D4.1 Preliminary Specification of Case Studies

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NOSTROMO

NEXT-GENERATION OPEN-SOURCE TOOLS FOR ATM PERFORMANCE MODELLING AND OPTIMISATION

This deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 892517 under European Union's Horizon 2020 research and innovation programme.

Abstract

This deliverable provides the methodological framework which will enable to specify the case studies that will be used to demonstrate and evaluate the maturity of the NOSTROMO approach as well as the capabilities of the methodology defined in WP3 and the tools developed in WP5 and WP6. The preliminary set of case studies includes a variety of solutions, ATM phases and KPAs/KPIs sufficiently heterogeneous to allow a comprehensive benchmarking against the performance modelling methodologies currently in use, with the aim to analyse the added value and the limitations of the NOSTROMO approach. For this purpose, the deliverable uses the latest applicable solution descriptions and ensures that any possible deviations from these references are properly justified and documented in the description of the case studies.

Additionally, the potential combinations of the operational concepts underpinning several promising SESAR solutions are proposed in this deliverable. It also defines the research questions that will be assessed in the different case studies in order to capture the specific added value delivered by the proposed metamodeling methods based on active learning schemes.

Finally, this deliverable follows the incremental approach on the specification of the case studies (solutions and scenarios) that ensures the flexibility and tractability in their selection through evaluation and refinements of different metamodels' versions and development stages.

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Executive summary

The aim of the deliverable is to **specify the preliminary set of cases studies** that will test the ability of the simulation metamodels to **evaluate the impact of different SESAR solutions** covering different ATM phases and KPAs/KPIs. The **dedicated framework** is proposed to facilitate the process of definition and selection of the scenarios following a notion of the incremental approach adopted by the NOSTROMO project. In other words, the metamodelling methodology will be evaluated and refined in the light of the results obtained during the development and execution of different case studies. Thus, the selection of the Solutions and their detailed specification will be based on the close communication with the methodology defined in WP3, in order to ensure that the proposed case studies are suitable to be tackled by the metamodeling approach built upon on an active learning strategy.

The deliverable aims to **gather**, **consolidate** and **analyse** the **information from different sources** in order to provide a state-of-the-art review in the latest achievements in SESAR industrial research and deployment phases. The main sources of information used for this purpose are collected from:

1. Performance Assessment and Gap Analysis Report (PAGAR) 2019 - confidential and non-confidential edition
2. Performance Assessment Report (PAR) of individual solutions, if available online.
3. SESAR Solutions Catalogue 2019 (third eds.)
4. European ATM Master Plan 2020

The core of the framework dedicated to the selection of the case studies contains five different and inter-related modules, which have to be combined progressively in an incremental way:

1. **Identification of the initial set of Solutions**. The primarily aim of the exploration is to create a comprehensive insight into the concept of each individual Solution and its progress with respect to the performance assessment based on the information available in relevant reports/documents.
2. **Filtering the selected Solutions**. The selected Solutions have to be considered with respect to the capabilities and characteristics of the microsimulation tools, Mercury and FLITAN.
3. **Specification of scenarios**. Each Solution within the two groups (the solutions suitable to be modelled by either Mercury or FLITAN) will be particularised by further instantiation of the scenario.
4. **Metamodelling execution and validation**. Each scenario will be run by the simulation metamodels which, in conjunction with active learning schemes, aim to decrease the computational barriers for an efficient and comprehensive exploration of the input-output space defined by ATM microsimulation tool.

The selection of the initial set of solutions is based on two criteria - the number of KPAs impacted by the specific solution and the magnitude of the remaining gap in performance assessment. The assessment led to the selection of **9 solutions** that have **not achieved V3 maturity level** yet and **3 solutions** that already achieved V3 maturity level. The thorough examination of the technical capabilities of each individual microsimulation tool with respect to the operational environment and requirements defined within each Solution selected was performed. The outcome of these actions was

a prioritisation on **five different concepts** which can be modelled by two microsimulation tools, namely:

- Some modules related to **UDPP (PJ.07-02)** and **E-AMAN (PJ.01-01)** are already present in Mercury, developed during previous project. Another module implemented "Dynamic Cost Indexing", a concept which is loosely related to various solutions, e.g. **Collaborative network management** (**PJ.09-03)**. These three concepts are the ones for which Mercury was developed, and thus the model is particularly suited to them.

- Two solutions have been identified by the ISA team as suitable for a micro simulation model and can be achieved using FLITAN: **PJ.08-01** (Management of dynamic airspace configurations) and **PJ.02-08** (Traffic optimisation on single and multiple runway airports).

In addition to these five solutions which will be further elaborated throughout the instantiation of scenarios, the combination of several solutions is also proposed:

- **PJ.07-02** and **PJ.09-03** - PJ.09-03 deals with 4D trajectory, there is a notion of contract in space and time between the airline and the ANSP/NM, i.e. a consensus taking into account supply (capacity) and demand (preferred trajectories). This is reminiscent of UDPP, where ATFM slots can be considered as a contract in time (which may be exchanged between airlines). Hence, theses concepts are naturally interrelated;

- **PJ.01-01** and **PJ.09-03** - for the same reason as it the previous case, the Extended Arrival Manager is also closely related to PJ.09-03, as it implies to change a 4D trajectory in order to meet constraints at the arrival airport, and

- **PJ.01-01, PJ.09-03PJ.07-02** and **PJ.09-03** - **t**he kind of unified constraint management and prioritisation process envisioned by PJ.09-03 is a good opportunity for NOSTROMO to test combinations of these solutions.

The **five selected solutions** will be further instantiated by defining the potential set of different input and output variables which will enable to design the particular set of scenarios (i.e. case studies). **The data required** to successfully implement the case studies will be also provided. Finally, producing an exhaustive and strict definition of all the potential scenarios is avoided at this stage to enable the flexibility of further selection and instantiation of scenarios with feedback from the Advisory Board. The final specification of the case studies assumes the close interactions with different ATM stakeholders from the Advisory Board as well as tight coordination between the members within the NOSTROMO consortium. This will be realised through the organisation of the following events:

- **The 2nd NOSTROMO Stakeholder Workshop** that will provide the feedback to the consortium on which scenarios to further prioritise and develop which will further trigger the refinement of the final release of active learning metamodelling methodology;

- **Internal meetings** between the consortium members which will be periodically carried out to ensure synchronisation of the detailed specification of scenarios and metamodel framework development, identification of new tasks that are required, identification of bottleneck, etc.

Two set of research questions (RQs) are designed to address the benefits of the simulation metamodels proposed in NOSTROMO - the first set of RQs aims at estimating the overall operational benefit of the metamodelling approach at a system level, whereas the second one encompasses the research questions tailored to address its benefits for each specific solution identified.

In order to effectively manage and track the progress of the case study definition improvement, the results of the different versions of metamodels and feedback obtained during the stakeholder workshops will be stored in the dedicated page created in Confluence collaborative tool.

1 Introduction

1.1 Scope and Objectives

The primary objective of the Preliminary Specification of Case Studies deliverable is to define the set of preliminary case studies that will be used to develop, demonstrate and evaluate the ATM metamodels performance and visual analytics tools proposed by NOSTROMO. The deliverable aims to gather, consolidate and analysed the information from different sources in order to provide a state-of-the-art review in the latest achievements in SESAR industrial research and deployment phases. The main sources of information used for this purpose are collected from:

1. Performance Assessment and Gap Analysis Report (PAGAR) 2019 - confidential and non-confidential edition
2. Performance Assessment Report (PAR) of individual solutions, if available online.
3. SESAR Solutions Catalogue 2019 (third eds.)
4. European ATM Master Plan 2020

The deliverable provides **the initial set of Solutions** obtained by the careful exploration of the remaining gap in the performance assessment with respect to different KPAs and the level of maturity at the beginning of SESAR Wave2. Each individual Solution will be analysed with respect to its maturity level and gap in performance assessment with respect to different KPAs impacted. The gap analysis will provide an overview of the assessment of the performance delivered at different phases of the SESAR programme compared to the ATM Master Plan Ambitions for each KPA. (These types of information were obtained from available PARs and PAGAR (confidential edition) documents, while the SESAR Catalogues serves as a complementary material which provides the detail description of each Solutions.) In addition, the process of selection of the initial set of Solutions also incorporates the feedback obtained through bilateral meeting with PJ.19-04 member. The deliverable will mainly focus on the Solutions which have not achieved the V3 maturity level, but will be continued in SESAR2020 Wave 2. As found in the PAGAR confidential document, for **V1** and **V2 Solutions** estimates in most cases are based **on expert judgment** which **limits their confidence level.** Thus, their performance assessments impose a particular challenge for future validation activities which can be successfully overcome by the metamodelling methodology proposed in the project.

The deliverable will analyse the operational requirements of the initial set of Solutions with respect to the capabilities of the detailed microscopic models of Mercury and FLITAN tools. Note that the capabilities of the tools are, in some cases, limited to simulation of the specific elements or set of the elements of the given Solution. Thus, the operational environment and simulation scenarios will be defined within the broader context (or more generic interpretation) of the selected Solution. In addition, NOSTROMO is a model-driven project which highly relies on the data availability. This means that some of the functionalities of the metamodels and scenarios will need to be gradually developed and adjusted. This will comply with the **iterative approach** adopted in the project. The deliverable will specify **the preliminary specification of the Solutions selected** by identifying the input variables required to model the scenarios and the output KPIs and PIs with the aim to ensure the correct transfer to the metamodels. In addition, the data requirements to design each respective scenario will be also provided in this deliverable.

However, the Relationships between Solutions must be considered when consolidating the overall performances assessment for each KPA. PAGAR document identifies that generally there is a **lack of exercises combining several Solutions**, which have cross effect or other relationships which appears to be relevant for join application. This is the main reason for the increasing uncertainty about the overall performance of some Solutions when they are combined together. Thus, an investigation on the combination of solutions will be performed to determine if the case studies already proposed can be extended by designing the deployment scenarios containing two or more solutions.

Finally, the deliverable identifies the set of research questions that will be assessed in different scenarios in order to demonstrate the benefits of the metamodelling approach.

1.2 Intended readership

This document is intended to be used by SESAR JU and NOSTROMO members.

1.3 Deliverable structure

The document is structured in 9 sections:

- Section 2 provides the brief introduction to the SESAR Performance Framework and Performance Assessment in order to facilitate the alignment of the project work with the SESAR Performance Framework. The Section also provides a brief explanation on the concept around SESAR Solutions and measurement of performance gains with respect to validation targets.
- Section 3 introduces the methodology applied to define the preliminary set of case studies. The concept involves four different and inter-related modules that will be gradually conducted to ensure that the proposed case studies are suitable to be tackled by the microsimulation tools as well as by the metamodelling approach.
- Section 4 presents the conceptual framework which will enable the identification of the initial set of Solutions. The methodology primarily leverages on the information on gap in performance assessment with respect to different KPAs, available in PAGAR confidential report. These sets of solutions will serve as a meaningful foundation that will be further elaborated in terms of the microsimulation tools capabilities.
- Section 5 investigates each individual Solution selected with respect to the capabilities of the microsimulation tools, Mercury and FLITAN, separately. It also lays out the potential combinations of the solution selected.
- Section 6 defines the potential set of different input and output variables which will enable to design the particular set of scenarios (i.e. case studies) within each individual Solution. The data required to successfully implement the case studies will be also provided.
- Section 7 identifies two set of research questions (RQs) designed to address the benefits of the metamodels proposed in NOSTROMO.
- The deliverable closes with next steps and look ahead (Section 8).
- References are provided in Sections 9.

1.4 Terminology and Acronyms

Term	Acronyms
ACC	Area Control Centre
ANSP	Air Navigation Service Provider
APOC	Airport Operation Centre
ATCo	Air Traffic Controller
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
AU	Airspace User
CDM	Collaborative Decision Making
CHILL	Collaborative Human-In-Loop Laboratory
CMAN	Centre Manager
CWP	Controller Working Position
DAC	Dynamic Airspace Configuration
DB	Deployment Baseline
DCB	Demand Capacity Balancing
DFS	Deutsche Flugsicherung GmbH
DMA	Dynamic Mobile Areas
ECAC	European Civil Aviation Conference
E-AMAN	Extended Arrival Management
E-TMA	Extended Terminal Manoeuvring Area
E-OCVM	European Operational Concept Validation Methodology
eFPL	Extended Flight Plan
FCL	Flexible Credits for LVUC concept
FF-ICE	Flight and flow information for the collaborative environment concept
FL	Flight Level

Term	Acronyms
Flite	**F**uture **L**ong-term ATM concept, **I**nfrastructure, **T**echnologies and operational **E**nvironment
FMP	Flow Management Position
FOC	Flight Operations Centre
FTS	Fast Time Simulation
HMI	Human Machine Interface
HLGs	High Level Goals
ICAO	International Civil Aviation Organization
INAP	Integrated Network ATC Planning
KPA	Key Performance Area
KPI	Key Performance Indicator
LVUC	Low Volume Users in a Constraint
NM	Network Manager
NOP	Network Operations Plan
NOSTROMO	Next-generation Open Source Tools for peRfOrmance Modelling and Optimisation
OE	Operating Environment
OI	Operational Improvement
PAGAR	Performance Assessment and Gap Analysis Report
PAR	Performance Assessment Report
RAMS	Reorganised ATM Mathematical Simulator
R&D	Research and Development
RTS	Real Time Simulation
RQ	Research Question
SES	Single European Sky
SESAR	Single European Sky ATM Research Programme
SESAR IR	SESAR Industrial Research

Term	Acronyms
SESAR JU	SESAR Joint Undertaking
SESAR PF	SESAR Performance Framework
SID	Standard Instrument Departure
SME	Subject Matter Expert
STAR	Standard Terminal Arrival
TMA	Terminal Manoeuvering Area
TRL	Technological Readiness Level
TTA	Target Time of Arrival
UDPP	User-Driven Prioritisation Process
VT	Validation Target

2 SESAR Performance Framework and the performance assessment of the Solutions

2.1 SESAR Solution in the context of SESAR Performance Framework

The Single European Sky (SES) initiative was launched by the European Commission in 1999 with the primary aim of meeting future capacity and safety needs through the creation of a legislative framework for European aviation. SESAR stands as a technological pillar that strongly contributes to high-level goals (HLGs) stipulated by 'Single European Sky' (SES) programme. The HLGs are measured relative to 2005 and aim to achieve **four major goals [1]**:

- improving the safety performance by a factor of 10;
- three-fold increase in ATM capacity which will also reduce delays both on the ground and in the air;
- enabling a 10% reduction in the effects flights have on the environment; and
- providing ATM services to airspace users at a cost of at least 50% less.

