# CARE ASAS Activity 2: WP 2
# System Performance Metrics

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## Record of changes

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| 0.A | 7 June 2002 | Draft for internal review |
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## Executive summary

The ASAS concept is anticipated to provide significant benefits for the air transport environment. In order that these benefits might be measured, it is necessary to:

1. Design scenarios for ASAS usage within which the benefits of ASAS may be measured. This has been the concern of Work Package 1.
2. Identify the measurements (or metrics) that may be used within these scenarios to quantify the benefits. This has been the concern of Work Package 2 (System Performance) and Work Package 3 (Human Performance).

The aim of the current project is to specify a Validation Framework (VF) that provides for comparability and consolidation of results across various ASAS research projects. The wide-range of potential operational concepts and diverse techniques that may be used for their validation have led to the requirement for the framework to be generic.

The project involves two complementary work packages, WP2 & WP3, identifying metrics that may be used to measure performance in an ATM environment. This report presents an analysis of system performance metrics that can be used in the ATM environment in general and an ASAS environment in particular.

It is essential that the benefits of ASAS relate to the strategic objectives for Air Traffic Management as defined by the EUROCONTROL ATM2000+ Strategy and the EATMS Operational Concept Document. In earlier work, only four main objectives have been considered as relevant, but a fifth namely Security & Defence is now also considered relevant. The five key objectives are therefore:

- Safety
- Capacity
- Efficiency
- Environment
- Security & Defence

The existing definition of Security & Defence in the ATM 2000+ Strategy document is concerned with civil-military co-operation and military access to airspace. It does not encompass the infiltration of the civil air transport infrastructure for the purposes of carrying out malicious (e.g. terrorist) acts[1]. As a consequence, it has been necessary to extend the definition for the purposes of this project.

The link between strategic objectives and system performance has been the subject of much previous study (although not necessarily from an ASAS viewpoint). Consequently, there have been a number of approaches that are broadly similar but not entirely consistent with each other. In particular the taxonomy differs considerably. The first challenge for Work Package 2 was therefore to try to rationalise the taxonomy whilst creating a consistent hierarchical breakdown linking strategic objectives to measurement of system performance.

Work Package 2 has divided the hierarchy into three main layers:

**OBJECTIVES ? PERFORMANCE AREAS ? METRICS**

[1] The influence of ASAS in respect to malicious infiltration is likely to be a negative one. There are no clear benefits, whilst the ability to generate false traffic using ADS-B and ASAS technologies is a significant risk.

This structure recognises a "many-to-many" linkage between the layers. For example, **Flight Efficiency** is a **PERFORMANCE AREA** that influences **OBJECTIVES** of both **Efficiency** and **Environment**.

Where appropriate, **PERFORMANCE AREAS** have been further broken down into ASPECTS. For example, **Access** may be divided into **Airports**, **Sectors** & **Routes**. This simplifies the use of this structure with scenarios that may look at specific aspects of airspace usage.

The term **METRICS** is used in line with the definition provided by the MAEVA Validation Guideline Handbook. Other sources make use of the term "Indicator" at this level and it is important to be aware of this equivalence when making comparisons. **METRICS** are the means of measuring benefits against **OBJECTIVES** and therefore it is important to maintain the distinction between **METRICS** and **OBJECTIVES**. To avoid this confusion, the analysis used in Work Package 2 has resisted the approach that **METRICS** themselves constitute a hierarchy of levels (some approaches for example, consider **Capacity** as a "high level" metric).

At a lower level than **METRICS** is the concept of a **MEASURE**. This is the particular measurement or data item that quantifies a specific metric. The Work Package 2 analysis considers that the **MEASURE** forms part of the definition of a **METRIC** and therefore does not constitute a further layer in the hierarchy.

In addition to the hierarchical breakdown, the analysis carried out by Work Package 2 has also introduced the concept of "perspective". This permits the complete data set to be viewed in different contexts. This acknowledges the fact that, for example, airline operators may recognise the same key objectives as ATM service providers, but may recognise different metrics as significant measures of benefit (an example of this would be the use of fuel savings as a measure of efficiency).

The concept of perspective is also usefully extended to the important overlap between System Performance and Human Performance. Those metrics that have a significant Human Performance element can be readily selected from those that do not.

Perspective may usefully be extended further to deal with the four different categories of ASAS use[2]. This will become valuable if it is found that there are significant differences in the metrics that are relevant for each category of ASAS use. The value of this perspective may become clearer with more analysis as the Validation Framework becomes more mature.

Key to being able to perform this perspective filtering is the accurate classification of the metrics themselves. Upon identification, each metric must be assessed for its suitability from all the perspectives that may be considered. This may not always be straightforward, and often may require subjective judgement. It is recommended that classification process must be subject to a wider consensus before it can be considered complete.

As a demonstration of the metric identification process, this report has analysed System Performance Metrics for two example ASAS applications identified in Work Package 1, namely "*Time based sequencing in approach*" and "*Airborne self separation in en-route airspace*". This is believed to be a meaningful exercise in metrics analysis but should not be considered as definitive until the classification of metrics has been subject to wider consensus.

[2] Situational awareness; Airborne Spacing; Airborne Separation; Airborne Self-separation.

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# 1 Introduction

## 1.1 Objectives of the project

1.1.1 EUROCONTROL's CARE-ASAS Action aims to consolidate previous work on ASAS and to co-ordinate future EUROCONTROL sponsored research in this area. As part of this programme, EUROCONTROL invited tenders for the development of a validation framework for the assessment of proposed ASAS applications.

1.1.2 ASAS applications cover a wide spectrum of delegation of responsibilities and therefore a wide range of potential operational concepts that will need to be evaluated. An evaluation process or validation is required in order to ensure that application is able to deliver the anticipated benefits and therefore be a worthwhile investment for the ATC providers and airlines. The commonly agreed European definition of validation is stated below.

1.1.3 The process through which a desired level of confidence in the ability of a deliverable to operate in a real-life environment may be demonstrated against a pre-defined level of functionality, operability and performance.

1.1.4 While there is consistency in the definition of validation, the many approaches used in past validation exercises has meant it has been impossible to compare their results and conclusions, and thereby identify the best future operational concept on a Europe-wide basis. Projects such as CAVA, DEVAM and MAEVA have started to provide more detailed guidance to those responsible for the conduct of validation exercises to meet this need.

1.1.5 The aim of the current project is to specify a Validation Framework (VF) that provides for comparability and consolidation of results across various ASAS research projects. The wide-range of potential operational concepts and diverse techniques that may be used for their validation have led to the requirement for the framework to be generic.

## 1.2 Objective of WP2

1.2.1 The project is divided into one management and four technical work packages defined as follows:

- WP0 - Management
- WP1 - Identification of ASAS operational scenarios
- WP2 - System performance metrics
- WP3 - Human performance metrics
- WP4 - Application of validation framework

1.2.2 The project involves two complementary work packages, WP2 & WP3, identifying metrics that may be used to measure performance in an ATM environment. This report presents an analysis of system performance metrics that can be used in the ATM environment in general and an ASAS environment in particular.

1.2.3 The use of recognised and accepted metrics is fundamental to measuring system performance in a consistent and reproducible way. Most important is the ability to

make comparisons of performance gains provided by the introduction of new tools and technologies. Identifying system performance metrics suitable for measuring the benefits of introducing ASAS applications is the primary objective of WP2.

1.2.4 The approach has been to:

- Agree the main goals (or strategic objectives) of an ATM system
- Identify the key performance areas which support the main ATM goals
- Identify metrics that shall allow system performance to be measured

### 1.3 Scenarios & metrics

1.3.1 The activity of WP1 has developed a formalised method for defining scenarios to demonstrate ASAS applications. This permits scenarios to be defined in a consistent way.

1.3.2 The intention is that WP2 and WP3 shall identify metrics that allow the benefits of ASAS applications to be measured in a consistent way.

1.3.3 The combination of the work on scenarios and metrics shall then form the basis of an ASAS validation framework.

## 2 Approach

### 2.1 Overview

2.1.1 Earlier work on CARE ASAS Activity 2 [1] identified a number of studies of ATM performance and a number of sources of performance metrics.

2.1.2 The ATM performance projects reviewed were:

- Performance Review Commission
  European ATM Performance Measurement System
- CNS/ATM Focus Team (C/AFT)
- TORCH
- INTEGRA

2.1.3 The intention of this current work is not to generate or invent new metrics but to review and consolidate the research carried out in the earlier Activity 2 report. To achieve this, it was first necessary to understand the differences in approach between the various research groups and to achieve a common understanding of the way in which metrics can be linked to the overlying objectives of an ATM system. It was also necessary to recognise that the perceived importance of the objectives and their related performance measures differs between different groups or stakeholders.

2.1.4 The activity of WP2 has endeavoured to achieve the following:

- A clear top down analysis, such that methods of measuring system performance (metrics) are clearly linked to the overlying ATM objectives
- A consistent taxonomy to avoid the potential for confusion in terminology across the various performance studies

– The ability to apply different perspectives to the same body of information, such that the interests of the different stakeholders can be expressed

## 2.2 Tools

2.2.1 To assist with the work of consolidating and analysing the metrics a Microsoft Access database has been developed. This has allowed the top-down hierarchy to be defined and the relationships altered and refined as necessary. It also provides the necessary mechanism to view the data from different perspectives through the use of database 'query' structures and allows the necessary flexibility to add or alter perspectives as necessary.

2.2.2 Whilst the database is not a deliverable of WP2, much of the information presented in this report has been generated using the database.

## 2.3 Top down analysis

2.3.1 The link between strategic objectives and system performance has been the subject of much previous study (although not necessarily from an ASAS viewpoint). Consequently, there have been a number of approaches that are broadly similar but not entirely consistent with each other. In particular the taxonomy differs considerably. The first challenge for Work Package 2 was therefore to try to rationalise the taxonomy whilst creating a consistent hierarchical breakdown linking strategic objectives to measurement of system performance.

2.3.2 Work Package 2 has divided the hierarchy into three main layers, comparable to the MAEVA Validation Guideline Handbook [2] (Activity 1.4):

**OBJECTIVES ? PERFORMANCE AREAS ? METRICS**

2.3.3 **OBJECTIVES** are defined and explained in section 3. **PERFORMANCE AREAS** break down the strategic objectives down to levels of operation where it is easier to measure performance and are defined in 3.2.

2.3.4 The structure recognises a "many-to-many" linkage between the layers. For example, **Flight Efficiency** is a **PERFORMANCE AREA** that influences **OBJECTIVES** of both **Efficiency** and **Environment**.

2.3.5 Where appropriate, **PERFORMANCE AREAS** have been further broken down into ELEMENTS[3]. For example, **Access** may be divided into **Airports**, **Sectors** & **Routes**. This simplifies the use of this structure with scenarios that may look at specific aspects of airspace usage.

2.3.6 The term **METRICS** is used in line with the definition provided by the MAEVA Validation Guideline Handbook [2]. Other sources make use of the term "Indicator" at this level and it is important to be aware of this equivalence when making comparisons. For the purposes of this study:

**METRICS º INDICATORS**

2.3.7 **METRICS** are the means of measuring benefits against **OBJECTIVES** and therefore it is important to maintain the distinction between **METRICS** and

[3] *This term still to be agreed*

**OBJECTIVES**. To avoid this confusion, the analysis used in Work Package 2 has resisted the approach that **METRICS** themselves constitute a hierarchy of levels (some approaches for example, consider **Capacity** as a "high level" metric).

2.3.8 At a lower level than **METRICS** is the concept of a **MEASURE**. This is the particular measurement or data item that quantifies a specific metric. The Work Package 2 analysis considers that the **MEASURE** forms part of the definition of a **METRIC** and therefore does not constitute a further layer in the hierarchy.

2.3.9 The hierarchy outlined here and its application to a broad set of metrics is analysed in more detail in Section 3.

# 3 Analysis

## 3.1 ATM objectives

3.1.1 As stated earlier, one of the aims of this activity has been to identify how metrics are linked to the strategic objectives of an ATM system. In order to scope what those objectives are, it was decided to use the work of the EUROCONTROL ATM Strategy for 2000+ [3] as an authoritative source.

3.1.2 A number of strategic objectives were identified as valid for the analysis of system performance metrics in relation to ASAS.

