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COMPAIR

COMPETITION FOR AIR TRAFFIC MANAGEMENT

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Abstract

The purpose of this document is to define an assessment framework allowing the evaluation of the different institutional designs proposed by COMPAIR in a consistent and comparable manner throughout the entire project. The assessment framework will be an input for the specification of the outputs of the COMPAIR models. This will ensure that the same indicators are defined in a consistent manner across the different models, so that we can benefit from the synergies and complementarities between such models.

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Executive summary

The goal of COMPAIR is to study how to introduce competitive incentives in ATM so as to best contribute to achieving the European high-level policy objectives for aviation. The successful introduction of competition requires a comprehensive impact analysis of different regulatory approaches along a variety of dimensions. The purpose of this document is to define an assessment framework allowing the evaluation of the different institutional designs proposed by COMPAIR in a consistent and comparable manner throughout the entire project. The assessment framework will be an input for the specification of the models to be developed by COMPAIR. This will ensure that the same indicators are defined in a consistent manner across the different models.

The same or similar performance areas being referred by different names in the literature, the COMPAIR assessment framework establishes a common understanding of a set of relevant concepts. We aim to be as consistent as possible with those used by the ICAO Performance Framework, the SES Performance Scheme and the SESAR Performance Framework.

- A **key performance area** (KPA) is defined as a broad focus area encompassing one or several goals or objectives.
- **Performance indicators** are defined as a means of measuring and/or summarising the current position and the direction and rate of change of progress towards a particular goal or objective.
- The term **key performance indicators** (KPI) is reserved for those performance indicators used for the purpose of performance target setting, in line with the interpretation of the SES and SESAR.
- Indicators are calculated by means of **supporting metrics** according to certain formulas.
- Finally, **influence factors** are defined as particular characteristics or parameters that help determine and/or drive performance.

The COMPAIR assessment framework has been defined with the goal of capturing the full range of economic, social and environmental impacts of the different institutional designs under study. For this purpose, we have first selected the subset of the indicators defined by the ICAO Performance Framework, the SES Performance Scheme and the SESAR Performance Framework that are considered more relevant to COMPAIR. Then, we have complemented these indicators with additional indicators aimed to capture dimensions that fall outside the scope of the three aforementioned performance schemes, but are considered necessary for a comprehensive assessment framework.

The COMPAIR assessment framework comprises two sets of KPAs and associated performance indicators:

- a first set of higher level, more aggregated economic KPAs and indicators, encompassing economic efficiency, distributional effects, and one additional KPA measuring the resilience of the rest of economic indicators vis-à-vis a pre-defined set of disturbances;
- a second set of operational KPAs and indicators, composed by a selection of those KPAs proposed by the ICAO performance framework, the SES performance scheme and the SESAR performance framework that are expected to be potentially influenced in a significant manner by the institutional frameworks analysed by COMPAIR, and one additional KPA measuring the resilience of the rest of operational indicators vis-à-vis a pre-defined set of disturbances.

Additionally, we propose to evaluate a number of influence factors that, even if they are not policy objectives per se, are considered particularly relevant to understand the effect of the different institutional frameworks under study on the proposed KPAs. These influence factors are grouped into three focus areas: competition, collaboration & interoperability and stakeholders' opinion.



1. Introduction

1.1 Goal of COMPAIR

Since 2004, the European Union gained competences in ATM. The Single European Sky (SES) initiative aims to re-structure the European airspace as a function of air traffic flows, create additional capacity and increase the efficiency of the ATM system. This in order to cope with sustained traffic growth under safe, cost-efficient and environmentally friendly conditions. The political objective of the SES is to achieve a future European ATM system which can, relative to 2005 performance, enable a three-fold increase in ATM capacity; improve safety performance by a factor of 10; enable a 10% reduction in the effects flights have on the environment; and provide ATM services to airspace users at a cost of at least 50% less. Today's progress towards these objectives is perceived as slow: the steps taken towards enhanced collaboration between air navigation service providers (ANSPs) are sometimes considered ineffective; the implementation of functional airspace blocks (FABs) to defragment the European landscape of national ANSPs and enable economies of scale has had limited success; and the Research & Innovation cycle is still too long. In this context, the question of how to provide the appropriate organisational structures, institutions and incentives for new operational concepts and technologies to yield the expected results stands high on the policy agenda.

The introduction of competition has been proposed as a means to provide the right incentives for the realisation of the high-level objectives of the SES, through the speed up of the innovation cycle and the fostering of more efficient operations. On the other hand, competition does not prevent every market failure (e.g., negative externalities) and, depending on market conditions, liberalisation can also have undesired outcomes, such as the emergence of oligopolies or monopolies. The goal of COMPAIR is to study how to introduce competitive incentives in ATM so as to best contribute to achieving the European high-level policy objectives for aviation. The project objectives are:

1. Propose a set of new institutional market designs for the introduction of competition in the European ATM sector.
2. Define a framework allowing a comprehensive assessment of the impact of different institutional market designs.
3. Develop a variety of economic and network simulation models allowing the assessment of the proposed approaches.
4. Assess the feasibility and acceptability of the proposed institutional changes for various market actors.
5. Propose a vision for the implementation of the most desirable institutional structures.

This deliverable focuses on the second objective: defining an assessment framework which enables the comparison of different institutional designs in a consistent manner throughout the project.

1.2 Scope and objectives of the deliverable

Competition does not exist abstractly, but is influenced by the legal and regulatory framework, and can be introduced at various levels and in different ways. Hence, the successful introduction of competition requires a comprehensive impact analysis of different regulatory approaches along a variety of dimensions. The purpose of this document is to define an assessment framework allowing the evaluation of the different institutional designs proposed by COMPAIR in a consistent and comparable manner throughout the entire project.

COMPAIR is to a large extent a modelling project. In view of the complexity of the problem under study, the project has adopted an eclectic approach. A variety of models will be developed to study the potential benefits and the risks of several market designs from different perspectives. The assessment framework will be an input for the specification of the outputs of the COMPAIR models. This will ensure that the same indicators are defined in a consistent manner across the different models. This way we can benefit from the synergies and complementarities between such models. This does not necessarily mean that all models shall be able to produce all the indicators proposed in the COMPAIR assessment framework: different modelling paradigms may produce different subsets of indicators. There may even be certain indicators which are not included in any of the models (either because they are subject to more qualitative considerations, because there is not enough information, or because they cannot be modelled in a reliable manner), but that still are worth considering for providing a complete picture of the implications of the institutional frameworks under study.