However, in order to achieve these high ambitious goals, SESAR established SESAR Performance Framework (PF) within which it delivers and deploys the **SESAR solutions** with demonstrated and measurable performance gains. In this way, SESAR PF ensures that the programme develops the operational concepts and technical enablers needed to meet the performance ambitions as described in the 2020 edition of the ATM Master Plan [1]. The SESAR PF is based on the framework concept from the ICAO Doc 9883 [2], where concrete expectations of the future ATM system are defined using the eleven KPAs identified in the ICAO Global ATM Operational Concept [3]. However, some refinements of the KPAs are conducted in the SESAR PF in order to support the SESAR requirements in more efficient way. Thus, in contrast to ICAO's eleven KPIs, SESAR PF covers eight KPAs with two cross-cutting Focus Areas defined, which influence and relate to multiple KPAs. In contrast to ICAO which uses Performance Objectives, SESAR 2020 uses Validation Targets that are allocated to each SESAR Solution. Validation targets are defined as the overall contribution that solutions should make to the achievement of the performance ambitions set in the ATM Master Plan [4]. It is worth mentioning that SESAR KPIs are not always equivalent to those described in the ATM Master Plan due to distinctive nature of the SESAR programme, which is purely driven by research and development environment.

Key performance area	SES high-level goals 2005	Key performance indicator	Performance ambition vs. baseline: Baseline value (2012)	Ambition value (2035)	Absolute improvement	Relative improvement
Capacity	Enable 3-fold increase in ATM capacity	Departure delay[4], min/dep	9.5 min	6.5-8.5 min	1-3 min	10-30%
		IFR movements at most congested airports[5], million	4 million	4.2-4.4 million	0.2-0.4 million	5-10%
		Network throughput IFR flights[5], million	9.7 million	~15.7 million	~6.0 million	~60%
		Network throughput IFR flight hours[5], million	15.2 million	~26.7 million	~11.5 million	~75%
Cost efficiency	Reduced ATM services unit costs by 50% or more	Gate-to-gate direct ANS cost per flight[1]-EUR(2012)	EUR 960	EUR 580-670	EUR 290-380	30-40%
Operational efficiency		Gate-to-gate fuel burn per flight[2], kg/flight	5280 kg	4780-5030 kg	250-500 kg	5-10%
		Additional gate-to-gate flight time per flight, min/flight	8.2 min	3.7-4.1 min	4.1-4.5 min	50-55%
		Within the: Gate-to-gate flight time per flight[3], min/flight	(111 min)	(116 min)		
Environment	Enable 10% reduction in the effects flights have on the environment	Gate-to-gate CO_2 emissions, tonnes/flight	16.6 tonnes	15-15.8 tonnes	0.8-1.6 tonnes	5-10%
Safety	Improve safety by factor 10	Accidents with direct ATM contribution[6], #/year Includes in-flight accidents as well as accidents during surface movement (during taxi and on the runway)	0.7 (long-term average)	no ATM related accidents	0.7	100%
Security		ATM related security incidents resulting in traffic disruptions	unknown	no significant disruption due to cyber-security vulnerabilities	unknown	-

1 Unit rate savings will be larger because the average number of Service Units per flight continues to increase.
2 "Additional" means the average flight time extension caused by ATM inefficiencies.
3 Average flight time increases because the number of long-distance flights is forecast to grow faster than the number of short-distance flights.
4 All primary and secondary (reactionary) delay, including ATM and non-ATM causes.
5 Includes all non-segregated unmanned traffic flying IFR, but not the drone traffic flying in airspace below 500 feet or the new entrants flying above FL 600
6 In accordance with the PRR definition: where at least one ATM event or item was judged to be DIRECTLY in the causal chain of events leading to the accident. Without that ATM event, it is considered that the accident would not have happened.

Figure 1 - SESAR Performance Ambition for 2035 for controlled airspace (Source: ATM Master Plan, 2020)

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Figure 1 depicts the SESAR performance ambitions categorised in six major KPAs relative to the 2012 baseline scenarios at general ECAC level. It is worth emphasising that these ambitions are aspiration al since Program need to take into account the lengthy investment period, a characteristic of industries like ATM.

2.2 Description of the supplementary documents

As already mentioned, the aim of the deliverable is to identify the list of preliminary case stud ies (i.e. SESAR solutions) that will address the evaluation of the impact of new SESAR solutions at the ECAC level. The fruitful round of discussion performed with the SESAR Joint Undertaking team help us to scope our exploration by focusing initially on the Solutions which performance assessment were difficult to performed with the traditional approaches that assume the application of either microscopic and macroscopic models. For this purpose, the information from different available sources have been collected and consolidated in order to understand the causes of the gap in performance assessment with respect to each KPA. Some of these gaps are attributed to the low confidence level in some solutions, whereas others are related to incomplete set of quanti tative data. The following documents have been used to create the potential list of preliminary case studies, namely:

1. **Performance Assessment and Gap Analysis Report (PAGAR) 2019**. This document provides the important insight into the overall achievement in performance ambitious with respect to each KPA delivered by the SESAR research and innovation programme until the end of Wave 1 (Dec. 2019). Moreover, the document helps to identify the performance gaps that need to be addressed in the next wave and underlies the potential source of these gaps. Thus, it stands as one of the key reference documents, publicly available which identify the solutions and their progress, providing in this way a solid base for identifying the potential gaps in performance assessment.

2. **Performance Assessment Reports (PARs) of individual solutions**. Each individual Solution project is obliged to report the achievements in the performance assessment by the means of Performance Assessment Reports. The report contains the detailed information on the

operational/technical context of the project together with the work performed and key project results. The information provided serves as an input to PAGAR document to develop a consolidated performance assessment at programme level. The Solutions have to provide a PAR for each change in maturity level. 33 Solutions have so far produced PARs for their Maturity Gates. Consequently, to compensate for the lack of performance information and PARs, PJ19 has also reviewed draft PAR prior to maturity gate or developed a performance questionnaire to collect the performance estimates from the Solutions.

3. **SESAR Solution Catalogue 2019 (third eds.)**. The catalogue provides the comprehensive view of the status of SESAR R&D in 2019 by offering the Solutions to some of the most challenges present in the European aviation today. The catalogue provides the results of the first R&D programme (SESAR1) with more than 60 solutions, many of which are currently in the process of deployment at local and European levels. In addition, it also describes the ongoing R&D (candidate solutions) which will be continued in SESAR Wave 2. These solutions are of particular interests for the scope of our project, as their performance assessment can be supported by the metamodels developed within the NOSTROMO project. Finally, the Catalogue also presents some of the results coming out of the SESAR's exploratory research programme.

4. **The 2020 Edition of the European ATM Master plan**. The document stands as the main planning tool for ATM modernisation across Europe that connects ATM research and development activities with deployment scenarios to achieve the SES performance objectives. It also defines the development and deployment priorities entailed by SESAR vision.

2.3 The gap in performance assessment

The assessment of the overall performance benefits of the results which come from SESAR R&D activities presents one of the key activities carried out by the PJ.19-04 members. Supported by a team of experts in their domain, the PJ.19-04 is involved in gathering the inputs from the different Solutions and consolidates them at the ECAC level for the different KPAs considering the dependencies between Solutions themselves. The information is then processed and published in the Performance Assessment and Gap Analysis Report (PAGAR) for the Wave 1 of the SESAR 2020 programme. The PAGAR document also reports the gap analysis in performance assessment of each individual solution with respect to different KPAs based on the consolidation of data provided by Solution projects by means of Performance Assessment Reports (PARs). The gap analysis provides important milestone in identifying the causes for the current performance and at the same time indicates the corrective actions which need to be performed in order to close the gap between the total assessed performance and the Master Plan Ambition.

Figure 2 presents an overview of the assessment of the performance delivered at different phases of the SESAR programme compared to the ATM Master Plan Ambitions. The four major phases comprise the performance assessment of:

1. The non-SESAR improvements and the Deployment Baseline (DB) prior to the start of SESAR 2020 (represented by the purple bar);

2. Solutions which reached V3 at the end of SESAR 1 (in dark blue);

3. Solutions which reached V3 at the end of SESAR 2020 Wave 1 (in light blue);

4. Solutions non-fully V3 at the end of SESAR 2020 Wave 1 but continuing in Wave 2 is (in grey).

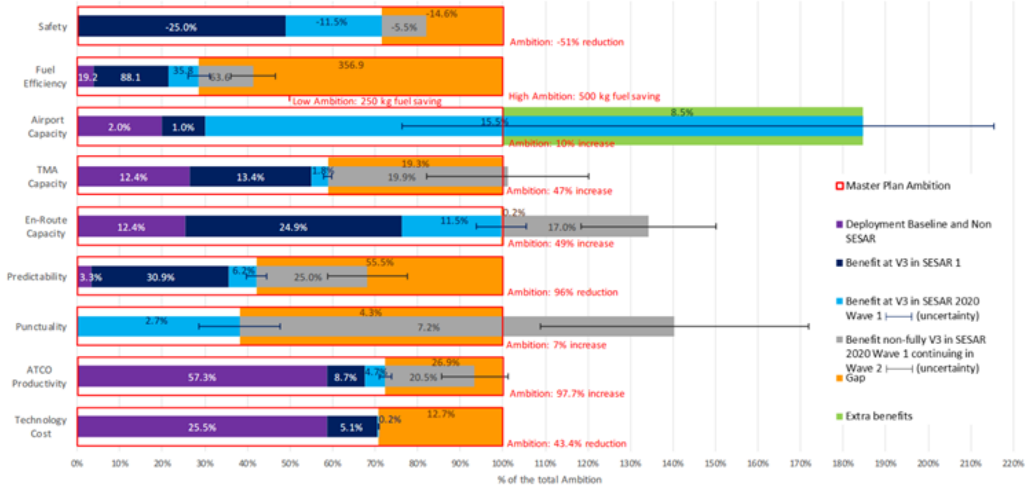


Figure 2 - Summary of performance assessment for different maturity level Solutions at the end of SESAR2020 Wave 1 [4].

As observed from Figure 2, Ambitions for Airport Runway Capacity and En-Route Capacity are likely to be met considering only the benefit of the Solutions which already achieved V3 maturity level at the end of SESAR Wave 1. On the other hand, with the benefits that might be fulfilled from non-V3 Solutions continuing in Wave 2, TMA Capacity, Punctuality and ATCO productivity Ambitions are also likely to be met, however there are still a lot of uncertainties because of the levels of maturity of these Solutions. However, as reported in PAGAR, still only **38% to 90%** (depending on the KPA) of the performance **results** are **available** and **performance results** are **still based on expert judgment**, even for some V3 Solutions. As part of the second wave of SESAR research, the main goal is to further develop selected solutions to the final maturity level in the R&D lifecycle and bring them closer to deployment.

2.4 Maturity level of the Solutions

Generally, the maturity levels of the SESAR ATM Solutions are defined in line with the European Operational Concept Validation Methodology (E-OCVM). E-OCVM and validation are mainly concerned with lifecycle phases V1, V2 and V3 but are also concerned with V0 to ensure that the correct initial conditions have been met [5]. On the other hand, the TRL levels TRL3 (Gate V1), TRL4 (Gate V2) and TRL6 (Gate V3) will be applied to SESAR Technological Solutions, whereas TRL7 (Gate Demo) will be applied to Very Large Scale Demonstration (Figure 3).

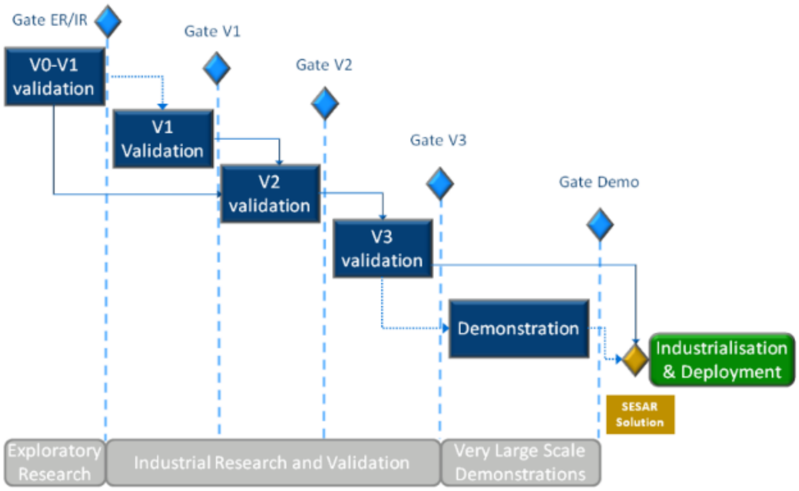


Figure 3 - Gates and phases of the SESAR Solution Development life cycle (Source: [6])

In this light, at each maturity level the Solution has to meet a specific set of requirements:

- V0 maturity level corresponds to identification of potential benefit and risks,
- V1 maturity level Solutions will have initial assessment of the KPA and KPIs primarily affected,
- V2 solutions will have Quantitative intermediate assessment of all KPAs and KPIs, while
- V3 solution assumes complete assessment including final quantitative results for all KPAs and KPIs.

It is worth emphasising that for V3 Solutions the assessment is based on validation exercises, whereas for V1 and V2 Solutions estimates in most cases are based on expert judgment. In this way, their confidence level might be substantially limited. The confidence level is essentially a qualitative, broad-brush self-assessment made by the projects, together with PJ19.04 support, reflecting the degree of uncertainty in their data/conclusions.

2.5 Relationship between SESAR Solutions

The investigation the relationships between SESAR Solutions presents an important aspect of the overall performance assessment. Understanding the interactions between Solutions will enable to create the comprehensive picture to support the performance assessment and design the deployment planning processes. Each Solution is obliged to provide the report on its potential relationship with other Solutions by the means of PAR, questionnaires or during interviews. The information is then gathered and analysed by the PJ.19.04.02 members by using a MS excel spreadsheet which is deemed as a convenient tool for identifying the potential inconsistencies between each pair of the Solutions.

As defined in PAGAR confidential part [4], two main possible types of relationships between two Solutions can be distinguished from a deployment perspective - they can be either ‘compatible’ or ‘incompatible’ (Figure 4).

