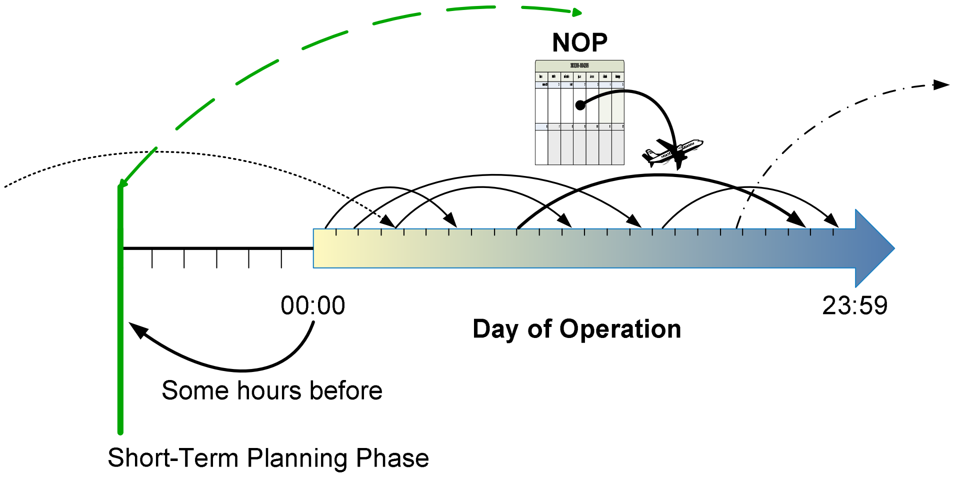

Figure 2-1 EP3 WP3.3.5 Operational Context

EP3 WP3.3.5 exercise takes place in the short-term planning phase, i.e. some hours before the day of operation starts. The validation scenario starts with a **balanced situation** between:

- Planned **demand** (traffic sample/forecast plus airspace reservations);
- And **capacity** (including airports and airspace capacity increases).

Traffic demand is balanced in a static way, i.e. if no unexpected events occur, the uncertainty of the demand is zero and there is no uncertainty associated with airports operations (see §2.5.4 Airport Information), then the network capacity (airports and airspace) is able to handle the planned demand with no delays (see §2.5.8 Additional Information). The reason of this assumption is that the focus of the exercise is to study the benefits of the implementation of certain OIs in face of a **specific imbalance**, controlled in size and nature.

This static DCB situation is reflected in the short-term planning NOP. EP3 WP3.3.5 studies **ECAC wide ATM performances** and **behaviour** associated with the **execution of the short-term planning one day NOP**.

For the execution of the NOP, the time is not a continuous variable. A **time interval** (see 3.1.2 Execution activities) is defined and planned traffic is thus grouped into flows.

EP3 WP3.3.5 Validation Scenario allows exploring the **benefits of planning** by taking into consideration the **application of OIs** (DCB-0103, DCB-0208 and DCB-0305) **during the short-term planning phase**. Besides, EP3 WP3.3.5 Validation Scenario contemplates the application of operational procedures and **OIs** (DCB-0208) **related to the execution phase**, and the validation of their benefits at ECAC wide level.

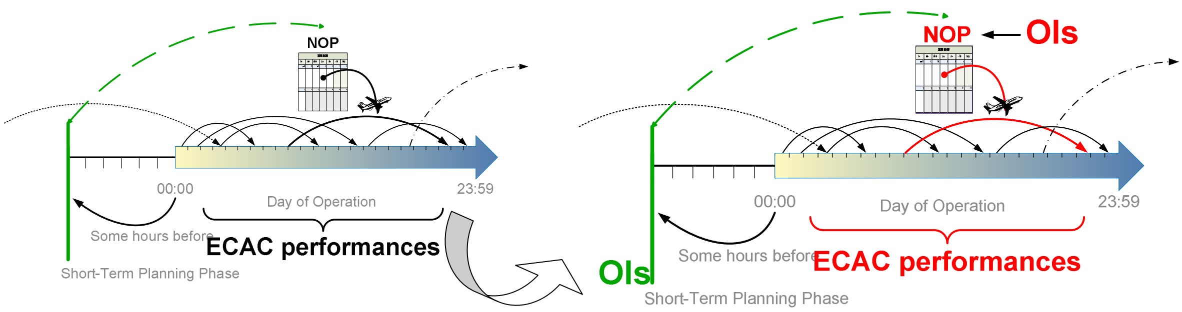

Figure 2-2 Application of OIs related to Short-Term Planning and Execution Phases

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2.5.2 Validation (Study) Environment Parameters

The baseline scenario for EP3 WP3.3.5 considers the following operating procedures and parameters:

- Management of flights gives priority to flights delayed on ground and holdings over scheduled flights. Other than that, flights are managed in a first come first served basis;
- Arrival capacity availability at destination airports is only checked prior departure in the case of a severe capacity shortfall impacting arrivals at the destination airport;
- Flight duration, as well as times over/ time of arrival, have associated certain variability, affecting the individual flights ability to accurately comply with TTA/TTO and CTA/CTO;
- In case of demand and capacity imbalance, DCB measures are not in place, which means that delays can only be managed on ground (no absorption of delay en-route is considered).

For the execution of the NOP, the following aspects are considered:

- The **short-term demand** has associated **uncertainty**. Based on the estimation of this uncertainty and the type of demand changes that can be expected in the short-term planning phase, EP3 WP3.3.5 Validation Scenario contemplates two scenarios implying changes in the short-term planning demand [21]:
    - Scenario 1: The probability of flight cancelation is 10%; The probability of new flight demand (only for those connections over percentile 80 in terms of number of flights per day) is 20%; The probability of variation of EOBT (Estimated Off Block Time) is 10% (EOBT changes considered of [-10 min, +10 min]).
    - Scenario 2: The probability of flight cancelation is 5%; The probability of new flight demand is 10%; The probability of variation of EOBT (Estimated Off Block Time) is 10%.
- A variety of different **triggers** can give rise to **demand-capacity imbalances** across the ATM network. Taking into account their probability of occurrence, their typical duration and size of the imbalance, EP3 WP3.3.5 Validation Scenario allows the simulation of the following situations:
    - Non-Severe (No UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term. There are simultaneous capacity shortfalls (affecting both arrivals and departures) of diverse severity (10, 20 or 30% of **capacity decrease**) for a period of 3 hours each affecting three nodes of the network, two of them highly interconnected between them and the third, one of the bigger airports of the network in terms of movements per hour. The capacity shortfall can be sudden or known with 1 hour anticipation.
    - Severe (UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term. There are simultaneous capacity shortfalls (affecting both arrivals and departures) of diverse severity (50 or 70% of capacity decrease) anticipated 3 hours in advance affecting three nodes of the network, two of them highly interconnected between them and the third, one of the bigger airports of the network in terms of movements per hour. The duration of the capacity shortfall can be 3 or 6 hours.

      Additionally, one or two en-route sectors – one belonging to the same FAB than one of the two highly interconnected nodes, and the other one belonging to the same FAB than the big airport - can experience a 3 hours non-severe capacity shortfall (30% of capacity decrease) known 1 hour in advance.

Hub airports are crucial nodes of the network. In order to study the impact on the whole ECAC area of increasing the capacity of some of the main hubs in Europe, EP3 WP3.3.5 Validation Scenario includes parameters for the capacity of three main hubs.

Finally, the activation of **reserved military training areas** is foreseen. These areas affect the airspace capacity of the impacted airspace node, causing a non-severe capacity shortfall (30% of capacity decrease) with duration of 3 hours and known 2 hours in advance.

All these situations are combined together with the implementation of the OIs addressed and the integrated results of previous WP3 exercises to define the EP3 WP3.3.5 Simulation Scenarios (see 2.5.7 Simulation Scenarios).

2.5.2.1 Parameters associated with Addressed OIs

Regarding the OIs addressed, EP3 WP3.3.5 Validation Scenario considers the implementation of the following operational ruling:

- DCB-0103. Departures across the whole ECAC area are aligned with actual network conditions; taking into account constraints such as capacity and demand balancing and target time of arrival at capacity constraint airports. Ground delays imposed to departures are the mean to ensure that capacity is not exceeded at destination airports. In this sense, departures are released only when expected capacity at destination airport for the estimated arrival time interval is not overloaded.
- DCB-0208. Uncertainty associated with flight duration and to times over/ time of arrival is negligible, and individual flights are able to accurately comply with TTA/TTO and CTA/CTO.
- DCB-0305. In case of severe capacity shortfall departure flights can be prioritised according to diverse prioritisation criteria: first come first served (P1), shortest flights first served (P2) or prioritise flights according to the number of topological connections of their destination airport (P3 – higher number of connections of destination airport served first) [21].

2.5.2.2 Parameters associated with Integration of Results

Regarding the **integration of results** of previous WP3 validation exercises, EP3 WP3.3.5 Validation Scenario considers the implementation of the following operational ruling (see 2.7 Links to other Validation Exercises):

- EP3 WP3.3.2. In case of medium severe capacity shortfall affecting arrivals, the application of DCB measures is triggered when the delays associated with the arrival queue exceed a certain threshold and the time to QTA is above a certain limit. DCB measures allow absorption of delay en-route up to a certain percentage of the total delay to be absorbed.

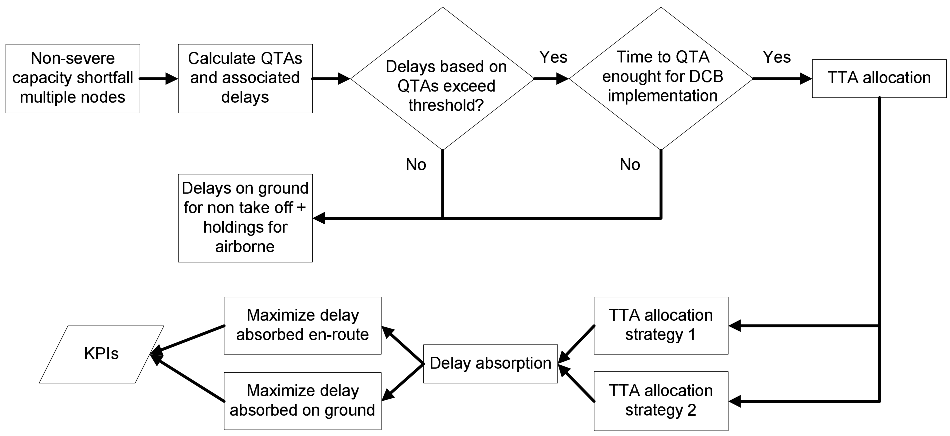

Figure 2-3 Validation Scenarios for the integration of EP3 WP3.3.2 results

For the allocation of TTAs, two strategies can be applied. With first planned first served, the arrival sequence is not changed with respect to planning. The other option is to give absolute priority to airborne flights, for which the total delay to be absorbed is minimised.

Finally, the absorption of delay can be done on ground, en-route (up to the maximum percentage previously mentioned) or, eventually, in a stack. While for airborne flights the absorption of delay en-route is preferred, two strategies for the absorption of delays are foreseen for flights that have not take-off yet: either maximize the delay absorbed en-route or absorb all the delay on ground.

- EP3 WP3.3.3. The outcomes of EP3 WP3.3.3 affect the parameters associated with the activation of reserved military training areas. The application of AFUA concept together with the agreed Reference Business/Mission Trajectory through collaborative flight planning allows the reduction of the reservation duration and size.

  The reservation duration is reduced up to a certain percentage. The impact on trajectories is lessened, so fewer trajectories are affected by the non-severe capacity shortfall in the impacted node. A percentage of the trajectories subject to the impacted node capacity restrictions are released, in the sense that they become direct links between origin and destination airports.

- EP3 WP3.3.4. In this case, the results are considered in terms of departure delays. The benefits of airport collaborative planning and decision making supported by network function counteract the uncertainty associated with airport operations. Three possible values for this parameter are considered, the three of them improving (decreasing) the uncertainty associated with airport operations (and impacting the departure delays) of the baseline model.

2.5.3 Hypotheses

The following hypotheses lead the design of the EP3 WP3.3.5 Simulation Scenarios:

H1: In case of severe disruptions of the network and at congested airports, the prioritisation of departure flights that have the highest number of connections and the shorter flight distances have a positive impact on ECAC wide efficiency and capacity.