### 3.1.3 Safety

*"To improve safety levels by ensuring that the number of ATM induced accidents and serious or risk bearing incidents do not increase and, where possible, decrease."*

Safety is often stated as the most important objective of ATM. Generally high levels of safety are achieved and this actually creates difficulty in measuring safety directly. Metrics relating to accidents and near accidents can be used in the real environment, but the number of incidents available, even using extensive historical records, can be extremely limited for the purpose of meaningful statistics.

Measuring safety in a simulated environment is even more problematic. Certainly in real time simulation there will never be sufficient simulated hours to generate statistically significant numbers of incidents. Even in fast time simulation there are few system performance metrics than can be brought to bear.

Human performance metrics such as measurement of workload are a less direct measure, but are more useful because they can measure improvements in areas that are known to relate to safety.

The INTEGRA project recognises the difficulty of providing useful metrics for the measurement of safety and has introduced the concept of 'Propensity' and 'Resilience' [5].

ASAS applications are expected to have an important influence on the safety of the ATM system. Roles, responsibilities and procedures will change for controllers and

flight crews, as will the way that flight crews will obtain and maintain their situational awareness.

### 3.1.4 Capacity

*"To provide sufficient capacity to accommodate the demand in typical busy periods without imposing significant operational, economic or environmental penalties under normal circumstances."*

The capacity of an ATM system is achieved through complex interaction of various performance areas. It can also be broken down into constituent elements such as airports, TMAs and en-route sectors. The complexity is such that it is rarely meaningful to analyse the capacity of a complete ATM system, but rather to look at specific elements.

Capacity is well suited to quantitative measurement, with a wide range of performance metrics available. It is also well suited to analysis through fast and real time simulation.

Human performance is closely linked to capacity because workload is generally recognised as a limiting factor for system capacity.

INTEGRA takes a broader view of capacity limitations through workload. Traditionally, workload has been a performance limitation applied to the Air Traffic Controller. The INTEGRA approach recognises that the introduction of new tools and technologies spreads workload across a number of 'actors' – including the Air Traffic Controller, but also including the flight crew and automatic / semi-automatic systems. It therefore introduces the concept of 'Processor Load' to be applied to each actor.

ASAS applications are expected to bring capacity benefits through the ability to delegate responsibility thus achieving greater flexibility of operation.

### 3.1.5 Efficiency

*"The implementation of CNS/ATM concepts, procedures and systems which help to minimise unnecessary use of time and resources."*

Capacity and efficiency are related. It is self evident that capacity can be maximised if all the elements of a system work together as efficiently as possible. In practice however, capacity and efficiency are not always complementary. Capacity of an ATM system can often be maintained only at the expense of efficiency (e.g. allocation of non-optimum flight levels).

It is broadly true that ATM service providers are primarily interested in capacity whilst aircraft operators place greater emphasis on efficiency. Therefore the metrics that can measure efficiency improvement are often of greater importance to operators than those that measure capacity gains. This is an important aspect of metric 'perspective' that is dealt with in WP2.

Efficiency is well suited to quantitative measurement, with a wide range of performance metrics available. Some aspects are well suited to analysis through fast and real time simulation, whilst others, such as the cumulative costs of delays,

can only be accurately measured through the analysis of real data over an extended period.

ASAS applications are expected to bring efficiency benefits through the ability to permit more efficient routing, and more efficient manoeuvring (including climbs and descents).

### 3.1.6 Environment

*"The implementation of CNS/ATM concepts, procedures and systems which help to mitigate the impact of aviation on the environment."*

Air traffic and its supporting infrastructure has a high impact on the environment in terms of noise, emissions and use of natural resources. Some aspects, such as noise, are under strict regulatory control. Other aspects of environmental impact can be minimised by making more efficient use of resources.

While ASAS technology is not being introduced for its environmental impact, it may reasonably be expected to have a positive influence. Any fuel savings identified through improved flight efficiency can also be directly attributed as an environmental benefit. Similarly, any improvement in the ability to fly noise abatement procedures accurately or to avoid go-around situations through delegated spacing responsibility will reduce the potential for infringement of noise regulations.

Flight efficiency aspects can be measured readily through simulation. It may be possible to measure some aspects of noise impact through simulation also.

### 3.1.7 Security / Defence

*"To determine mechanisms, criteria and structures to enhance civil-military co-operation and co-ordination."*

*"To ensure access to airspace for military purposes through the implementation of special procedures where necessary."*

*"To prevent unlawful interference with the civil air transport system with the intention of carrying out malicious or terrorist acts."*

ATM 2000+ [3] identifies two aspects of the Security/Defence objective. For the purposes of the CARE ASAS Activity 2, a third aspect has been added ensure that more recent concerns of the security of air transport are addressed.

With respect to military co-operation and military access to civil airspace it is relatively easy to identify where metrics may be applied to measure the effectiveness or otherwise of ATM procedures. It is also easy to identify potential benefits of ASAS through the delegation of separation responsibility and improved situational awareness.

It is less straightforward to identify methods of measuring resistance to malicious interference. Suitable metrics have not been identified in earlier studies so in this case it has been necessary to suggest them within the activity of WP2. Clearly a count of the number of incidents is not a practical or statistically meaningful approach. Illegal interference with civil air transport is unusual in that ASAS actually

creates a potentially serious problem because of the relative ease with which ADS-B technology might be misused to create false targets. The following metrics are suggested as relevant to an ASAS environment:

- Time taken to identify an abnormal deviation from expected flight behaviour
- Time taken to identify a false ADS-B type target
- Time taken to notify a false ADS-B type target

## 3.2 Performance areas

3.2.1 Thirteen Performance Areas have been used in the WP2 analysis. Most of these have been derived from the PRC performance measurement system [4] as this demonstrates the greatest commonality across all of the studies reviewed. With the addition of 3 performance areas related to Security/Defence, it is believed that this permits an adequate breakdown of strategic objectives into measurable performance areas.

**Safety** — *Safety levels ensured through the ATM system*.

**Delay** — *The time in excess of the optimum time that it takes a user to complete an operation.*
Delay may be related to either a lack of capacity or a lack of efficiency (see Objectives).

**Cost effectiveness** — *The value for money that the user receives from the supply of air traffic services*.

**Predictability** — *The ability of the user to predict variation and to build and maintain optimum flight schedules.*
When asking for predictability the user is looking for a quality of the system through the continuity of system capacity and an understanding of fallback modes where capacity is exceeded or is lost through some failure mode.

**Access** — *The accessibility to the airspace, ATM service and airport facilities under controllable conditions.*
The user is asking to be able to use airspace when required. This translates to the system having enough capacity to allow the user to enter it when required. However an aircraft must be expected to meet a minimum performance requirement (including equipment) for a given type or area of airspace. It is not reasonable for any aircraft to expect access to any airspace at any time.

**Flexibility** — *The ability of ATM to accommodate changing user needs in real time or without penalty*.

**Flight efficiency** — *The ability of ATM system to allow a user to adopt the preferred flight in terms of flight level and route.*
Flight efficiency relates to user operating efficiency and thus to costs, but also relates to environmental issues.

| | |
|---|---|
| **Availability** | *The availability of ATM critical resources and of the ATM services provided to the user.*<br>Understanding that all the ATM service are oriented to allow aircraft flying as they want to fly, this availability is an internal measurement of the ATM system capacity implying that the system should manage the internal resources to give and guarantee the user the required capacity. |
| **Environment regulation** | *The conformance of air transport to environmental regulations.* |
| **Equity** | *Equity of treatments of flights by all aircraft operators within and between specific classes of users.*<br>Equity per se is not a performance of the system but a policy of system operation. That means a commonly agreed basis and principle for ATM operation. |
| **Civil-military co-operation** | *Co-operation levels between civil and military users of airspace.* |
| **Military access** | *Accessibility of civil airspace and civil ATM to military users in peacetime.* |
| **Security of air transport** | *Resilience of the air transport system to malicious interference.* |

3.2.2 The link between ATM objectives and Performance Areas is a many-to-many relationship. This is summarised in Table 3-1. This shows that *Delay* relates to the objectives of both *Capacity* and *Efficiency*. This is an important distinction as it demonstrates the difference in perception of delay by airspace users and service providers.

3.2.3 The only other multiple link identified is that of flight efficiency. Flight efficiency relates directly to fuel usage, which affects both emissions and operational costs. Therefore Flight Efficiency has been linked to the objectives of Efficiency and Environment.

**Objective link to Performance Area**

| Objective | Performance Area |
|---|---|
| **Capacity** | |
| | Equity |
| | Availability |
| | Flexibility |
| | Access |
| | Predictability |
| | Delay |
| **Efficiency** | |
| | Delay |
| | Flight efficiency |
| | Cost effectiveness |
| **Environment** | |
| | Environment regulation |
| | Flight efficiency |
| **Safety** | |
| | Safety |
| **Security/Defence** | |
| | Security of air transport |
| | Military access |
| | Civil-military co-operation |

*Table 3-1 Link of Objective to Performance Area*

## 3.3 Metrics

3.3.1 As stated earlier, the term Metrics is used in line with the definition provided by the MAEVA Validation Guideline Handbook. Other sources make use of the term "Indicator" at this level and it is important to be aware of this equivalence when making comparisons.

3.3.2 Metrics are linked to performance areas on a many-to-many relationship. The number of system performance metrics available is large (100+) and so the full listing is not included here but is added as Appendix B.

3.3.3 At a lower level than Metrics is the concept of a Measure. This is the particular measurement or data item that quantifies a specific metric. The Work Package 2 analysis considers that the Measure forms part of the definition of a Metric and therefore does not constitute a further layer in the hierarchy.

3.3.4 The detail in which a metric is recorded by WP2 is shown in Figure 3-1. This identifies the metric, its definition and the measure by which it is quantified. The study source from where the metric was originally obtained is also included to allow traceability. There are then a number of additional 'check box' type fields that

facilitate the application of perspectives to the data. This means information can ultimately be presented in a multitude of different ways. There are also a number of fields indicating important characteristics about the use of any metric, including any restrictions on its use. These parameters have been identified through the activity of WP3 as pertinent to the identification of suitable metrics.

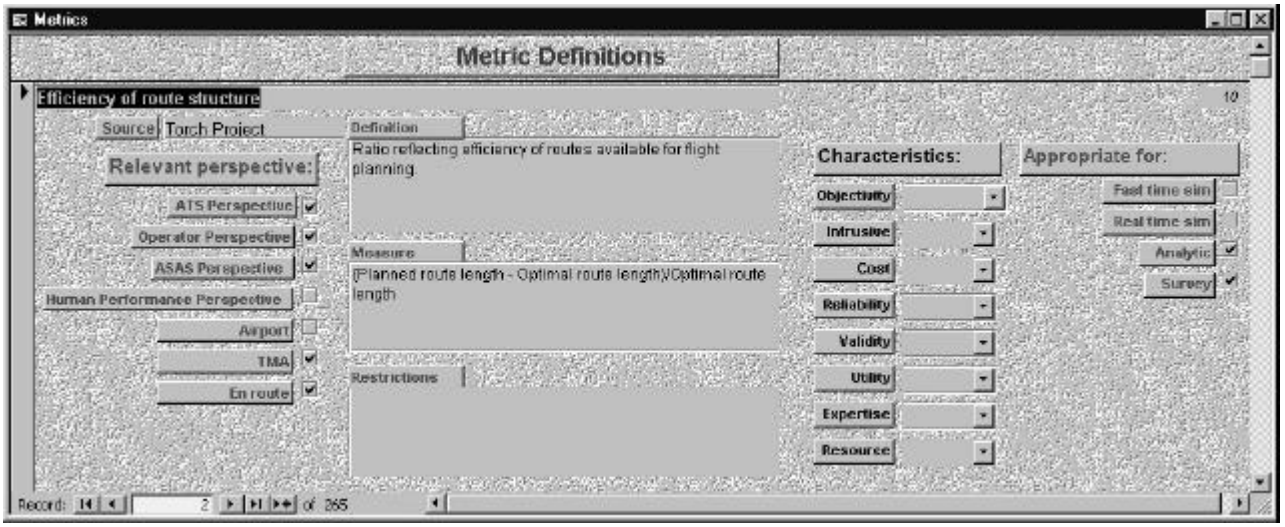


*Figure 3-1 WP2 metric definition*

3.3.5 Classification of metrics in terms of:

- relevant perspective;
- appropriate validation methodology
- characteristics;

is very important to the subsequent filtering and selection process. The more care that is applied to the classification process, then the more effective the selection process will be.