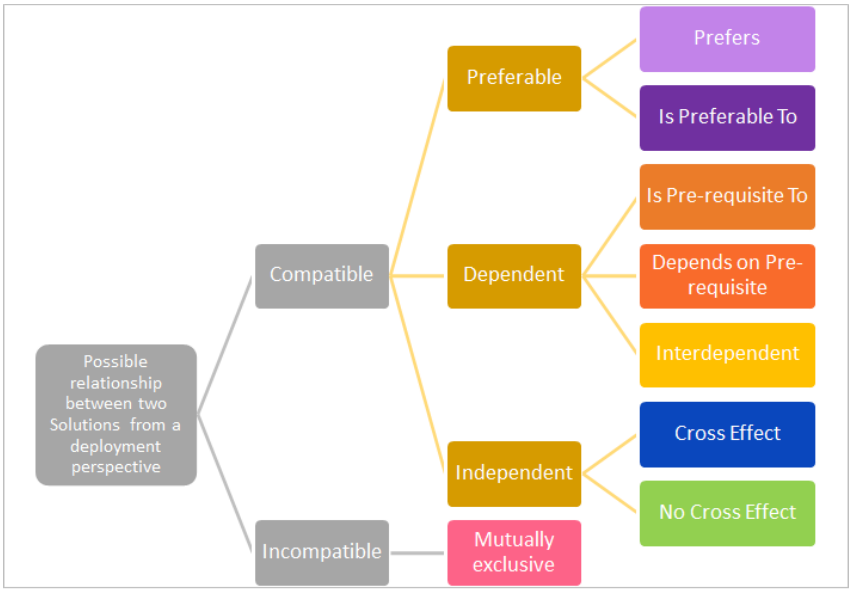


Figure 4 - Possible relationships between two Solutions (Source: [4]).

If Solutions are identified as 'incompatible', they are mutually exclusive of each other and cannot coexist in the same operational environment. This is for instance the case for PJ.10-01b Flight Centric ATC and PJ.10-01c Collaborative Control which are incompatible as different mode of operations cannot be applied at the same time in the same airspace area. Additionally, in the situation when Solutions are 'compatible' and 'dependent' on each other, it is necessary to understand how they should be deployed — one after the other (e.g. Solution x is pre-requisite to Solution y and Solution y depends on pre-requisite Solution x). In the case where both Solutions depend on each other, their relationship would be qualified as 'interdependent'. There are cases where two 'compatible' and 'independent' Solutions deployed could result in a greater or a lesser benefit than the sum of the benefits that these Solutions could provide on their own; this is considered as a 'cross-effect' relationship which could be positive or negative.

y \ x	PJ.03b-03	PJ.03b-05	PJ.03b-06	PJ.04-01	PJ.04-02	PJ.05-02
PJ.03b-03				No Cross Effect		
PJ.03b-05				No Cross Effect		
PJ.03b-06				No Cross Effect		
PJ.04-01	No Cross Effect	No Cross Effect	No Cross Effect		Depends On Pre-requisite	No Cross Effect
PJ.04-02				Is Pre-requisite To		
PJ.05-02				No Cross Effect		

Figure 5 - Illustration of a relationship in the matrix (Source: [4])

Figure 5 presents a screenshot from the MS excel spreadsheet which provides an illustrative example on how to interpret the relationship between the two Solutions indicated - PJ.04-01 and PJ.04-02. Thus, as observed from the matrix, the Solution PJ.04-01 is a pre-requisite to PJ.04-02, whereas on the other hand PJ.04-02 depends on pre-requisite of PJ.04-01. The full set of relationships has not yet been identified, and the work to identify and resolve remaining inconsistencies is ongoing.

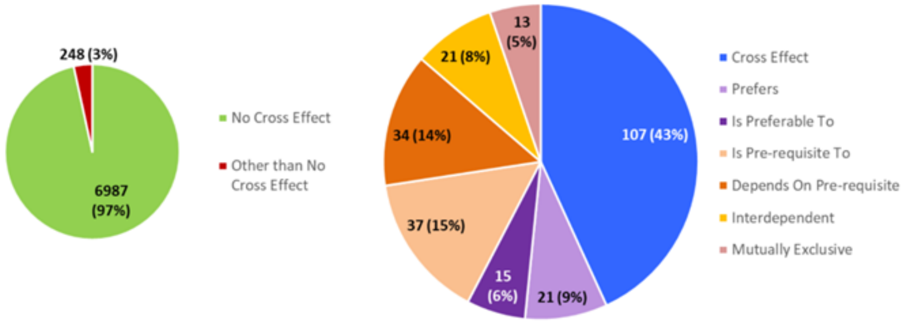


Figure 6 - Relationship identified between Solutions and detailed distribution of the relationships other than "No Cross effect" (Source: [4])

Finally, out of 6653 relationships identified, around 98% are classified as independent, 1.3% as dependent, 0.5% preferable and only 0.2% as incompatible (Figure 6).

3 Selection of the Solutions – concept and approach

This section describes the process of selection of Solutions followed in this deliverable. The selection of the case studies needs to be tailored to reflect the iterative approach adopted in the NOSTROMO project. As already detailed in [7], the project will follow an incremental approach, by evaluating and refining the metamodelling methodology in an iterative manner in the light of the results obtained during the development and execution of the different case studies. The selection of the Solutions and their detailed specification will be based on the close communication with the methodology defined in WP3, in order to ensure that the proposed case studies are suitable to be tackled by the metamodelling approach.

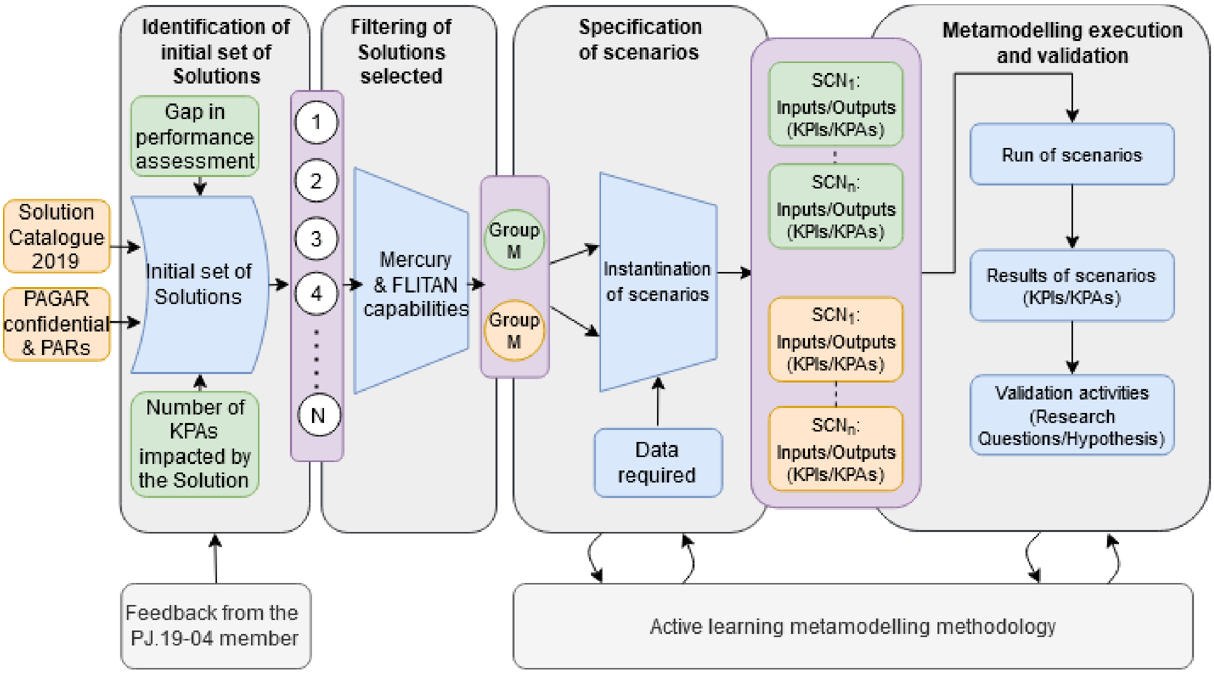


Figure 7- The concept of selection of the Solutions

The overall concept of the selection of the case studies is illustrated in Figure 1Figure 7. As observed, this process is composed of four different and inter-related modules, which have to be combined progressively in an incremental way following the iterative approach:

1. **Identification of the initial set of Solutions**. Several relevant documents (e.g., PARs, PAGAR etc.) have been extensively explored prior to the process of selection of the Solutions. The primer aim of the exploration is to create a comprehensive insight into the concept of each individual Solution and its progress with respect to the performance assessment. The initial set of Solutions is eventually selected based on the two criteria - number of KPAs impacted by the Solution and the gap in performance assessment with respect to particular KPAs. The selection is additionally facilitated by using the feedback obtained through a consultation meeting with a representative of PJ.19-04.

2. **Filtering the selected Solutions**. The selected Solutions have to be considered with respect to the capabilities and characteristics of the microsimulation tools, Mercury and FLITAN. Both tools demonstrated their broad capabilities in assessing ATM performance - Mercury has been successfully used in the past to evaluate different mechanisms (inspired and aligned by SESAR solutions) and the impact of exogenous factors, while FLITAN is able to simulate the entire ATM network under nominal, sub-nominal or enhanced conditions. Although broad and successful in their applications, the tools still have some restrictions and limitations with respect to specific Solutions and their respective operational aspects, as their assessment may require the development of the additional modules that are currently not available. Thus, the dedicated bilateral meeting within the consortium is performed to determine the set of Solutions which can be potentially modelled with the tools. The outcome of this action was a prioritisation of two groups of the Solutions - the first group comprises the Solutions which will be modelled by Mercury, whereas the second group consists of the Solutions which performance assessment will be simulated by FLITAN.

3. **Specification of scenarios**. Each Solution within the two groups will be particularised by further instantiation of the scenario. The specific scenario will address the performance evaluation of particular concept (or some of its elements) related to the solution, using the latest applicable Solution descriptions as far as practicable and making sure that any possible deviations from these references are properly justified and documented in the description of the scenario.

4. **Metamodelling execution and validation**. Each scenario will be run by the simulation metamodels which, in conjunction with active learning schemes, aim to decrease the computational barriers for an efficient and comprehensive exploration of the input-output space defined by ATM microsimulation tool. In order to facilitate and drive the assessment of the results obtained by the metamodels, two sets of research questions are designed aiming to estimate the operational benefits of the active learning metamodelling approach.

The next section will analyse the Solutions with respect to these two selection criteria - the gap in performance assessment and the number of KPAs impacted. Additionally, a brief description on the validation exercises performed in order to assess the performance of the given Solution will be also discussed.

4 Identification of the initial set of Solutions

4.1 Conceptual framework

As explained in Section 3, the selection of the initial set of Solutions is based on the assumption that performance results of some Solutions are still based on expert judgment, even for some Solutions that already achieved V3 maturity level. Hence, the confidence level of the results for the particular Solution may substantially vary with respect to different KPAs. For instance, in the case where inputs are predominantly qualitative and not derived from multiple validation exercises, the confidence level of the results would be considered as low. Thus, this phase aims at checking the results of the gap in performance assessment for different Solutions with respect to different KPAs impacted.

The process of selection of the Solutions is based on the gap analysis between the actual targets and assessment values. The actual targets (i.e. Validation Targets) are apportionment of the Master Plan Performance Ambition providing an indication of the Solution's relative weight and contribution within a certain KPA. The Solution which received a Validation Target in any KPA has to finally assess its performance. As observed from Figure 8, the target and assessment value are provided for each Solution. The "Value" column shows the total KPA benefit that was set for this Solution in the targets. The **"Criticality"** column shows the portion (%) of target assigned this Solution as a proportion of the total target for that KPI, if the expected percentage of target is high, the criticality of the Solution is considered high.

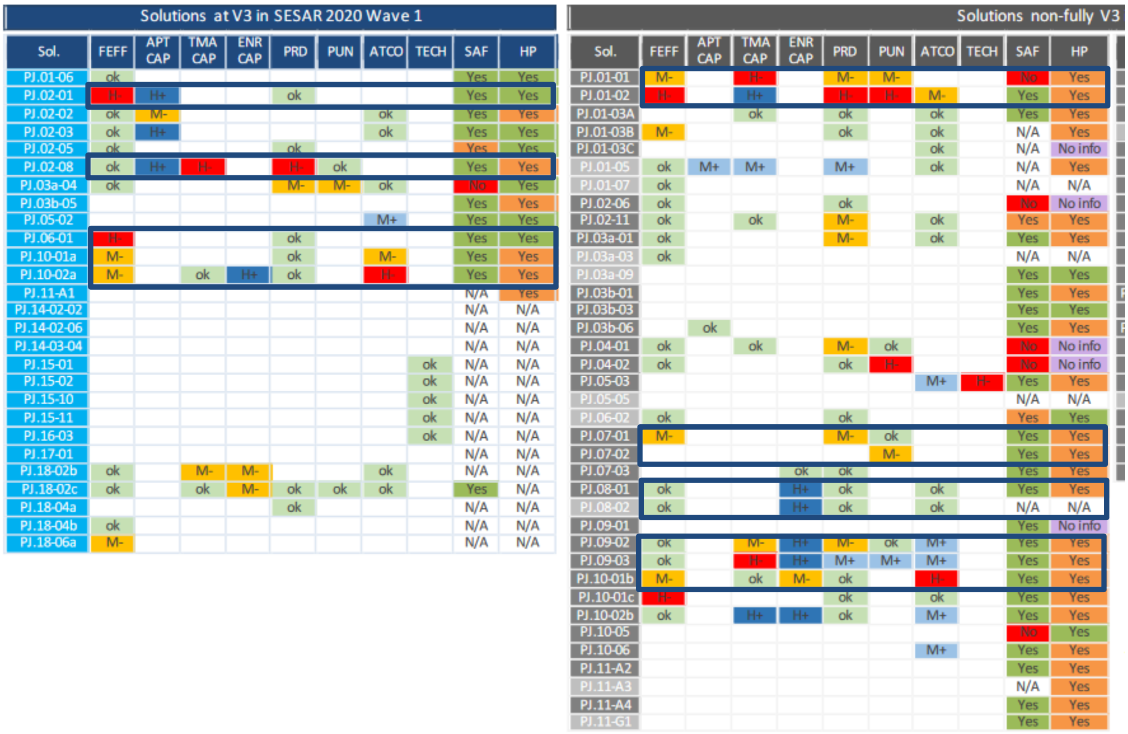
KPA	Target		Assessment	% ratio Assessment / Target	Gap
	Value	Criticality (Contribution to total KPI)			
FEFF	27.18	6.9%	4.1	15.1%	M-
APT CAP	2.57%	36.8%	7.9%	306.9%	H+
TMA CAP	0.37%	3.2%	0.5%	135.7%	ok
ENR CAP	1.59%	2.6%	3.6%	227.2%	M+
PRD	5.01%	8.1%	1.4%	27.0%	H-
PUN	0.25%	3.5%	0.0%	0.0%	M-
ATCO	0.21%	0.7%	0.0%	0.0%	ok
TECH	1.40%	10.9%	0.0%	0.0%	H-

Criticality Contribution of Solution to total KPI	% ratio Assessment / Target				
	<50%	50%-75%	75%-125%	125%-150%	>150%
>7.5%	H-	M-	ok	M+	H+
5%-7.5%	M-	M-	ok	M+	M+
2.5%-5%	M-	ok	ok	ok	M+
<2.5	ok	ok	ok	ok	ok

Figure 8 - Solution assessment of the overall gap analysis (Source: [4])

The "criticality" column is then combined with the "**% ratio Assessment / Target**" of benefit into a form of "heat chart". For example, if the criticality is high and the assessment/target ratio is medium (75%-125%) this is summarized as "ok". If, on the other hand, the criticality is high and the assessment/target ratio is low (<50%) then this is classed as "H-" indicating that the benefit is perhaps lower than expected and that maybe the Solution needs to be reviewed.