H2: For departure and delay management, increased coordination with arrival management (taking into account constraints such as capacity and demand balancing and target time of arrival at capacity constraint airports) has a positive impact on ECAC wide predictability.

H3: Reduced uncertainty of flight duration and/or fulfilment of CTA/CTOs allows reducing capacity buffers and therefore has a positive impact on ECAC wide capacity and efficiency.

H4: The application of DCB measures, increasing the flexibility to assign the delay in case of non-severe capacity shortfall at arrivals, has a positive impact on ECAC wide capacity and efficiency. Moreover, the quantification of this impact depends on the strategy applied for the allocation of TTAs and on the percentage of delay that is absorbed on ground and en-route.

H5: The reduction of the size and duration of reserved military training areas thanks to the application of AFUA concept has a positive impact on ECAC wide capacity and efficiency.

H6: The decrease of the uncertainty associated with airport operations, thanks to airport collaborative planning and decision making supported by network function, has a positive impact on ECAC wide capacity and efficiency.

2.5.4 Airport Information

EP3 WP3.3.5 **macroscopic** approach considers airports as **network's nodes with capacity restrictions**. Number of runways, length and orientation, etc. is implicitly considered to obtain the airport capacity, i.e. the maximum movements per hour that the airport can handle.

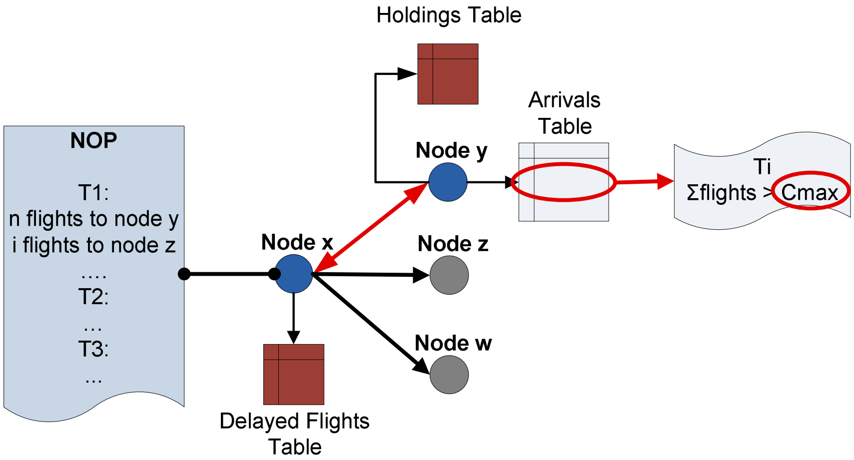

Figure 2-4 EP3 WP3.3.5 Airport Operational Context

The following specifications apply to airports in EP3 WP3.3.5 validation scenario:

- Airports are sources/ drains of aircraft flows, and are characterised by maximum input and output capacities;
- Parking capacity on ground is infinite;
- Limiting factor of capacity is runway capacity;
- Airport's operations uncertainty is considered through an uncertainty factor associated with departures, having an impact on the actual departure time;
- Holdings for arrivals are considered when flight arrivals for a certain time interval exceed the airport input capacity. Flights on hold have priority over other arrivals flights for landing on the next time step;
- Delays on ground are considered when flight departures for a certain time interval exceed the airport output capacity, or when they are used for DCB purposes;
- Management of departures is considered through prioritisation criteria applying to individual flights;
- Arrivals and departures are linked in order to take into account the existence of reactionary delays and to capture network effects.

The number of airports considered is 133; in particular the **first 133 European airports** in terms of capacity, which together handle 90% of the IFR traffic (see §2.5.8 Additional Information).

Traffics from or to airports outside the main ECAC 133 are considered as **boundary conditions**. Two additional nodes represent, respectively, traffic connections outside the ECAC and connections with smaller ECAC airports.

2.5.5 Airspace Information

EP3 WP3.3.5 macroscopic approach doesn't consider airspace structures and their associated management. Furthermore, it is assumed "the SESAR concept will create sufficient terminal area and en-route capacity so that it is no longer a constraint in normal operations" [2].

Free routing is assumed to be in place for most connections between airports, and thus airports are linked by the shortest routes.

"SESAR will still use sector-based operations, and route structures similar to those in use today may be deployed in order to deliver capacity in high density airspace" [20]. Highly congested areas are considered in EP3 WP3.3.5 as additional nodes of the network with capacity restrictions. In order to obtain high density areas associated with SESAR 2020 traffic (see §2.5.6 Traffic Information), a modelling tool is used to obtain an ECAC wide **airspace density map**, as well as the trajectories (links between airport nodes) crossing each area.

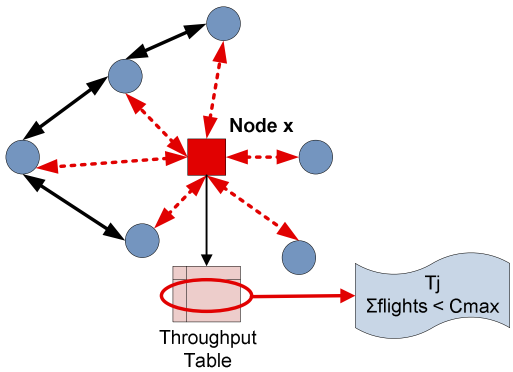

Figure 2-5 High Density Area and Affected Links between Airports

Unitary airspace volumes are defined, and day peak aircraft density per airspace volume is calculated for each volume. High density areas are composed of aggregations of those airspace volumes with peak densities over a certain percentile. This percentile is defined in order to obtain a manageable number of high density areas (less than 5). All trajectories crossing any of the airspace volume units within the high density area identified are cut by the high density node in the EP3 WP3.3.5 macromodel.

The maximum throughput of the high density area is the result of multiplying the number of airspaces volumes composing the area by a pre-defined maximum density per airspace volume. Departures of flights which trajectories cross the high density area are delayed on ground in the event that the maximum throughput of the area is expected to be surpassed for a certain time interval.

2.5.6 Traffic Information

Initially, there are two options to get a traffic sample that fulfils the needs of EP3 WP3.3.5 and is representative of the traffic demand expected for the year 2020:

- Adapting EP3 WP2 traffic sample to EP3 WP3.3.5 macromodel;
- Using an already treated traffic sample, i.e. the one from T231 SESAR Definition Phase.

Taking into account that the effort needed to model the ATM network at ECAC level and the implementation of certain OIs is very high, the second option has been selected. In this way, some effort can be maintained avoiding to adapt the traffic sample provided by EP3 WP2.

The traffic sample used as the reference in EP3 WP3.3.5 is based on the traffic provided by EUROCONTROL for the simulation exercises run within SESAR T231 in the Definition Phase. This traffic is built through the increment of a reference traffic corresponding to the 19th of July 2005 and is selected taken into account the following criteria:

- Year 2005 for consistency with the latest LCIPs (Local Convergence and Implementation Plan);
- Within the last 2 weeks of July used for Mid-Term Capacity planning (therefore current and mid-term future ACC capacities are known);
- No special events such as:
  - External perturbation (industrial action);
  - Anomalous demand (e.g. sport events);
  - Significant meteorological perturbation (thunderstorms, fog).
- Best correlation at ACC level between day and full period (2 weeks), both for traffic and delay (or trade-off).

The traffic for 2020 is built from this 2005 scenario by applying the expected traffic growths provided by EUROCONTROL Statistics and Forecast Service (STATFOR) and the estimated modifications in the scenario for the future horizons. The main assumptions applied for obtaining the 2020 traffic sample are:

- The STATFOR long-term forecast identified four different scenarios built on the STATFOR medium-term, 7-year forecast. In the long-term the forecast scenarios differ in structural ways, rather than just in the amount of economic growth. For consistency reasons, the long term scenario from STATFOR LTF-04-A is used for 2020. This scenario corresponds to globalisation and rapid growth;
- The planned route network (ARNV5) and shortest routes on this network are applied. However since in 2020 there will not be route structures, the traffic is modified in order to adapt it to the future concept. Therefore, to assess the future demand, simulations were performed to show how the traffic currently handled by the CFMU would be distributed over the future route network. This implies following the user's preference for the shortest routes along that future network, without vertical profile constraints;
- Airport capacities are taken into account building the traffic samples. The action on overload is to redistribute the hourly demand over the airport and otherwise to redirect flows to neighbouring airports;
- In the cloning process used to build the future traffic samples, a "strategic/scheduling" hourly capacity in movements/hour for each airport has been defined (called "theoretical limit"). It is set at 8.5% above the declared planned capacities (2005). This process allows simultaneous modelling of un-accommodated demand (slot limits) as well as delay due to insufficient runway capacity.

  It should be noted that declared capacities are known for only approximately 100 airports. No capacity constraints are considered for other airports to build the traffic.

Finally, it is important to highlight that although one of the criteria to select the 2005 reference traffic is to avoid days with special events, during the exercise the conditions that lead to a capacity shortfall are created and it is analysed how the unexpected events affect the demand at ECAC level.

2.5.7 Simulation Scenarios

As previously indicated in the description of the EP3 WP3.3.5 Validation Scenario (see 2.5 Validation Scenario), diverse unexpected events are combined together with the implementation of the OIs addressed and the integrated results of previous WP3 exercises to define the EP3 WP3.3.5 Simulation Scenarios.

In the context of EP3 WP3.3.5, each Simulation Scenario consist of a particularisation of the Validation Scenario designed to study the behaviour of the ECAC network under specific

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operational conditions and facing specific disruptions. EP3 WP3.3.5 Simulation Scenarios are highly linked to the exercise hypothesis (see 2.5.3 Hypotheses).

Each EP3 WP3.3.5 Simulation Scenario is further subdivided into Simulation Runs, each one corresponding to a specific configuration of the related parameters. Table 2-5 shows all possible configurations between events/ disruptions and operational conditions (OIs and integrated results), including possible values for the associated parameters. The parameters combined to build the Simulation Scenarios are described in §2.5.2 Validation (Study) Environment Parameters. Supported by Table 2-5, EP3 WP3.3.5 Simulation Scenarios and their related Simulation Runs are designed.

Annex 2 Simulation Runs includes the tables showing the configurations to be simulated in EP3 WP3.3.5 Simulation Scenarios 2 to 9.

Additionally, a **theoretical simulation scenario** is planned. The objective is to obtain the theoretical demand limit of the ECAC network:

- Airports' capacities are set as maximum estimated 2020 capacities;
- Topology of the network is set according to current flight connections between airports;
- The independent variable is the total number of aircraft input to the network. At t_0, this total input flow is distributed among the nodes proportionally to their capacities;
- At each time step, each airport diffuse all its aircraft among their surrounding (linked by connections) airports according to probabilities proportional to their capacities;
- When arrival airport capacity is exceed for certain time interval, the affected flights are delayed on ground at origin;
- Dependent variables are:
    - Number of delayed flights per airport with time;
    - Average delay of delayed flights per airport with time;
    - Total average delay at network level with time.

The output of this theoretical scenario is the relation between the total number of aircraft diffusing along the network and the three dependent variables obtained. The theoretical demand limit is considered as the total number of aircraft causing divergence with time of the dependent variables.

Model Configuration			Options explored		
Airports	**Severe** (UDPP) capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	50%	70%	
		Node 2 shortfall	50%	70%	
		Node 3 shortfall	50%	70%	
		Node 1 duration	3h	6h	
		Node 2 duration	3h	6h	
		Node 3 duration	3h	6h	
	Non-severe capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	10%	20%	30%
		Node 2 shortfall	10%	20%	30%
		Node 3 shortfall	10%	20%	30%
		Node 1 anticipation	0	1h	
		Node 2 anticipation	0	1h	
		Node 3 anticipation	0	1h	
	Increased capacity in **hub** airports	Airport 4	20%	30%	50%
		Airport 5	20%	30%	50%
		Airport 6	20%	30%	50%
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✓		
		Node 8 shortfall		✓	
	Military training areas		✓		
NOP	Uncertainty of **Demand**	Scenario 1	✓		
		Scenario 2		✓	
OIs	**DCB-0103** SWIM enabled NOP		✓		
	DCB-0208 Dynamic ATFCM using RBT			✓	
	DCB-0305 Network Management Function In Support of UDPP		P1	P2	P3
Integrated results	**WP3.3.2**	Delay Threshold	DT1	DT2	DT3
		Time to implement DCB	Ti1	Ti2	Ti3
		% delay absorbed en-route	D1	D2	D3
		TTA allocation strategy	ST1	ST2	
		Maximize delay on ground/en-route	OG	ER	
	WP3.3.3	% of affected trajectories	At1	At2	
		Node shortfall duration	T1	T2	
	WP3.3.4	Uncertainty associated to airport operations affecting departure times	U1	U2	U3

Table 2-5 EP3 WP3.3.5 Simulation Scenarios

- Simulation Scenario 1 (linked to H2 of §2.5.3 Hypotheses). Events and operational conditions combined in Simulation Scenario 1 to obtain the related Simulation Runs are:
  - No capacity shortfall;
  - Uncertainty of demand;
  - DCB-0103.