## 3.4 Perspectives

3.4.1 The relative importance of any metric is dependent upon the context of the experiment in which it is used. In recognition of this, the concept of 'perspective' has been introduced to assist in the analysis.

3.4.2 For example, *Delay* is a recognised performance area of an ATM system (see 3.2.1). Both ATS providers and air transport operators have an interest in the measurement and reduction of delay. However, the ATS provider will consider delay in terms of capacity of the various system elements whilst the operator will be primarily concerned with the cost efficiency and reliability of the service provided to their customers.

3.4.3 Therefore ATS and Operators can be considered to have different perspectives on the same performance area, and different metrics would be appropriate assessing the impact of any change.

3.4.4 Similarly, only some of the metrics relating to *Delay* will be relevant to the use of ASAS. For example, arrival delay may be influenced by the ability of aircraft to accept delegated separation responsibility. Departure delay will not be influenced in this way (except indirectly through the improved efficiency of the arriving traffic stream). Hence, applying ASAS as a perspective can usefully assist in the filtering and selection of suitable metrics.

3.4.5 Table 3-2 lists *Delay* related metrics and identifies their relevance to the perspectives of ATS, Operator and ASAS.

| **Performance Area: Delay** | | **Perspective** | | |
|---|---|---|---|---|
| **ID** | **Metric** | **ATS** | **Operator** | **ASAS** |
| *996* | Taxi-in delay | YES | YES | |
| *997* | Taxi-out delay | YES | YES | |
| *998* | ATC delays | YES | YES | |
| *999* | Total delay | YES | YES | YES |
| *1000* | Flights delayed | YES | YES | YES |
| *1001* | Average delay | YES | YES | YES |
| *1002* | Causes of delays | YES | YES | |
| *1003* | CFMU delay (overall) | YES | YES | YES |
| *1004* | CFMU delay (peak) | YES | YES | YES |
| *1005* | CODA delay (overall) | YES | YES | YES |
| *1006* | CODA delay (most affected traffic) | YES | YES | YES |
| *1007* | CODA, CFMU reports (departure delays) | YES | YES | |
| *1008* | Departure delay (by total flights) | YES | YES | |
| *1009* | Departure delay (proportion of flights delayed) | YES | YES | |
| *1010* | Departure delay (by delayed flights) | YES | YES | |
| *1011* | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | YES | YES | YES |
| *1012* | TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) | YES | YES | YES |
| *1013* | Arrival delay (function of departure delays and flight delays) | YES | YES | YES |
| *1014* | Causes of delay (ATM, aircraft operator, airport) | YES | YES | |
| *1015* | Relationship among delay, traffic volume and capacity | YES | YES | YES |
| *1016* | Capacity management (index) | YES | | YES |
| *1017* | Capacity management (target variation) | YES | | YES |
| *1018* | Capacity management (traffic variation) | YES | | YES |
| *1019* | Flight delay | YES | YES | YES |
| *1020* | Causes of flight delays | YES | YES | |
| *1021* | ATFM delay | YES | YES | YES |
| *1022* | ATC delays | YES | YES | YES |
| *1023* | Ground delays | YES | YES | |
| *1024* | Record of time | | YES | YES |
| *1025* | Initial trajectory duration | | YES | YES |
| *1026* | Real trajectory duration | | YES | YES |
| *1027* | Duration increase | | YES | YES |
| *1028* | Delay before creation | YES | YES | YES |
| *1029* | Diversions due to weather | YES | YES | |
| *1034* | Variations in system performance associated with changes in weather | YES | YES | YES |
| *1036* | Variation in the ATM system as experienced by the user | | YES | YES |
| *1037* | Impact of system outages | YES | YES | |
| *1038* | Impact of system outages | YES | YES | |

| Performance Area: Delay | | Perspective | | |
|---|---|---|---|---|
| *1039* | Impact of system outages | YES | YES | |
| *1041* | Standard deviation | | YES | YES |
| *1042* | Components (arrival delay) | YES | YES | YES |
| *1043* | Causes (arrival delay) | YES | YES | YES |
| *1044* | Taxi-in variation (variability in arrival delay) | YES | YES | |
| *1045* | Taxi-out variation (variability in arrival delay) | YES | YES | |
| *1046* | Punctuality of arrival | | YES | YES |
| *1047* | Anticipated delay | | YES | YES |
| *1048* | Cancel flight- instantaneous aircraft count | YES | YES | YES |
| *1051* | Airport capacity utilisation (average) | YES | | |
| *1052* | Airport capacity utilisation (average) | YES | | |
| *1053* | Airport capacity | YES | | |
| *1054* | Sector capacity | YES | | YES |
| *1056* | Availability of airport capacity (peak hours) | YES | | |
| *1057* | Availability of airport capacity (unconstrained runway capacity) | YES | | |
| *1058* | Availability of airport capacity (peak hour demand) | YES | | |
| *1072* | ATM restrictions (flow) | YES | YES | YES |
| *1073* | ATM restrictions (average time) | YES | YES | YES |
| *1074* | Missed approaches- non conflict errors | YES | YES | YES |
| *1081* | Airport capacity | YES | | |
| *1083* | Restrictions | YES | YES | YES |
| *1084* | Restrictions (flights) | YES | YES | YES |
| *1085* | Restrictions (amount not constrained) | | YES | YES |
| *1086* | Restrictions (impact) | | YES | YES |
| *1090* | Deviation between ATC preferred route and flight plan route | | YES | YES |
| *1091* | Distance between preferred routes and final route | | YES | YES |
| *1092* | Flights able to fly in the requested altitude | | YES | YES |
| *1093* | Deviation between the requested and flown route (descent) | | YES | YES |
| *1094* | Deviation between the requested and flown route (mean lateral deviation) | | YES | YES |
| *1098* | GAT freedom rate | YES | YES | YES |
| *1109* | Distance difference | | YES | YES |
| *1114* | Initial trajectory length | | YES | YES |
| *1115* | Real trajectory length | | YES | YES |
| *1116* | Length increase | | YES | YES |
| *1125* | Time lost due to any component of the ATM system being unavailable | YES | YES | |
| *1126* | Time lost due to any component of the ATM system being unavailable (all critical system) | YES | YES | |
| *1127* | Disruption caused by unavailability | YES | YES | |
| *1128* | Disruption caused by unavailability (all critical system) | YES | YES | YES |
| *1129* | Number of hold/turn delays | YES | YES | YES |
| *1130* | Communication delay | YES | YES | YES |
| *1131* | Number of communication delays | YES | YES | YES |

*Table 3-2 DELAY metrics with perspective*

## 3.5 Classification of metrics

3.5.1 Key to an effective selection of metrics for a given purpose is the appropriate classification of the metrics themselves. In addition the basic metric definition, three areas of classification are considered important.

- Perspective
  - ATS
  - Operator
  - ASAS
  - Airport
  - TMA
  - En-route

  The concept of perspective has already been discussed in 3.4. The perspective categories identified here are intended to permit the selection of metrics based broadly upon the type of airspace and the type of user. The inclusion of ASAS assists in eliminating those metrics inappropriate for ASAS based applications.

  More specific categories (for example ASAS application types) would not be useful at this level as this could effectively 'pre-judge' the planned experiment and unnecessarily eliminate useful metrics.

- Appropriate validation methodology
  - Fast time simulation (FTS)
  - Real time simulation (RTS)
  - Analytic
  - Survey

  Not all metrics are appropriate for all types of validation. For example, statistical measures of infrequent events (e.g. TCAS RAs) are not appropriate for RTS experiments. Appropriate classification of the appropriate methodology will assist in the effective selection of suitable metrics.

- Characteristics
  - Objectivity Objective/Subjective
  - Intrusive High/Low
  - Cost High/Low
  - Reliability High/Low
  - Validity High/Low
  - Utility High/Low
  - Expertise High/Low
  - Resource High/Low

  The characteristics of a metric are likely to influence its suitability for an experiment. For example metrics that are intrusive and resource intensive are unlikely to be appropriate for trials to establish the basic feasibility of a concept. Appropriate classification of the metric characteristics will assist in the effective selection of suitable metrics.

This characterisation is particularly appropriate for metrics relating to Human Factors.

3.5.2 The classification process may not always be straightforward, and often may require subjective judgement. However, in cases of difficulty it is not essential to fully identify all perspectives at the outset. The simple rule is that a metric should be considered suitable for any perspective until subsequently decided otherwise. This will ensure that a metric is not incorrectly excluded during any perspective filtering exercise.

## 3.6 Human performance metrics

3.6.1 The approach outlined here is also appropriate for the management of Human Performance Metrics. However certain differences need to be understood. The hierarchy of Objectives, Performance Areas and Metrics remains valid. The Objectives (identified in 3.1) are the strategic objectives of an ATM system and remain the same. However, a different set Performance Areas has been identified as more useful to the analysis.

3.6.2 The Human Performance Areas as used within Work Package 3 are listed below. They are discussed in more detail in the report of WP3.

- Workload
- Situational Awareness
- System Monitoring
- Teamwork
- Usability / Acceptance
- Trust

3.6.3 Another important difference to recognise is that *Human Performance Metrics* must be considered within the context of human tasks while *System Performance Metrics* provide a more direct measure against the performance area in question. For example, *Flight Efficiency* can be measured in terms of fuel usage – a *System Performance Metric*. From a human performance perspective, *Efficiency* can clearly be affected by *Workload*. However, it is necessary to identify the human tasks that influence *Efficiency*. Subsequently, for each task, appropriate metrics can then be identified to measure *Workload*.

## 3.7 Relationship to INTEGRA

3.7.1 The INTEGRA project [5] addresses metrics and methodologies relating to the objectives of Safety and Capacity. However INTEGRA does not use the approach of identifying individual System Performance Metrics.

### 3.7.2 Safety

INTEGRA addresses the issue of measuring safety in a simulated environment by concentrating not on incidents but on situations that might lead to incidents. The ideas of Propensity and Resilience were identified in [Ref 5] as two independent safety characteristics of an ATM system for which safety metrics were needed.

- **Propensity** is the likelihood of a safety significant event occurring during normal operations.

– **Resilience** is the extent to which the ATM system responds to a safety significant event without causing more such events.

The Propensity and Resilience metrics developed here are aimed at addressing the question 'How safe was a particular (simulated) air traffic situation?'. This is clearly related to risk as determined by risk assessment methodologies. However, there are significant differences. In particular, risk is concerned with the probability of occurrence and consequences of safety significant events given a particular generic scenario, operating procedures etc. It is evaluated 'before the event' and represents an average for the whole set of possible situations that can occur for the relevant scenario, operating procedures etc. rather than to a specific instance. The safety metrics, however, are concerned with the safety of a specific situation that has actually happened (or been simulated).

For example, the risk involved in a particular region of airspace operating with specific procedures and with a specific loading may have been evaluated. It involves probabilities that reflect the range of actual situations that could occur. Suppose that the air traffic movements on two similar days are recorded. The risk evaluation is valid for both, the risk was the same in each case. Nevertheless, the air traffic movements are different. Was the degree of safety actually achieved the same on both days? The safety metrics are aimed at answering that question.

### 3.7.3 Capacity

The INTEGRA metric for capacity is aimed at providing a measure of capacity rather than individual performance indicators.

Traditionally controller workload has been identified as the bottleneck with respect to capacity. The INTEGRA approach recognises that in any ATM system there is an amount of "information" to be processed to perform an activity and the introduction of new controller assistance tools and associated concepts spreads the "information processing load" across a number of "actors" – including the controller, but also including pilots and automatic/semi-automatic systems.

The INTEGRA metric is an algorithm which identifies, from simulation data, this "information processing load" and allocates it to the requisite actor. By comparing the load with the maximum load that can be sustained by the requisite actor an indication of the capacity of the system can be derived.

# 4 Methodology

## 4.1 General

4.1.1 Section 3 presents a top-down analysis that links system performance metrics to the overall objectives of ATM. It also introduces the concept of perspectives to assist in the selection of suitable metrics.

4.1.2 This section now considers the methodology that may be applied when endeavouring to identify metrics for an experiment.