For the sake of the selection of potential solutions, we particularly used the information from PAGAR [4] on gap analysis between validation targets and performance assessment for each Solution with respect to each KPA impacted. The summary of the gap analysis outcome is presented in the Figure 9 below. As observed, the table makes the distinction between the solutions that achieved V3 level of maturity and those that still have status of "non-fully" V3 at the end of the SESAR Wave 1. Among the non-fully V3 solutions, it should be mentioned that there are the set of solutions that will be continued in SESAR Wave2 (indicated as "dark grey" in Figure 9) and those which will be discontinued at the current stage (indicated as "light grey" in Figure 9).



Solutions at V3 in SESAR 2020 Wave 1

Sol.	FEFF	APT CAP	TMA CAP	ENR CAP	PRD	PUN	ATCO	TECH	SAF	HP
PJ.01-06	ok								Yes	Yes
PJ.02-01	H-	H+			ok				Yes	Yes
PJ.02-02	ok	M-					ok		Yes	Yes
PJ.02-03	ok	H+					ok		Yes	Yes
PJ.02-05	ok				ok				Yes	Yes
PJ.02-08	ok	H+	H-		H-	ok			Yes	Yes
PJ.03a-04	ok				M-	M-	ok		No	Yes
PJ.03b-05									Yes	Yes
PJ.05-02							M+		Yes	Yes
PJ.06-01	H-				ok				Yes	Yes
PJ.10-01a	M-				ok		M-		Yes	Yes
PJ.10-02a	M-		ok	H+	ok		H-		Yes	Yes
PJ.11-A1									N/A	Yes
PJ.14-02-02									N/A	N/A
PJ.14-02-06									N/A	N/A
PJ.14-03-04									N/A	N/A
PJ.15-01								ok	N/A	N/A
PJ.15-02								ok	N/A	N/A
PJ.15-10								ok	N/A	N/A
PJ.15-11								ok	N/A	N/A
PJ.16-03								ok	N/A	N/A
PJ.17-01									N/A	N/A
PJ.18-02b	ok		M-	M-			ok		N/A	N/A
PJ.18-02c	ok		ok	M-	ok	ok	ok		Yes	N/A
PJ.18-04a					ok				N/A	N/A
PJ.18-04b	ok								N/A	N/A
PJ.18-06a	M-								N/A	N/A

Solutions non-fully V3

Sol.	FEFF	APT CAP	TMA CAP	ENR CAP	PRD	PUN	ATCO	TECH	SAF	HP
PJ.01-01	M-		H-		M-	M-			No	Yes
PJ.01-02	H-		H+		H-	H-	M-		Yes	Yes
PJ.01-03A			ok		ok		ok		Yes	Yes
PJ.01-03B	M-				ok		ok		N/A	Yes
PJ.01-03C							ok		N/A	No info
PJ.01-05	ok	M+	M+		M+		ok		N/A	Yes
PJ.01-07	ok								N/A	N/A
PJ.02-06	ok				ok				No	No info
PJ.02-11	ok		ok		M-		ok		Yes	Yes
PJ.03a-01	ok				M-		ok		Yes	Yes
PJ.03a-03	ok								N/A	N/A
PJ.03a-09									Yes	Yes
PJ.03b-01									Yes	Yes
PJ.03b-03									Yes	Yes
PJ.03b-06		ok							Yes	Yes
PJ.04-01	ok		ok		M-	ok			No	No info
PJ.04-02	ok				ok	H-			No	No info
PJ.05-03							M+	H-	Yes	Yes
PJ.05-05									N/A	N/A
PJ.06-02	ok				ok				Yes	Yes
PJ.07-01	M-				M-	ok			Yes	Yes
PJ.07-02						M-			Yes	Yes
PJ.07-03				ok	ok				Yes	Yes
PJ.08-01	ok			H+	ok		ok		Yes	Yes
PJ.08-02	ok			H+	ok		ok		N/A	N/A
PJ.09-01									Yes	No info
PJ.09-02	ok		M-	H+	M-	ok	M+		Yes	Yes
PJ.09-03	ok		H-	H+	M+	M+	M+		Yes	Yes
PJ.10-01b	M-		ok	M-	ok		H-		Yes	Yes
PJ.10-01c	H-				ok		ok		Yes	Yes
PJ.10-02b	ok		H+	H+	ok		M+		Yes	Yes
PJ.10-05									No	Yes
PJ.10-06							M+		Yes	Yes
PJ.11-A2									Yes	Yes
PJ.11-A3									N/A	Yes
PJ.11-A4									Yes	Yes
PJ.11-G1									Yes	Yes

Figure 9 - Gap analysis for Solutions at V3 and Solutions non-fully V3 in SESAR 2020 Wave 1 (Source: [4])

The selection of the solutions is particularly based on two criteria. Namely, the first one is the number of KPAs impacted by the specific solution, while the second one refers to the magnitude of the remaining gap in performance assessment as defined in the "heat chart". In other words, the solutions classified as "H-" and "M-" will be of particular interests as their assessments do not provide the satisfactory results at the current stage of development.

Based on these two criteria, **9 solutions** have been selected that have **not achieved V3 maturity level** yet, namely:

1. PJ.01-01 - Extended arrival management with overlapping AMAN operations and interaction DCB and CTA
2. PJ.01-02 - Use of arrival and departure management information for traffic optimisation within the TMA
3. PJ.07-01- AU Processes for trajectory definition
4. PJ.07-02 - Airspace user fleet prioritisation (UDPP)

5. PJ.08-01 - Management of dynamic airspace configurations
6. PJ.08-02 - Dynamic airspace configuration supporting moving areas
7. PJ.09-02 - Integrated local DCB processes
8. PJ.09-03 - Collaborative network management
9. PJ.10-01b - Flight-centric air traffic control

It is worth emphasizing that within these 9 solutions there are three Solutions that we already identified in the proposal (i.e., PJ.01-01, PJ.07-02 and PJ.08-01) as they can be addressed with the current architecture in-built in the microsimulation tools. Additionally, we identified 3 solutions which already achieved V3 maturity level, but still some improvements in their performance assessment could be potentially obtained, namely:

1. PJ.02-08 - Traffic optimisation on single and multiple runway airports
2. PJ.06-01 - Optimised traffic management to enable free routing in high and very high complexity environment
3. PJ.10-02a - Improved performance in the provision of separation

In addition to two criteria applied to narrow the large set of Solutions, the process of selection also incorporates the feedback received from a member of PJ.19-04 on the challenges facing during the performance assessment of particular Solutions and/or their combinations.

4.2 In-depth analysis of the initial set of Solutions selected

4.2.1 Non-fully V3 Solutions

The information from the PAGAR document has been consolidated in order to gain a more detailed insight on the Solutions that have not achieved V3 maturity level yet. For each Solution identified, an in-depth analysis has been performed with the aim to identify the major causes of the gap in the performance assessment. In addition, the analysis summarises the validation activities that have been performed within individual Solution project. This information will serve as a solid foundation in the process of specifying the scenarios that will be simulated by the microsimulation tools.

Solution PJ.01-01: Extended arrival management with overlapping AMAN operations and interaction DCB and CTA

The solution PJ.01-01 is based on the fact that arrival streams can be planned at an earlier stage which will enable delays to be absorbed in the en-route phases of flight, saving fuel and emissions compared with stack holding or long transitions in the terminal manoeuvring area [8].

Table 1 - Performance assessment of the solution PJ.01-01

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	Quantitative data has not been obtained for all of the OI steps or flight phases. A wider range of aircraft with different performances in different scenarios	3.6%	Medium -
TMA capacity	More exercises are needed for the Solution to be able to make the assessment of the expected benefit and the gap with the validation target	9.3%	High -
Predictability	Validation Gap: Further analysis recommended as not all OI steps were quantitatively covered	6.7%	Medium -
Punctuality	Programme Gap: No expected impact on Punctuality. Validation target needs to be revised.	3.5%	Medium -

The gap in performance assessment of this solution with respect to different KPAs is generally medium to high (Table 1) underling that given gap in Fuel efficiency and Predictability are mainly due to the fact that quantitative data has not been obtained for all of the OI steps or flight phases and generally more exercises is needed. In addition, the Solution appears to have no expected impact on Punctuality, and thus validation target for this KPA needs to be revised.

PJ.01-01 Validation activities

However some validation works have been already performed including **2 Fast Time Simulations**, **1 Modelling Analysis** and **3 Real Time Simulations**. Some of the exercises conducted assessed the various benefit of this concept, such as for instance [9]:

- the benefit of changes to the E-AMAN to facilitate the sequencing and metering of aircraft into systemised airspace PBN main and 'offload' arrival routes as determined by the Systemised Airspace Manager (SYSMAN) developed in solution PJ.01-02;
- the interaction between multiple extended AMAN systems and Network DCB. A simplified Network Management and AMAN algorithm is used to examine the effect of synchronization and continual re-planning;
- characterising the arrival management process and identifying any potential interactions with network management measures, at a macroscopic level;
- handling non-coordinated AMAN advisories from multiple airports in an Extended AMAN context. The Focus of the simulation was to evaluate the effect on En-route sectors when implementing non-coordinated AMAN advisories;
- validation of the inclusion of various DCB parameters published in the Airport Operations Plan into an E-AMAN.

Solution PJ.01-02: Use of arrival and departure management information for traffic optimisation within the TMA

This solution is highly related to the previous one. The solution is based on the idea on using the information from departure management systems, and integrates this with information from arrival management systems to improve traffic flow within the extended TMA [8].

Table 2. Performance assessment of the solution PJ.01-02

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	Expected benefit is not high as the validation target due to the fact that only arrival traffic was measured. Lack of data related to departure traffic. Also the cancellation of planned validation activities addressing the operational improvement covered by Solution.	10%	High -
TMA capacity	Even if the obtained benefit is higher than the expected one, its level of confidence is considered low as it has been obtained from qualitative feedback on potential TMA capacity gain. The result needs to be quantitatively.	9.3%	High +
Predictability	Validation Gap: Expected benefit is not high as the validation target.	8.8%	High -
Punctuality	Programme Gap: No expected impact on Punctuality. Validation target needs to be revised.	3.5%	High -

As observed from Table 2. Performance assessment of the solution PJ.01-02, the gap in performance assessment with respect to different KPAs is still very high as the solutions lacks more validation exercises related to departure traffic. It is worth mentioning that with respect to TMA capacity, even if the obtained benefit is higher than the expected one indicated by the dark blue box, its level of confidence is considered low as it has been obtained from qualitative feedback.

PJ.01-02 Validation activities

For the purpose of validation, 1 Fast Time Simulation (FTS) and 2 Real Time Simulations (RTS) were conducted in high density and complexity TMA/E-TMA environments [9]. The exercises conducted assessed:

- the integration of Systemised Airspace Management data into an E-AMAN for route balancing purposes in systemised TMA/E-TMA airspace;
- the operational feasibility of distributing traffic across primary and alternative (offload) routes to reduce bunching of aircraft and reduce route and stack over demand. SYSMAN' prototype

tool was assessed in the Very High Complexity multi-airport Extended Terminal Manoeuvring Area (E-TMA) in Southeast of the UK;

- the Step 2 V2 mock-up for the OI-Step TS-0307 at the DFS premises in Langen, Germany to balance the sector load by predicting sector entry times for all relevant traffic and controlling the sector entry times. The validation was run using a new mock-up with new functionalities and HMI called 'Advanced CMAN';

Solution PJ.07-01: AU Processes for trajectory definition

The solution under PJ.07-01 refers to the airspace users and their preferences in trajectory definition. The main objective of this solution is to develop procedures and workflows for Flight Operations Centres enabling them to interact better with other ATM stakeholders. This is especially the case with the Network Manager regarding trajectory definition in the planning phase. This includes defining and validating an iterative trajectory planning process for each flight covering different steps such as creation of the trajectory, update, negotiation, and agreement [8].

Table 3 - Performance assessment of the solution PJ.07-01

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	Validation gap: still some OIs to validate	3.4%	Medium -
Predictability	Validation Gap: PJ19 expectations include TMA as Operating environment where PJ07-01 results may provide benefits regarding Predictability. However, PJ07.01 only focuses on En-Route Very High, High and Medium complexity sub-operating environments. AUO-0207 validation should also provide benefits in this KPA but it was only addressed qualitatively, so no quantitative feedback is provided	3.5%	Medium -
Punctuality	Validation Gap: AUO-0207 validation should also provide benefits in this KPA, but it was only addressed qualitatively, so no quantitative feedback is provided	5.0%	Ok

Still, some operational improvements of the solution need to be validated in order to close the gap in fuel efficiency (Table 3). The remaining performance assessment gap in Predictability stem from the fact PJ.07-01 only focuses on the validation exercises in En-Route phase including Very High, High and Medium complexity sub-operating environments, whereas TMA as an operating environment where this solution can contribute to better predictability has not been validated yet. Additional assessment of this solution may result in closing the gap with respect to predictability and this may present the indication to our research within the project, as UDPP has been already identified as a potential case study.