  Each combination of the parameters associated with this Simulation Scenario is simulated in a Simulation Run.

			Simulation Scenario 1			
Configuration			S1.1	S1.2	S1.3	S1.4
	Uncertainty of Demand	Scenario 1	X	X		
		Scenario 2			X	X
OI	DCB-0103 SWIM enabled NOP			X		X

Table 2-6 EP3 WP3.3.5 Simulation Scenario 1

Thereby, Simulation Run 1.1 (S1.1) represents a situation where the uncertainty of demand corresponds to scenario 1 and DCB-0103 is not implemented. S1.2 at its turn, contemplates the implementation of DCB-0103.

- Simulation Scenario 2 (linked to H2 of §2.5.3 Hypotheses).
  - Severe (UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term (airports);
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network (airspace);
  - Uncertainty of Demand;
  - DCB-0103.
- Simulation Scenario 3 (linked to H3 of §2.5.3 Hypotheses).
  - Severe (UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term (airports);
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network (airspace);
  - Uncertainty of Demand;
  - DCB-0208.
- Simulation Scenario 4 (linked to H1 of §2.5.3 Hypotheses).
  - Severe (UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term (airports);
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network (airspace);
  - Uncertainty of Demand;
  - DCB-0305.
- Simulation Scenario 5 (linked to H1, H2 & H3 of §2.5.3 Hypotheses).
  - Severe (UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term (airports);
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network (airspace);
  - Uncertainty of Demand;
  - DCB-0103;
  - DCB-0208;
  - DCB-0305.
- Simulation Scenario 6 (linked to H4 of §2.5.3 Hypotheses).

- Non-severe Capacity Shortfall impacting Multiple Nodes of the Network;
- Integrated results of EP3 WP3.3.2.

- Simulation Scenario 7.
  - Severe (UDPP) Capacity Shortfalls impacting Multiple Nodes of the Network in the Short-Term (airports);
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network (airspace);
  - Uncertainty of Demand;
  - Increased capacity in hub airports.
- Simulation Scenario 8 (linked to H5 of §2.5.3 Hypotheses).
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network;
  - Military training areas;
  - Uncertainty of Demand;
  - Integrated results of EP3 WP3.3.3.
- Simulation Scenario 9 (linked to H6 of §2.5.3 Hypotheses).
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network;
  - Non-severe Capacity Shortfall impacting Multiple Nodes of the Network (airspace);
  - Integrated results of EP3 WP3.3.4.
- Simulation Scenario 10. Finally, it is foreseen to build ad-hoc simulation scenarios during EP3 WP3.3.5 execution phase, taking into account the results from previous EP3 WP3.3.5 Simulation Scenarios, and thus capturing most promising combinations of OIs and integrated results from previous WP3 validation exercises.

2.5.8 Additional Information

Main validation scenario assumptions are:

1. Airport limiting factor of capacity is runway capacity;
2. Airports outside the 133 first airports have a negligible impact on ECAC wide performances and network behaviour and stability;
3. For every airport, capacity on ground (parking and taxiing area) is highly enough to be considered infinite;
4. In the short-term planning phase demand and capacity are balanced (estimated for 2020);
5. Delayed flights on arrival are prioritized based on FIFO queue;
6. All aircraft have the same performances and their speed between two nodes is a constant. The deviation in time of flight is considered negligible compared to the time-interval;
7. For the uncertainty of demand, the following possible situations are considered:
   - Probability of flight cancelation can be 10 or 5%;
   - Probability of appearance of new flight demand (only for those connections over percentile 80 in terms of number of flights per day) can be 20 or 10%;

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- o Probability of variation of EOBT is 10% (EOBT changes considered of [-10 min, +10 min]).

8. Non-severe capacity shortfalls (airports) severity can be 10, 20 or 30% (capacity decrease), during three hours, and sudden or known with one hour anticipation;
9. Severe capacity shortfalls (airports) severity can be 50 or 70% (capacity decrease), during three or six hours, and known with three hours anticipation;
10. Non-severe capacity shortfalls (airspace) severity is 30% (capacity decrease), during three hours, and known with one hour anticipation;
11. Non-severe capacity shortfalls (reserved military training areas) severity is 30% (capacity decrease), during three hours, and known with two hours anticipation.

2.5.9 Equipment scenario requirements

For the execution of EP3 WP3.3.5 a new platform is developed in the framework of the validation exercise. Thus, all scenario requirements are taken into account for the design and development of the new tool.

2.6 Exercise Tool, Technique and/or Platform

The underlying approach of the validation tool used in EP3 WP3.3.5 exercise is an **innovative application of complex system modelling to the ATM network**. The tool used is ISDEFE's software platform **ATM-NEMMO** (ATM Network MacroMOdel).

Complex systems are composed by a large number of elements, and are characterised by emergent behaviours and collective phenomena when looked from a holistic viewpoint. These patterns appear due to the interactions between the elements, but can not be inferred from the behaviour and relations of the constituent elements. The intrinsic non-linearity of a complex system makes it more than the sum of its elements.

The ATM network presents non-linear coupling of local dynamics, queuing generation and congestion propagation phenomena, all characteristics of complex networks. The performances of the air transportation system are embedded in the network, and accordingly the global topology of the underlying network guide or affect the aircraft diffusion patterns. It is then very important, in order to capture complex system phenomenology, to model and simulate the effects and interactions between the ATM infrastructure and dynamics.

ATM-NEMMO novel approach is based on techniques within the complex system field, such as diffusion analysis, graph theory and cooperative analysis. Among the main characteristics of the platform are:

- **Coarse level of detail**, by modelling the main and fundamental aspects of the ATM system. Details are incorporated to the modelling as "stochastic effects" that deviate the deterministic performance provided by the rules;
- The model is **tractable**, both in computational and in modelling time;
- The degree of flexibility is high; it is **flexible** enough to incorporate different rules or operational improvements in a way that they can be implemented independently.

The validation approach chosen is suitable for the first assessment of the fitness for purpose of new concept functions in an early stage of maturity. To undertake the first step of validation for functions that are in an early stage of development, ATM-NEMMO represents a non expensive tool allowing quick modifications and the simulation of a number of different configurations/operational functions in a short period of time. Coarse (macroscopic) level of detail keeps computational and execution time within the scope of EP3 WP3.3.5 exercise, whereas modelling certain specific details doesn't have a significant impact on macroscopic behaviour. The tool allows obtaining indicative ECAC performances, while exploiting the trade-off between accuracy and flexibility, focussing on capturing the performances evolution.

The flexible model used allows exploring how ECAC network ATM performances can benefit from new concept elements before the detailed operational procedures are available and **without requiring an intensive platform refinement effort**. ATM-NEMMO innovative application of complex system modelling to the ATM network is **modular and easy to customize** in order to implement new features.

The model is a macroscopic approach to the ATM network in terms of graphs, analytical equations and statistical analysis. A general view of the model is presented here below:

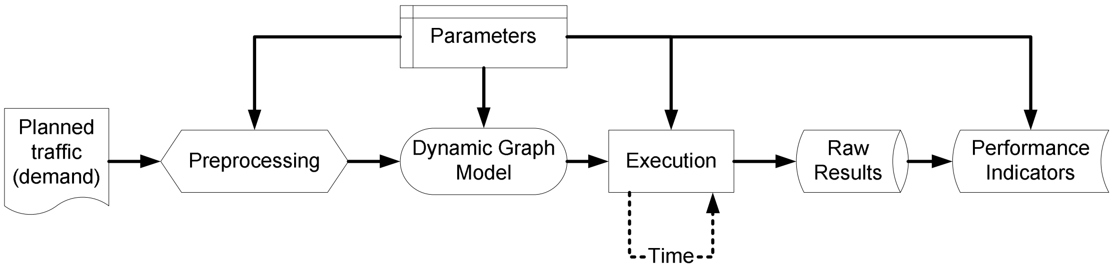

Figure 2-6 Overall View of ATM-NEMMO Logical Structure

The model network is composed of heterogeneous nodes (saturated/congested areas and airports) linked by air routes aggregations:

- Nodes are ATM elements (airports, airspace configurations) with capacity restrictions and they have associated local rules;
- Two nodes are connected by a link if there is a flight connection between them. This constitutes the network topology;
- A distance layer represents the distances between nodes or, what is the same, the link's lengths;
- Simulations parameters (number of nodes, distances, connectivity, nodes' design capacities, etc.) define the network characteristics;
- Local rules are interactions between nodes and model the node's behaviour. These rules manage the input and output traffic flows and the evolution of this traffic with time is determined by three aspects:
  - Traffic Demand;
  - Local rules;
  - Unexpected events and uncertainty.
- Global and local variables are defined to obtain indicators.

A dynamic graph is generated from the traffic demand in the short-term planning phase. Distances between airports/nodes are modelled in terms of time units (each time unit representing a time-interval). A time interval is defined for each simulation (typical values between 3 to 10 minutes). Planned traffic is thus grouped into flows, according to the defined time interval, generating the dynamic graph.

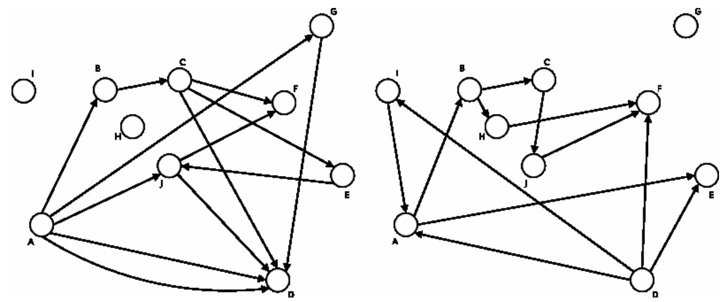

Figure 2-7 Dynamic Graph of Traffic Demand

Next some details are given about how local rules are defined and implemented. Specifically, the example describes the basic local rules for airports for input traffic (arrivals) and output traffic (departures).

2.6.1 Model Basic Local Rules for Airport Departures

For an airport node *n*, output (departure) capacity is a function of time. Departure capacity represents the maximum number of flights that can take-off at node *n* in the time interval T_j.

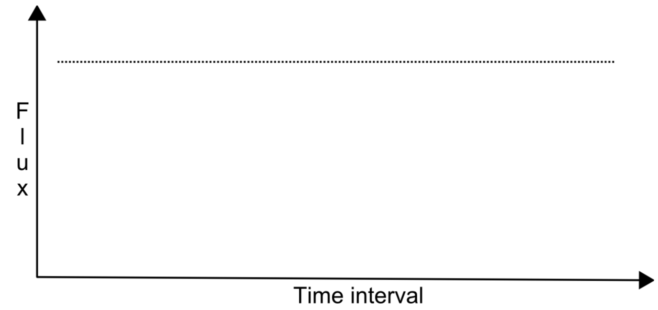

Figure 2-8 Departure Capacity of Node *n*

According to the traffic demand, the number of *programmed flights* departing from node *n* at interval T_j is obtained.

The *delayed traffic* for node *n* at interval T_j is the number of flights that are delayed on ground due to insufficient departure capacity.

The programmed flights for the time interval are combined with the delayed traffic, generating the *total output demand* for this interval.

Figure 2-9 depicts local rules at node *n* managing departures. Flights can be prioritised for taking-off using diverse algorithms (delayed first, prioritised airports, etc.) To take into account reactionary delays, for certain flights and airports (when possible and relevant) the first check is to ensure that precedent aircraft is at the airport (the concept of precedent aircraft is linked to stop-over flights and hub airports).