## 4.2 Step 1: Establish a metrics repository

4.2.1 WP2 proposes the creation of a comprehensive metrics repository obtained from previous evaluation and validation exercises. This would allow future work to draw upon previous experience. More importantly it would introduce a level of consistency and comparability across all validation work.

4.2.2 In order for such a repository to be useful, it is essential that all of the metrics stored are properly classified (see 3.5) and are linked to the higher level performance areas and objectives of an ATM system (see 3.3).

4.2.3 WP2 has attempted to demonstrate the feasibility of this approach through the inclusion of an extensive set of metrics in a Microsoft Access database. This database was developed to include the necessary links between Metrics, Performance Areas (see 3.2) and high level Objectives (3.1). The database also included the necessary structure for adequate classification of the metrics. This classification was the subject of an extensive review, but is not considered to be complete or definitive at this stage.

4.2.4 Although the database developed in WP2 is not a deliverable of the CARE ASAS Activity 2 work programme, a number of outputs generated using this prototype database have been included in the WP2 report to illustrate the methodology in action.

## 4.3 Step 2: Develop a validation scenario

4.3.1 The technique for development of an ASAS validation scenario has been formalised in WP1 [6], this work being based upon the MAEVA Validation Guideline Handbook [2].

4.3.2 WP1 (Section 3) identifies the three steps of scenario development as:

- *What to obtain?* [Operational Objectives]
- *What to validate?* [ASAS Application]
- *What to test?* [Validation Scenario]

4.3.3 The scenario designer is assisted through the process by use of a scenario template. Completion of this template will then assist the designer in deriving the selection criteria for suitable metrics.

## 4.4 Step 3: Identify metrics selection criteria

4.4.1 Suitable metrics can be selected based upon the scenario design. Reference to the scenario template should allow the designer to address the following criteria:

**Objectives**

The high level objectives will have been identified as the initial step of the scenario design process.

**Performance Areas**

Not all of the performance areas linked to the identified objectives may be relevant to the scenario design. The performance areas should be filtered based upon the context of the scenario.

**Validation methodology**

The scenario design will explicitly define the relevant validation methodology:

- Fast Time Simulation
- Real Time Simulation
- Analytic
- Survey

**Airspace**

The scenario design will indicate the relevant type or types of airspace. More than one of these may be relevant. For example, a ‘gate-to-gate’ scenario may wish to include all three.

- En-route
- TMA
- Airport

**Perspective**

- Confirm that the scenario is concerned only with the ASAS perspective.
  *This assumes the repository described in Step 1 is not limited to ASAS metrics only. Therefore if the scenario wishes to restrict itself to measuring the effects of ASAS, this must be positively identified*.
- Identify whether the scenario has an Operator or an ATS provider perspective.
- Identify whether the scenario wishes to consider Human Performance Metrics or be based entirely upon System Performance Metrics.

**Characteristics**

The scenario designer may wish to refine the selection further based upon various additional characteristics:

- Objectivity Objective/Subjective
- Intrusive High/Low

- Cost High/Low
- Reliability High/Low
- Validity High/Low
- Utility High/Low
- Expertise High/Low
- Resource High/Low

The characteristics of a metric are likely to influence its suitability for an experiment. For example metrics that are intrusive and resource intensive are unlikely to be appropriate for trials to establish the basic feasibility of a concept. Appropriate classification of the metric characteristics will assist in the effective selection of suitable metrics.

This characterisation is particularly appropriate for metrics relating to Human Factors.

## 4.5 Step 4: Identify metrics

4.5.1 The criteria chosen for selecting appropriate metrics can now be used to automatically filter the metrics repository, assuming the repository has been designed to permit this.

4.5.2 In order to illustrate the feasibility for WP2, a Microsoft Access database was constructed to hold all of the identified metrics together with the necessary layers of classification. The automatic filtering process could then be carried out using database queries constructed in SQL.

4.5.3 Once the automatic selection process is complete, it is necessary for a manual overview to be carried out to select the most appropriate metrics, and to identify any metrics which may have been selected as a consequence of poor or incorrect classification within the repository.

4.5.4 The metrics selection process provides guidance. It will present metrics that have been defined and used in previous experimental work. It is therefore recommending metrics that will allow consistency and comparability with other work. However, the metrics presented should not be considered as definitive or restrictive.

## 4.6 Step 5: Feedback to metrics repository

4.6.1 Upon completion of a validation exercise it is likely that there will useful information to feed back into the metrics repository. It is anticipated that this will take three forms:

- New or adapted metrics based upon knowledge gained in the validation process.
- Revisions to the metrics classification where poor or incorrect classification of metrics has been identified.
- Identification of additional classifications that may allow the metrics selection process to be more effective in future (e.g. Quality of Service, Communications, Conflict, etc).

# 5 Metrics for ASAS

## 5.1 General

5.1.1 Section 3.4 illustrated how the full set of metrics can be filtered to satisfy different perspectives. This included the identification of metrics relating to ASAS in general.

5.1.2 Section 5 shall perform a more detailed analysis of how one might identify metrics for specific ASAS applications. This shall be achieved through two example ASAS applications as identified in Work Package 1 [6]. The two examples were selected to illustrate two different categories of ASAS applications, namely:

- Airborne Separation
  *The controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew… limited to designated aircraft, specified by a new clearance… limited in time, space, and scope*.[7]
- Airborne Self-Separation
  *Require flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation minima and rules of flight*.[7]

5.1.3 The Airborne Separation application is:

- Time based sequencing in approach
  *Analysed in Section 5.2*

5.1.4 The Airborne Self-separation application is:

- Airborne self-separation in en-route airspace
  *Analysed in Section 5.3*

5.1.5 The effectiveness of the analysis that follows depends upon the effectiveness of metric classification as described in 3.5. At this stage, the ongoing classification process is not considered to be totally complete or rigorous. Therefore the tables provided should not be considered as definitive at this stage. However, because the metrics are recorded in database form, the tables can be easily regenerated when the classification process is more mature.

## 5.2 Time based sequencing in approach

5.2.1 It is identified that *Time based sequencing in approach* is an application of ASAS that will impact on airport and runway throughput, whilst maintaining existing safety levels.

5.2.2 The application can therefore be related to various strategic objectives [3]. The analysis in WP1 chooses to focus on the objectives of Safety, Capacity & Efficiency[4]. Therefore the scenario definition concentrates upon these. However, it

[4] The Work Package 1 report actually identifies Safety, Capacity & Economics. However, Work Package 2 identifies that Economics lies within the broader strategic objective of Efficiency.

is possible to choose any other strategic objective such as Environment or Security/Defence and identify metrics that may be appropriate.

5.2.3 Having chosen the high level objectives, it is then possible to further filter the metrics under consideration through the choice of Performance Areas that may be relevant.

5.2.4 Those Performance Areas considered relevant to the application are selected from the complete set of Performance Areas in the list below. Limiting the Performance Areas that are included limits the number of metrics that shall be identified for the scenario. Performance Areas that are not considered relevant are in grey:

| | |
|---|---|
| **Safety** | *Safety levels ensured through the ATM system*. |
| **Delay** | *The time in excess of the optimum time that it takes a user to complete an operation.* |
| **Cost effectiveness** | *The value for money that the user receives from the supply of air traffic services.* |
| **Predictability** | *The ability of the user to predict variation and to build and maintain optimum flight schedules.* |
| **Access** | *The accessibility to the airspace, ATM service and airport facilities under controllable conditions.* |
| **Flexibility** | *The ability of ATM to accommodate changing user needs in real time or without penalty.* |
| **Flight efficiency** | *The ability of ATM system to allow a user to adopt the preferred flight in terms of flight level and route.* |
| **Availability** | *The availability of ATM critical resources and of the ATM services provided to the user.* |
| **Equity** | *Equity of treatments of flights by all aircraft operators within and between specific classes of users.* |

5.2.5 Work Package 1 further divides the application into two separate scenarios, based upon different validation methodologies, namely:

- Analytic & Fast time simulation
- Real time simulation

5.2.6 Metrics can be selected appropriate to the validation methodology. In addition, metrics can be selected by choosing the perspective of Operator or Service Provider (see 3.4).

5.2.7 The following tables are database extracts that identify metrics by the various combinations of perspectives outlined above. The tables contain a limited definition

of each metric to save space. However, the metric ID can be used to reference the full details of each metric as listed in Annex A.

### 5.2.8 Analytic or fast time simulation – Safety metrics

Safety metrics are largely unaffected by the choice of perspective (operator or ATS provider). Therefore the table identifies all safety metrics relevant for an analytic or fast time simulation.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 933 | Incidents (separation infringements) | Number of separation infringements per period | C/AFT Study |
| 940 | Accident risk probability | Number of Hazardous event/ total of flight hours | Torch Project |
| 941 | Air-misses per flight | Total number of air-misses/ total number of flights | Torch Project |
| 942 | Air-misses per flown distance | Total number of air-misses/ total number of flown Kms. | Torch Project |
| 943 | Air-misses per flown hour | Total number of air-misses/ total number of flown hours | Torch Project |
| 945 | Alerting mechanism failures (ACAS failures) | Total number of false ACAS events (producing unsafe situations) | Torch Project |
| 946 | Alerting mechanism failures (STCA failures) | Total number of false STCA events (producing unsafe situations)] | Torch Project |
| 947 | Alerting mechanism failures (ACAS/STCA reliability) | Number of false ACAS/STCA events / number of ACAS/STCA events | Torch Project |
| 951 | Standard conflict en-route variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 952 | Standard conflict duration variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 953 | Standard conflict terminal variable | 5 miles lateral and 1.000 feet vertical | FAA Study |
| 954 | Standard conflict cumulative duration variable | 3 miles lateral and 1.000 feet vertical | FAA Study |
| 955 | User specifiable conflict, cumulative duration and terminal variable | User specifiable conflict criteria for lateral and vertical separation | FAA Study |
| 956 | Primary conflict measure for aircraft that are on final approaches and are in trail of one another | Measures longitudinal conflicts of aircraft on approach | FAA Study |
| 957 | The cumulative duration of longitudinal conflicts | The conflict duration in seconds | FAA Study |
| 958 | Parallel conflict frequency variable | Frequency of conflicts between aircraft on simultaneous parallel approaches | FAA Study |
| 959 | Parallel conflict frequency cumulative duration variable | Duration of conflict for aircraft pair conflicting on simultaneous parallel approach | FAA Study |
| 960 | Between sector conflict frequency variable | Conflict between aircraft pair when each aircraft is under control from a different controller | FAA Study |
| 961 | Between sector conflict frequency cumulative duration variable | Duration of conflict between aircraft pair when each aircraft is under control from a different controller | FAA Study |
| 962 | Aircraft proximity index variable | A weighted measure of conflict intensity where 100 is a mid-air collision and 1 is a minor separation of the violation standards | FAA Study |
| 963 | Airspace conflict frequency variable | Frequency of intrusion | FAA Study |
| 964 | Airspace conflict frequency cumulative duration variable | Duration of the intrusion into restricted airspace | FAA Study |
| 972 | Horizontal separation (miles)- Conflicts | Horizontal separation of aircraft in conflict measured in miles | FAA Study |
| 973 | Vertical separation (feet)- Conflicts | Vertical separation of aircraft in conflict measured in feet | FAA Study |
| 974 | Number of non-solved conflicts | It is the number of conflicts that the resolution algorithm was not able to solve | MAICA project |
| 975 | Number of missed resolutions | Total number of resolution attempts which have failed | MAICA project |
| 976 | Number of conflicts with missed resolution attempt | The number of conflicts which were solved after more than one attempt and the number of attempts | MAICA project |
| 977 | Number of class 1 resolutions | The number of conflicts which have been solved using a solution allowing to return before the end of the resolution period to a trajectory leading to the exit point | MAICA project |
| 978 | Number of class 2 resolutions | The number of conflicts that a class 1 resolution has not been able to solve | MAICA project |
| 979 | Number of lateral resolutions | Number of conflicts that have been solved using only lateral manoeuvres | MAICA project |
| 980 | Number of vertical resolutions | Number of conflicts that have been solved using only vertical manoeuvres | MAICA project |
| 981 | Number of aircraft taken into account for a resolution | For each resolution, the number of aircraft that the one in charge of it had to take into account | MAICA project |
| 982 | Resolution complexity | The number of manoeuvres required to solve a conflict | MAICA project |
| 983 | Number of illegal horizontal exit | The number of aircraft which have left the space outside the horizontal tolerance around the exit point | MAICA project |
| 984 | Number of illegal vertical exit | The number of aircraft which have left the space outside the vertical tolerance around the exit point | MAICA project |
| 985 | Detected "convergence" conflicts versus FL | These conflicts can either be "convergences" or "overtakes" or "headons" | MAICA project |
| 986 | Total number of detected conflicts in ADS-B range versus FL | It is considered that a conflict becomes "visible" when the other aircraft involved is within ADSB-range and when it has received the predicted trajectory of this aircraft till the conflict start time (look-ahead time) | MAICA project |
| 987 | Simultaneously detected conflicts in ADS-B range per aircraft versus FL | The number of conflicts which are currently visible by each aircraft for each FL | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 988 | Active conflict resolution versus flight level | Number of conflicts solved by a particular aircraft (depending on the altitude of both aircraft) | MAICA project |
| 989 | Time between a conflict detection and resolution | The time between the detection of the conflict by the aircraft involved and the first resolution attempt | MAICA project |
| 990 | Time between conflict resolution and beginning times | The difference between the conflict resolution time and its beginning time | MAICA project |
| 991 | Time between active resolutions | For an aircraft, it is the flight duration divided by the number of actively solved conflicts | MAICA project |
| 992 | Cluster density versus size, expressed in number of aircraft | Number of clusters present in the air situation sorted by size expressed in number of aircraft | MAICA project |
| 993 | Cluster density versus size, expressed in number of conflicts | Number of clusters present in the air situation sorted by size expressed in number of conflicts | MAICA project |
| 994 | Number of induced conflicts | Number of conflicts that start while the aircraft has not yet finished the resolution of the previous one | MAICA project |
| 995 | Time before induced conflicts resolution | The time between the beginning of the resolution of this conflict and the beginning of the resolution under progress | MAICA project |
| 1032 | Variations in system performance associated with changes in weather | Difference between highest EPS VFR capacity and smallest CAT I IFR capacity | C/AFT Study |
| 1049 | Approved approaches | Number of airports with approved approaches | C/AFT Study |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1118 | VFR tower services | Number of operations provided with VFR tower services | C/AFT Study |
| 1119 | CNS coverage | CNS coverage (various altitudes) | C/AFT Study |
| 1124 | Availability and quality of flight services to the system user | Availability and quality of flight services to the system user | C/AFT Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1138 | ATFM overloads | Number of flights exceeding the capacity per sector per hours | C/AFT Study |
| 1194 | Propensity | The likelihood of a safety significant event occurring during normal operations | INTEGRA |
| 1195 | Resilience | The extent to which the ATM system responds to a safety significant event without causing more such events. | INTEGRA |