PJ.07-01 Validation activities

Three validation exercises have been performed covering these two topics [9]:

1. On Topic 1 (Use of enhanced What-ifs function, enriched DCB information), two validation exercises were run:
    - EXE 07.01.02/01, Human-in-the-loop exercise to capture AU detailed requirements, assess the benefits of the concept and perform operational and technical feasibility;
    - EXE 07.01.02/03, to perform automated runs simulating AU behaviours to obtain quantitative measure on network stability.
2. On Topic 2 (use of AU preferences in DCB processes), one validation exercise was run:
    - EXE 07.01.02/02, Human-in-the-loop exercise to capture AU detailed requirements, assess the benefits of the concept and perform operational and technical feasibility.

These validation activities were performed in close coordination with PJ09.03. This PJ09.03 solution provided to PJ07.01 all the pertinent evolving DCB information (network DCB constraints, congestion Indicators along /around trajectories and route opportunities) and related functionalities to support the AUs in the calculation of optimal trajectories.

Solution PJ.07-02: Airspace user fleet prioritisation (UDPP)

The solution PJ.07-02 called Airspace user fleet prioritisation, very well known as a UDPP, provides the extension of airspace user capabilities allowing them to recommend a priority order request to the Network Manager, with other ATM stakeholders and appropriate airport authorities, for flights affected by delays on departure, arrival and en-route in capacity-constrained situations [8].

Table 4 - Performance assessment of the solution PJ.07-02

KPA covered	Description of causes	Criticality	Perf. Gap
Punctuality	UDPP is a Solution for situations of disruption causing delays to flights. UDPP is not a Solution designed to impact Punctuality but to improve the situation for airspace users depending on their business needs. Therefore, the benefits are expected to be little to no improvements to Punctuality.	3.5%	Medium -

In SESAR Wave 1, this solution is primarily set to improve the punctuality. Basically, UDPP is not a Solution designed to impact Punctuality but to improve the situation for airspace users depending on their business needs, and thus has very little or even no effect on punctuality (Table 4).

PJ.07-02 Validation activities

Regarding the validation exercises performed so far, there have been two validation work concerning V1 and V2 maturity level of the Solution, namely [10]:

- In V1, work continued from SESAR 1 on AUO-0107 "UDPP for Low Volume Users in a Constraint (LVUC)" and developed the Flexible Credits for LVUC concept (FCL) that was assessed mid-V1 with the airspace users.
- In V2, **Human-in-the-loop real time simulation** with the goal to assess operational feasibility of UDPP and to measure the performance impacts for AUs and for APOC (Airport Operation Centre) in the operational environment. The exercise connected four systems/tools to emulate the behaviour and interaction with each stakeholder concerned:
    - INNOVE platform emulates the ATFCM system with NM functionalities including B2B services.
    - FOC system replicates a simplified Flight Operations Centre (FOC) interface for the flight dispatcher.
    - UDPP Server system receives the prioritisations from the AUs and calculates the new sequence of flights within the UDPP Measure.
    - POC system simulates the runway and ground movements at the airport. APOC actors were able to create the UDPP Measure, monitor the airport performance indicators and change the stand allocation planning.

Regarding the validation exercises performed so far, it is worth to mention Human-in-the-loop real time simulation with the main objective to assess operational feasibility of UDPP. The exercise connected four systems/tools to simulate the behaviour and interaction with each stakeholder including network manager, FOC, APOC and UDPP Server system. Finally, APOC actors were able to create the UDPP Measure, monitor the airport performance indicators and change the stand allocation planning.

Solution PJ.08-01: Management of dynamic airspace configurations

The solution PJ.08-01 refers to the Management of dynamic airspace configurations and presents one of the solutions that we already identified in the proposal. The main idea of the solution is to manage airspace in a more dynamic way by designing sectors based around predicted traffic flow which can eventually increase capacity while reducing delays and emissions. SESAR research is making progress on the concept of dynamic airspace configuration (DAC), which allows ANSPs to organise, plan, and manage airspace configurations with enough flexibility to respond to changes in traffic demand [8].

Table 5 - Performance assessment of the solution PJ.08-01

KPA covered	Description of causes	Criticality	Perf. Gap
En-route capacity	The obtained results exceed the allocated target, even being conservative and not including additional gains reported by ATCOs in their feedback.	12.6%	High +

The performance assessment analysis provides an ample evidence that the obtained results exceed the allocated target with respect to en-route capacity, even taking into account that these results do not include additional gains reported by ATCo (Table 5). Additionally, [11] address Air Traffic

Controllers' (ATCOs') acceptance of DAC by developing a prototype controller working position (CWP) that supports ATCOs in understanding changes in airspace configurations and their effect. The experiments conducted show that DAC was acceptable to ATCOs, both subjectively and based on measures of human performance, operational feasibility and security. ATCOs reacted positively to using the DAC solution and to the proposed UIs, which they provided suggestions for improving.

PJ.08-01 Validation activities

As observed, a substantial amount of exercises has been performed so far in order to validate the Solution including a series of activities such as model based, shadow-mode trials, gaming, and real-time simulations, whose objectives focused on the benefit assessment and the operational feasibility of the DAC concept elements, on the impact on CWP and ATCOs, and on the feasibility of the overall DAC process. The validation activities have been run as follows [12]:

- Model based:
  - Two exercises to perform a benefit assessment of DMA type 1 and DMA type 2 in the context of the DAC, within a FRA (Free Route Airspace) environment
- Gaming:
  - To assess the operational feasibility of the pre-tactical DAC CDM process
- Real Time/Human in the Loop Simulations – shadow mode exercises:
  - To assess the operational feasibility of the DAC concept elements focused on Flow Management Position (FMPs) and Area Control Centre (ACC) Supervisors activities, in the context/timeframe of Integrated Network ATC Planning (INAP) processes;
  - To assess the impact of DAC concept on CWP and ATCOs;
  - To assess the feasibility of the overall DAC concept/process up to execution.

Solution PJ.08-02: Dynamic airspace configuration supporting moving areas

The solution PJ.08-02 comes from the same DAC family and includes an impact assessment of the integration of area that are potentially unsafe due to weather phenomena in the DAC process. These moving hazard zones can be extended to other phenomena, such as volcanic ash [8] .

Table 6 - Performance assessment of the solution PJ.08-02

KPA covered	Description of causes	Criticality	Perf. Gap
En-route capacity	This is in very early stage of development, no exercise has been performed. This Solution only included study work in Wave 1, so the provided figure is just an estimation.	9.5%	High +
ATCO Productivity	This is in very early stage of development, no exercise has been performed. This Solution only included study work in Wave 1, so the provided figure is just an estimation.	1.3%	Ok

PJ.08-02 Validation activities

This solution consisted of two OIs [12]:

- AOM-0208-C Dynamic Mobile Areas (DMA) Type 3
- AOM-0209 Integrate Hazard Zones in DAC process In Wave 1 the Solution only addressed the AOM-0209 OI Step and its sole related Enabler AAMS-01 Automated impact of Hazard Zones.

However, this Solution is only included study work in Wave 1, and will be not continued in SESAR Wave 2.

Solution PJ.09-02: Integrated local Demand Capacity Balancing processes

The solution PJ.09-02 is one of these solutions which has high interrelationship with other solutions. This solution takes into account the needs of the network as a whole, as well as local factors, in order to avoid capacity overload in a seamless process. This solution looks in particular at the integration of local network management with extended planning and short-term arrival management activities [8].

Table 7 - Performance assessment of the solution PJ.09-02

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	N/A	0.4%	Ok
TMA Capacity	No available data to provide input for performance assessment. AMAN integration was disregarded at the beginning of the project due to the limitations of the systems	3.5%	Medium -
En-route capacity	The gap can be due to the fact that PJ.19 considered PJ.09.02 performance results would contribute to TMA and En-Route Capacity, while only En-Route Capacity has been finally assessed. Additionally, En-Route Capacity has been addressed in Very High and High Complexity sub-operating environments, while PJ.19 also indicated targets for Medium Complexity sub-OE	9.2%	High +
Predictability	Validation Gap: VT includes TMA, En-Route and Airport Predictability and in Very High, High and Medium Complexity sub-operating environments. PJ.09.02 assesses PRD1 for En-Route and in Very High and High sub-Operating environments.	4.4%	Medium -
ATCO productivity	Very detailed assessment. Validation Target is too low		Medium+

This solution is aimed to significantly contribute to TMA and En-Route Capacity, while only En-Route Capacity has been finally assessed (Table 7). Additionally, En-Route Capacity has been addressed in Very High and High Complexity environments, while PJ.19 also indicated targets for Medium Complexity operating environments.

Solution PJ.09-03: Collaborative network management

It is very well known that SESAR is progressing the notion of collaborative constraint management in four dimensions - 4D trajectory contract. The aim of the Solution is to consolidate DCB procedures in order to minimise the adverse impact on airspace user operations and on overall network performance. It allows all stakeholders (i.e., airports, air traffic control, the Network Manager and airspace users) to agree on reconciliation measures with the aim to identify the optimum solution to satisfy all constraints [8].

Table 8 - Performance assessment of the solution PJ.09-03

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	No assessment, but gap “ok” due to the small contribution to fuel	1.2%	Ok
TMA Capacity	This Solution does not bring additional benefit to that reported in SESAR 1 (5 %).	9.6%	High -
En-route capacity	Provided figures are based on expert judgement, which will be corroborated by exercises to be performed in Wave 2. This estimation will be confirmed in the next SESAR Wave.	9.2%	High +
Predictability	N/A	7.0%	Medium+
Punctuality	N/A	32.0%	Medium+
ATCO productivity	N/A	13.0%	Medium+

The results of the assessment performance for this Solution indicate that further validation activities will need to be performed with respect to En-route capacity. The figures presented in Table 8 - Performance assessment of the solution PJ.09-03Table 8 are based on the expert judgement which brings additional uncertainty in the estimations.

PJ.09-03 Validation activities

PJ. 09-03 PAR [13] reports that Solution PJ.09-03 has been designed around one activity and two validation exercises. The main outcomes for each of them are:

- ACT-09.03.01, a gaming/expert judgement activity to explore the DCB Collaborative Framework,
- EXE-09.03.02, a series of three shadow-mode trials including sub-sessions a simulation and a study. They cover the Network Operations Plan (NOP) collaborative functionalities (integration of AOP/NOP data SID, STAR and TTA in eFPL), the integration of DCB and Flight in support to FF-ICE (enhanced DCB information, What-If& What-Else for AU)), and the improvement of traffic demand predictions, by a simulation focused on Preliminary flight plan and a study focused on predicted flight data
- EXE-09.03.03, two modelling simulations to address DCB constraints reconciliation and optimisation at network level.

Solution PJ.10-01b: Flight-centric air traffic control

The solution PJ.10-01b presents a fundamental shift from sector-based airspace structure to a flight-centred structure without reference to geographical sectors. Such approach opens up the opportunity to distribute the traffic more evenly, and to avoid lost productivity in under-loaded sectors [8].

Table 9 - Performance assessment of the solution PJ.10-01b

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	Validation gap: only a few runs were performed in the RTS / FTS. In addition, only small airspaces were examined in the various exercises.	4.9%	Medium -
En-route capacity	The numbers provided here are **based on a very small set of exercise runs**. Furthermore, not all complexities were covered. Hence the **confidence in the obtained values is very low** and **more exercise runs are recommended** to be undertaken before a more profound impact assessment can be made.	5.0%	Medium -
Predictability	Validation Gap: **Confidence in the results is very low as only a few runs were performed in the RTS / FTS.** In addition, only small airspaces were examined in the various exercises.	0.5%	Ok
ATCO productivity	Assessment has not been completed	10.0%	High -

The solution is aimed to significantly contribute to ATCO productivity, although assessment has not been completed. Concerning the performance assessment gap in En-route capacity, it can be observed that it mainly comes from a very small set of exercise runs and limited complexities covered by the exercises (Table 9). Therefore, this solution generally needs more exercise runs and more operational environment to be included in the future validation processes.

PJ.10-01b Validation activities

For the purpose of validations, PJ.10-01b conducted workshops, fast-time simulations and real-time simulations [14] on research platforms and pre-industrial prototypes in V1 and V2 phases.

Flight Centric ATC was investigated in four validation exercises that covered the following areas:

- Budapest ACC between FL325 and FL660;
- Madrid ACC from GND to UNL (excluding all airports and Madrid TMA);
- ATC sectors Heide, Aller, Hamburg West, Hamburg East (within Bremen ACC) between FL105 and FL245;
- Prague ACC at all altitudes, finding the lower boundary down to which Flight Centric ATC can be applied was part of this validation exercise

4.2.2 Fully V3 Solutions

In addition to "non-fully" V3 Solutions examined in the previous section, the aim of this section is to present some of the Solutions which already achieved V3 maturity level, but their gap analysis indicate that some expected benefits with respect to validation targets have not been achieved yet. This opens the room for potential reconsideration of the selected Solutions in order to determine if some gaps in performance assessment could be closed by employing the metamodelling approach. However, the solution selected will be not continued in SESAR Wave 2.

Solution PJ.02-08: Traffic optimisation on single and multiple runway airports

The solution PJ.02-08 called "Traffic optimisation on single and multiple runway airports" focuses on an integrated runway sequence function to balance arrival flights and departure flights on single runway, dependent runways or parallel runways with the option to balance also flights between parallel runways [8].

The solution already achieved the V3 maturity level and presents one of the solutions that are specific airport-oriented, which means that the benefit obtained within a given airport operational environment is very difficult to translate to ECAC level. Although this solution is not foreseen to be continued in Wave2, still some validation gap in the predictability needs to be closed as not all Concepts have been evaluated (Table 10).

Table 10 - Performance assessment of the solution PJ.02-08

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	No gap analysis provided	2.5%	Ok
Airport capacity	This high benefit can be achieved by implementing one of the concepts this	19.2%	High +

KPA covered	Description of causes	Criticality	Perf. Gap
	Solution offers, which corresponds to the maximum benefit that could be achieved by this Solution		
Predictability	Validation Gap: Expected benefit is not as high as the validation target. This is due to the fact that the validation target is related to the overall contribution of the Solution in terms of PRED1 while the result provided by the Solution is only related to the contribution of TS-0301.	8.1%	High -

Solution PJ.06-01: Optimised traffic management to enable free routing in high and very high complexity environment

Similar to the previous solution, the PJ.06-01 already reached V3 maturity level. This solution is based on the Optimisation of traffic management to enable free routing in high and very high complexity environment. It essentially allows **airspace users to plan a route along segments of the great circle**, which connect any combination of published waypoints and is due to become available above 31,000 feet from 2022 under European regulations [8]. Free routing is already **available in a number of low to medium complexity environments** following validation work completed under SESAR 1, paving the way for the latest SESAR research, which is focused on high and very high complexity cross-border environments. Although there are many validation exercises that have been done so far, still there is no available performance assessment in terms of fuel efficiency area (Table 11).