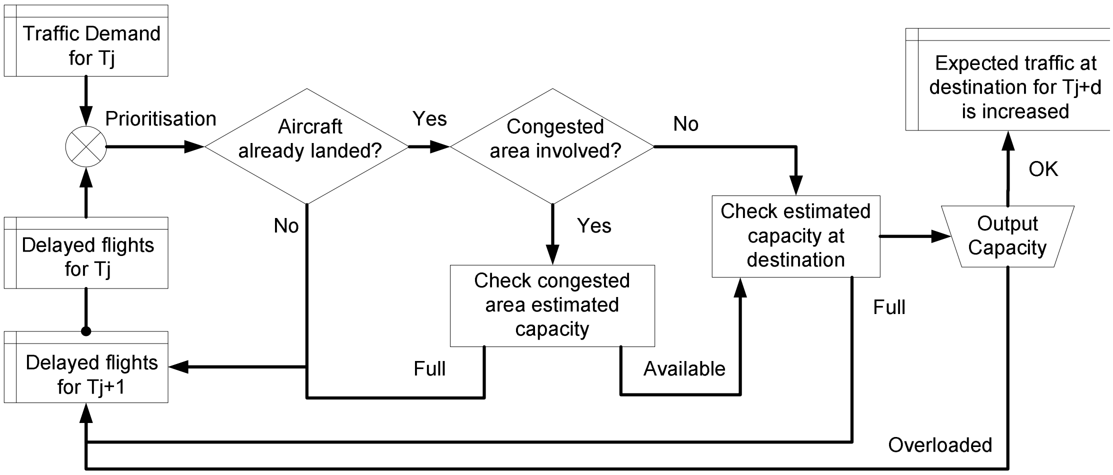

Figure 2-9 Output Flow from Node *n*

Congested areas can be involved in the trajectory linking node *n* with the destination node for a certain flight. Every congested area has a maximum throughput capacity which can, also, vary with time.

The availability of the destination airport arrival capacity is checked for the time interval T_j + d, being d the distance between airports.

Finally, output flow is checked against the **real** departure capacity at T_j. which can be different from the estimated one, due to unexpected occurrences.

2.6.2 Model Basic Local Rules for Airport Arrivals

For an airport node *n*, input (arrival) capacity is a function of time. Arrival capacity represents the **estimated arrival capacity** of node *n* at time interval T_j.

The *expected arrival traffic* for node *n* at time interval T_j is the total number of flights which arrival at node *n* is expected to occur within T_j.

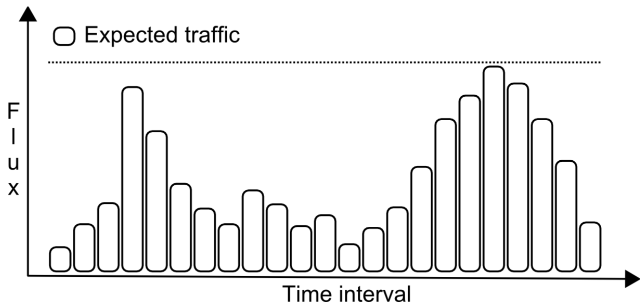

Figure 2-10 Expected Traffic per Time Interval

Flights departing from other nodes with destination to node *n*, may check estimated arrival capacity at destination before departing (see Figure 2-11).

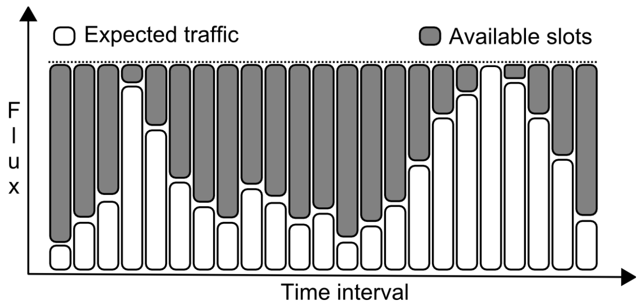

Figure 2-11 Comparison between Estimated Arrival Capacity and Expected Arrival Traffic for Node *n*

If no events occur, any arrival congestion can be avoided by adjusting arrival traffic to estimated arrival capacity. However, the **real arrival capacity** of node *n* at T_j may differ from the estimated arrival capacity (sudden capacity shortfall).

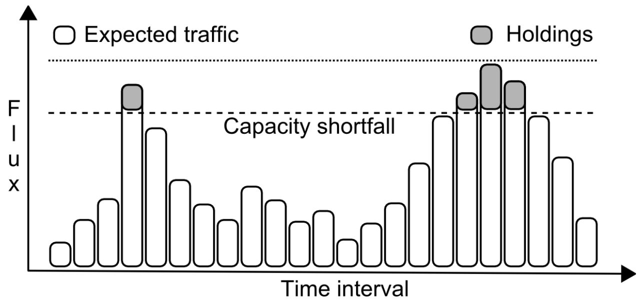

Figure 2-12 Holdings at Arrivals to Node *n* due to Capacity Shortfall

The *holdings* for node *n* at interval T_j is the number of flights that haven't yet landed at node *n* due to an overload situation affecting arrivals (arrival traffic exceeding real arrival capacity).

For an airport node *n*, the *arrival traffic* for T_j is the addition of the expected arrival traffic and the holdings. Next figure depicts local rules at node *n* managing arrivals.

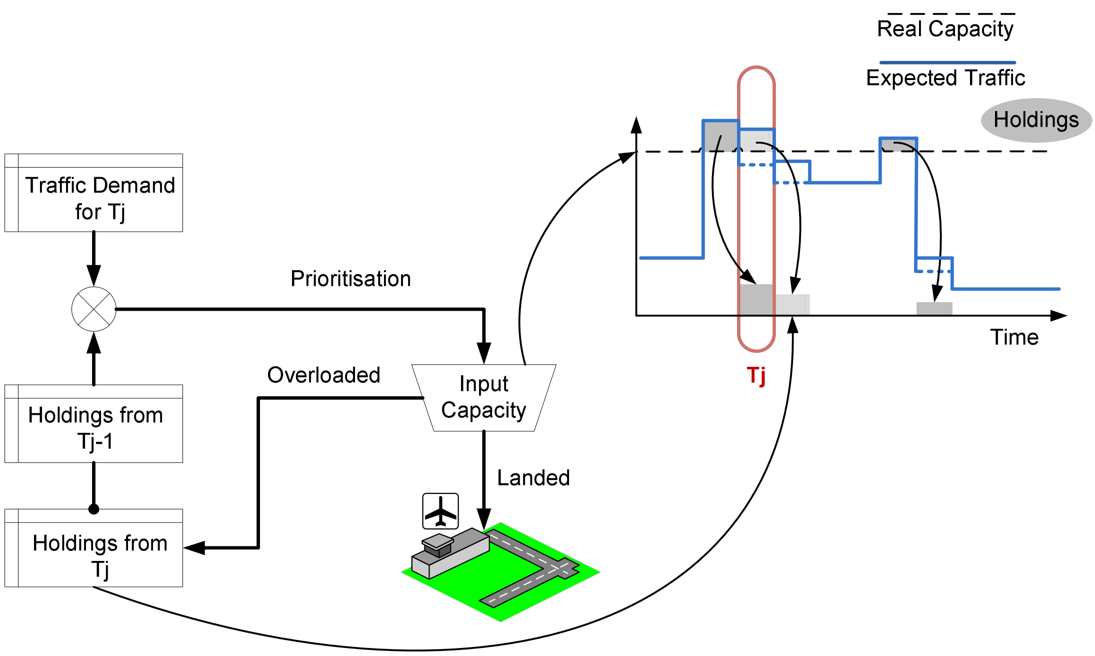

Figure 2-13 Input Flow to Node *n*

Each airport of origin sends to node *n* the arrival demand. For T_j, arrival traffic (arrival demand + holdings) is confronted with the real capacity at node *n*. If an arrival capacity shortfall occurs, arrival traffic at T_j will exceed real capacity at node *n*. This occurrence leads to the appearance of new holdings at node *n*. Arrival flights can be prioritised using diverse algorithms (holdings first, prioritised airports, etc.)

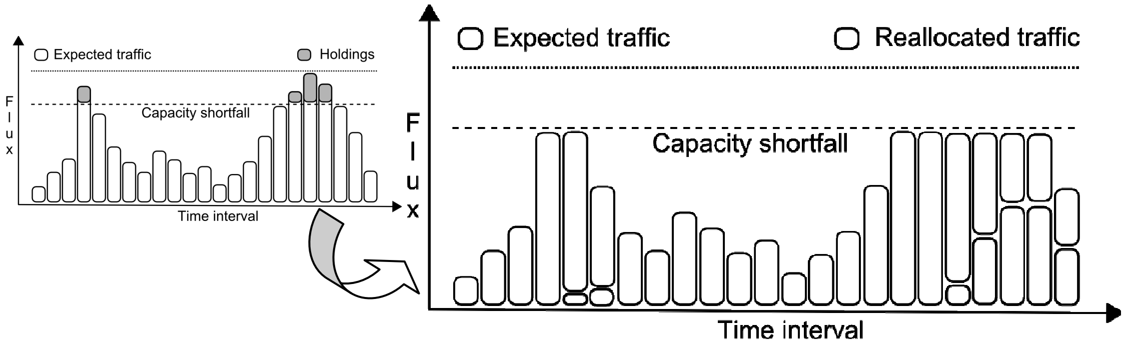

Figure 2-14 Traffic Reallocated at Node *n*

2.7 Links to other Validation Exercises

EP3 WP3.3.5 is part of Episode 3 WP3 Collaborative Planning Processes. Figure 2-15 illustrates the EP3 WP3 validation activities structure and the main relations between them.

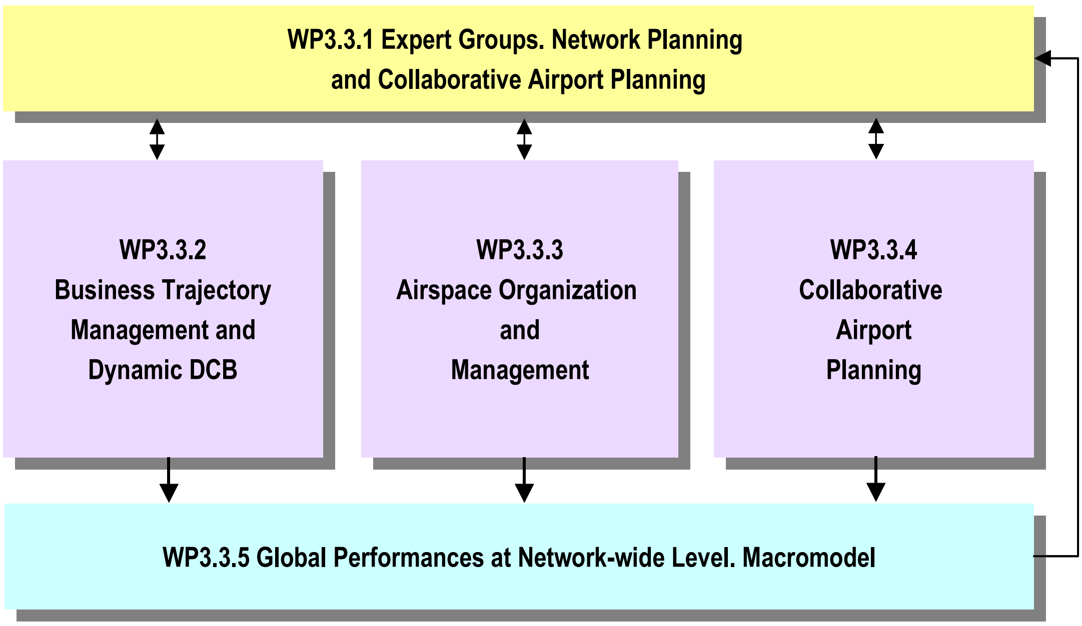

Figure 2-15 EP3 WP3 Validation Activities

All the WP3 previous validation exercises feed their local results/ conclusions to EP3 WP3.3.5, whereas WP3.3.1 Expert Group supports EP3 WP3.3.5 planning and results analysis by providing expert advice about the DODs, the Operational Scenarios and the Validation Scenarios [5].