1.3 Acronyms and terminology

The same or similar performance areas being referred by different names in the literature, in this document we aim to establish a common understanding of a set of relevant concepts. The concepts and terminology used intend to be as consistent as possible with those used by the ICAO Performance Framework (ICAO, 2008), the SES Performance Scheme (EU, 2013) and the SESAR Performance Framework (SESAR JU, 2015a).

1.3.1 Acronyms

Acronym	Definition
ANSP	Air Navigation Service Provider
ARES	Airspace Reservation / Restriction
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATFM	Air Traffic Flow Management
BIC	Best In Class
CBA	Cost-Benefit Analysis



Acronym	Definition
CDR	Conditional Route
DUC	Determined Unit Cost
EU	European Union
FAB	Functional Airspace Block
GAT	General Air Traffic
ICAO	International Civil Aviation Organization
JC	Just Culture
KPA	Key Performance Area
KPI	Key Performance Indicator
OECD	Organisation for Economic Co-operation and Development
RAT	Risk Assessment Tool
RBT	Reference Business Trajectory
RWY	Runway
SES	Single European Sky
SESAR	Single European Sky ATM Research Programme
TMA	Terminal Manoeuvring Area

1.3.2 Concepts and definitions

The **COMPAIR assessment framework** is the set of key performance areas, performance indicators and supporting metrics that will be used to evaluate and compare the different institutional designs proposed by COMPAIR.

A **key performance area (KPA)** can be defined as a broad focus area encompassing one or several goals or objectives. Key Performance Areas are a way of categorising performance subjects as a function of the high level ambitions and expectations they relate to (ICAO, 2008).

Performance indicators can be defined as a means of measuring and/or summarising the current position and the direction and rate of change of progress towards a particular goal or objective. To be relevant, indicators need to correctly express the intention of the associated performance objective. The use of indicators for the control and monitoring of processes:

- helps evaluate and monitor developments,
- focuses the discussion with stakeholders,
- promotes the idea of integrated action,
- demonstrates progress towards goals and objectives, and
- ultimately supports decision-making.

Although the terms performance indicator and key performance indicator are often used as synonyms in other contexts, both the SES Performance Scheme and the SESAR Performance Framework differentiate between them: in the context of SES and SESAR, the term **performance indicators (PIs)** means the indicators used for the purpose of performance monitoring, benchmarking and reviewing, while the term **key performance indicators (KPIs)** is reserved for those performance indicators used for the purpose of performance target setting.

Indicators can be classified according to many different criteria. We will classify indicators according to the following categories:

- **Quantitative Indicators vs qualitative indicators:**
 - Quantitative indicators use numbers and express amounts or quantities.
 - Qualitative indicators use words, symbols or colours to express attitudes and views.
- **Local indicators vs global indicators:**
 - Local indicators are measured at airport/national/FAB level.
 - Global indicators are measured at network level¹.
- **System-wide indicators vs stakeholder-specific indicators:**
 - System-wide (or social) indicators are measured at societal level (e.g., social welfare).
 - Indicators linked to a specific stakeholder (e.g., airline surplus).

While performance indicators measure progress towards policy objectives (i.e., variables one wants to optimise in the system), other indicators provide useful information about the system (e.g., they may have an influence on their evolution), but are not policy objectives per se. Such indicators are sometimes referred to as intermediate indicators or process indicators. To be consistent with the terminology used by the SESAR performance framework, we will refer to these indicators as influence factors. An **influence factor** is considered to be a particular characteristic or parameter that helps determine and/or drives performance (SESAR JU, 2015a).

Indicators are not often directly measured. They are calculated by means of **supporting metrics** according to certain formulas, e.g. cost-per-flight-indicator = $\text{Sum}(\text{cost})/\text{Sum}(\text{flights})$. Performance measurement is done through the collection of data for the supporting metrics (ICAO, 2008). Metrics are not necessarily indicator-specific; but they can be used to calculate a variety of indicators.

Cost-benefit analysis (CBA) is a systematic process for calculating and comparing benefits and costs of a policy decision. benefits and costs are expressed in monetary terms and adjusted for the time value of money, so that all benefits and costs over time are expressed on a common basis in terms of their net present value.

Economic efficiency measures the ratio between the total social welfare created and the maximum welfare that could be created.

¹ In the context of COMPAIR, global indicators will be evaluated at the level of the European network, most likely through a simplified/reduced model of the whole network.

Social welfare is the sum of consumer and producer surplus and net benefits to third parties (externalities).

Distributional analysis measures the way total benefits and costs are distributed among different stakeholders.

1.4 Structure of the document

The document is organised as follows:

- Section 1 described the scope and objectives of the deliverable and defined the key concepts used in the rest of the document.
- Section 2 discusses the requirements to be met by a meaningful and comprehensive performance framework, and summarises the main inputs and the guiding principles that have been taken into consideration for defining the COMPAIR assessment framework.
- Section 3 presents the proposed assessment framework.
- Section 4 summarises the main conclusions of the work done and explains how the COMPAIR performance framework will be used and maintained throughout the project.

2. Properties, inputs and guiding principles

2.1 Required properties

There is abundant literature on the requirements to be met by a performance framework to properly achieve its intended functions. Ill-defined indicators can result in misinterpretations or inconsistencies, preventing a comprehensive comparison of policy alternatives. We consider that the COMPAIR assessment framework should have the following properties:

- the framework should be comprehensive, i.e. encompass the full range of economic, social and environmental impacts of the different institutional designs under study;
- performance indicators should be relevant to the target they intend to measure;
- indicators should be measurable, in a quantitative or at least in a qualitative way;
- it should be understandable to all stakeholders;
- the dependencies between performance indicators should be clearly identified.

When using indicators for the ex-post evaluation of real-world situations, a property often cited in the literature is that indicators should be measurable based on available and reliable data. We will somewhat relax this constraint. The reason is that, while most indicators are typically easier to measure in an operational environment than to assess ex-ante (e.g., delay indicators), there may be other indicators that may be very difficult or impossible to measure in practice, but can however be relevant for the ex-ante assessment of policy options and can possibly be evaluated by means of the analytical and simulation models developed by COMPAIR (e.g., resilience indicators).