*Table 5-1 Metrics for Analytic or Fast Time Simulation - Safety*

### 5.2.9 Analytic or fast time simulation – Operator perspective

This table identifies metrics from an operator perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 999 | Total delay | Total delay | C/AFT Study |
| 1000 | Flights delayed | Number of flights delayed | C/AFT Study |
| 1001 | Average delay | Average delay per flight (total, airborne, gate, taxi-in…) | C/AFT Study |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1012 | TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) | Total minutes of TMA delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1015 | Relationship among delay, traffic volume and capacity | Weekly minutes of ATM delay by volume of traffic | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1024 | Record of time | Measure of total flight time with and without delegation | ECAC experiments on ASAS |
| 1025 | Initial trajectory duration | The duration required to fly the initial trajectory | MAICA project |
| 1026 | Real trajectory duration | This is the real duration of a flight | MAICA project |
| 1027 | Duration increase | This is the ratio: real trajectory duration divided by initial trajectory duration | MAICA project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1032 | Variations in system performance associated with changes in weather | Difference between highest EPS VFR capacity and smallest CAT I IFR capacity | C/AFT Study |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1041 | Standard deviation | Standard deviation of arrival delay | PRC Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1046 | Punctuality of arrival | Difference between actual and scheduled arrival time | Torch Project |
| 1047 | Anticipated delay | Difference between schedule and optimum gate to gate time in minutes | Torch Project |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1065 | Unconstrained runway capacity | Declared capacity/ unconstrained runway capacity | Torch Project |
| 1066 | Saturation capacity (airport) | Number of total actual hourly operations/ number of maximum operations (saturation capacity) | Torch Project |
| 1067 | Practical capacity (airport) | Practical capacity (airport capacity) | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1085 | Restrictions (amount not constrained) | Amount of aviation activity not constrained by procedural restrictions | C/AFT Study |
| 1086 | Restrictions (impact) | Severity of impact of the procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1090 | Deviation between ATC preferred route and flight plan route | Lateral deviation between ATC preferred route and flight plan route, among flights subject to ATC preferred routes | C/AFT Study |
| 1091 | Distance between preferred routes and final route | Distance between preferred routes and great circle distance by origin-destination pair, weighed by level of traffic | C/AFT Study |
| 1092 | Flights able to fly in the requested altitude | Number of flights whose max. Altitude equalled the requested altitude in flight plan | C/AFT Study |
| 1093 | Deviation between the requested and flown route (descent) | Excess descent time over that of an ideal managed descent (From Top of Descent to Wheels Down) | C/AFT Study |
| 1094 | Deviation between the requested and flown route (mean lateral deviation) | Mean lateral deviation between flight plan route and actual flown route | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1100 | Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i | Number of change request granted in real time/ number of change requests submitted | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1109 | Distance difference | Measure of the difference of flight distance with and without delegation | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1114 | Initial trajectory length | The initial trajectory of an aircraft contains three fixed points: the entry point, a virtual waypoint and the exit point. | MAICA project |
| 1115 | Real trajectory length | This is the length of the trajectory that was really flown | MAICA project |
| 1116 | Length increase | Ratio: real trajectory length divided by initial trajectory length | MAICA project |
| 1128 | Disruption caused by unavailability (all critical system) | Number of flights delayed, re-routed, cancelled or diverted as a result of downtime of all critical systems/ number of planned flights | PRC Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1138 | ATFM overloads | Number of flights exceeding the capacity per sector per hours | C/AFT Study |
| 1139 | ATFM underdeliveries | Number of lost slots per regulation per hour | C/AFT Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-2 Metrics for Analytic or Fast Time Simulation – Operator perspective*

### 5.2.10 Analytic or fast time simulation – ATS perspective

This table identifies metrics from an ATS Provider perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 999 | Total delay | Total delay | C/AFT Study |
| 1000 | Flights delayed | Number of flights delayed | C/AFT Study |
| 1001 | Average delay | Average delay per flight (total, airborne, gate, taxi-in…) | C/AFT Study |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1012 | TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) | Total minutes of TMA delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1015 | Relationship among delay, traffic volume and capacity | Weekly minutes of ATM delay by volume of traffic | PRC Study |
| 1016 | Capacity management (index) | Capacity index | PRC Study |
| 1017 | Capacity management (target variation) | Actual capacity variation/ target capacity variation (%) | PRC Study |
| 1018 | Capacity management (traffic variation) | Actual capacity variation/ actual traffic variation (%) | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1032 | Variations in system performance associated with changes in weather | Difference between highest EPS VFR capacity and smallest CAT I IFR capacity | C/AFT Study |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1054 | Sector capacity | Sector capacity per period of time under different weather conditions and procedures | C/AFT Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1065 | Unconstrained runway capacity | Declared capacity/ unconstrained runway capacity | Torch Project |
| 1066 | Saturation capacity (airport) | Number of total actual hourly operations/ number of maximum operations (saturation capacity) | Torch Project |
| 1067 | Practical capacity (airport) | Practical capacity (airport capacity) | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1128 | Disruption caused by unavailability (all critical system) | Number of flights delayed, re-routed, cancelled or diverted as a result of downtime of all critical systems/ number of planned flights | PRC Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1138 | ATFM overloads | Number of flights exceeding the capacity per sector per hours | C/AFT Study |
| 1139 | ATFM underdeliveries | Number of lost slots per regulation per hour | C/AFT Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-3 Metrics for Analytic or Fast Time Simulation – ATS perspective*

### 5.2.11 Real Time Simulation – Safety metrics

Safety metrics are largely unaffected by the choice of perspective (operator or ATS provider). Therefore the table identifies all safety metrics appropriate for real time simulation tools.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 933 | Incidents (separation infringements) | Number of separation infringements per period | C/AFT Study |
| 949 | Operational errors | Number of operational errors/ total number of facility activities over a selected operating time | Torch Project |
| 951 | Standard conflict en-route variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 952 | Standard conflict duration variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 953 | Standard conflict terminal variable | 5 miles lateral and 1.000 feet vertical | FAA Study |
| 954 | Standard conflict cumulative duration variable | 3 miles lateral and 1.000 feet vertical | FAA Study |
| 955 | User specifiable conflict, cumulative duration and terminal variable | User specifiable conflict criteria for lateral and vertical separation | FAA Study |
| 965 | Conflict alerts | Number of conflict alerts that occurs during the simulation | FAA Study |
| 966 | Vertical separation | Vertical separation of the aircraft pair in conflict in feet | FAA Study |
| 967 | Closest point-of-approach | Slant range of the aircraft pair in conflict measured in feet | FAA Study |
| 968 | Slant range miss distance- measure of aircraft separation | The shortest distance between two aircraft in conflict. It is measured by a straight line formed by the aircraft centres | FAA Study |
| 969 | Blunders and associated conflicts | An unexpected turn by an aircraft already established on the localizer toward another aircraft on an adjacent approach | FAA Study |
| 970 | Blundering aircraft and the next aircraft receiving a path change message | Planned deviations from the localizer in which one aircraft crosses into the landing path of another | FAA Study |
| 971 | Deviation (feet, L-left, R-right), MX (maximum deviation in feet) | Deviation from the ILS enter line in feet | FAA Study |
| 972 | Horizontal separation (miles)- Conflicts | Horizontal separation of aircraft in conflict measured in miles | FAA Study |
| 973 | Vertical separation (feet)- Conflicts | Vertical separation of aircraft in conflict measured in feet | FAA Study |
| 974 | Number of non-solved conflicts | It is the number of conflicts that the resolution algorithm was not able to solve | MAICA project |
| 975 | Number of missed resolutions | Total number of resolution attempts which have failed | MAICA project |
| 976 | Number of conflicts with missed resolution attempt | The number of conflicts which were solved after more than one attempt and the number of attempts | MAICA project |
| 977 | Number of class 1 resolutions | The number of conflicts which have been solved using a solution allowing to return before the end of the resolution period to a trajectory leading to the exit point | MAICA project |
| 978 | Number of class 2 resolutions | The number of conflicts that a class 1 resolution has not been able to solve | MAICA project |
| 979 | Number of lateral resolutions | Number of conflicts that have been solved using only lateral manoeuvres | MAICA project |
| 980 | Number of vertical resolutions | Number of conflicts that have been solved using only vertical manoeuvres | MAICA project |
| 981 | Number of aircraft taken into account for a resolution | For each resolution, the number of aircraft that the one in charge of it had to take into account | MAICA project |
| 982 | Resolution complexity | The number of manoeuvres required to solve a conflict | MAICA project |
| 983 | Number of illegal horizontal exit | The number of aircraft which have left the space outside the horizontal tolerance around the exit point | MAICA project |
| 984 | Number of illegal vertical exit | The number of aircraft which have left the space outside the vertical tolerance around the exit point | MAICA project |
| 985 | Detected "convergence" conflicts versus FL | These conflicts can either be "convergences" or "overtakes" or "headons" | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 986 | Total number of detected conflicts in ADS-B range versus FL | It is considered that a conflict becomes "visible" when the other aircraft involved is within ADSB-range and when it has received the predicted trajectory of this aircraft till the conflict start time (look-ahead time) | MAICA project |
| 987 | Simultaneously detected conflicts in ADS-B range per aircraft versus FL | The number of conflicts which are currently visible by each aircraft for each FL | MAICA project |
| 988 | Active conflict resolution versus flight level | Number of conflicts solved by a particular aircraft (depending on the altitude of both aircraft) | MAICA project |
| 989 | Time between a conflict detection and resolution | The time between the detection of the conflict by the aircraft involved and the first resolution attempt | MAICA project |
| 990 | Time between conflict resolution and beginning times | The difference between the conflict resolution time and its beginning time | MAICA project |
| 991 | Time between active resolutions | For an aircraft, it is the flight duration divided by the number of actively solved conflicts | MAICA project |
| 992 | Cluster density versus size, expressed in number of aircraft | Number of clusters present in the air situation sorted by size expressed in number of aircraft | MAICA project |
| 993 | Cluster density versus size, expressed in number of conflicts | Number of clusters present in the air situation sorted by size expressed in number of conflicts | MAICA project |
| 994 | Number of induced conflicts | Number of conflicts that start while the aircraft has not yet finished the resolution of the previous one | MAICA project |
| 995 | Time before induced conflicts resolution | The time between the beginning of the resolution of this conflict and the beginning of the resolution under progress | MAICA project |
| 1032 | Variations in system performance associated with changes in weather | Difference between highest EPS VFR capacity and smallest CAT I IFR capacity | C/AFT Study |
| 1035 | Variation in the ATM system as experienced by the user | Timeliness and quality of data provided to the user on weather, traffic and system status | C/AFT Study |
| 1049 | Approved approaches | Number of airports with approved approaches | C/AFT Study |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1119 | CNS coverage | CNS coverage (various altitudes) | C/AFT Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1130 | Communication delay | The accumulated time variable based on the duration of time between the aircraft calls for service and the controllers' initial response | FAA Study |
| 1131 | Number of communication delays | This is the cumulated frequency of communication delays that exceed 20 seconds | FAA Study |
| 1194 | Propensity | The likelihood of a safety significant event occurring during normal operations | INTEGRA |
| 1195 | Resilience | The extent to which the ATM system responds to a safety significant event without causing more such events. | INTEGRA |