Table 11 - Performance assessment of the solution PJ.06-01

KPA covered	Description of causes	Criticality	Perf. Gap
Fuel efficiency	No gap analysis provided	8.1%	High -
Predictability	Validation Gap: Positive / negative effect on Predictability (depending on airspace design of cross-border FRA at local level).	1.5%	Ok

Solution PJ.10-02a: Improved performance in the provision of separation

The similar comment can be drawn for the solution PJ.10-02a called "Improved performance in the provision of separation" in terms of performance assessment gaps. The idea behind this solution is very promising comprising the use of aircraft-derived data, and reducing the need for so many tactical interventions [8]. However, the confidence in the results should be considered as "medium" as controllers need to gain sufficient familiarity and trust in the tools, which is often difficult to achieve fully in the context of a V3 exercise. On the other hand, there are no validation exercises which will prove the benefit in fuel efficiency (Table 12), although the criticality of this solution is medium with respect to this KPA.

Table 12 - Performance assessment of the solution PJ.10-02a

KPA covered	Description of causes	Criticality	Perf. Gap
TMA Capacity	The full benefit of the tools is only realized once the controllers have gained sufficient familiarity and trust in the tools, which is often difficult to achieve fully in the context of a V3 exercise. Furthermore, controller workload, which has been used as the basis for calculating capacity impact in the exercises, is also an imprecise measure. For these reasons, the confidence in the results should be considered as "medium".	10.7%	Ok
En-route capacity	The performance benefit of controller tools is hugely sensitive to the environment in which it is operated. In addition, the full benefit of the tools is only realized once the controllers have gained sufficient familiarity and trust in the tools, which is often difficult to achieve fully in the context of a V3 exercise.	11.5%	High +
Fuel efficiency	N/A	4.0%	Medium -

5 Selection of Solutions with respect to micromodel tools

This section thoroughly examines the technical capabilities of each individual microsimulation tool with respect to the operational environment and requirements defined within specific Solution. As described in [7], NOSTROMO will extensively use detailed microscopic models to capture the performance impact of different Solutions and concepts in order to efficiently build performance macromodels. The use of micromodelling techniques will provide the computational traceability and the interpretability of the results. Thus, the aim of this section is to scope the initial set of the Solutions by selecting ones which operational concepts can be efficiently addressed with the architecture inbuilt in the microsimulation tools. Subsequently, different scenarios will be defined to test the ability of the proposed metamodels to evaluate the impact of the selected solutions, covering different ATM phases and KPAs/KPIs. Following the incremental approach adopted by the project, several test cases (conceived as a “case zero”) were already specified (see Appendix) with the aim to demonstrate the technical feasibility of the methodology proposed, rather than its operational aspect. In this way, we take advantage of the micromodels already developed in previous ER projects, such as Vista, Domino, FLITE, APACHE and INTUIT. The conclusions that will involve both the architecture and the interfaces will be presented in the first workshop to get the feedback of the experts. In this light, the metamodelling methodology will be refined in WP3 taking into account the initial results of the “case zero” obtained in the first iteration. This action will be performed prior to the run of the case studies defined in this deliverable.

The validation activities for the selected Solutions are performed by the means of different validation tools and approaches which may range from small-scale operational simulations to very intensive real-time (human-in-the-loop) simulations. The extensive analysis on the validation platforms applied for the validation purposes of SESAR Solutions have identified three main categories which vary in the level of details and complexity (Table 13), namely:

- Collaborative gaming platform
- Fast-time simulators and
- Micro Simulation Models

The main characteristics of each platform are summarised in Table 13.

Table 13 - Characteristics of different platforms used in ATM performance assessment

Platform used	Main characteristics	Type of platforms
Collaborative gaming platform	• Operational Concept fuzzy and unclear • Involvement of Multiple actors (NM, FMPs, FOC, ATC, etc.) • Slow pace of simulation execution	• INNOVE • CHILL platform • …

Platform used	Main characteristics	Type of platforms
	• Several iterations to refine the operational concept and the contingency plan	
Fast-time simulators	• Operational Concepts mature and well-defined • Low-level validation activities • Produce fine-grained metrics	• RAMS Plus, …
Micro Simulation Models	• Evaluator of solutions • Based on simple mathematical formulation • Suitable for large simulation scale	• FLITAN, …

As observed from Figure 10, **collaborative gaming platforms** have been extensively used in the validation of a great number of Solutions. Among several available platforms, Eurocontrol's INNOVE platform is one of the widely used as it enables the air traffic flow management real-time simulation for the validation of Network Management solutions at E-OCVM V2 maturity level [15]. With its ability to connect with various platforms such as RAMS ATC simulator, INNOVE Figure 10 enables a closed loop simulation between ATFM and ATC triggering the opportunity to tailor different scenarios. Additionally, INNOVE platform is particularly suitable for validation of new operational concepts that are still in the early phase of concept elaboration. The main simulation challenge lies not in INNOVE performance, but in the overall process of translating step-by-step abstract concepts into well-detailed and concrete operational procedures. During this process of translation and refinement, simulation clock is paused several times to allow the many involved actors to engage in brainstorming sessions with the objective of providing solutions to questions raised during the simulation exercise. The solutions are then implemented and new simulation exercises are planned for execution. As it can be seen, refining an abstract concept is deeply intertwined with a process of "stop and go" necessary to avert pitfalls and paradoxes, which naturally leads to a slow pace of simulation execution.

On the other hand, the platforms based on **fast-time simulation** find a broad application in the validation processes of mature and well-defined operational concepts and Solutions. As seen from Table 13, RAMS has been one of the largely exploited platforms for performing low-level validation activities developed by Eurocontrol. The RAMS Plus platform provides gate-to-gate fast-time discrete-event simulation to quantify performance benefits for ATM management decision support. It contains functionality for study and analysis of airspace structures, air traffic control systems, future ATC concepts, and airport ground operations. The behaviour of the human actors (controllers and pilots) can be also modelled in RAMS Plus by using a set of internal rules. The result of the simulation is a variety of outputs that can be used to create a bunch of aggregated metrics, measurements, and quantifications to describe the system's behavior [16]. Figure 10 - Different platforms used for the validation of SESAR solutionsFigure 10 depicts the application of RAMS Plus in the validation campaign of several SESAR Solutions (e.g., E-AMAN, DAC, etc.,).

Finally, the third type of platforms based on **micro simulation models** (e.g., FLITAN) may be particularly applied as an evaluator of Solutions. They are often built upon simple mathematical formulation enabling large simulation scale. It is also worth mentioning that, as fast-time simulation is very often based on micro simulation models, these two categories are not necessarily exclusive.

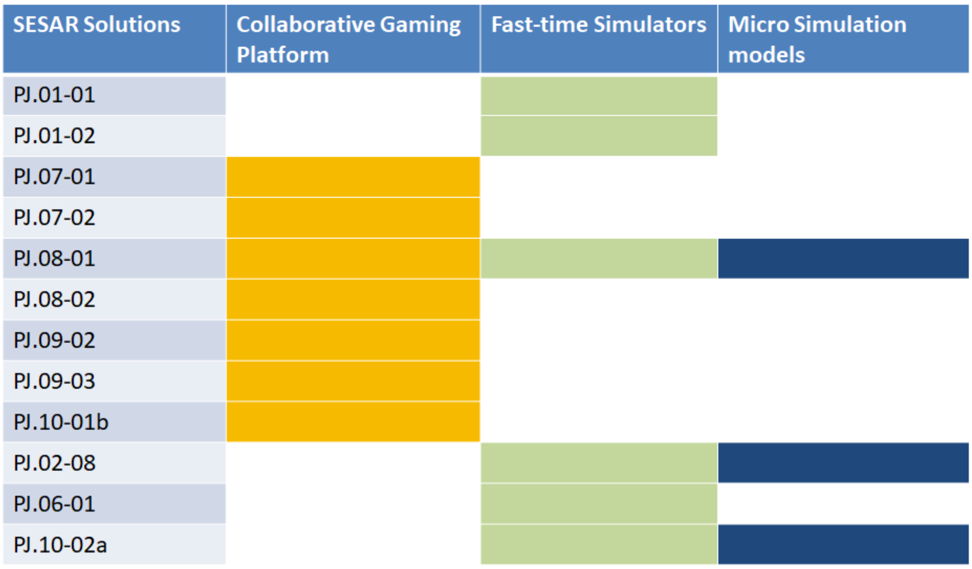


Figure 10 - Different platforms used for the validation of SESAR solutions

Despite a continuous progress in the validation activities performed in a great number of Solutions, there are still a large gap in their performance assessment with respect to different KPAs/KPIs. The following subsection will thoroughly discuss the applicability of two microsimulation tools, to model some of the new ATM concepts proposed by the set of Solutions listed in Figure 10. However, as underlined in [7], these models also face some limitations that hinder their operational use: the richness of the model comes at the cost of computational complexity, which makes it difficult to explore the simulation space in a systematic manner. These limitations will be tackled by the metamodelling approach that approximates the behaviour of computationally expensive simulation models so as to allow a systematic and efficient exploration of the model input-output space by exploiting recent advances in the field of active learning. In this light, the results for different ATM concepts obtained from two detailed microscopic model tools will be transferred to more stylised metamodels built in a bottom-up manner, developing models that are useful for decision-making while keeping the ability to anticipate possible emergent behaviours.

5.1 Selection of the Solutions with respect to Mercury

Mercury is a full flight and passenger mobility model developed, among others, in the H2020 Vista and Domino projects [17]. Mercury considers individual flights (with schedules, flight plans and rotations) and passengers' itineraries and provides their tactical execution at a European level for a full day of operations. Mercury can measure indicators for different stakeholders, namely: airlines (including specific flight-centric metrics), passengers, airports, ANSPs and the environment. Mercury has been successfully used in the past to evaluate different mechanisms (inspired and aligned by SESAR solutions) and the impact of exogenous factors, such as cost of fuel.

A few modules already developed are related to some of the selected Solutions. In particular, some modules related to UDPP (PJ.07-02) and E-AMAN (PJ.01-01) are already present in Mercury, developed during previous project. Another module implemented "Dynamic Cost Indexing", a concept which is loosely related to various solutions, e.g. PJ.09-03. These concepts are the ones for which Mercury was developed, and thus the model is particularly suited to them. As a consequence, we plan to start from these concepts for the case studies in NOSTROMO. Table 14 presents a summary of the preliminary set of Solutions that are planned to be modelled with the given microsimulation tool.

Table 14 - The description of preliminary set of Solutions identified to be modelled with Mercury

Solution	Brief description	KPAs impacted	Interrelationship with other solutions

PJ.01-01: Extended arrival management with overlapping AMAN operations and interaction DCB and CTA	Arrival streams can be planned at an earlier stage which will enable delays to be absorbed in the en-route phases of flight, saving fuel and emissions compared with stack holding or long transitions in the terminal manoeuvring area.	• Fuel efficiency
		• TMA capacity
		• Predictability
			• Prefers:
			  ○ PJ.09-02
			• Cross effect with:
			  ○ PJ.18-02a
			  ○ PJ.18-06a
			  ○ PJ.18-06b

PJ.07-02: Airspace user fleet prioritisation (UDPP)	This candidate solution sees the extension of airspace user capabilities, through the UDPP, allowing them to recommend a priority order request to the Network Manager, with other ATM stakeholders and appropriate airport authorities, for flights affected by delays on departure, arrival and en-route in capacity-constrained situations.	• Punctuality?	• Cross effect with:
			  ○ PJ.04-02
			  ○ PJ.09-02
			  ○ PJ.09-03

PJ.09-03: Collaborative network management	SESAR is progressing the notion of collaborative constraint management in four dimensions (4D) – latitude, longitude, altitude and time. The aim is to consolidate DCB procedures in order to minimise the adverse impact on airspace user operations and on overall network performance. For example, in place of the current slot allocation procedure based on first-planned, first-served;	• Fuel efficinecy
		• TMA capacity
		• En-route capacity
		• Predicatbility
		• Punctuality
		• ATCO productivity
			• Depends on pre-requisite of:
			  ○ PJ.04-01
			  ○ PJ.09-01
			• Interdependent with:
			  ○ PJ.07-01
			  ○ PJ.09-02

Solution	Brief description	KPAs impacted	Interrelationship with other solutions
	the solution supports a coordinated 4D constraints management process, which arbitrates between the owners of the constraint, the actors involved in the solution and the overall network performance needs.		○ PJ.18-02c • Prefers: ○ PJ.07-03 ○ PJ.15-01 • Preferable to: ○ PJ.08-01 • Cross effect with: ○ PJ.07-02

The current implemented modules are only loosely related to the corresponding SESAR solutions, and thus would require a redevelopment for the case studies. In any case, it is still difficult at this stage to assess how close the simulator could be to the real concepts. First, these concepts are still being developed, which implies a certain degree of fuzziness, ambiguity, and untold assumptions in their description. Second, the model may not have the degree of detail required to implement some solutions, which may trigger additional assumptions on the modelling side. However, the three concepts above are the ones which are the most adapted to Mercury, and thus we are confident in the capacity of the model to simulate them with enough realism.

Our first selections of solutions for the case studies is thus **PJ.01-01**, **PJ.07-02,** and **PJ.09-03**. While the first two are quite well defined and bounded in terms of stakeholders involved, the last one is a lot broader. In fact, it blends together a lot of other concepts, as can be seen from its numerous relationships with other solutions. In particular, because PJ.09-03 deals with 4D trajectory, there is a notion of contract in space and time between the airline and the ANSP/NM, i.e. a consensus taking into account supply (capacity) and demand (preferred trajectories). This is reminiscent of UDPP, where ATFM slots can be considered as a contract in time (which may be exchanged between airlines). Hence, these concepts are naturally interrelated. For the same reason, the Extended Arrival Manager is also closely related to PJ.09-03, as it implies to change a 4D trajectory in order to meet constraints at the arrival airport.