2.2 Main inputs for the definition of the assessment framework

The COMPAIR assessment framework intends to be as consistent as possible with the ICAO Performance Framework (ICAO, 2008), the SES Performance Scheme (EU, 2013) and the SESAR Performance Framework (SESAR JU, 2015a). For this purpose, we have reviewed the three performance schemes to identify those KPAs/KPIs that are considered relevant for COMPAIR (see section 2.2.1). Since the KPAs/KPIs defined in these performance schemes have a strong operational focus, we have then reviewed other documents that can provide useful inputs on how to consolidate operational indicators into higher level, more aggregated economic indicators. In particular, we have reviewed the Standard Inputs for EUROCONTROL Cost-Benefit Analyses (EUROCONTROL, 2015) (section 2.2.2) and a previous SESAR WP-E project in the field of Economics, the ACCESS project (section 2.2.3). Finally, in order to derive other KPAs/KPIs that are not considered in the aforementioned references but can be necessary/useful for a comprehensive impact assessment, we have analysed the academic literature about competition and market designs in different sectors (section 2.2.4) and the stakeholder consultation carried out in the frame of COMPAIR (section 2.2.5).

2.2.1 ICAO Performance Framework, SES Performance Scheme and SESAR Performance Framework

2.2.1.1 ICAO Performance Framework

ICAO has identified 11 KPAs in the ATM system suitable for monitoring performance. These are described in ICAO's Manual on Global Performance of the Air Navigation System (Doc 9883) (ICAO, 2008). The major operational performance KPAs are cost effectiveness, safety, capacity and efficiency. Other KPAs are directly related to these (e.g., environment and predictability are closely related to capacity and efficiency). As part of the elaboration of the Global Performance Manual, a comparison of ATM performance indicators in use by different organisations was undertaken by ICAO in order to determine if an example set of indicators could be derived. The investigation yielded no identical indicators, although some commonality was identified in certain indicators. The main results of this investigation are summarised in Table 1.

Table 1. ICAO Key Performance Areas and Key Performance Indicators. Source: CANSO (2015).

KPA	KPIs
Access and Equity	- Unsatisfied demand versus overall demand.
Capacity	- Number of flights or flight hours that may be accommodated. <i>Separate measures for airspace and airport.</i> <i>Values may be specific for a weather condition.</i>
Cost Effectiveness	- Average ATM cost per flight. - Total operating cost plus cost of capital divided by IFR flights. - Total labour obligations to deliver one forecast IFR flight. <i>All of the above using flight hour instead of flight to normalise for flight duration.</i>
Efficiency	- Percentage of flights departing on-time. - Percentage of flights with on-time arrival. - Average departure delay per delayed flight. - Percentage of flights with normal flight duration. - Average flight duration extension of flights with extended flight duration. - Total number of minutes to actual gate arrival time exceeding planned arrival time. <i>For all of the above consider 1) ATM caused delay, 2) target time for delay (filed or schedule) and 3) delay threshold value.</i>
Environment	- Amount of emissions attributable to ATM inefficiency. - Number of people exposed to significant noise. - Fuel efficiency per revenue plane-mile.
Flexibility	- Number of rejected changes to the number of proposed changes to the number of flight plans initially filed each year. - Proportion of rejected changes for which an alternative was offered and taken.
Global Interoperability	- Number of filed differences with ICAO Standards and Recommended Practices. - Level of compliance of ATM operations with ICAO CNS/ATM plans and global interoperability requirements.
Participation by ATM Community	- Number of yearly meetings covering planning, implementation and operations.
Predictability	- Closely related to delay measures under efficiency. - Possible refinement to delay measures by phase of flight.

KPA	KPIs
Safety	- Number of accidents normalised to number of operations or number of flight hours.
Security	<ul style="list-style-type: none"> - Number of acts of unlawful interference to ATC. - Number of incidents involving direct unlawful interference to aircraft that require air traffic service provider response. - Number of incidents due to unintentional factors such as human error, natural disasters, etc., that have led to unacceptable reduction in capacity.

2.2.1.2 SES Performance Scheme

The SES Performance Scheme seeks to enhance the performance of Air Navigation Services in Europe by adopting EU-wide performance targets for fixed reference periods, requiring States to adopt binding Performance Plans that are consistent with EU-wide targets, monitoring achieved performance against agreed targets, and taking corrective actions as required (EU, 2013). The Performance Scheme encompasses four KPAs: safety, capacity, cost efficiency and environmental flight efficiency. The performance targets associated to the indicators are set both at EU-wide level and National/FAB level. These targets are legally binding for EU Member States. The Performance Scheme distinguishes between KPIs, which are performance indicators with a target assigned, and PIs, used for transparency reasons/monitoring purposes.

Table 2. SES II Key Performance Areas and Performance Indicators

KPA	KPIs	PIs
Safety	<ul style="list-style-type: none"> - Effectiveness of safety management. - Application of severity classification scheme (Risk Analysis Tool (RAT) methodology). - Application of Just Culture (JC). 	<ul style="list-style-type: none"> - Separation infringements. - Runway incursions. - ATM-specific occurrences (i.e., technical occurrences affecting the capability to provide safe ATM/ANS services). - Airspace infringements. - Level of occurrences reporting. - Application of automatic data recording for separation minima infringement monitoring. - Application of automatic data recording for runway incursion monitoring.
Environment	<ul style="list-style-type: none"> - Horizontal flight efficiency of last filed flight plan (KEP). - Horizontal flight efficiency of actual trajectory (KEA). 	<ul style="list-style-type: none"> - Effectiveness of booking procedures for flexible use of airspace. - Rate of planning of CDRs. - Effective use of conditional routes CDRs. - Additional time in taxi-out phases (related to outbound traffic). - Additional time in terminal airspace (related to inbound traffic)
Capacity	<ul style="list-style-type: none"> - En-route ATFM delay. - Arrival ATFM delay. 	<ul style="list-style-type: none"> - ATFM slot adherence. - ATC pre-departure delay.
Cost efficiency	<ul style="list-style-type: none"> - Determined Unit Cost (DUC) for en-route-ANS. - Determined Unit Cost (DUC) for terminal ANS. 	<ul style="list-style-type: none"> - Costs of Eurocontrol.