*Table 5-4 Metrics for Real Time Simulation - Safety*

### 5.2.12 Real Time Simulation – Operator perspective

This table identifies metrics from an operator perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 9 | Efficiency of actual route flown | Ratio reflecting route distance saving over a single flight. | Torch Project |
| 11 | Efficiency of routing service | Comparison of actual routing to agreed flight plan. | Torch Project |
| 14 | Route fuel average | Route fuel saving for an operator averaged over a specified period of time/flights. | dummy |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1012 | TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) | Total minutes of TMA delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1024 | Record of time | Measure of total flight time with and without delegation | ECAC experiments on ASAS |
| 1025 | Initial trajectory duration | The duration required to fly the initial trajectory | MAICA project |
| 1026 | Real trajectory duration | This is the real duration of a flight | MAICA project |
| 1027 | Duration increase | This is the ratio: real trajectory duration divided by initial trajectory duration | MAICA project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1032 | Variations in system performance associated with changes in weather | Difference between highest EPS VFR capacity and smallest CAT I IFR capacity | C/AFT Study |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1036 | Variation in the ATM system as experienced by the user | Number of delay allocation decisions made with direct user input | C/AFT Study |
| 1041 | Standard deviation | Standard deviation of arrival delay | PRC Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1046 | Punctuality of arrival | Difference between actual and scheduled arrival time | Torch Project |
| 1047 | Anticipated delay | Difference between schedule and optimum gate to gate time in minutes | Torch Project |
| 1048 | Cancel flight- instantaneous aircraft count | Number of cancelled flights that occurred during an experimental run | FAA Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1065 | Unconstrained runway capacity | Declared capacity/ unconstrained runway capacity | Torch Project |
| 1066 | Saturation capacity (airport) | Number of total actual hourly operations/ number of maximum operations (saturation capacity) | Torch Project |
| 1067 | Practical capacity (airport) | Practical capacity (airport capacity) | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1074 | Missed approaches- non conflict errors | Frequency of missed approaches executed during a run | FAA Study |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1085 | Restrictions (amount not constrained) | Amount of aviation activity not constrained by procedural restrictions | C/AFT Study |
| 1086 | Restrictions (impact) | Severity of impact of the procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1090 | Deviation between ATC preferred route and flight plan route | Lateral deviation between ATC preferred route and flight plan route, among flights subject to ATC preferred routes | C/AFT Study |
| 1091 | Distance between preferred routes and final route | Distance between preferred routes and great circle distance by origin-destination pair, weighed by level of traffic | C/AFT Study |
| 1092 | Flights able to fly in the requested altitude | Number of flights whose max. Altitude equalled the requested altitude in flight plan | C/AFT Study |
| 1093 | Deviation between the requested and flown route (descent) | Excess descent time over that of an ideal managed descent (From Top of Descent to Wheels Down) | C/AFT Study |
| 1094 | Deviation between the requested and flown route (mean lateral deviation) | Mean lateral deviation between flight plan route and actual flown route | C/AFT Study |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1100 | Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i | Number of change request granted in real time/ number of change requests submitted | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1104 | Altitude- complexity measures | Frequency of altitude clearance issued during a run | FAA Study |
| 1105 | Heading- complexity measures | Frequency of heading clearances issued during a run | FAA Study |
| 1106 | Speed- complexity measures | Frequency of speed clearances issued during a run | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1109 | Distance difference | Measure of the difference of flight distance with and without delegation | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1114 | Initial trajectory length | The initial trajectory of an aircraft contains three fixed points: the entry point, a virtual waypoint and the exit point. | MAICA project |
| 1115 | Real trajectory length | This is the length of the trajectory that was really flown | MAICA project |
| 1116 | Length increase | Ratio: real trajectory length divided by initial trajectory length | MAICA project |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1130 | Communication delay | The accumulated time variable based on the duration of time between the aircraft calls for service and the controllers' initial response | FAA Study |
| 1131 | Number of communication delays | This is the cumulated frequency of communication delays that exceed 20 seconds | FAA Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1184 | ATS productivity | The productivity of the ATS provided to users | Torch Project |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-5 Metrics for Real Time Simulation – Operator perspective*

### 5.2.13 Real Time Simulation – ATS perspective

This table identifies metrics from an ATS Provider perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 11 | Efficiency of routing service | Comparison of actual routing to agreed flight plan. | Torch Project |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1012 | TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) | Total minutes of TMA delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1017 | Capacity management (target variation) | Actual capacity variation/ target capacity variation (%) | PRC Study |
| 1018 | Capacity management (traffic variation) | Actual capacity variation/ actual traffic variation (%) | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1032 | Variations in system performance associated with changes in weather | Difference between highest EPS VFR capacity and smallest CAT I IFR capacity | C/AFT Study |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1048 | Cancel flight- instantaneous aircraft count | Number of cancelled flights that occurred during an experimental run | FAA Study |
| 1054 | Sector capacity | Sector capacity per period of time under different weather conditions and procedures | C/AFT Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1065 | Unconstrained runway capacity | Declared capacity/ unconstrained runway capacity | Torch Project |
| 1066 | Saturation capacity (airport) | Number of total actual hourly operations/ number of maximum operations (saturation capacity) | Torch Project |
| 1067 | Practical capacity (airport) | Practical capacity (airport capacity) | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1074 | Missed approaches- non conflict errors | Frequency of missed approaches executed during a run | FAA Study |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1104 | Altitude- complexity measures | Frequency of altitude clearance issued during a run | FAA Study |
| 1105 | Heading- complexity measures | Frequency of heading clearances issued during a run | FAA Study |
| 1106 | Speed- complexity measures | Frequency of speed clearances issued during a run | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1130 | Communication delay | The accumulated time variable based on the duration of time between the aircraft calls for service and the controllers' initial response | FAA Study |
| 1131 | Number of communication delays | This is the cumulated frequency of communication delays that exceed 20 seconds | FAA Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1184 | ATS productivity | The productivity of the ATS provided to users | Torch Project |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-6 Metrics for Real Time Simulation – ATS perspective*

## 5.3 Airborne self separation in en-route airspace

5.3.1 It is identified that *Airborne self-separation in en-route airspace* is an application of ASAS that will:

- maintain or improve safety through improved situational awareness
- optimise flight efficiency through improved flexibility and direct routing

5.3.2 The effect upon airspace capacity is still an unresolved issue, but is clearly a relevant objective against which the performance of this ASAS application must be measured.

5.3.3 The application can therefore be related to various strategic objectives [3]. The analysis in WP1 chooses to focus on the objectives of Safety, Capacity & Efficiency. Therefore the scenario definition concentrates upon these. However, it is possible to choose any other strategic objective such as Environment or Security/Defence and identify metrics that may be appropriate.

5.3.4 Having chosen the high level objectives, it is then possible to further filter the metrics under consideration through the choice of Performance Areas that may be relevant.

5.3.5 Those Performance Areas considered relevant to the application are selected from the complete set of Performance Areas in the list below. Limiting the Performance Areas that are included limits the number of metrics that shall be identified for the scenario. Performance Areas that are not considered relevant are in grey:

| | |
|---|---|
| **Safety** | *Safety levels ensured through the ATM system*. |
| **Delay** | *The time in excess of the optimum time that it takes a user to complete an operation.* |
| **Cost effectiveness** | *The value for money that the user receives from the supply of air traffic services.* |
| **Predictability** | *The ability of the user to predict variation and to build and maintain optimum flight schedules.* |
| **Access** | *The accessibility to the airspace, ATM service and airport facilities under controllable conditions.* |
| **Flexibility** | *The ability of ATM to accommodate changing user needs in real time or without penalty.* |
| **Flight efficiency** | *The ability of ATM system to allow a user to adopt the preferred flight in terms of flight level and route.* |
| **Availability** | *The availability of ATM critical resources and of the ATM services provided to the user.* |
| **Equity** | *Equity of treatments of flights by all aircraft operators within and between specific classes of users.* |

5.3.6 Work Package 1 further divides the application into two separate scenarios, based upon different validation methodologies, namely:

- Analytic & Fast time simulation
- Real time simulation

5.3.7 Metrics can be selected appropriate to the validation methodology. In addition, metrics can be selected by choosing the perspective of Operator or Service Provider (see 3.4).

5.3.8 Metrics shall be restricted to those pertaining to en-route airspace.

5.3.9 The following tables are database extracts that identify metrics by the various combinations of perspectives outlined above. The tables contain a limited definition of each metric to save space. However, the metric ID can be used to reference the full details of each metric as listed in Annex A.