One of the objectives of EP3 WP3.3.5 validation exercise is to **extent/analyse/refine the local conclusions** of previous WP3 exercises related to the validation/ clarification of Operational Improvements/ Procedures. EP3 WP3.3.5 macromodel is used to integrate these local conclusions at an ECAC wide network level and then to study the impact on the global performances and behaviour, by capturing the network coupling effects.

The conclusions/results of previous WP3 exercises addressing a set of Operational Improvements (OIs) are integrated differently depending on their nature:

- **Local performances** measured as a result of the implementation of the set of OIs: these performances are input as **local parameters** in the EP3 WP3.3.5 macromodel, obtaining a first assessment of the influence of local performances, and, by extension, local OIs, in global performances. Assumptions and parameters used by the local exercise to obtain the local performances are also tracked by the EP3 WP3.3.5 macromodel (to the extent that they are relevant to its level of detail);
- Details/clarification about the **operational procedures** and **variables** associated with the OIs: these details/variables are input as **local rules** in the EP3 WP3.3.5 macromodel, obtaining a first assessment of the impact of local OIs in global performances/ behaviour. Assumptions and parameters used by the local exercise to obtain the local performances are also tracked by the EP3 WP3.3.5 macromodel (to the extent that they are relevant to its level of detail);
- **Assumptions**/ **parameters** used by the local exercise to validate the **operational feasibility** of the operational procedure(s) associated with OIs: same assumptions/parameters are used by the EP3 WP3.3.5 macromodel to the extent that they are relevant to its level of detail, obtaining a first assessment of the impact in global performances/ behaviour of the assumptions/ parameters associated with the local feasibility of the OI.

The integration of local results is performed by extrapolating them to other local areas in the network, in accordance with the local exercise representativeness.

As already indicated in this Experimental Plan, it is out of the scope of EP3 WP3.3.5 validation exercise the integration and the extension to ECAC wide level of **all** the results and conclusions of WP3 validation exercises. Besides, the analysis of which results of previous WP3 exercises are suitable to be integrated by EP3 WP3.3.5 could not be completed until those previous WP3 exercises have completed their respective execution phases. The **final record** of validation results from previous WP3 exercises being further processed by EP3 WP3.3.5 will be included in **EP3 WP3.3.5 Report**.

An **initial analysis** has led to the identification of the following links between EP3 WP3.3.5 and previous WP3 validation exercises:

EP3 WP3.3.2. Business trajectory management and dynamic DCB

EP3 WP3.3.2 **Gaming Exercise** is mainly focussed on clarification of the operational procedures related to dynamic DCB measures, in the context of short-term planning and execution phases, arrivals and medium severity capacity shortages. The exercise delivers some metrics, although performance assessment is out of the scope of the exercise, in order to demonstrate that useful metrics can be produced. However, metrics can not be considered as highly accurate or representative. Thus, the results to be integrated are mainly details/clarification about the operational procedures and variables associated with the OIs addressed by the exercise [17]:

- One variable associated with the implementation of DCB measures is the Delay Threshold above which the DCB processes are triggered. EP3 WP3.3.2 Gaming Exercise uses for the pre-simulations default values based on experience, which are further refined suited to the pre-simulation experiences. Same **thresholds** are used in EP3 WP3.3.5 to define the **triggering conditions** for the rules associated with **DCB measures**.
- The study of the time window during which DCB solutions can be effectively implemented is another objective of EP3 WP3.3.2 Gaming Exercise. The outcome to be input to the EP3 WP3.3.5 is the **time needed to implement a DCB solution**, which is used as time constraint for the application of DCB measures. The time

needed by airspace users to reply to/implement a constraint is an assumption of EP3 WP3.3.2 Gaming Exercise that is tracked to EP3 WP3.3.5 macromodel.

- EP3 WP3.3.2 Gaming Exercise studies the level of congestion that DCB measures can address. EP3 WP3.3.5 macromodel uses as input the **% of delay that can be absorbed en-route thanks to DCB measures**. EP3 WP3.3.5 also plans to take into account any other conclusions, if any and/or relevant to the level of detail of the macromodel, related to the characterisation of DCB solutions in terms of type of flight (short, medium, long haul), type of "capacity change" situation, etc.

EP3 WP3.3.2 **Process Simulation Exercise** addresses in detail Operational Scenario 11 Non severe capacity shortfall impacting arrivals in the short term [10]. Among the objectives of the exercise are the design of three different TTA allocation algorithms and the subsequent assessment of both the effectiveness and the delay impact on the different type of flights. EP3 WP3.3.5 macromodel is fed with the outcomes related to TTA allocation operational procedures, extending the scope of the assessment to network level. EP3 WP3.3.5 simulates two of the **TTA allocation strategies** ("First planned first served" and "Flights in air have absolute priority"), and explores the network impact of their wide application when a non-severe capacity shortfall affects multiple nodes of the network.

EP3 WP3.3.3. Airspace Organisation and Management

The focus of EP3 WP3.3.3 exercise [18] is the analysis of the DCB negotiation processes at local/sub-regional level among civil airspace users, military users, civil/military airspace manager and the sub-regional manager. Specifically, the gaming exercise proposes a situation where a military exercise is re-planned, resulting in a new reserved area impacting a FAB. The following concepts are addressed:

- Modular sectorisation adapted to variations in traffic flows;
- Modular temporary segregated and reserved areas/ military variable profile areas;
- Flexible military airspace structures/ variable geometry area.

EP3 WP3.3.5 undertakes the integration of EP3 WP3.3.3 Gaming Exercise by including as **local parameters** in the macromodel the local performances measured as a result of the implementation of the set of OIs addressed by EP3 WP3.3.3 [18].

The hypothesis of EP3 WP3.3.3 area that the implementation of the addressed set of OIs **increases**:

- The **airspace capacity** through the identification of the most suitable airspace configuration adapted to the military and civil users;
- The **flight efficiency** as the distortion of users trajectories is minimised (temporal and fuel efficiency).

The macroscopic outcomes at FAB level are an increase of the maximum number of aircraft than can enter the airspace volume and a decrease of the airspace volume total delay. These outcomes are related to **EP3 WP3.3.5 local parameters** framing reserved military training areas: **size** (number of trajectories affected) and **duration** of the reservation.

EP3 WP3.3.4. Collaborative Airport Planning

The **holistic approach** of EP3 WP3.3.4 validation exercise considers not only the collaborative planning process at an airport and the associated benefits, but also the effects of collaborative decision making at airport level on the surrounding airspace network [19].

First, a gaming exercise is held to solve pre-tactical planning events at an airport level in the APOC. Second, a network management experiment is conducted to diagnose the consequences of collaboratively reached decisions in the APOC at a network level. These consequences are **fed back** to the decision makers in the APOC, supporting them in making better decisions in response to the simulated planning events.

The result of EP3 WP3.3.4 initially chosen to be integrated into EP3 WP3.3.5 is the decrease of the **departure delay** due to the application of DCB-0206 Coordinated network management operations extended within day of operation. EP3 WP3.3.4 indicator is fed into the macromodel as a parameter affecting the **uncertainty associated with airport operations** which induces departure delays. Both EP3 WP3.3.4 gaming exercise and network management modelling explores how the implementation of the set of OIs addressed in EP3 WP3.3.4 contributes in the decrease of departure delays, counteracting the impact of the uncertainty of airport operations.

Finally, it must be highlighted the link between EP3 WP3.3.5 and **EP3 WP2.4.1** Performance Framework [4]. An initial analysis performed reveals the following links between the two WPs:

- EP3 WP3.3.5 provides ECAC wide performances to populate the Influence Model;
- EP3 WP3.3.5 provides an assessment of the influence of local performances in global performances, which can be used to define and quantify the influences captured by the Influence Model.

To specify in detail which influences could be defined or quantified by means of the EP3 WP3.3.5 macromodel, it is necessary to complete the analysis of the results from all previous EP3 WP3 validation exercises, which is done once those exercises have completed their respective conduction phases. A detailed description of the links between EP3 WP3.3.5 and EP3 WP2.4.1 will be provided in WP3.3.5 Report.

2.8 Concept Assumptions

Main concept assumption considered in EP3 WP3.3.5 validation exercise is that the SESAR concept will create sufficient terminal area and en-route capacity so that it is no longer a constraint in normal operations.

2.9 Summary

Annex 1 Exercise Overview Table provides a summary and overview of the exercise scope.

3 PLANNING AND MANAGEMENT

3.1 ACTIVITIES

3.1.1 Preparatory activities

In line with the objectives of EP3 WP3.3.5 exercise (see 2.3 Exercise objectives), the activities needed to be performed prior the execution phase are:

- Exercise scope definition. In line with validation requirements and WP3 Validation Strategy [5], and according to E-OCVM methodology [3], the following steps are performed: identification of stakeholder's acceptance criteria and performance requirements, definition of exercise objectives, identification of the list of indicators and metrics and specification of validation and platform scenario requirements.

- Design and development of a mathematical model and emulation software. As a first step, a detailed macroscopic analysis of current ATM operations is needed in order to produce a baseline mathematical dynamic model. The model structure and parameterisation is fixed taking into account the scope of EP3 WP3.3.5 validation exercise, and the input needed (traffic, airports data, airspace characteristics, etc.) are framed.

  A **Toy Model** approach is followed in order to validate the innovative tool feasibility to produce the looked-for results. The preliminary specifications of the Toy Model are focused on a coarse level of detail, setting up the development framework of a tool with a high degree of flexibility in terms of scope of processes to be modelled, easy to modify and with reasonable computational requirements. The model is based on deterministic equations plus stochastic components, and it is composed by the following layers: Network Definition, Interactions Underlying Topology (topological and geometrical information), Variables Definition (local and global, dependent and independent) and Local Dynamic Rules. A number of different models (different networks and topologies) are programmed. For each model, a number of simulations are performed in order to perform the system behaviour characterisation, each simulation having a variable parameter and certain objectives.

  After the **verification** of the tool consistency, the programming of the model using Matlab is performed. Matlab language enables the development and refinement of the model with the projected final level of detail performing computationally intensive tasks faster than traditional programming languages.

- Preparation of the platform to represent **ECAC network**. The network nodes and their associated parameters are established, together with the topological layer and the boundary conditions. These tasks have associated the research work to define the necessary parameters, mainly the geodesic coordinates and the capacities of the ECAC airports to be modelled. Within this task, it is also included the necessary work to define the ECAC high density areas through obtaining a density map (see 2.5.5 Airspace Information).

- Definition of the list of **performance indicators**, taking into the level of detail of the model and the exercise objectives.

- Refinement and implementation of **basic** variables, parameters, set of rules and outputs. The analysis of the desired outputs (performance indicators) and Operational Improvements to be validated led to the definition of a set of variables and rules, which embody the simulation scenarios.

- Refinement and implementation of **integration** variables, parameters, set of rules and outputs. The examination of WP3 previous exercises, through in deep analysis, is needed in order to update the scope of EP3 WP3.3.5 exercise and the model for the integration of results.
- **Traffic** filtering. Input traffic is filtered in order to adapt it to the model.
- Definition of **Simulation Scenarios** and simulation runs. The possible combination of rules and parameters is large enough to require an appropriate selection of scenarios of interest. The selection of simulation runs is performed trying to cover stakeholder's acceptance criteria and performance requirements.

3.1.2 Execution activities

Once the platform is ready, the simulation runs are executed (Montecarlo simulations). The configuration of the tool is required prior to each Simulation Scenario and to each particular simulation run. The configuration of the model includes parameter tuning in order to maximise computation charge/accuracy ratio. An example is the time interval (see 2.5.1 Operational Context) is determined in this phase. Results are stored for a posterior analysis.

It is also foreseen to build ad-hoc simulation scenarios during the execution phase, taking into account the results from previous simulations, and thus capturing most promising combinations of OIs and integrated results from previous WP3 validation exercises.

3.1.3 Post execution activities

After all the simulation runs are performed, post analysis is completed in order to find emergent phenomena, global behaviours or just performances indicator changes. Statistical analysis of data is based on chosen significance levels and null hypothesis testing (see §4.3 Analysis method).

3.2 Resources

The main expertise and skills required to perform EP3 WP3.3.5 exercise can be summarised as follows:

- Comprehensive understanding of the ATM Network (actors, operation, architecture and business drivers);
- Familiarisation with SESAR programme and with the SESAR Concept of Operations Document (CONOPS);
- Expertise in validation methodologies, tools and techniques, in particular applied to ATM systems;
- Know-how in graph theory and statistical methods;
- Experience in simulation design, verification and development, and data analysis.