2.2.1.3 SESAR Performance Framework

SESAR performance targets are related to, but not the same as, the SES Performance Scheme targets. While the SES Performance Scheme is used for regulatory purposes and drives performance improvement in the deployed system, the SESAR Performance Framework (SJU, 2015a) aims to steer the overall Research & Innovation work in respect of the Performance Ambitions set in the European ATM Master Plan (SJU, 2015b). SESAR Performance Ambitions are presented as ranges to reflect the uncertainty implied by the long timeframe, and are aspirational rather than binding. These Performance Ambitions are mapped with the so-called SESAR Performance Expectations, which represent the main performance enhancements expected from SESAR concept components. These high-level Performance Ambitions and Expectations at ECAC-level are then broken down into Validation Targets that are allocated to SESAR Solutions. The operational improvements brought by SESAR Solutions are assessed for performance benefits and expected costs and benefits for key stakeholders, and are then extrapolated into general ECAC-wide figures in order to feed a Business Case process.

The SESAR 2020 Performance Framework, which includes a refined set of KPAs and indicators with respect to SESAR 1, is based on the set of KPAs of the ICAO Performance Framework, with several adaptations to support SESAR requirements. Each KPA has one or more Focus Areas, and two additional, cross-cutting Focus Areas are also defined (Civil-Military Coordination and Human Performance) due to considering that they relate to multiple KPAs and cannot be assigned to simply one. As in the SES Performance Scheme, a distinction is made between KPIs (i.e., those performance indicators that have associated validation targets) and PIs (i.e., those that shall also be measured, where relevant, but are not used for target setting).

Table 3. SES II SESAR 2020 KPAs, Focus Areas and KPIs

KPAs	Focus Areas	KPIs	PIs
Access and Equity	-	-	-
Capacity	Airspace capacity	- CAP1: TMA throughput, in challenging airspace, per unit time - CAP2: En-route throughput, in challenging airspace, per unit time	- TMA Increased Throughput (CAP1.1) - En-Route Increased Throughput (CAP2.1)
	Airport capacity	- CAP3: Busy hour throughput at best-in-class airport	- Peak Departure throughput of already BIC airport per hour (CAP3.1) - Relative increase of RWY throughput of already BIC airport (CAP3.2) - Peak Arrival throughput of already BIC airport per hour (CAP3.3)
	Resilience	- RES1: % Loss of airport capacity avoided - RES2: % Loss of airspace capacity avoided	- Airport time to recover from non-nominal to nominal condition (RES3.1) - Airspace time to recover from non-nominal to nominal condition (RES3.2) - Minutes of delay and number of cancellations (RES4)

KPAs	Focus Areas	KPIs	PIs
Cost efficiency	ANS Cost efficiency	- CEF2: Flights per ATCO hour on duty - CEF3: Technology Cost per flight	-
	Airspace User Cost efficiency	-	- Direct operating costs for an airspace user (AUC1) - Indirect costs for an airspace user (AUC2) - Overhead costs for an airspace user (AUC3)
Environment	Fuel efficiency	- FEFF1: Average fuel burn per flight	- CO2 Emissions (FEFF2) - Reduction in Average Flight Duration (FEFF3)
	Noise	-	- Relative noise (NOI1) Size of noise contours (NOI2)
	Local air quality	-	- Geographic distribution of pollutant concentrations (LAQ1)
-	Human Performance	-	- Role consistency (HP1) - Usability (HP2) Supportive team structure (HP3) - Transition feasibility (HP4)
Flexibility	-	-	-
Predictability and punctuality	Variance of actual and reference business trajectories	- PRD1: Variance of differences between actual and flight plan or Reference Business Trajectory (RBT) durations	-
	Departure punctuality	- PUN1: % of Flights departing (Actual Off-Block Time) within +/- 3 minutes of Scheduled Off-Block Time after accounting for ATM and weather related delay causes	-
Safety	Accidents/incidents with ATM contribution	- SAF1: Accidents and incidents with ATM contribution per year	-
Security			- Security risk mitigation (SEC1) Residual security risk (SEC2)
	Civil-Military Cooperation and Coordination		- Transit Distance from base to ARES (CMC1.2) - Offered fuel and distance saving (for GAT operations) (CMC2) - Optimality of ARES Design, Allocation & Capacity (CMC3.1) - % GAT flights using ARES / GAT flights for which ARES is available (CMC4.2) - Available training duration within ARES (CMC5)

2.2.1.4 Relationship between ICAO, SES and SESAR KPAs

The following figure summarises the relationship between ICAO, SES and SESAR KPAs:

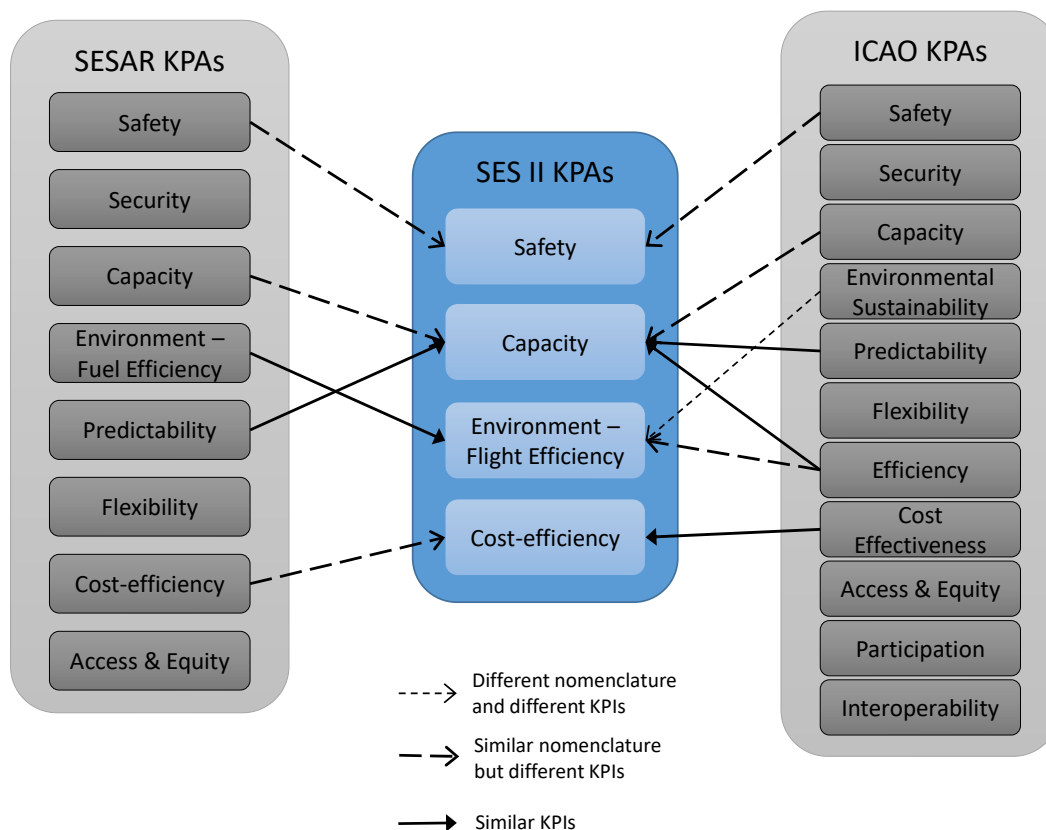


Figure 1. Relationship between ICAO, SES and SESAR 2020 KPAs
 (Source: ALG, ACCESS project – revised for SESAR 2020 performance framework)

2.2.1.5 Relevance of ICAO, SES and SESAR performance frameworks to the COMPAIR project

The ICAO, SES and SESAR performance frameworks provide a detailed list of KPAs that allow a comprehensive characterisation of ATM performance at the operational level. The SES Performance Scheme and the SESAR Performance Frameworks are based on the ICAO Performance Framework, with some differences in the terminology used and the number of KPAs considered (see Figure 1). Considering that COMPAIR is a project funded in the frame of SESAR, and that the SESAR performance framework is the one providing the most comprehensive set of KPAs and KPIs, the COMPAIR assessment framework will adopt, wherever possible, the nomenclature used by SESAR. The indicators defined by ICAO and the SES performance schemes will be considered only when they provide some added value with respect to the ones defined by SESAR.

Taking into account the scope and objectives of COMPAIR, the relevance of the different KPAs and KPIs defined by the SESAR performance framework is discussed below:

- Safety and security are explicitly excluded from the analysis conducted by COMPAIR, as the methods required for assessing such KPAs are out the scope of the project.
- COMPAIR aims to carry out an economic assessment of different institutional market designs. Capacity and cost-efficiency are the KPAs that are most relevant to COMPAIR, as both are expected to be significantly influenced by the introduction of competition and their assessment is considered indispensable for the economic assessment. The SESAR KPIs and PIs are useful inputs for the computation of high level, aggregated economic indicators.
- The environment and predictability KPAs are also relevant for the economic assessment, since both the cost of fuel and the cost of delay are important inputs for assessing airline costs. In the case of environment, SESAR fuel efficiency indicator will be a useful input. In the case of predictability, what is most important for COMPAIR is the cost of delay, and therefore we consider that, in addition to the departure punctuality indicators considered by the SESAR performance framework, arrival punctuality indicators are also needed.
- Flexibility addresses the ability of the ATM system to respond to changes to planned flights. As of today, there are no flexibility KPIs nor mandatory PIs within the SESAR 2020 Performance Framework because “there are currently no flexibility-related performance ambitions” and “there is currently no evidence base with which to support a programme-wide target” (SJU, 2015a).
- Access and equity is also considered relevant. A lack of equity can arise if, for example, a particular airspace user or group of airspace users is subject to additional cost or additional delay (SESAR JU, 2015a). However, as in the case of flexibility, the current SESAR 2020 Performance Framework defines no equity KPIs nor mandatory PIs. In COMPAIR, we consider that this aspect will be adequately covered by a distributional analysis of the different institutional market designs.

2.2.2 Review of EUROCONTROL Cost Benefit Analyses

The Standard Inputs for EUROCONTROL Cost-Benefit Analyses (EUROCONTROL, 2015) provides values for commonly used data items in cost-benefit analyses, together with details of the sources and a discussion of the applicability and use of the values. The costs considered in the document include airline operating costs, cancellation costs, cost of delay, cost of diversion, ANS costs, and cost of noise and pollutants. The main use of this document in the context of COMPAIR will be the obtention of the values to be used for some of the parameters of the COMPAIR models. However, the document also contains a number of considerations that can be useful for the consolidation of the impacts captured by operational indicators into more aggregated economic indicators:

- The cost of cancelling a commercial scheduled flight varies strongly with the distance between the day of cancellation and the day of operations. Therefore, indicators about cancelled flights should incorporate information about the timing of these cancellations.
- The cost of delay is an important and controversial value as it is frequently used to quantify the benefits of investments in ATM. The report recommends the monetisation of delays based on the methodology developed by the University of Westminster for the PRU (University of Westminster, 2011), and makes the following observations:



- The tactical cost of delay reflects the costs associated with ‘unplanned’ airborne delays, while strategic delay costs reflect the costs ‘planned’ into the schedule (e.g., a flight that could be performed in 1 hour is planned for 1 hour 10 minutes based on historical data which shows 10 minutes of delay). The overall value of strategic delay is lower than that of tactical delay.
- The direct cost to an airline should be used when considering the cost of delay at the network level (i.e., delay over the whole fleet for all airlines).
- The overall delay cost values should be used when considering the cost of delay to a single airline. In addition to the direct cost to an airline, the overall delay cost values include the passenger opportunity cost. This cost should not be considered when the cost of delays is analysed for the whole fleet, as the loss to one airline will, to a large extent, be a gain to another airline.
- The passenger opportunity cost implicitly comprises the passenger value of time as the latter will depend on the passenger’s acceptance of the occurred delay. Therefore, including the passenger value of time in addition to the passenger opportunity cost would be double counting.

Additionally, the document defines several KPIs of ANSPs cost-effectiveness and productivity:

- ATCO-hour productivity expressed as composite flight-hours per ATCO-hour.
- Employment costs per ATCO-hour.
- Support staff ratio: the ratio of Gate-to-gate ANS staff to ATCO in OPS.