### 5.3.10 Analytic or fast time simulation – Safety metrics

Safety metrics are largely unaffected by the choice of perspective (operator or ATS provider). Therefore the table identifies all safety metrics relevant for an analytic or fast time simulation.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 933 | Incidents (separation infringements) | Number of separation infringements per period | C/AFT Study |
| 940 | Accident risk probability | Number of Hazardous event/ total of flight hours | Torch Project |
| 941 | Air-misses per flight | Total number of air-misses/ total number of flights | Torch Project |
| 942 | Air-misses per flown distance | Total number of air-misses/ total number of flown Kms. | Torch Project |
| 943 | Air-misses per flown hour | Total number of air-misses/ total number of flown hours | Torch Project |
| 945 | Alerting mechanism failures (ACAS failures) | Total number of false ACAS events (producing unsafe situations) | Torch Project |
| 946 | Alerting mechanism failures (STCA failures) | Total number of false STCA events (producing unsafe situations)] | Torch Project |
| 947 | Alerting mechanism failures (ACAS/STCA reliability) | Number of false ACAS/STCA events / number of ACAS/STCA events | Torch Project |
| 951 | Standard conflict en-route variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 952 | Standard conflict duration variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 953 | Standard conflict terminal variable | 5 miles lateral and 1.000 feet vertical | FAA Study |
| 954 | Standard conflict cumulative duration variable | 3 miles lateral and 1.000 feet vertical | FAA Study |
| 955 | User specifiable conflict, cumulative duration and terminal variable | User specifiable conflict criteria for lateral and vertical separation | FAA Study |
| 957 | The cumulative duration of longitudinal conflicts | The conflict duration in seconds | FAA Study |
| 960 | Between sector conflict frequency variable | Conflict between aircraft pair when each aircraft is under control from a different controller | FAA Study |
| 961 | Between sector conflict frequency cumulative duration variable | Duration of conflict between aircraft pair when each aircraft is under control from a different controller | FAA Study |
| 962 | Aircraft proximity index variable | A weighted measure of conflict intensity where 100 is a mid-air collision and 1 is a minor separation of the violation standards | FAA Study |
| 963 | Airspace conflict frequency variable | Frequency of intrusion | FAA Study |
| 964 | Airspace conflict frequency cumulative duration variable | Duration of the intrusion into restricted airspace | FAA Study |
| 972 | Horizontal separation (miles)- Conflicts | Horizontal separation of aircraft in conflict measured in miles | FAA Study |
| 973 | Vertical separation (feet)- Conflicts | Vertical separation of aircraft in conflict measured in feet | FAA Study |
| 974 | Number of non-solved conflicts | It is the number of conflicts that the resolution algorithm was not able to solve | MAICA project |
| 975 | Number of missed resolutions | Total number of resolution attempts which have failed | MAICA project |
| 976 | Number of conflicts with missed resolution attempt | The number of conflicts which were solved after more than one attempt and the number of attempts | MAICA project |
| 977 | Number of class 1 resolutions | The number of conflicts which have been solved using a solution allowing to return before the end of the resolution period to a trajectory leading to the exit point | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 978 | Number of class 2 resolutions | The number of conflicts that a class 1 resolution has not been able to solve | MAICA project |
| 979 | Number of lateral resolutions | Number of conflicts that have been solved using only lateral manoeuvres | MAICA project |
| 980 | Number of vertical resolutions | Number of conflicts that have been solved using only vertical manoeuvres | MAICA project |
| 981 | Number of aircraft taken into account for a resolution | For each resolution, the number of aircraft that the one in charge of it had to take into account | MAICA project |
| 982 | Resolution complexity | The number of manoeuvres required to solve a conflict | MAICA project |
| 983 | Number of illegal horizontal exit | The number of aircraft which have left the space outside the horizontal tolerance around the exit point | MAICA project |
| 984 | Number of illegal vertical exit | The number of aircraft which have left the space outside the vertical tolerance around the exit point | MAICA project |
| 985 | Detected "convergence" conflicts versus FL | These conflicts can either be "convergences" or "overtakes" or "headons" | MAICA project |
| 986 | Total number of detected conflicts in ADS-B range versus FL | It is considered that a conflict becomes "visible" when the other aircraft involved is within ADSB-range and when it has received the predicted trajectory of this aircraft till the conflict start time (look-ahead time) | MAICA project |
| 987 | Simultaneously detected conflicts in ADS-B range per aircraft versus FL | The number of conflicts which are currently visible by each aircraft for each FL | MAICA project |
| 988 | Active conflict resolution versus flight level | Number of conflicts solved by a particular aircraft (depending on the altitude of both aircraft) | MAICA project |
| 989 | Time between a conflict detection and resolution | The time between the detection of the conflict by the aircraft involved and the first resolution attempt | MAICA project |
| 990 | Time between conflict resolution and beginning times | The difference between the conflict resolution time and its beginning time | MAICA project |
| 991 | Time between active resolutions | For an aircraft, it is the flight duration divided by the number of actively solved conflicts | MAICA project |
| 992 | Cluster density versus size, expressed in number of aircraft | Number of clusters present in the air situation sorted by size expressed in number of aircraft | MAICA project |
| 993 | Cluster density versus size, expressed in number of conflicts | Number of clusters present in the air situation sorted by size expressed in number of conflicts | MAICA project |
| 994 | Number of induced conflicts | Number of conflicts that start while the aircraft has not yet finished the resolution of the previous one | MAICA project |
| 995 | Time before induced conflicts resolution | The time between the beginning of the resolution of this conflict and the beginning of the resolution under progress | MAICA project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1119 | CNS coverage | CNS coverage (various altitudes) | C/AFT Study |
| 1124 | Availability and quality of flight services to the system user | Availability and quality of flight services to the system user | C/AFT Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1138 | ATFM overloads | Number of flights exceeding the capacity per sector per hours | C/AFT Study |
| 1194 | Propensity | The likelihood of a safety significant event occurring during normal operations | INTEGRA |
| 1195 | Resilience | The extent to which the ATM system responds to a safety significant event without causing more such events. | INTEGRA |

*Table 5-7 Metrics for Analytic or Fast Time Simulation - Safety*

### 5.3.11 Analytic or fast time simulation – Operator perspective

This table identifies metrics from an operator perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 14 | Route fuel average | Route fuel saving for an operator averaged over a specified period of time/flights. | dummy |
| 999 | Total delay | Total delay | C/AFT Study |
| 1000 | Flights delayed | Number of flights delayed | C/AFT Study |
| 1001 | Average delay | Average delay per flight (total, airborne, gate, taxi-in…) | C/AFT Study |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1015 | Relationship among delay, traffic volume and capacity | Weekly minutes of ATM delay by volume of traffic | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1024 | Record of time | Measure of total flight time with and without delegation | ECAC experiments on ASAS |
| 1025 | Initial trajectory duration | The duration required to fly the initial trajectory | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1026 | Real trajectory duration | This is the real duration of a flight | MAICA project |
| 1027 | Duration increase | This is the ratio: real trajectory duration divided by initial trajectory duration | MAICA project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1040 | Anticipated delay | Difference between scheduled and optimum gate-to-gate time | PRC Study |
| 1041 | Standard deviation | Standard deviation of arrival delay | PRC Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1046 | Punctuality of arrival | Difference between actual and scheduled arrival time | Torch Project |
| 1047 | Anticipated delay | Difference between schedule and optimum gate to gate time in minutes | Torch Project |
| 1050 | Special use airspace access | Percentage of air carrier flights that penetrate special use airspace, for those origin-destination pairs in which at least one flight penetrated special use airspace | C/AFT Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1064 | Movements | Number of movements/ declared capacity | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1085 | Restrictions (amount not constrained) | Amount of aviation activity not constrained by procedural restrictions | C/AFT Study |
| 1086 | Restrictions (impact) | Severity of impact of the procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1090 | Deviation between ATC preferred route and flight plan route | Lateral deviation between ATC preferred route and flight plan route, among flights subject to ATC preferred routes | C/AFT Study |
| 1091 | Distance between preferred routes and final route | Distance between preferred routes and great circle distance by origin-destination pair, weighed by level of traffic | C/AFT Study |
| 1092 | Flights able to fly in the requested altitude | Number of flights whose max. Altitude equalled the requested altitude in flight plan | C/AFT Study |
| 1093 | Deviation between the requested and flown route (descent) | Excess descent time over that of an ideal managed descent (From Top of Descent to Wheels Down) | C/AFT Study |
| 1094 | Deviation between the requested and flown route (mean lateral deviation) | Mean lateral deviation between flight plan route and actual flown route | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1100 | Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i | Number of change request granted in real time/ number of change requests submitted | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1109 | Distance difference | Measure of the difference of flight distance with and without delegation | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1114 | Initial trajectory length | The initial trajectory of an aircraft contains three fixed points: the entry point, a virtual waypoint and the exit point. | MAICA project |
| 1115 | Real trajectory length | This is the length of the trajectory that was really flown | MAICA project |
| 1116 | Length increase | Ratio: real trajectory length divided by initial trajectory length | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1128 | Disruption caused by unavailability (all critical system) | Number of flights delayed, re-routed, cancelled or diverted as a result of downtime of all critical systems/ number of planned flights | PRC Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1136 | ATFM equity | Deviation from standard equity rule (slots) | C/AFT Study |
| 1138 | ATFM overloads | Number of flights exceeding the capacity per sector per hours | C/AFT Study |
| 1139 | ATFM underdeliveries | Number of lost slots per regulation per hour | C/AFT Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1145 | Equity of the planning functions | % of user equity achieved | Torch Project |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-8 Metrics for Analytic or Fast Time Simulation – Operator perspective*

### 5.3.12 Analytic or fast time simulation – ATS perspective

This table identifies metrics from an ATS Provider perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 999 | Total delay | Total delay | C/AFT Study |
| 1000 | Flights delayed | Number of flights delayed | C/AFT Study |
| 1001 | Average delay | Average delay per flight (total, airborne, gate, taxi-in…) | C/AFT Study |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1015 | Relationship among delay, traffic volume and capacity | Weekly minutes of ATM delay by volume of traffic | PRC Study |
| 1016 | Capacity management (index) | Capacity index | PRC Study |
| 1017 | Capacity management (target variation) | Actual capacity variation/ target capacity variation (%) | PRC Study |
| 1018 | Capacity management (traffic variation) | Actual capacity variation/ actual traffic variation (%) | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1040 | Anticipated delay | Difference between scheduled and optimum gate-to-gate time | PRC Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1050 | Special use airspace access | Percentage of air carrier flights that penetrate special use airspace, for those origin-destination pairs in which at least one flight penetrated special use airspace | C/AFT Study |
| 1054 | Sector capacity | Sector capacity per period of time under different weather conditions and procedures | C/AFT Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1064 | Movements | Number of movements/ declared capacity | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1128 | Disruption caused by unavailability (all critical system) | Number of flights delayed, re-routed, cancelled or diverted as a result of downtime of all critical systems/ number of planned flights | PRC Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1136 | ATFM equity | Deviation from standard equity rule (slots) | C/AFT Study |
| 1138 | ATFM overloads | Number of flights exceeding the capacity per sector per hours | C/AFT Study |
| 1139 | ATFM underdeliveries | Number of lost slots per regulation per hour | C/AFT Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1145 | Equity of the planning functions | % of user equity achieved | Torch Project |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-9 Metrics for Analytic or Fast Time Simulation – ATS perspective*

### 5.3.13 Real Time Simulation – Safety metrics

Safety metrics are largely unaffected by the choice of perspective. Therefore the table identifies all safety metrics appropriate for real time simulation tools.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 933 | Incidents (separation infringements) | Number of separation infringements per period | C/AFT Study |
| 949 | Operational errors | Number of operational errors/ total number of facility activities over a selected operating time | Torch Project |
| 951 | Standard conflict en-route variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 952 | Standard conflict duration variable | 5 miles lateral and 1.000 feet vertical (>FL290= 2.000ft vertical) | FAA Study |
| 953 | Standard conflict terminal variable | 5 miles lateral and 1.000 feet vertical | FAA Study |
| 954 | Standard conflict cumulative duration variable | 3 miles lateral and 1.000 feet vertical | FAA Study |
| 955 | User specifiable conflict, cumulative duration and terminal variable | User specifiable conflict criteria for lateral and vertical separation | FAA Study |
| 965 | Conflict alerts | Number of conflict alerts that occurs during the simulation | FAA Study |
| 966 | Vertical separation | Vertical separation of the aircraft pair in conflict in feet | FAA Study |
| 967 | Closest point-of-approach | Slant range of the aircraft pair in conflict measured in feet | FAA Study |
| 968 | Slant range miss distance- measure of aircraft separation | The shortest distance between two aircraft in conflict. It is measured by a straight line formed by the aircraft centres | FAA Study |
| 972 | Horizontal separation (miles)- Conflicts | Horizontal separation of aircraft in conflict measured in miles | FAA Study |
| 973 | Vertical separation (feet)- Conflicts | Vertical separation of aircraft in conflict measured in feet | FAA Study |
| 974 | Number of non-solved conflicts | It is the number of conflicts that the resolution algorithm was not able to solve | MAICA project |
| 975 | Number of missed resolutions | Total number of resolution attempts which have failed | MAICA project |
| 976 | Number of conflicts with missed resolution attempt | The number of conflicts which were solved after more than one attempt and the number of attempts | MAICA project |
| 977 | Number of class 1 resolutions | The number of conflicts which have been solved using a solution allowing to return before the end of the resolution period to a trajectory leading to the exit point | MAICA project |
| 978 | Number of class 2 resolutions | The number of conflicts that a class 1 resolution has not been able to solve | MAICA project |
| 979 | Number of lateral resolutions | Number of conflicts that have been solved using only lateral manoeuvres | MAICA project |
| 980 | Number of vertical resolutions | Number of conflicts that have been solved using only vertical manoeuvres | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 981 | Number of aircraft taken into account for a resolution | For each resolution, the number of aircraft that the one in charge of it had to take into account | MAICA project |
| 982 | Resolution complexity | The number of manoeuvres required to solve a conflict | MAICA project |
| 983 | Number of illegal horizontal exit | The number of aircraft which have left the space outside the horizontal tolerance around the exit point | MAICA project |
| 984 | Number of illegal vertical exit | The number of aircraft which have left the space outside the vertical tolerance around the exit point | MAICA project |
| 985 | Detected "convergence" conflicts versus FL | These conflicts can either be "convergences" or "overtakes" or "headons" | MAICA project |
| 986 | Total number of detected conflicts in ADS-B range versus FL | It is considered that a conflict becomes "visible" when the other aircraft involved is within ADSB-range and when it has received the predicted trajectory of this aircraft till the conflict start time (look-ahead time) | MAICA project |
| 987 | Simultaneously detected conflicts in ADS-B range per aircraft versus FL | The number of conflicts which are currently visible by each aircraft for each FL | MAICA project |
| 988 | Active conflict resolution versus flight level | Number of conflicts solved by a particular aircraft (depending on the altitude of both aircraft) | MAICA project |
| 989 | Time between a conflict detection and resolution | The time between the detection of the conflict by the aircraft involved and the first resolution attempt | MAICA project |
| 990 | Time between conflict resolution and beginning times | The difference between the conflict resolution time and its beginning time | MAICA project |
| 991 | Time between active resolutions | For an aircraft, it is the flight duration divided by the number of actively solved conflicts | MAICA project |
| 992 | Cluster density versus size, expressed in number of aircraft | Number of clusters present in the air situation sorted by size expressed in number of aircraft | MAICA project |
| 993 | Cluster density versus size, expressed in number of conflicts | Number of clusters present in the air situation sorted by size expressed in number of conflicts | MAICA project |
| 994 | Number of induced conflicts | Number of conflicts that start while the aircraft has not yet finished the resolution of the previous one | MAICA project |
| 995 | Time before induced conflicts resolution | The time between the beginning of the resolution of this conflict and the beginning of the resolution under progress | MAICA project |
| 1035 | Variation in the ATM system as experienced by the user | Timeliness and quality of data provided to the user on weather, traffic and system status | C/AFT Study |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1119 | CNS coverage | CNS coverage (various altitudes) | C/AFT Study |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1130 | Communication delay | The accumulated time variable based on the duration of time between the aircraft calls for service and the controllers' initial response | FAA Study |
| 1131 | Number of communication delays | This is the cumulated frequency of communication delays that exceed 20 seconds | FAA Study |
| 1194 | Propensity | The likelihood of a safety significant event occurring during normal operations | INTEGRA |
| 1195 | Resilience | The extent to which the ATM system responds to a safety significant event without causing more such events. | INTEGRA |