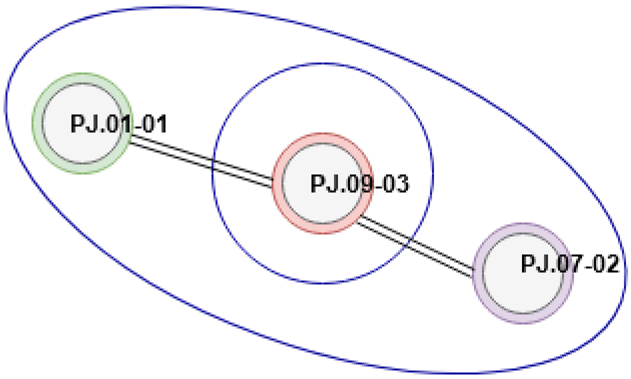


Figure 11 - Possible combination of Solutions

The kind of unified constraint management and prioritisation process envisioned by PJ09-03 is a good opportunity for NOSTROMO to test combinations of solutions (Figure 11). In particular, combining airspace slots and arrival slots management, taking into account network effects and airlines' costs is a tough problem, but Mercury has been designed to answer to these issues. NOSTROMO will study more in detail each candidate solution and will assess the feasibility of the possible implementations.

NOSTROMO also plans to use the same mechanisms in the second and third iterations of the model. The mechanisms will be refined or modified in the last iteration.

5.2 Selection of the Solutions with respect to FLITAN

FLITAN is a simulation platform developed by ISA in support of SESAR JU WP-E FLITE project to support the network-wide performance assessment of different scenarios of operation. The micro-simulation model was initially developed to support Turn-Around Analysis for EU FP7 project (TITAN) by enabling to:

- Introduce turn-around processes and milestones into extended Airport-CDM (A-CDM) scenario(s)
- Include turn-around processes in the overall ATM Network Planning process
- Support Network impact analysis due to issues in the turn-around process

The micro-simulation tool developed for TITAN was subsequently adapted to support the SESAR JU WP-E FLITE project with the aim to:

- Investigate the Flight Path 2050 target of 4-hours door-to-door;
- Create and analyse future traffic scenarios for the 2050 timeframe;
- Assess future long-term capacity/infrastructure needs to ensure target performance:

- Those that are projected to be achieved through SESAR Operational Improvements
- Additional capacity needed '*from elsewhere*' to address capacity shortfall

In FLITAN, ATM (and other) system(s) are abstracted as **network of nodes and connectors** in which nodes represent resource entities (e.g. airport, sector, runway, apron, gate etc.) and connectors represent links between nodes (e.g. Airway, SID, STAR, Taxiway, etc.). Nodes and connectors are characterised by occupancy time distribution(s) using nominal time and variance which can be derived from other simulation tools and/or analysis of historical operations data. Each node can be expanded into its own (new) sub networks with the aim to:

- create a more detailed model of how it functions
- or be *completely replaced* by real logic to simulate more detailed operational concepts

Finally, SMEs can be elicited to help quantify impact of future OIs on ATM efficiency and to help inform the required adaptation of associated nodes. The platform is able to simulate the entire ATM network under nominal, sub-nominal or enhanced conditions. In support of NOSTROMO, the FLITAN model will be used to carry out performance assessment on the network level for the introduction of one or more portfolios of SESAR solutions.

Figure 10 shows that three SESAR Solutions out of 12 initially identified can be efficiently addressed by micro simulation tool. Among these three solutions, two solutions have been identified by the ISA team as suitable for a micro simulation model and can be achieved using FLITAN:

- **PJ.08-01** (Management of dynamic airspace configurations) and
- **PJ.02-08** (Traffic optimisation on single and multiple runway airports).

Table 15 summarises the two Solutions suitable for modelling with FLITAN.

Table 15 - The description of preliminary set of Solutions identified to be modelled with FLITAN

Solution	Brief description	KPAs impacted	Interrelationship with other solutions
PJ.02-08: Traffic optimisation on single and multiple runway airports	This candidate solution focuses on an integrated runway sequence function to balance arrival flights and departure flights on single runway, dependent runways or parallel runways with the option to balance also flights between parallel runways. This solution enables efficient operations through early planning to support predictability, continuous decent and	• Fuel efficiency • Airport capacity • Predictability	• Depends on pre-requisite of: ○ PJ.02-01

Solution	Brief description	KPAs impacted	Interrelationship with other solutions
	enhanced runway throughput operations		
PJ.08-01: Management of dynamic airspace configurations	The solution is composed of procedures and tools, which take account of 4D trajectory forecasts, fixed and flexible routing, and reserved or restricted airspace. It foresees dynamic sectorisation and airspace reservation/restriction (ARES) as part of the broader DCB process, where airspace configuration is a dynamic part of cross-border integrated capacity management	• En-route capacity	• Prefers: ○ PJ.07-03 ○ PJ.09-03 • Is preferable to: ○ PJ.08-02 • Depends on pre-requisite of: ○ PJ.09-01 ○ PJ.09-02 • Interdependent with: • PJ.18-01b • Cross effect with: • PJ.18-02a

6 Specification of Case studies

As explained in Section 1, the definition and selection of the scenarios play an important role during the development of the metamodelling methodology. Different scenarios will test the ability of the new models to evaluate the impact of new solutions, covering different ATM phases and KPAs/KPIs; and as described Section 3, an interrelation between the specification of particular scenarios and particular functionalities of metamodel exists, as each scenario will generate specific set of requirements that need to be considered as part of the implementation (e.g., defining how to build the Gaussian Process models associated to the microsimulation tools that will be used in the NOSTROMO case studies). Moreover, when a given scenario is defined, a set of data requirements will arise. For this reason, a consultative approach is suggested which is in line with incremental approach adopted in the project. The consortium will define the characteristics of the different components of the scenario (input variables, parametrisation, candidate output metrics etc.) which are relevant, but the specific characteristics of these will be consulted with the SESAR JU team and the Advisory Board members. This will facilitate the selection of scenarios which are more relevant but also for which necessary data could be acquired.

Finally, producing an exhaustive and strict definition of all the potential scenarios is avoided at the current stage to enable the flexibility of further selection and instantiate of scenarios with feedback obtained from the interaction with the SESAR JU team and the Advisory Board. Understanding the particular concept underpinning the Solutions selected is of the utmost importance for a proper implementation of the scenarios and thus, further discussion and insight from the SESAR JU team on their particularisation is needed. The number of different scenarios executed will increase as the project progresses and as more mature versions of the metamodels are available. The next two subsections briefly describe a preliminary specification of the scenarios selected as well as the data required to successfully implement the scenarios.

6.1 Specification of case studies - Mercury

Mercury has a lot of input parameters that can be used in the case studies. Below we show the most relevant ones, which are common to all case studies (Table 16). More input can be considered during implementation.

Table 16 - General input parameters (not exhaustive)

Input variable	Brief description
Fuel Price	Price per kg of fuel
Regulation delay level	Drives the severity of regulations
Flight plan choice	Behavioural parameters driving the the flight plan choice of airlines
Wait for passenger	Delay threshold after which the airline does not wait for passengers.
Cost index choice	Parameters driving the choice of cost index for flights (including during execution)
Non-ATFM delay	Severity of non-ATFM delay

Input variable	Brief description
Ad hoc cancellations	Proportion of randomly cancelled flights
Passenger compensation	Compensation thresholds and magnitude for passenger (Reg. 261)

Mercury also produces a very high amount of data, and lots of metrics and performance indicators can be computed on its output. Below are the outputs that we will compute in all case studies (Table 17).

Table 17 - General performance indicators measured with Mercury (not exhaustive)

Output metrics (all with statistics: average etc)	Description	Relationship with KPAs
Flight delay (arrival, departure)	Average, std, 90th perc. Arrival, Departure	• Capacity • Punctuality
Cost of delay	Total cost incurred by airlines due to all types of delays	• Cost efficiency/operational efficiency
Cost of fuel	Additional cost due to extra fuel consumed w.r.t baseline	• Operational efficiency
Flight delay per types of company	Segmented as scheduled flights, low-cost, charter, regional, and others.	• Capacity • Punctuality
Proportion of flights cancelled		• Capacity
Equity metrics for flights (delay, cost)	Capture how different airlines are impacted differently by mechanisms.	• Equity and Fairness
Passenger delay	Different from flight delay because of various number of passengers per flight and connection.	• Passenger
Proportion of disrupted trips	Number of passengers who did not see they initial trip go through, either because of delays, cancellations, missed connections etc.	• Passenger

Finally, additional parameters will be used in each case study, as well as output variables.

Table 18 - Additional input variables and files required for PJ.01-01 (E-AMAN)

Input	Brief Description
Airports implementing E-AMAN	Not all airports in the simulations will have access to the advanced E-AMAN capabilities
E-AMAN strategic and tactical horizons	Time horizons at which the E-AMAN starts managing the flight and fixes the final queue sequence, respectively
Expectation on flights delays	The E-AMAN needs to estimate the probability of delays for flights reaching the strategic horizon

Additional output monitored for **PJ.01-01**:

- Additional delay absorbed by E-AMAN
- Difference of delays at airports with and without E-AMAN

Table 19 - Additional input variables and files required for PJ.07-02 (UDPP)

Input	Brief Description
Type of UDPP mechanism	Several flavours of UDPP exist and/or are in development, using swaps, priorities, margins, credits, etc.
Behavioural parameters	UDPP mechanisms are particularly sensitive to airlines behaviours. Parameters will be taken from other studies.

Additional output monitored for **PJ.07-02**:

- Number of actions needed to reach final allocation.
- Arbitrage possibilities (qualitative, with examples).

Table 20 - The specification of the input variables and files required for PJ.09-03

Input	Brief Description
Constraints taken into account	Different constraints can be applied to 4D trajectories (time, space, sector-based etc)
Flavour of UDPP	The UDPP mechanisms considered above may be used to create and manage constraints in time close to departure
Flavour of E-AMAN	The E-AMAN mechanisms considered above may be used to create and manage constraints in time close to arrival

The output variables for **PJ.09-03**:

- Number of constraints fulfilled at execution time

6.2 Specification of case studies – FLITAN

6.2.1 Specification of Solution PJ.08-01: DAC

As explained in the Section 5, FLITAN was designed from the outset as an evaluator of ATM solutions at the network wide level. As such, its current capabilities make FLITAN very suitable in assessing capacity management solutions based on the adaptation of airspace configurations in response to over demand (as opposed to other ATFCM measures/regulations) in an efficient and timely manner.

In addition, the knowledge acquired by ISA team in developing collaborative ATFCM gaming platforms such as INNOVE and CHILL will be instrumental during the enhancement of FLITAN to support DAC concepts and to respond to the challenge presented by PJ.08-01. The specification of the input variables is summarised in Table 21, followed by the specification of the outputs (KPIs/KPAs).

Table 21 - The specification of the input variables and files required for PJ.08-01

Input	Description	Input files type
Airspace boundary file	It defines the 2D contour of unit volumes (air blocks) that are available in the current AIRAC cycle	• .gar files
Sector file	It defines the boundaries used for each airspace sector as well as the floor and ceiling altitudes for each air block	• .gsl files
Sector configuration file	It defines the different configuration of sectors that are available for use in a given airspace region	• .cfg files
Airspace files	They define the different airspace types (eES, CS, UNIT, AUA, etc.) in a given airspace region	• .spc files
Sector Configuration Plan files (*opening scheme*)	They define the proposed opening schemes and times for each of the available sector configurations	• .cos files
Traffic Volume files	They describe the TV or sets of TV used by NM in the ATFCM collaborative DCB processes	• .ntfv, .ntvs files
Traffic Volume Activation files	They describe the capacity activation information for the different TV for use in the DCB process	• .nact files
ATFM Flow definition files	They describe the flows and sub-flows used to specialise the various TV used in the DCB process	• .nflw files

Input	Description	Input files type
Airspace/Airport (demand) capacity files	It defines the 20-min and 1-hour demand capacity for the various TV and airspaces and airports used in the ATFCM DCB process	• .ncap20, .ncap files
OTMV Capacity files	They define peak and sustained capacities for the Occupancy Threshold Monitoring Validation and DCB processes for the various TV and airspaces	• .nocp and .nocs files
Airport files	They define the various airports and sets of airport in the analysis region (not directly needed for DAC features but used in the TV specifications so required to be present for completeness)	• .narp and aerodromeSet
ATFCM Flight Trajectories file (AllFT+)	They provide planned operational flight trajectory data for the selected analysis time period(s)	• .allft+ files
Aircraft Performance data files	The files used if recalculating ATFCM trajectories as part of the analysis process (text versions of EUROCONTROL BADA data or proprietary custom data from ISA simulation tools	
Controller count files	They provide details of the available ATCo workforce for specific configurations / regions (optional if workforce availability / constraints analysis is to be included in the analysis)	• .ncnc files

Output metrics will include (but are not necessarily limited to):

- Flight Duration
- Flight Distance
- Sector load (Demand and Occupancy)
- Flight Delay
- On-Time Performance
- Hotspots / Demand-Capacity Unbalance
- No of operational sectors
- Sector configuration operating duration
- ATCo activity

6.2.2 Specification of Solution PJ.02-08: Traffic optimisation on single and multiple runway airports

FLITAN has already implemented a runway manager. However, the current version of FLITAN's runway manager will definitely require upgrading to be in full alignment with PJ.02-08 requirements. In this light, the information on the input variables and data required is currently provided at a high level and will be updated with more precise information once the activity for third iteration commences. The preliminary specification of the input variables is provided in Table 22.