2.2.3 Review of SESAR WP-E ACCESS project performance framework

To complement the inputs from the documentation reviewed in sections 2.2.1 and 2.2.2, we have also reviewed the work performed by a previous SESAR WPE project in the area of Economics. In particular, the SESAR WPE ACCESS project (www.access-sesar.eu) defined an assessment framework for the evaluation of different mechanisms for airport capacity allocation. Although the focus is on a different problem, some of the KPAs defined in the ACCESS performance framework (Ranieri et al., 2013) are also relevant for COMPAIR^{2,3}:

- **Economic efficiency.** Economic efficiency measures the ratio between the total social welfare created and the maximum welfare that could be created. Social welfare is the sum of consumer and producer surplus (i.e., the sum of the effects on airlines, airports and

² Although ACCESS focuses on the allocation of airport capacity and COMPAIR focuses on the provision of ATM services, many of the expected benefits (e.g., increased efficiency), risks (e.g., market failures) and policy design criteria (e.g., proper balance between efficiency in the short-term and incentives for long-term investments) analysed in ACCESS are also relevant to COMPAIR. Therefore, it has been considered interesting to review the ACCESS performance framework and analyse which elements can be reused or adapted for COMPAIR.

³ In this section we discuss those KPAs that are different from those discussed in the previous sections: the rest of KPAs included in the ACCESS performance framework (interoperability and capacity & delay) are already covered by the performance schemes presented in section 2.2.2 and therefore will not be discussed again here.

passengers) and net benefits to third parties (externalities). The property of maximising economic efficiency is often referred to as social optimality. According to economic theory, maximum efficiency is achieved only if a good is produced by the lowest cost producers and the products are consumed by the consumers with the highest willingness-to-pay. The concepts of economic efficiency and social optimality are fully applicable to the problem investigated by COMPAIR, and should therefore be included in our assessment framework. The ACCESS assessment framework also discusses some of the elements that should be taken into account when evaluating economic efficiency. These elements include the cost of operating the selected system (which in the case of COMPAIR would be equivalent to the cost of regulation implementation, financial controls and regulatory oversight) and the so-called dynamic efficiency, which is concerned with the cost of uncertainty and the trade-off between efficiency in the short and in the long term.

- **Equity and distributional issues.** The assessment of different institutional frameworks should not only address the total social welfare, but also the distributional impacts of different options, as they will alter how much different stakeholders gain or lose. Mechanisms that could in principle have the potential of increasing social welfare may raise distributional issues if they don't include appropriate compensation mechanisms. The ACCESS performance framework proposes as KPI for equity and distributional issues an indicator stating whether each stakeholder gets a non-negative utility (surplus). To compute such indicator, it is in turn necessary to measure stakeholder-specific indicators which account for the surplus per stakeholder (i.e., total benefit minus costs per stakeholder).
- **Access and competition.** Two main ingredients necessary for a competition environment are identified: first, market regulation should be set in a way that does not hamper competition; second, anticompetitive behaviours should be prohibited and punished within an effective antitrust framework. The project reviews the indicators developed by institutions like the OECD to measure the institutional quality of competition regimes (Alemani et al., 2013), mainly qualitative indicators aiming to measure the ability to discover, stop and punish anticompetitive behaviours. It is also argued that, in some cases, the maximisation of social welfare may occur for a high level of market concentration. On the other hand, market concentration naturally increases the risk of anticompetitive behaviours. This suggests the idea that competition should not be considered as a KPA, but a focus area grouping certain influence factors (e.g., market concentration) which have an effect on performance indicators.
- **Flexibility, resilience and adaptability.** Flexibility, as defined by ICAO, addresses the ability of airspace users to modify flight trajectories dynamically and adjust departure and arrival times to exploit operational opportunities. While the ICAO concept is restricted to operations at the tactical level, the ACCESS performance framework uses flexibility in a wider sense, covering the ability to modify the trajectory at its different instantiations, from the strategic phase across the collaborative layered planning process, to the tactical phase, in order to cater for a changing environment. The concept is related to that of resilience, which is defined as the ability of a system to absorb disturbances and reorganise so as to retain its basic structure and functions. Flexibility, resilience and adaptability are seen as a sort of “metaKPA” which measures the ability of the system to retain its performance vis-à-vis changing conditions.

2.2.4 Literature review

COMPAIR has conducted a literature review on possible institutional/regulatory approaches for the introduction of competition in ATM, including a review of experiences in other industries⁴. From the analysis of the potential benefits and risks of different institutional designs pointed out in the literature, we have derived a number of elements that shall be taken into account for the definition of the COMPAIR assessment framework. These elements are summarised below:

- When measuring the economic impact of different regulatory options, it is important to assess not only the effect on total economic welfare, but also the distributional impacts on various actors (ATM service providers, airlines, airports, passengers, government and society). The deployment of SESAR solutions may need financial incentives and/or regulatory action based on partners' business cases. This is especially the case when a synchronised deployment is required and one type of stakeholder has to deploy elements (enablers) without gaining direct benefit from this deployment.
- Different approaches entail the need of different levels of regulation, financial controls and regulatory oversight (Jones and Guthrie, 2008). It is therefore important that the assessment framework accounts for implementation and transaction costs.
- Different authors recommend regulators and antitrust authorities to monitor market concentration, which can be an influence factor increasing the risk of strategic behaviour/manipulative collusion (Klemperer, 2005). It seems therefore interesting to include in our framework some measure of market concentration, such as the Herfindahl index or the concentration ratio, as well as for the capability (sometimes referred to as competitive efficiency) of promoting competition through non-discrimination and the elimination of entry barriers for newcomers.
- Another key aspect to prevent manipulative collusion is the level of transparency regarding what information is shared and when. Transparency may thus be another influence factor for which some (possibly qualitative) indicator may be useful.
- Dynamic efficiency should be taken into account. Sacrificing efficiency in the short run may be justified, for example, to reduce the cost of managing uncertainty in the long run, in order to facilitate ANSPs long term planning and investments. This element is important, for example, for defining the optimal frequency of tenders. The assessment framework should therefore include proper indicators to evaluate the trade-off between static and dynamic efficiencies over different periods of time.
- Another important element of any regulatory environment is its ability to cater for a changing environment, including circumstances implied by temporal, force majeure causes, strong disturbances, etc. (e.g., major traffic drops). It seems therefore interesting to include in our assessment framework some indicator(s) for vulnerability, resilience and adaptability to abnormal conditions.