Table 3-1 **Expected effort** shows the distribution of person-month (pm) per identified activity.

Activities	Detail	Effort (pm)
Preparatory	Activity 1.1 Exercise scope definition	2
	Activity 1.2 Design and development of mathematical model	3,5
	Activity 1.3 Preparation of the platform to represent ECAC network	1,5
	Activity 1.4 Definition of performance indicators	0,5

Activities	Detail	Effort (pm)
	Activity 1.5 Refinement and implementation of basic variables, parameters, set of rules and outputs	2
	Activity 1.6 Refinement and implementation of integration variables, parameters, set of rules and outputs	2,5
	Activity 1.7 Traffic filtering	0,3
	Activity 1.8 Definition of Simulation Scenarios and simulation runs	1,5
Execution	Activity 2.1 Tool configuration	1
	Activity 2.2 Execution of simulation runs	0,3
	Activity 2.3 Definition of new ad-hoc Simulation Scenarios and simulation runs	0,4
Post-Exercise	Activity 3.1 Data analysis	1
	Activity 3.2 Results analysis and conclusions	1,5
TOTAL (pm)		18

Table 3-1 Expected effort

3.3 Responsibilities in the exercise

The work and responsibilities of the partners of EP3 WP3.3.5 exercise is distributed as follows:

- **ISDEFE** is the leader of EP3 WP3.3.5 exercise, and is in charge of general management and coordination. Besides, ISDEFE is the main contributor, in terms of effort, being present and leading all the identified activities.
- **AENA** actively contributes to the exercise scope definition, assists in the refinement of variables, parameters, set of rules and outputs, provides and process input data (activity 1.3), and participates in results analysis. AENA also provides its operational expertise to check the operational consistency and significance of the results.
- **EUROCONTROL** inputs its expertise in network modelling during the planning, execution and results analysis phases of the exercise, by means of periodic internal progress meetings, elaboration/review of working documents and performance of ad-hoc tasks. Additionally, EUROCONTROL actively contributes to the exercise report.

3.4 Training

Participants in the exercise are selected in order to cope with the required expertise and skills. Moreover, it is expected that the same work team in charge of developing the mathematical model and tool run the simulations. Thus, no especial training is required.

3.5 Time planning

The preparatory activities extend until middle of July 2009. Execution phase takes place from the end of the preparatory phase up to end of August 2009, and simultaneously post-exercise phase starts with the analysis of preliminary data. It is expected that the result report is ready for beginning of October 2009.

A detailed planning of the activities is specified in §5.3 Time planning for the exercise.

3.6 RISKS

Risk 1:	Lack of inputs		
Description:	Inputs for airports or airspace data are not available for the exercise		
Impacted Area:	☒ Own Exercise	☐ Other Exercise	☐ WP
Level:	☐ Low	☒ Medium	☐ High
Possibility of occurrence:	☐ Low	☒ Medium	☐ High
Contingency Actions:	Identify alternative data sources		
Mitigation Actions:	N/A		
Responsible party:	WP3.3.5 / WP3		
Risk 2:	Planning		
Description:	Due to tight planning, the simulation reports from previous WP3 exercises are due at the beginning of EP3 WP3.3.5 execution phase, not leaving time for EP3 WP3.3.5 to analyse results to be integrated and to define integration rules, variables and parameters		
Impacted Area:	☐ Own Exercise	☐ Other Exercise	☒ WP
Level:	☐ Low	☒ Medium	☐ High
Possibility of occurrence:	☐ Low	☐ Medium	☒ High
Contingency Actions:	Integration of results performed adapting to time planning constraints		
Mitigation Actions:	Close coordination between EP3 WP3.3.5 and previous WP3 exercises in order to dispose of results without having to wait for simulation reports to be available		
Responsible party:	WP3.3.5 / WP3		
Risk 3:	Platform		
Description:	Platform doesn't comply with the required tractability, both in computational and in modelling time		
Impacted Area:	☒ Own Exercise	☐ Other Exercise	☐ WP
Level:	☐ Low	☐ Medium	☒ High
Possibility of occurrence:	☒ Low	☐ Medium	☐ High
Contingency Actions:	Adaptation of EP3 WP3.3.5 scope to the model capabilities		
Mitigation Actions:	Expertise of participants in simulation design, verification and development guarantees an accurate and realistic outline of the platform possible capabilities from the start		
Responsible party:	WP3.3.5		

Table 3-2 Risk identification

4 ANALYSIS SPECIFICATION

4.1 DATA COLLECTION METHODS

As it has been described before, EP3 WP3.3.5 exercise is based on a mathematical model, supported by a software simulation tool. Different KPIs are obtained, covering various KPA including: Capacity, Efficiency and Flexibility.

It is important to remark that that the looked-for quantitative results are focused on capturing network effects and emergent phenomena at ECAC level.

Quantitative data are divided into two categories: raw data and KPIs. Raw data are direct outputs of the simulation software, and different KPI are computed from raw data (see Table 4-1 **Influence of some raw data in** the KPI **results**). In some cases, assumptions have to be made to be able to provide estimation for some KPIs.

After the simulation runs, the quantitative data are subject of a proper analysis in order to capture the evolution and changes of the KPIs face to the simulated situations.

KPA	KPI	Description	Expected flights	Delayed flights at destination	Delayed flights at origin	Planned flights	On-Air Holdings
Capacity	CAP.ECAC.PI 2	Daily number of IFR flights that can be accommodated in Europe	+			+	+
	CAP.ECAC.PI 3	Hourly throughput overloads, number of occurrences of capacity overload level per sector/airport/point		+	+		+
Efficiency	EFF.ECAC.PI 1	Percent of flight departure on time			+	+	
	EFF.ECAC.PI 2	Average departure delay per flight			+	+	
	EFF.ECAC.PI 3	Percent of flight with normal flight duration		+	+	+	+
	EFF.ECAC.PI 4	Average extra flight duration	+				+
Predictability	PRED.ECAC.PI 1	Percentage of delayed flights		+	+	+	
	PRED.ECAC.PI 2	Average delay of flight suffering delay	+			+	+
	PRED.ECAC.PI 6	Total delay due to disruption (min)				+	+
	PRED.ECAC.PI 7	Number of reactionary delay (min)			+	+	

Table 4-1 Influence of some raw data in the KPI results

4.2 OPERATIONAL AND STATISTICAL SIGNIFICANCE

Due to the nature of complex systems, it is expected to find some emergent behaviour, and therefore randomness inherent to the whole system. In fact the use of stochastic parameters for modelling unknown real world events and distributions make the model unpredictable.

The KPIs obtained have to be considered as random variables (or even stochastic functions) with associated probability distributions. An empirical distribution is build based on an adequate number of repeated simulations (see §4.3 Analysis method).

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The number of simulation needed to build a proper empirical distribution is defined to obtain a significance level. A typical significance level of 5% is used for the statistical test. This value is commonly used in operational research, and implies a truthful of at least 95% of cases. It is expected that more confident results (significance level under 5%) will require a large number of simulations, making the process unapproachable in terms of computation time.

Typical computation time extends up to 1 hour. If after the full simulation no solution under the significance level is obtained, a new significance level >5% is used.

4.3 ANALYSIS METHOD

As a consequence of the complexity of the system under analysis and the large number of components interacting in a non-linear fashion, the distribution pattern of specific KPIs can not be determined. Even more, it is not possible to find a family of possible distributions. Therefore classical statistical analysis based on parameters estimation is discarded.

One of the main aspects of the simulation software used in this exercise is the optimization of the use of resources and fast execution. Therefore large number of samples can be obtained in a relative short time period.

Instead of trying to estimate the explicit distribution pattern of each KPI, a probability over a proper space sample partition is estimated. This estimation is sufficient to perform the comparative evaluation between the diverse EP3 WP3.3.5 Simulation Scenarios.

As a result of the previous considerations, EP3 WP3.3.5 exercise uses a self-contained hypothesis test based on a **Chi-squared test** with defined significance level over an empirical distribution. Annex 3 Statistical Methods used provides an overview of the methodology used for the statistical analysis.

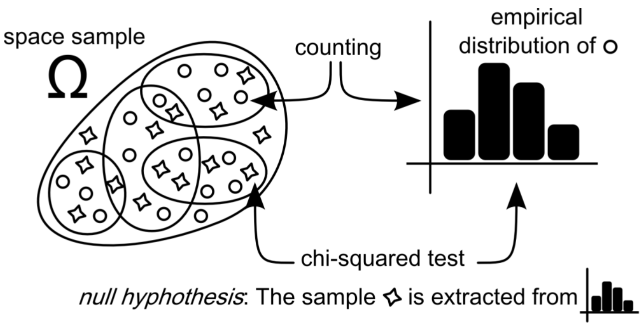

Figure 4-1 EP3 WP3.3.5 Analysis Method

Regarding the operational significance, the analysis of the operational relevance and validity of the results is done internally in the exercise (taking advantage of AENA's operational expertise). For the analysis of results, inputs from the EP3 WP3.3.1 Expert Group will be also taken into account.

4.4 DATA LOGGING REQUIREMENTS

The size of data changes for each different Simulation Scenario. In most cases data logging requirements can be afford by a standard PC.

As a result of the flexibility of the platform being used in the exercise different data would be logged in different simulation. A common data (called raw data) would be automatically generated.

Main data captured are:

- For each time interval, **number of flights delayed at destination**. In this variable, data to be logged are the flights scheduled at a given time interval that can not arrive when it was planned.

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- **Expected flights arriving** at a given time interval. When a flight gets airborne, estimated time of arrival is given, so for every time interval a table of expected flights is logged. The size of the inputs of this table is limited by the estimated capacity of the airport.
- **Number of flights that take-off** at a given time interval. Even if EP3 WP3.3.5 starts with a demand – capacity balance planning situation, due to the random factors of the model it is possible that a capacity overload occurs and thus not all the flights can take off at the planned time. This variable logs the number of flights that actually take-off in a given time interval.
- For each time interval, **number of flights delayed at origin**. This variable stores, the number of flights programmed for a given time interval that can not take-off whatever the reason. Duration of the delay and delay cause are also stored.
- For every time interval and every node **holdings at destination**. When a capacity shortfall occurs in a destination airport, execution flights are waiting for landing. This variable stores the number of flights in this situation, and the duration of the holding process.

4.5 Representativeness

N/A (The exercise carries out an ECAC Wide performance assessment, so results represent the ECAC area).

4.6 Outline reporting plans

The Simulation Report is due to be delivered for EP3 Internal review on beginning of October 2009 according to the template provided by EP3 WP2.3 [22].

- Aim of the document – the aim of the report is to summarise the performed exercise and to objectively present the key findings. It is not meant to state conclusions about whether or not a concept is worth pursuing.
- Target Audience – A distribution list of the target audience is drawn up before work commences on the report. This list typically involves the internal stakeholders and management in WP3/4/5. This report should always be made easily available to interested parties.
- Scope – The report concerns a particular phase in the development of the concept. The results of the work done during previous phases can be referred to in order to show progress and development. Recommendations for future work should also be outlined.
- Key information – It is not advisable to include all results generated in the body of the report. Only the key results (statistically and operationally) need to be included. Details should be given in Annexes.

5 DETAILED EXERCISE DESIGN

5.1 Dependent and Independent Variables

Independent variables related to the simulation (simulation parameters) are:

- Size of time interval, estimated in order to reduce computational charge;
- Number of airports to consider;
- Target significance level (a common target of 5% of chance of error is usually accepted in all statistical null hypothesis testing).

Independent variables related to the network topology and network dynamics are:

- Airport I/O capacity;
- High density areas size, location and capacity (see §2.5.5 Airspace Information);
- Traffic demand. NOP table.

Dependent variables (raw results of the simulations) are:

- For each time interval number of flights delayed at destination;
- Expected flights arriving at a given time interval;
- Number of flights that take-off at a given time interval;
- For each interval number of flights delayed at origin;
- For each time interval and every node holdings at destination.

5.2 Length and Number of Runs

Each simulation run (see 2.5.7 Simulation Scenarios) has a maximum length of 1 hour. The exact number of simulation runs is related to the results statistical significance (a typical signification level is 5%).