Table 22 - The preliminary specification of the input variables for Solution PJ.02-08

Input	Brief Description
Airport data files	They describe the airports that are available in a given region
Runway configuration data files	They describe the available configurations of each airport
Runway dependency file	It defines runways blocking by other runways of the same or different airports
Parallel runway file	They define parallel or near-parallel runways where simultaneous operations are possible (e.g. independent or segregated operations)
TV/ Airspace / Airport capacity files	They provide operation capacities for the airports in the region under different operating configurations
Airport Arrival and Departure route data files	They define the available SID/STAR routes for all airport configurations
ATFCM Flight Trajectories file (AllFT+)	They used to provide planned operational flight trajectory data for the selected analysis time period(s) (.allft+ files)
Aircraft Performance data files	They are used if recalculating ATFCM trajectories as part of the analysis process (text versions of EUROCONTROL BADA data or proprietary custom data from ISA simulation tools)

The output will include (but is not limited to):

- Runway capacity and throughput
- Airport / Runway use / delays
- Flight Delay
- On-Time Performance
- Flight distance
- Network level delays

7 Research Questions

Two set of research questions (RQs) are designed to address the benefits of the metamodels proposed in NOSTROMO. The first set of RQs aims at estimating the overall operational benefit of the metamodelling approach at a system level. These research questions can be addressed by most of the scenarios considered in NOSTROMO (see Section 6) as they tried to address the advantages of the metamodels with respect to microsimulation approach. Therefore, we will try to validate each question with as many scenarios as possible (i.e., using large number of combinations of the model input parameters, etc.). Objective and quantifiable success criteria will be defined for each RQ in order to validate or refute the corresponding hypothesis. The second set of RQs is tailored to address the benefits of metamodelling approach for each specific solution identified. The aim is to evaluate the added value delivered by the new methods and tools developed by NOSTROMO in each particular Solution in comparison to micromodels approach.

A number of **working sessions among the consortium members** was carried out to identify an initial list of research questions to be investigated in the case studies. A subset of these research questions will be selected and refined in collaboration with different ATM stakeholders, through the 1st NOSTROMO Stakeholder Workshop. Modifications to the research questions or the inclusion of new ones might be required in the light of the obtained feedback. This section summarises the different research questions to validate the overall benefit of the metamodels (Table 23) and the specific benefit provided for each individual solution (Table 24).

- Table 23 summarises the research questions for assessing the overall operational benefit of the developed metamodels. The validation activities will aim at quantifying some of the metamodel results of the different planned scenarios. The RQs will be validated internally by ad-hoc interaction within consortium members.
- Table 24 summarises the research questions for each particular Solution selected in Section 5. Note that for the validation activities some of them will be validated as part of the planned 2nd NOSTROMO Stakeholder workshop while others will require ad-hoc interaction within consortium members. The goal is to answer the research questions which aim at identifying the practical benefits of the metamodelling approach for new ATM concepts proposed by SESAR R&D.

Table 23 - Research questions and hypothesis for validation of the metamodels at a system level

ID	Rational	Research Question (RQ)	Hypothesis	Success criteria
RQ-01	Validate that the metamodeling methodology will allow for a more efficient exploration of the simulation input-output space	Will the results obtained by the metamodel methodology provide more informative input-output data in a more timely manner than the respective miscrosimulation tools?	Once the metamodel has been trained, it will allow the exploration of solutions not directly executed in the micromodel tool.	The number of input-outputs data obtained by metamodels will be larger than with micromodels and will constitute a reasonably good approximation for the real simulated data. Note that the concern for a balanced trade-off between minor accuracy loss and the

ID	Rational	Research Question (RQ)	Hypothesis	Success criteria
				metamodel's computational performance should always be present
RQ-02	Validate the benefit of the metamodel ability to find extreme cases for each KP	Will the information on the extreme cases for each KPI impacted be more valuable than information obtained solely by microsimulation model?	The efficient input space exploration underpinning the metamodels will enable and enhance the identification of the inputs, and their corresponding values, for which one can expect the worst and best performance for each KPIs.	The extreme cases for each KPI will be found for each specific scenario run by the metamodels. This feature might not be available by micromodelling approach.
RQ-03	Validate the benefit of the metamodelling methodology when deployed as part of an optimisation process	Will the active learning method show benefit of driving the optimisation search in the space of targeted KPIs?	With a selective search combining exploration and exploitation, the active learning can be considered as a heuristic to drive the optimisation search in the space of solutions.	If feasible, metamodels will provide the result of the process that aims to optimise the inputs to obtain targets to KPIs. This feature might not be available by the micromodelling approach.
RQ-04	Validate the benefits of the metamodels to provide the information on uncertainty on their predictions	Will the information on uncertainty (lower and upper bounds, variance, quantiles, etc.) help to take a more informed decision on specific KPAs and their respective targets?	The information on uncertainty provided by metamodels will be supportive and informative enough in the decision-making process.	The statement will be validated based on the feedback obtained from the experts from the Advisory Board who will assess the benefits.

Table 24 - Research questions assessed in the different scenarios

Solution	A set of RQs addressed
PJ. 01-01: Extended arrival management with overlapping AMAN operations and interaction DCB and CTA	• What are the airports of the network where E-AMAN should be deployed to maximise the benefit-cost ratio? • What kind of strategic horizon can be expected to be efficient given the level of uncertainty on flights departure/arrival?

Solution	A set of RQs addressed
PJ.02-08: Traffic optimisation on single and multiple runway airports	• What is the cost benefit on runway overall throughput as well as airlines operations predictability and efficiency?
PJ.07-02: Airspace user fleet prioritisation (UDPP)	• How allow inter-airline exchange of slots in a fair, simple, and efficient manner?
PJ.08-01: Management of dynamic airspace configurations (DAC)	• What are the overall benefits of an optimal airspace adjustment to traffic demand on airlines operations and en-route capacity in contrast to other ATFCM measures?
PJ.09-03: Collaborative network management	• How to design multi-resource allocation in order to have consistent and harmonised prioritisation processes throughout the airspace? • How to balance flexibility for airspace users and predictability for NM/ANSPs?

8 Next step and look ahead

The deliverable has presented the framework which thoroughly describes the preliminary specification of case studies (i.e. SESAR solutions) addressing the performance assessment of new SESAR Solutions at ECAC level. As presented in this document, the project will follow an incremental development for both metamodelling methodology and scenarios to be modelled. The former will be evaluated and refined iteratively in the light of the results obtained during the development and execution of the different case studies. The development in this project has already started as a part of WP3: Methodology Definition and Metamodelling Toolset with the set of test cases aiming to provide evidences on technical feasibility of metamodels proposed. The results that will contain both the architecture and the interfaces will be presented in **the first workshop** to get the feedback of the experts.

The particularisation of scenarios continues with ad-hoc interactions with representatives of the SESAR JU. Data acquisition and preparation have already started and will be continued in order to execute the different scenarios designed and prioritised. This data acquisition includes the dataset required for the simulation of the micromodel tools and training the active learning models as as part of WP5: *Model development and Calibration*, and substantial work has been already performed in the selection of datasets required to model the different scenarios. **Simplified two test-cases** have been already produced for the lean verification of a metamodel prototype to evaluate the proposed architecture.

The consortium aims at having the preliminary metamodels fully developed (constructed) and released by the end of July 2021. Therefore, the first results from the preliminary release of the ATM performance metamodels can be ready for further analysis in WP7: *Models Evaluation and Benchmarking*. In the light of these results, the preliminary definition of the case studies will be updated (e.g., to further investigate questions identified during the first validation exercises that may have been overlooked in the case studies initially defined, etc.). The outcome of the benchmarking analysis will be used during the **2nd NOSTROMO Stakeholder workshop** scheduled for September 2021. The final specification of the case studies will also consider as input the feedback obtained in the 2nd NOSTROMO Stakeholder Workshop organised by WP8: *Communication, Dissemination and Exploitation*, which will be used to disseminate the initial project findings. Due to the COVID-19 outbreak, all these interactions with the SESAR JU team and the Advisory Board members might be arranged through online meetings. Finally, the results and conclusions of the evaluation and benchmarking activities will be used to develop a **consolidated set of guidelines and applicability methodology** for the integration of the NOSTROMO models and tools into the three pillars of the E-OCVM framework and SESAR IR programme, and compiled in D7.2 - Evaluation of the NOSTROMO Performance Evaluation Toolset and Implementation Guidelines (due in M22). The results will particularly serve as a valuable input to the regulatory bodies who will be able to define the validation targets more accurately for many different KPIs at the ECAC level, avoiding in this way the fuzziness and arbitrariness in the evaluation inbuilt into the expert judgement process.

9 References

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Appendix A

A.1 Specification of "zero" test case – Mercury

Table 25 - General information on the test case simulated by Mercury

Test case title	Objective of test case	Gap to be solved/improved by test case
Impact of different turn-around processes	See how the typical turn-around times have a sytemic impact on the system. In reality, airlines adapt their behaviours strategically to changing turn-around times. Here, the objective is to estimate how much it would cost (and what is the impact on the network) if they don't adapt their behaviours strategically.	Catch systemic effects due to knock-on effects.

Table 26 – Description of input variables by Mercury

Input variable	Name in model	Parametrisation	Theoretical range	Practical range	Default	Priority	Status
Turn-around time	alpha_tat_mean	Proportional increase in exponential location and lambda parameter.	[0, infinity)	[0, 5]	1	1	✔
Fuel price	fuel_price	Absolute price	[0, infinity)	[0.1, 10] (Note: euros.kg-1)	0.5	3	✔
Cost of delay function		Linear coefficient, quadratic coefficient, knock-on effect multiplier				6	✖
Regulation delay level		By quantiles	[0, 100]			4	✖
Flight plan choice	anchor	Anchor: tendency to keep old	[0, 1]	Roughly the same	0.3	7	✔

Input variable	Name in model	Parametrisation	Theoretical range	Practical range	Default	Priority	Status
	smoothness	flight plan even if a better one is available (after a disruption) Smoothness of logit choice	(0, infinity)	(100., 10000.)	200.		
Wait for passenger	wait_for_passenger_thr	Delay threshold after which the airline does not wait for passengers.	[0, infinity)	[0, 45]	15	8	✓
Cost index choice	dci_min_threshold dci_max_threshold dci_p_bias	Threshold min: if the flight delay is under this threshold, company uses minimal speed Threshold max: if the flights delay is above this threshold, company uses maximal speed. Bias: starting point of speed at min threshold.	[0., infinity) [threshold_ min, infinity) [0, 1]	[0., 60.] [threshold_ min, 90.] [0, 1]	15 60 0.2	9	✓
Non-ATFM delay	alpha_non_ATFM	Proportional increase in exponential lambda parameter.	[0., infinity)	[0, 2]	1	2	✓

Input variable	Name in model	Parametrisation	Theoretical range	Practical range	Default	Priority	Status
Ad hoc cancellations	p_cancellation	Proportion of random cancelled flights	[0, 1]	[0, 0.2]	0.02	10	✓
Passenger compensation	first_compensation_threshold claim_rate alpha_compensation_magnitude	Threshold (min) claim compensation Percentile pax claiming compensation Proportional increase of compensation	[0, infinity) [0, 1] [0, infinity)	[0., 240] [0, 1] [0, 5]	180 0.11 1	11	✓
Airports with ATFM disruption		Number of airports with disruption	[0-800]			5	✗

Table 27 – Description of candidate output metrics to learn by Mercury

Candidate output metrics to learn	Comment	Priority	Relationship with KPAs	Status
Flight delay	Average, std, 90th perc. Arrival, Departure	1	Capacity	✓
Cost of delay	Average, std, 90th perc.	1	Cost efficiency/operational efficiency	✓
Cost of fuel	Average, std, 90th perc.	3	Operational efficiency	✓
Flight delay per types of company	Average, std	3	Capacity	✓
Proportion of flights cancelled		2	Capacity	✓
Equity metrics for flights (delay, cost)	For now, approximated by std of flight arrival delay	3	Equity and Fairness	✓

Candidate output metrics to learn	Comment	Priority	Relationship with KPAs	Status
Passenger delay	Average, std, 90th perc. Connecting/non-connecting pax	1	Passanger	✓ ✓
Ratio flight-passenger delay	Average	3	Passenger	✗
Proportion of disrupted trips		2	Passenger	✓
Network metrics (note: not sure we can do this for the TC, maybe for later cases)	Trip centrality? Causality density?	3	--	✗

A.2 Specification of "zero" test case – FLITAN

Table 28 - General information on the test case simulated by FLITAN

Test case title	Objective of test case	Gap to be solved/improved by test case
Impact of European airport capacity on network performance	The objective of the proposed test case is to assess the ability of European airports to handle various traffic growth scenarios with emphasis on capacity and efficiency for the 2050 timeframe.	Several simulation runs will be carried out to evaluate the efficiency of the airport integration as nodes into the air transport network and provide the basis for the development of fully scalable solutions that meet the requirements of future air travel performance targets. The analysis will focus on some of Statfor's Challenges of Growth scenarios namely scenario A (Global Growth), Scenario C (Regulation and Growth), Scenario C' (Happy Localism) and Scenario D (Fragmenting world)

Table 29 - Description of input variables by FLITAN

Input variable	Possible parametrization of input variable	Range of input variable	Priority
Airport Number of runways	It provides the number of runways at the simulated airport	No restriction is imposed on input variable	1
Airport Maximum Simultaneous Arrivals	It provides the number of flights that can arrive at the same time	No restriction is imposed on input variable	1
Airport Maximum Simultaneous Departures	It provides the number of flights that can depart at the same time	No restriction is imposed on input variable	1
En-Route Flight Time Distribution	It provides the flying time distribution type, including mean and standard deviation, from an origin airport to a destination airport based on aircraft types.	No restriction is imposed on input variable	2
TMA Departure Transit Time distribution	It provides the departure TMA's transit time distribution type, including mean and standard deviation, based on aircraft types	No restriction is imposed on input variable	1
TMA Arrival Transit Time distribution	It provides the arrival TMA's transit time distribution type, including mean and standard deviation, based on aircraft types	No restriction is imposed on input variable	1
Runway Occupancy time distribution	It provides the runway's transit time distribution type, including mean and standard deviation, based on aircraft wake categories	No restriction is imposed on input variable	1
Taxi-out time distribution	It provides the runway's taxi-out time distribution type, including mean and standard deviation, based on aircraft wake categories	No restriction is imposed on input variable	3
Taxi-in time distribution	It provides the runway's taxi-in time distribution type, including mean and standard deviation, based on aircraft wake categories	No restriction is imposed on input variable	3
Flight information and schedule	It contains flight specific information regarding its departure time, departure airport,		1

Input variable	Possible parametrization of input variable	Range of input variable	Priority
	departure runway, arrival airport, arrival runway, aircraft type, wake category, etc.		

Table 30 - Description of candidate output metrics to learn by FLITAN

Candidate output metrics to learn	Comment	Priority	KPAs/KPIs to be assessed
Gate-to-Gate time	Gate-to-Gate time can be derived from the other output metrics	5	Airport capacity
Taxi-out time		3	Departure delay
Departure runway queue time		1	Arrival delay
Departure runway occupancy time		1	
Departure TMA time		1	
En-route time		2	
Arrival TMA time		1	
Arrival runway queue time		1	
Taxi-in time		3	