⁴ This literature review is presented and discussed in detail in COMPAIR D2.2 Report on institutional design options.

- A well-known problem in auctioning goods with an element of uncertainty is the so-called winner's curse (Thaler, 1988): the bidder that makes the most optimistic assessment of future demand will win the bid, but it is very likely that his valuation is too optimistic, leading to poor performance or even bankruptcy, which is clearly an undesirable outcome. The indicators used in the assessment framework should thus properly account for this risk.
- Acceptability and ease of implementation often have a subjective component linked to the political perception of different regulations. Some sort of qualitative indicator of regulatory feasibility / ease of implementation may therefore be useful to complement quantitative considerations such as the cost-benefit analysis of each stakeholder.

2.2.5 COMPAIR stakeholder consultation

On 7th April 2016, the COMPAIR project organised a workshop with the members of the COMPAIR Advisory Board. While the main goal of the meeting was to assess the feasibility and the potential impact of the institutional market designs proposed by COMPAIR, the discussion with the Advisory Board included some elements relevant to the definition of the COMPAIR assessment framework. This included some hints on the KPAs/KPIs to be used in order to properly capture the concerns and expectations expressed by different stakeholders about the proposed solutions:

- The Advisory Board pointed out that competition is not end in itself but could be a tool to solve certain problems, and highlighted the importance of identifying the KPIs we will focus on. This confirms the usefulness of defining an assessment framework, and is aligned with the approach proposed in sections 2.2.3 of not considering competition as a KPA, but rather as an influence factor having an effect on some performance indicators.
- The Advisory Board emphasised the importance of evaluating the political feasibility of the proposed changes. This is in line with the idea suggested in section 2.2.4 of including some qualitative indicator of acceptability and ease of implementation.
- Management of ATM capabilities requires a very long-term focus. This is an argument pro long term contracts. Intermittency of tendering contracts may put a barrier on incentives to engage in long-term capability development, although there may be ways of dealing with this, e.g., valuating existing assets and selling them off to the next contractor. In any case, the discussion with the Advisory Board confirmed the argument about dynamic efficiency and stability for long term planning and investments presented in sections 2.2.3 and 2.2.4, and the importance of an assessment framework able to capture this effect.
- Indicators and metrics shall be defined at the appropriate scales to account for the fact that, given the strong network effects present in ATM, the modernisation of ATM capabilities often requires an integrated view and coordinated action at European scale to render benefits. The performance of ANSPs will strongly depend on the decisions taken by other actors (e.g., airlines investing in new navigation systems), hence the need to the distributional analysis mentioned in sections 2.2.3 and 2.2.4.
- The role of passengers was discussed: they should be involved, as “air” is a natural resource and they are an important stakeholder, as acknowledged by the European Commission. On the other hand, passengers do not buy ATM services, so there is a risk that they are overlooked. Passenger surplus should be included in the evaluation of social welfare for different regulatory options, and possibly also in the stakeholder distributional analysis.

2.3 Guiding principles of the COMPAIR assessment framework

Based on the scope and objectives of the project (see section 1.1), we consider that the COMPAIR assessment framework should take into account the following criteria and guiding principles:

- COMPAIR focuses on ATM services, and therefore airport capacity is out of the scope of the project, in the sense that will not analyse how the institutional mechanisms introduced by COMPAIR will influence investments in airport capacity (i.e., airport capacity will be considered as exogenous in our models).
- Safety considerations are out of the scope of the project.
- The technological feasibility of different institutional frameworks (i.e., the availability of the technological enablers required for the implementation of a certain regulation) will not be evaluated, but will be taken into account by means of different technology evolution scenarios (i.e., while we may model *technology adoption* under different institutional frameworks, *technology evolution* will be exogenous to our models).
- COMPAIR aims to evaluate the economic benefits of different institutional designs for the introduction of competition in ATM and provide a comprehensive picture of the expected impacts, risks, etc. of different institutional frameworks. For this reason, rather than an exhaustive list of indicators at the operational level, such as those provided by the ICAO, the SES and the SESAR performance framework, the COMPAIR performance framework will select only a subset of these, composed by those indicators meeting at least one of the following conditions:
 - They are expected to be influenced in a significant manner by the institutional frameworks analysed by COMPAIR.
 - They are needed to compute high level, aggregated economic indicators and conduct a cost-benefit analysis and a distributional analysis.

3. COMPAIR Assessment Framework

Taking into account the required properties, the inputs and the guiding principles described in section 2, we propose two sets of KPAs and associated performance indicators⁵:

- a first set of higher level, more aggregated **economic KPAs and indicators**, encompassing:
 - economic efficiency,
 - distributional effects, and
 - one additional KPA measuring the resilience of the rest of economic indicators vis-à-vis a pre-defined set of changing conditions.
- a second set of **operational KPAs and indicators**, composed by:
 - a selection of those KPAs proposed by the ICAO performance framework, the SES performance scheme and the SESAR performance framework that are expected to be influenced in a significant manner by the institutional frameworks analysed by COMPAIR and that are useful inputs for the computation of the high-level economic indicators, and
 - one additional KPA measuring the resilience of the rest of operational indicators vis-à-vis a pre-defined set of changing conditions;

Additionally, we propose to evaluate a number of **influence factors** that, even if they are not policy objectives per se, are considered particularly relevant to understand the effect of the different institutional frameworks under study on the proposed KPAs. These influence factors are grouped into three **focus areas**:

- competition between ANSPs,
- collaboration and interoperability,
- stakeholders' opinion, assessing how much different stakeholders would be in favour of a certain institutional framework.

Table 4 presents the proposed performance areas and indicators, classified according to the taxonomy defined in section 1.3.2. The minimum set of indicators that should be evaluated is highlighted in bold font. The indicators in italics are considered “nice-to-have”, but it still has to be evaluated whether they can be modelled or assessed in a reliable manner.

⁵ We avoid the distinction between KPIs and PIs made by the SES regulation and by SESAR, as we consider that in the case of COMPAIR it does not make sense to talk about indicators used for the purpose of target setting.