Several scenarios are simulated, in order to obtain a representative pattern of complex behaviour and networks effects.

5.3 Time Planning for the Exercise

The table below provides an estimation of the time planning of EP3 WP3.3.5 exercise:

Activity	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Activity 1.1 Exercise scope definition	■	■										
Activity 1.2 Design and development of mathematical model	■	■	■	■								
Activity 1.3 Preparation of the platform to represent ECAC network			■	■								
Activity 1.4 Definition of performance indicators				■								
Activity 1.5 Refinement and implementation of basic variables, parameters, set of rules and outputs				■	■	■						
Activity 1.6 Refinement and implementation of integration variables, parameters, set of rules and outputs					■	■	■					
Activity 1.7 Traffic filtering					■							
Activity 1.8 Definition of Simulation Scenarios and simulation runs				■								

Activity	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Activity 2.1 Tool configuration												
Activity 2.2 Execution of simulation runs												
Activity 2.3 Definition of new ad-hoc Simulation Scenarios and simulation runs												
Activity 3.1 Data analysis												
Activity 3.2 Results analysis and conclusions												

Table 5-1 Detailed time planning

6 REFERENCES AND APPLICABLE DOCUMENTS

Ref.	Document	Status
Reference documents		
[1].	"Guidance Material for steps 2.1 to 2.8 of the E-OCVM", E3-WP2-D2.3-03-TEC-V1.1, November 2008	Approved
[2].	"SESAR D3: The ATM Target Concept", DLM-0612-001-02-00, September 2007	Approved
[3].	"European Operational Concept Validation Methodology E-OCVM", 2nd Edition, February 2007	Approved
[4].	"Performance Framework", E3-WP2-D2.4.1-04-TEC-V3.03, March 2009	Under Acceptance
[5].	"WP3 Contribution to EP3 Validation Strategy", E3-WP3-D3.2.1-01-PLN-V1.00, October 2008	Accepted
[6].	"SESAR Detail Operational Description- General Purpose DOD –G", E3-WP2-D2.2-030-REP-V1.0, February 2009	Approved
[7].	"SESAR Detail Operational Description- Medium/Short Term Network Planning - M2", E3-WP2-D2.2-033-REP-V1.0, February 2009	Approved
[8].	"SESAR Detail Operational Description- Collaborative Airport Planning - M1", E3-WP2-D2.2-032-REP-V1.0, February 2009	Approved
[9].	"SESAR Detail Operational Description- Network Management in the Execution Phase - E4", E3-WP2-D2.2-036-REP-V1.0, February 2009	Approved
[10].	"Non-Severe (No UDPP) Capacity Shortfalls impacting Arrivals in the Short-Term", E3-WP2-I0214-OS-V0.60, December 2008	Draft
[11].	"Severe (UDPP) Capacity Shortfalls impacting Departures in the Short-Term", E3-WP2-I0231-OS-V0.50, November 2008	Draft
[12].	"Non-Severe (No UDPP) Capacity Shortfalls impacting Departures in the Short-Term", E3-WP2-I0220-OS-V0.20, October 2008	Draft
[13].	"Non-severe (no UDPP) capacity shortfalls impacting multiple nodes of the network in the short-term", E3-WP2-I0222-OS-V0.11, December 2008	Draft
[14].	"Military Collaboration during Medium/Short Term Planning", E3-WP2-I0221-OS-V0.20-os-34, December 2008	Draft
[15].	"Turn-round management", E3-WP2-I0217-OS-V0.30-os-16, December 2008	Draft
[16].	"Airport Operational Plan Lifecycle for Medium-Short-Execution Phases", E3-WP2-I0218-OS-V0.30-os-18, December 2008	Draft
[17].	"Experimental Plan for Business Trajectory Management and Dynamic DCB", E3-WP3-D3.3.2-01-PLN-V1.00, March 2009	Under acceptance
[18].	"Experimental Plan on Airspace Organization and Management", E3-WP3-D3.3.3-01-PLN-V1.01, March 2009	Under acceptance
[19].	"Experimental Plan on Collaborative Airport Planning", E3-WP3-D3.3.4-01-PLN-V0.10, April 2009	Draft (under approval)
[20].	"SESAR Detailed Operational Description- Conflict Management in En-Route High & Medium/Low Density Operations - E6", E3-WP2-D2.2-038-REP-V1.00, February 2009	Approved
[21].	"MINUTES OF 5th WP331 NETWORK EG MEETING", EP3-WP331-MWPM20090401-MIN-0.1, April 2009	Draft
[22].	"EP3 Experimental Plan Template", E3-WP0-I0331-GUI-V1.00, February 2009	Approved

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Ref.	Document	Status
Applicable documents		
[A]	“EP3, Contract Annex 1, DoW”, Revision 3.0, July 2008	Approved
[B]	“EP3 Guidance Material for identification of Validation issues at WP and programme level: steps 0.1 to 1.7 of the E-OCVM”, E3-WP2-D2.3-10-WKP, January 2008	Approved
[C]	“EP3 Consolidated Validation Strategy”, Version 1.0, December 2008	Accepted
[D]	“SESAR D2 Air Transport Framework: The Performance Target”, DLM-0607-001-02-00, November 2006	Approved
[E]	“SESAR D4 The ATM Deployment Sequence”, DLM-0706-001-02-00, January 2008	Approved
[F]	”SESAR D5 SESAR Master Plan”, DLM-0710-001-02-00, April 2008	Approved
[G]	“The SESAR Performance Booklet: Performance Objective and Targets”, RPT-0708-001-01-01, November 2007	Approved
[H]	“SESAR WP2.2.2/D3: Concept of Operations”, DLT-0612-222-01-00, July 2007	Approved
[I]	“SESAR WP2.2.3/D3 Definition phase”, DLT-0707-008-01-00, July 2007 (9 Scenarios illustrating the SESAR CONOPS)	Approved

Table 6-1 References and applicable documents

ANNEX 1 EXERCISE OVERVIEW TABLE

The following table provides a summary and overview of the scope of the exercise.

Validation Scenario	Summary/ Purpose	Hypothesis	Metrics/ Indicators	SESAR OI	SESAR KPA	DOD References
The operational context of EP3 WP3.3.5 Validation Scenario is: ECAC wide; Mixed picture (short-term planning phase). Some flights are in the planning phase, and some flights are already in execution. EP3 WP3.3.5 exercise takes place in the short-term planning phase, i.e. some hours before the day of operation starts. EP3 WP3.3.5 studies ECAC wide ATM performances and behaviour associated with the execution of the	EP3 WP3.3.5 Validation Scenario allows exploring the benefits of planning by taking into consideration the application of OIs during the short-term planning phase. Besides, EP3 WP3.3.5 Validation Scenario contemplates the application of operational procedures and OIs related to the execution phase, and the validation of their benefits at ECAC wide level. Additionally, EP3 WP3.3.5 exercise is the final step to close the loop of the EP3 WP3 validation activities. Thus, EP3 WP3.3.5 extents/analyses/refines the local conclusions of previous WP3 Validation Exercises related to the validation/ clarification of	H1: In case of severe disruptions of the network and at congested airports, the prioritisation of departure flights that have the highest number of connections and the shorter flight distances have a positive impact on ECAC wide efficiency and capacity. H2: For departure and delay management, increased coordination with arrival management (taking into account constraints such as capacity and demand balancing and target time of arrival at capacity constraint airports) has a positive impact on ECAC wide predictability. H3: Reduced uncertainty of flight duration and/or fulfilment of CTA/CTOs allows reducing capacity buffers and therefore has a positive impact on ECAC wide capacity and efficiency. H4: The application of DCB measures, increasing the flexibility to assign the delay in case of medium severity capacity shortfall at arrivals, has an impact on ECAC wide	CAP.ECAC.PI 2 Daily number of IFR flights in Europe; CAP.ECAC.PI 3 Hourly throughput overloads; EFF.ECAC.PI 1 Percent of flight departure on time; EFF.ECAC.PI 2 Average departure delay per flight (min); EFF.ECAC.PI 3 Percent of flights with normal flight duration; EFF.ECAC.PI 4 Average extra flight duration (min); PRED.ECAC.PI 1 Percentage of delayed flights; PRED.ECAC.PI 2 Average of delayed	DCB-0103 SWIM enabled NOP; DCB-0208 Dynamic ATFCM using RBT; DCB-0305 Network Management Function In Support of UDPP.	Capacity. EP3 WP3.3.5 exercise evaluates the improvement of network throughput due to collaborative planning reflected in the NOP, taking into account the airspace and airport capacity as a function of traffic demand patterns. Efficiency. EP3 WP3.3.5 exercise provides the ATM global efficiency improvement due to planning and information sharing, by evaluating the suitability of the ATM system to provide an agreed and stable demand and capacity situation, ensuring	DOD M2/3 A2.3.2.2.2 Apply the DCB Solution; DOD E4 A3.1.3.2.2 Apply the Dynamic DCB Solution; DOD E4 A3.1.1.1.2 Assess Airspace Capacity Load; DOD M2/3 A2.3.2.2.1 Assess Network Impact of the DCB Solution; DOD E4 A3.1.3.2.1 Assess Network Impact of the Dynamic DCB Solution; DOD M2/3 A2.3.1.2 Detect Airspace Demand Capacity Imbalance; DOD M2/3 A2.1.2.2 Optimise SBT; DOD M2/3 A2.3.2.1.3 Select/refine/Elaborate a DCB solution at Network Level;

Validation Scenario	Summary/ Purpose	Hypothesis	Metrics/ Indicators	SESAR OI	SESAR KPA	DOD References
short-term planning one day NOP.	certain Operational Improvements/ Procedures.	capacity and efficiency. Moreover, the quantification and quality of this impact depends on the strategy applied for the allocation of TTAs and on the percentage of delay that is absorbed on ground and en-route. H5: The reduction of the size and duration of reserved military training areas thanks to the application of AFUA concept has a positive impact on ECAC wide capacity and efficiency. H6: The decrease of the uncertainty associated with airport operations, thanks to airport collaborative planning and decision making supported by network function, have a positive impact on ECAC wide capacity and efficiency.	flights; PRED.ECAC.PI 6 Total delay due to disruption (min); PRED.ECAC.PI 7 Number of reactionary delay (min).		timely and flexible allocation of special airspace activities. Predictability. EP3 WP3.3.5 exercise shows the knock-on effects, in form of reactionary delays, produced when the capacity constrains are published and known in the system.	DOD E4 A3.1.3.1.3 Select/refine/Elaborate a dynamic DCB solution at Network level.

ANNEX 2 SIMULATION RUNS

This section includes the tables showing the configuration of the model parameters for EP3 WP3.3.5 Simulation Scenarios 2 to 9.