Table 5 presents the proposed focus areas and influence factors. Indicators of market concentration are attached both to the competition and the collaboration & interoperability focus area, as they are simultaneously indicators for the level of competition and the level of defragmentation/consolidation of ANSPs.

Table 4. COMPAIR Assessment Framework KPAs and KPIs

Economic KPAs			
KPAs		Performance indicators and supporting metrics	Type of indicator (1)
- Economic efficiency		- Social welfare = Consumer and producer surplus (sum of the effects on terminal ANSPs, en-route ANSPs, airlines, airports, passengers) + net benefits to third parties (externalities)	Quantitative, global, system-wide.
- Distributional effects		- En-route ANSPs surplus = En-route ANSPs (Benefit - Cost)	Quantitative, global, stakeholder-specific
		- Terminal ANSPs surplus = Terminal ANSPs (Benefit - Cost)	
		- Network Manager surplus = NM (Benefit-Cost)	
		- Airline surplus = Airlines (Benefit - Cost)	
		- <i>Airport surplus = Airport (Benefit - Cost)</i>	
		- <i>Passenger surplus = Passenger (Benefit - Cost)</i>	
		- <i>Government surplus = Government (Benefit - Cost) (including cost of regulation, financial controls and regulatory oversight)</i>	
		- Externalities: o Environmental costs.	Quantitative, global, system-wide.
- Resilience and vulnerability		- <i>Economic efficiency and distributional effects under a range of pre-defined external disturbances ⁽²⁾</i>	Quantitative, global, system-wide/stakeholder-specific
Operational KPAs			
KPAs		Performance indicators and supporting metrics	Type of indicator (1)
Capacity	Airspace capacity	- En-route throughput	Quantitative, local, system-wide.
		- TMA throughput	
Cost efficiency	ANS Cost efficiency	- En-route ANS cost per flight / service unit	Quantitative, global/local, stakeholder-specific.
		- Terminal ANS cost per flight / service unit	
	Network Manager cost efficiency	- Network Manager cost per flight / service unit	Quantitative, global, stakeholder-specific.
Environment	Fuel efficiency	- <i>Average flight efficiency of the actual trajectory</i> - <i>Distribution of flight efficiency</i>	Quantitative, global/local, system-wide.

Operational KPAs			
KPAs		Performance indicators and supporting metrics	Type of indicator ⁽¹⁾
Predictability and punctuality ⁽³⁾	Departure punctuality	<ul style="list-style-type: none"> - Average departure delay per flight - Distribution of departure delays, <i>Departure delay = (Actual Off-Block Time - Scheduled Off-Block Time)</i>	Quantitative, global/local, system-wide.
	Arrival punctuality	<ul style="list-style-type: none"> - Average arrival delay per flight - Distribution of arrival delays <i>Arrival delay = (Actual On-Block Time - Scheduled On-Block Time)</i>	
	Flight duration	<ul style="list-style-type: none"> - Average flight duration extension - Distribution of flight duration extension 	
Operational resilience		<ul style="list-style-type: none"> - Capacity, cost efficiency, environmental impact and punctuality under a range of pre-defined external disturbances⁽²⁾ 	Quantitative, global/local, system-wide.
		<ul style="list-style-type: none"> - Time to recover from non-nominal to nominal condition 	

(1) See classification of indicators in section 1.3.2.

(2) We will not address short term disruptions (e.g., ash cloud), but structural changes (e.g., a sustained change in fuel prices or air transport demand due to the evolution of the economy).

(3) The accurate modelling of tactical delays requires a modelling approach different from that of the models considered by COMPAIR, which are of a more strategic nature, so in principle this will not be modelled or will be modelled in a very coarse manner.

Table 5. COMPAIR Assessment Framework Focus Areas and Influence Factors

Focus Area	Influence Factors and supporting metrics	Type of indicator ⁽¹⁾
Competition between ANSPs	<ul style="list-style-type: none"> - Policy on anticompetitive behaviour: <ul style="list-style-type: none"> o Ability to discover anticompetitive behaviours o Ability to stop anticompetitive behaviours 	Qualitative, global, system-wide
	<ul style="list-style-type: none"> - Entry barriers 	
	<ul style="list-style-type: none"> - Market concentration: <ul style="list-style-type: none"> - Herfindahl index - Concentration ratio 	
Collaboration and interoperability	<ul style="list-style-type: none"> - Level of incentives for ANSP collaboration 	
Stakeholder opinion ⁽²⁾	<ul style="list-style-type: none"> - ANSPs' opinion 	Qualitative, global, stakeholder-specific
	<ul style="list-style-type: none"> - Airlines' opinion 	
	<ul style="list-style-type: none"> - Governments/national authorities' opinion 	
	<ul style="list-style-type: none"> - Labour unions opinion 	

(1) See classification of indicators in section 1.3.2.

(2) Stakeholders position will not be modelled, but will be assessed by means of the COMPAIR stakeholder consultation process.

4. Conclusions

The comparison of the different institutional designs proposed by COMPAIR will be carried out by means of a set of high level economic KPAs and indicators, encompassing economic efficiency, distributional effects, and one additional KPA measuring the resilience of the rest of economic indicators vis-à-vis a pre-defined set of structural changes, such as long-term changes in fuel prices and demand evolution.

The calculation of these economic indicators will be complemented with the calculation of more disaggregate, lower level “operational” indicators, which will have a twofold purpose: (i) they will be an input for the calculation of the economic indicators; and (ii) they will provide a more comprehensive picture of the impact of the different mechanisms. In order to maximise the usability of the project results by the SESAR programme, the set of proposed operational indicators is mainly based on the nomenclature and indicators defined in the SESAR Performance Framework, with some minor additions and adaptations considered necessary to meet the COMPAIR research objectives.

Finally, the review of the literature on competition and the COMPAIR stakeholder consultation has led us to complete the previous list of indicators with a number of influence factors that, even if they are not policy objectives per se, are considered relevant to understand the potential impact of the different institutional frameworks under study.

The COMPAIR assessment framework provides a basis for the evaluation of the different institutional designs proposed by COMPAIR in a consistent and comparable manner throughout the entire project.

The assessment framework will be an input for the specification of the outputs of the COMPAIR models. As the modelling work progresses, the need for refinements of the COMPAIR performance framework may arise. If this is the case, the present document will be updated to reflect such refinements.

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