Model Configuration			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16
			Simulation Scenario 2															
Airports	**Severe** (UDPP) capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%
		Node 2 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 3 shortfall	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 1 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h
		Node 2 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h
		Node 3 duration	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓			✓	✓
		Node 8 shortfall			✓	✓	✓	✓							✓	✓	✓	✓
NOP	Uncertainty of **Demand**	Scenario 1	✓	✓			✓	✓			✓	✓			✓	✓		
		Scenario 2			✓	✓			✓	✓			✓	✓			✓	✓
OIs	**DCB-0103** SWIM enabled NOP			✓		✓		✓		✓		✓		✓		✓		✓

Model Configuration			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16
			Simulation Scenario 3															
Airports	**Severe** (UDPP) capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%
		Node 2 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 3 shortfall	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 1 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h
		Node 2 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h
		Node 3 duration	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓			✓	✓
		Node 8 shortfall			✓	✓	✓	✓					✓	✓	✓	✓	✓	✓
NOP	Uncertainty of **Demand**	Scenario 1	✓	✓			✓	✓			✓	✓			✓	✓		
		Scenario 2			✓	✓			✓	✓			✓	✓			✓	✓
OIs	**DCB-0208 Dynamic ATFCM using RBT**			✓		✓		✓		✓		✓		✓		✓		✓

Model Configuration			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16	S2.17	S2.18	S2.19	S2.20	S2.21
			Simulation Scenario 4																				
Airports	**Severe** (UDPP) capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%
		Node 2 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 3 shortfall	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 1 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h	6h
		Node 2 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h	6h
		Node 3 duration	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✔	✔	✔	✔	✔	✔				✔	✔	✔	✔	✔	✔				✔	✔	✔
		Node 8 shortfall				✔	✔	✔	✔	✔	✔				✔	✔	✔	✔	✔	✔	✔	✔	✔
NOP	Uncertainty of **Demand**	Scenario 1	✔	✔	✔				✔	✔	✔				✔	✔	✔						
		Scenario 2				✔	✔	✔				✔	✔	✔				✔	✔	✔	✔	✔	✔
OIs	**DCB-0305** Network Management Function In Support of UDPP		**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**

Model Configuration			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16	S2.17	S2.18	S2.19	S2.20	S2.21	S2.22	S2.23	S2.24	S2.25	S2.26	S2.27	S2.28	S2.29	S2.30	S2.31	S2.32	S2.33
			Simulation Scenario 5																																
Airports	**Severe** (UDPP) capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 2 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 3 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%	20%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 1 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
		Node 2 duration	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
		Node 3 duration	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔												✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
		Node 8 shortfall												✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
NOP	Uncertainty of **Demand**	Scenario 1	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔																						
		Scenario 2												✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
OIs	**DCB-0103** SWIM enabled NOP			✔	✔	✔				✔	✔	✔	✔		✔	✔	✔				✔	✔	✔	✔		✔	✔	✔				✔	✔	✔	✔
	DCB-0208 Dynamic ATFCM using RBT						✔	✔	✔	✔	✔	✔	✔					✔	✔	✔	✔	✔	✔	✔					✔	✔	✔	✔	✔	✔	✔
	DCB-0305 Network Management Function In Support of UDPP			**P1**	**P2**	**P3**	**P1**	**P2**	**P3**		**P1**	**P2**	**P3**		**P1**	**P2**	**P3**	**P1**	**P2**	**P3**		**P1**	**P2**	**P3**		**P1**	**P2**	**P3**	**P1**	**P2**	**P3**		**P1**	**P2**	**P3**

Model Configuration			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16	S2.17	S2.18	S2.19	S2.20	S2.21	S2.22	S2.23	S2.24
			Simulation Scenario 6																							
Airports	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	10%	10%	10%	10%	10%	10%	10%	10%	10%	20%	20%	20%	20%	20%	20%	30%	30%	30%	30%	30%	30%	30%	30%	30%
		Node 2 shortfall	10%	10%	10%	20%	20%	20%	30%	30%	30%	10%	10%	10%	20%	20%	20%	30%	30%	30%	20%	20%	20%	30%	30%	30%
		Node 3 shortfall	10%	10%	10%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	30%	30%	30%	30%	30%	30%	30%	30%	30%
		Node 1 anticipation	1h	1h	1h	1h	1h	1h	1h	1h	1h	0h	0h	0h	1h	1h	1h	0h	0h	0h	1h	1h	1h	0h	0h	0h
		Node 2 anticipation	1h	1h	1h	1h	1h	1h	0h	0h	0h	1h	1h	1h	1h	1h	1h	1h	1h	1h	0h	0h	0h	0h	0h	0h
		Node 3 anticipation	1h	1h	1h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✔	✔	✔	✔	✔	✔				✔	✔	✔	✔	✔	✔	✔	✔	✔				✔	✔	✔
		Node 8 shortfall				✔	✔	✔	✔	✔	✔							✔	✔	✔	✔	✔	✔	✔	✔	✔
Integrated results	**WP3.3.2**	Delay Threshold	DT1	DT2	DT3	DT1	DT2	DT3	DT1	DT2	DT3	DT1	DT2	DT3	DT1	DT2	DT3	DT1	DT2	DT3	DT1	DT2	DT3	DT1	DT2	DT3
		Time to implement DCB	Ti1	Ti2	Ti3	Ti2	Ti3	Ti1	Ti3	Ti2	Ti1	Ti1	Ti2	Ti3	Ti1	Ti2	Ti3	Ti2	Ti3	Ti1	Ti3	Ti2	Ti1	Ti1	Ti2	Ti3
		% delay absorbed en-route	D1	D2	D3	D3	D2	D1	D2	D1	D3	D2	D3	D1	D1	D2	D3	D3	D2	D1	D2	D1	D3	D2	D3	D1
		TTA allocation strategy	ST1	ST1	ST2	ST2	ST1	ST1	ST2	ST2	ST1	ST1	ST2	ST2	ST1	ST1	ST2	ST2	ST1	ST1	ST2	ST2	ST1	ST1	ST2	ST2
		Maximize delay on ground	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR	OG	OR

Model Configuration			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16	S2.17	S2.18	S2.19	S2.20	S2.21	S2.22	S2.23	S2.24
			Simulation Scenario 7																							
Airports	**Severe** (UDPP) capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	50%	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%
		Node 2 shortfall	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	70%	70%
		Node 3 shortfall	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%	50%	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%
		Node 1 duration	6h	6h	6h	6h	6h	6h	6h	6h	6h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	3h	6h	6h	6h
		Node 2 duration	6h	6h	6h	6h	6h	6h	3h	3h	3h	3h	3h	3h	6h	6h	6h	3h	3h	3h	6h	6h	6h	6h	6h	6h
		Node 3 duration	6h	6h	6h	3h	3h	3h	6h	6h	6h	3h	3h	3h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h	6h
	Increased capacity in **hub** airports	Airport 4	20%	30%	50%	20%	30%	50%	20%	30%	50%	20%	30%	50%	20%	30%	50%	20%	30%	50%	20%	30%	50%	20%	30%	50%
		Airport 5	20%	30%	30%	20%	30%	30%	20%	30%	30%	20%	30%	30%	20%	30%	30%	20%	30%	30%	20%	30%	30%	20%	30%	30%
		Airport 6	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Airspace	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✔	✔	✔	✔	✔	✔				✔	✔	✔	✔	✔	✔	✔	✔	✔				✔	✔	✔
		Node 8 shortfall				✔	✔	✔	✔	✔	✔							✔	✔	✔	✔	✔	✔	✔	✔	✔
NOP	Uncertainty of **Demand**	Scenario 1	✔	✔	✔				✔	✔	✔				✔	✔	✔				✔	✔	✔			
		Scenario 2				✔	✔	✔				✔	✔	✔				✔	✔	✔				✔	✔	✔

Model Configuration			Simulation Scenario 8															
			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16
Airports	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	10%	10%	10%	10%	20%	20%	10%	10%	30%	30%	20%	20%	10%	10%	30%	30%
		Node 2 shortfall	20%	20%	20%	20%	30%	30%	30%	30%	10%	10%	20%	20%	20%	20%	30%	30%
		Node 1 anticipation	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	0h	0h	0h	0h
		Node 3 anticipation	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h
Airspace	Military training areas		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NOP	Uncertainty of **Demand**	Scenario 1	✓	✓			✓	✓			✓	✓			✓	✓		
		Scenario 2			✓	✓			✓	✓			✓	✓			✓	✓
Integration	**WP3.3.3**	% of affected trajectories	**At1**	**At2**	**At1**	**At2**	**At1**	**At2**	**At1**	**At2**	**At1**	**At2**	**At1**	**At2**	**At1**	**At2**	**At1**	**At2**
		Node shortfall duration	**T1**	**T1**	**T1**	**T1**	**T2**	**T2**	**T2**	**T2**	**T1**	**T1**	**T1**	**T1**	**T2**	**T2**	**T2**	**T2**

Model Configuration			Simulation Scenario 9																							
			S2.1	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7	S2.8	S2.9	S2.10	S2.11	S2.12	S2.13	S2.14	S2.15	S2.16	S2.17	S2.18	S2.19	S2.20	S2.21	S2.22	S2.23	S2.24
Airports	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 1 shortfall	10%	10%	10%	10%	10%	10%	20%	20%	20%	10%	10%	10%	20%	20%	20%	10%	10%	10%	20%	20%	20%	30%	30%	30%
		Node 2 shortfall	10%	10%	10%	20%	20%	20%	20%	20%	20%	20%	20%	20%	30%	30%	30%	20%	20%	20%	20%	20%	20%	30%	30%	30%
		Node 1 anticipation	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	0h	0h	0h	0h	0h	0h
		Node 3 anticipation	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h	0h
Airports	**Non-severe** capacity shortfall impacting multiple nodes of the network	Node 7 shortfall	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓
		Node 8 shortfall				✓	✓	✓				✓	✓	✓				✓	✓	✓				✓	✓	✓
Integration	**WP3.3.4**	uncertainty associated to airport operations affecting departure times	U1	U2	U3	U1	U2	U3	U1	U2	U3	U1	U2	U3	U1	U2	U3	U1	U2	U3	U1	U2	U3	U1	U2	U3

ANNEX 3 STATISTICAL METHODS USED

One of the principal aspects of the ATM is the large numbers of components related and working together. Some processes are locally well defined and easy to model; some others are not clear and cannot be modeled with deterministic techniques, some examples are human actors or weather conditions.

It's clear that a statistical approach is necessary. In this section, it is described a basic approach to the methodology used.

A **Sample Space partition** is a family of subsets $\{U_i\}_{i=1}^{L}$ such that:

$$\Omega \subseteq \bigcup_i U_i$$

The **Empirical Probability Distribution** for the sample $\{x_i\}_{i=1}^{M}$ $\{x_i\}_{i=1}^{m}$ over the Sample Space Partition is built using the formula:

$$\tilde{P}_i = \frac{\text{Number of } x_j \text{ in } U_i}{M}$$

And for every U_i U_i in the Sample Space Partition we have:

$$\tilde{P}_i \xrightarrow[M \to \infty]{} P_i$$

$\lim_{l\to\infty} \tilde{P}_i \to P_i$ were P_i P_i is the real probability of $X \in U_i$, that is $P_i = P(X \in U_i)$ $X \in U_i$

At this point a new sample is obtained $\{y_i\}_{i=1}^{K}$ $\{y_i\}_{i=1}^{k}$ and the following **estimator** is calculated:

$$\Delta = \sum_i \frac{(O_i - M \cdot P_i)^2}{M \cdot P_i}$$

were O_i O_i is the number of observed occurrences at U_i U_i of the sample $\{y_i\}_{i=1}^{K}$, $\{y_i\}_{i=1}^{k}$

Then we assume the **null hypothesis**:

H_0: *"The sample* $\{y_i\}_{i=1}^{K}$ $\{y_i\}_{i=1}^{k}$ *is extracted from the Empirical Probability Distribution* $\tilde{P}_i$ *"*

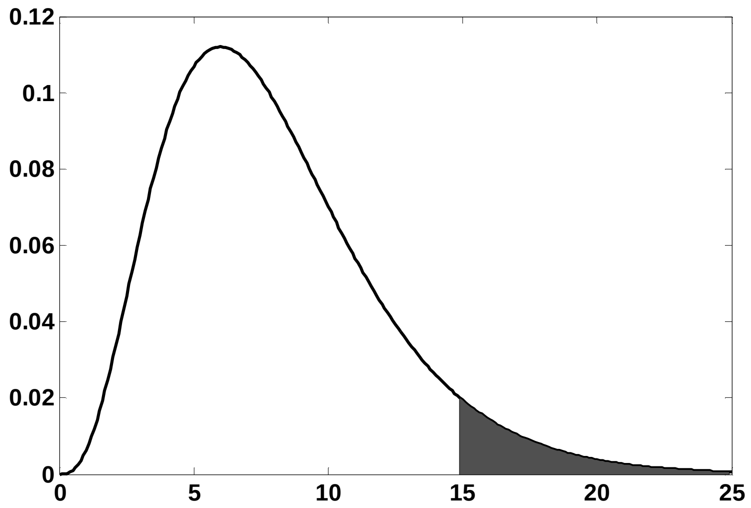
Under H_0 H_0 the estimator Δ Δ follow a **chi-squared distribution** of $L-1$ $l-1$ degrees of freedom.

So, for a given **significance level** α α we can reject the hypothesis if $\Delta \le \chi_{l-1,\alpha}$ $\Delta \le \chi_{L-1,\alpha}$

Some values of $\chi_{L-1,\alpha}$ are presented in the following table and figure:

$\chi_{L-1,\alpha}$	$L=10$	$L=20$	$L=100$	$L=150$	$L=200$
$\alpha = 0.05$	0.940	34.76	77.93	122.7	168.3

$\alpha = 0.10$	4.865	37.69	82.36	128.3	174.8



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