*Table 5-10 Metrics for Real Time Simulation - Safety*

### 5.3.14 Real Time Simulation – Operator perspective

This table identifies metrics from an operator perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 9 | Efficiency of actual route flown | Ratio reflecting route distance saving over a single flight. | Torch Project |
| 11 | Efficiency of routing service | Comparison of actual routing to agreed flight plan. | Torch Project |
| 14 | Route fuel average | Route fuel saving for an operator averaged over a specified period of time/flights. | dummy |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1024 | Record of time | Measure of total flight time with and without delegation | ECAC experiments on ASAS |
| 1025 | Initial trajectory duration | The duration required to fly the initial trajectory | MAICA project |
| 1026 | Real trajectory duration | This is the real duration of a flight | MAICA project |
| 1027 | Duration increase | This is the ratio: real trajectory duration divided by initial trajectory duration | MAICA project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1035 | Variation in the ATM system as experienced by the user | Timeliness and quality of data provided to the user on weather, traffic and system status | C/AFT Study |
| 1036 | Variation in the ATM system as experienced by the user | Number of delay allocation decisions made with direct user input | C/AFT Study |
| 1040 | Anticipated delay | Difference between scheduled and optimum gate-to-gate time | PRC Study |
| 1041 | Standard deviation | Standard deviation of arrival delay | PRC Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1046 | Punctuality of arrival | Difference between actual and scheduled arrival time | Torch Project |
| 1047 | Anticipated delay | Difference between schedule and optimum gate to gate time in minutes | Torch Project |
| 1048 | Cancel flight- instantaneous aircraft count | Number of cancelled flights that occurred during an experimental run | FAA Study |
| 1050 | Special use airspace access | Percentage of air carrier flights that penetrate special use airspace, for those origin-destination pairs in which at least one flight penetrated special use airspace | C/AFT Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1064 | Movements | Number of movements/ declared capacity | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1085 | Restrictions (amount not constrained) | Amount of aviation activity not constrained by procedural restrictions | C/AFT Study |
| 1086 | Restrictions (impact) | Severity of impact of the procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1090 | Deviation between ATC preferred route and flight plan route | Lateral deviation between ATC preferred route and flight plan route, among flights subject to ATC preferred routes | C/AFT Study |
| 1091 | Distance between preferred routes and final route | Distance between preferred routes and great circle distance by origin-destination pair, weighed by level of traffic | C/AFT Study |
| 1092 | Flights able to fly in the requested altitude | Number of flights whose max. Altitude equalled the requested altitude in flight plan | C/AFT Study |
| 1093 | Deviation between the requested and flown route (descent) | Excess descent time over that of an ideal managed descent (From Top of Descent to Wheels Down) | C/AFT Study |
| 1094 | Deviation between the requested and flown route (mean lateral deviation) | Mean lateral deviation between flight plan route and actual flown route | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1100 | Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i | Number of change request granted in real time/ number of change requests submitted | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1104 | Altitude- complexity measures | Frequency of altitude clearance issued during a run | FAA Study |
| 1105 | Heading- complexity measures | Frequency of heading clearances issued during a run | FAA Study |
| 1106 | Speed- complexity measures | Frequency of speed clearances issued during a run | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1109 | Distance difference | Measure of the difference of flight distance with and without delegation | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |
| 1114 | Initial trajectory length | The initial trajectory of an aircraft contains three fixed points: the entry point, a virtual waypoint and the exit point. | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1115 | Real trajectory length | This is the length of the trajectory that was really flown | MAICA project |
| 1116 | Length increase | Ratio: real trajectory length divided by initial trajectory length | MAICA project |
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1130 | Communication delay | The accumulated time variable based on the duration of time between the aircraft calls for service and the controllers' initial response | FAA Study |
| 1131 | Number of communication delays | This is the cumulated frequency of communication delays that exceed 20 seconds | FAA Study |
| 1136 | ATFM equity | Deviation from standard equity rule (slots) | C/AFT Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1145 | Equity of the planning functions | % of user equity achieved | Torch Project |
| 1184 | ATS productivity | The productivity of the ATS provided to users | Torch Project |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-11 Metrics for Real Time Simulation – Operator perspective*

### 5.3.15 Real Time Simulation – ATS perspective

This table identifies metrics from an ATS Provider perspective with respect to the strategic objectives of Capacity and Efficiency.

| ID | Metric | Definition | Source |
|---|---|---|---|
| 11 | Efficiency of routing service | Comparison of actual routing to agreed flight plan. | Torch Project |
| 1011 | Flight delay (delays on the ground before take-off, in the air, on the floor after landing) | Total minutes of gate-to-gate delay/ total number of flights | PRC Study |
| 1013 | Arrival delay (function of departure delays and flight delays) | Total minutes of arrival delay/ total number of flights | PRC Study |
| 1017 | Capacity management (target variation) | Actual capacity variation/ target capacity variation (%) | PRC Study |
| 1018 | Capacity management (traffic variation) | Actual capacity variation/ actual traffic variation (%) | PRC Study |
| 1019 | Flight delay | Difference between actual and optimum gate to gate time in minutes (for each phase of flight)] | Torch Project |
| 1021 | ATFM delay | Delays due to flow restrictions | Torch Project |
| 1022 | ATC delays | Total number of flights delayed by ATC causes/ total number of flights | Torch Project |
| 1028 | Delay before creation | The trajectory to be created must be free of conflicts during some time. If not, the creation is delayed | MAICA project |
| 1034 | Variations in system performance associated with changes in weather | Dispersion in expected arrival time vs. Actual arrival times | C/AFT Study |
| 1040 | Anticipated delay | Difference between scheduled and optimum gate-to-gate time | PRC Study |
| 1042 | Components (arrival delay) | Standard deviation of each delay component | PRC Study |
| 1043 | Causes (arrival delay) | Causes of delay in each delay component | PRC Study |
| 1048 | Cancel flight- instantaneous aircraft count | Number of cancelled flights that occurred during an experimental run | FAA Study |
| 1050 | Special use airspace access | Percentage of air carrier flights that penetrate special use airspace, for those origin-destination pairs in which at least one flight penetrated special use airspace | C/AFT Study |
| 1054 | Sector capacity | Sector capacity per period of time under different weather conditions and procedures | C/AFT Study |
| 1060 | Availability of airspace for military purposes (non-used time) | % Time a given restricted area is available and not used | PRC Study |
| 1061 | Availability of routes | Number of company preferred route accepted/ number of flight plans accepted | Torch Project |
| 1062 | Company preferred routes accepted | Number of company preferred routes accepted/ number of flight plans accepted | Torch Project |
| 1064 | Movements | Number of movements/ declared capacity | Torch Project |
| 1072 | ATM restrictions (flow) | Number of total flow of restriction areas ATM restrictions | Torch Project |
| 1073 | ATM restrictions (average time) | Average time of restrictions | Torch Project |
| 1078 | Number of intersecting flight paths | This is the number of routes or victor airways that cross within the sector | FAA Study |
| 1084 | Restrictions (flights) | Number of flights subject to procedural restrictions | C/AFT Study |
| 1088 | Number of flights subject to ATC preferred route | Percentage of number of flights subject to ATC preferred route | C/AFT Study |
| 1089 | Aviation activity not on ATC preferred route | Amount of aviation activity not on ATC preferred route, among flights subject to ATC preferred routes | C/AFT Study |
| 1095 | Pilot controller collaboration | Number of decisions involving pilot controller collaboration | C/AFT Study |
| 1096 | Freedom to change departure time or planned route at short notice (on the ground) | Number of regulated flights/ number of actual flights | PRC Study |
| 1097 | Freedom to exchange slots (on the ground) | Number of slots exchanged/ number of slot exchange requests | PRC Study |
| 1098 | GAT freedom rate | Weighted time of unconstrained route usage | Torch Project |
| 1101 | Level of CDM attempted (in the air) | Number of interactions between the service provider and the airspace user. | Torch Project |
| 1102 | Level of CDM achieved (in the air) | Frequency with which requests are granted. | Torch Project |
| 1103 | Complexity measures activity variance | Measure of aircraft clustering within a user specifiable criterion such as 10 miles. The higher the index is the more aircraft are clustering and potentially more likely to conflict | FAA Study |
| 1104 | Altitude- complexity measures | Frequency of altitude clearance issued during a run | FAA Study |
| 1105 | Heading- complexity measures | Frequency of heading clearances issued during a run | FAA Study |
| 1106 | Speed- complexity measures | Frequency of speed clearances issued during a run | FAA Study |
| 1107 | Standard instructions | Number of standard instructions, according to the type of instruction (Heading, Direct, Speed, Level) | ECAC experiments on ASAS |
| 1108 | Delegation instructions | Number of delegation instruction (Remain, ResumeThenRemain, Merge, ResumeThenMerge, End of Delegation) | ECAC experiments on ASAS |
| 1110 | Traffic density versus FL | Number of aircraft per FL | MAICA project |
| 1111 | Global traffic density | Global number of aircraft | MAICA project |
| 1112 | Traffic density versus range | Number of aircraft contained in some lateral ranges around the aircraft | MAICA project |
| 1113 | Heading distribution | The number of headings from the entry point to the exit point of the aircraft sorted by direction (0º-90º, 90º-180º, 180º-270º, 270º-360º) | MAICA project |

| ID | Metric | Definition | Source |
|---|---|---|---|
| 1129 | Number of hold/turn delays | The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration- non conflict | FAA Study |
| 1130 | Communication delay | The accumulated time variable based on the duration of time between the aircraft calls for service and the controllers' initial response | FAA Study |
| 1131 | Number of communication delays | This is the cumulated frequency of communication delays that exceed 20 seconds | FAA Study |
| 1136 | ATFM equity | Deviation from standard equity rule (slots) | C/AFT Study |
| 1140 | Flights not adhering to ATFM slots | Regulated flights departing outside slot window | C/AFT Study |
| 1145 | Equity of the planning functions | % of user equity achieved | Torch Project |
| 1184 | ATS productivity | The productivity of the ATS provided to users | Torch Project |
| 1193 | Information processing load | Information processed per unit time applied to each processing component or 'actor' in a system. The actor may be a human or automated component. | INTEGRA |

*Table 5-12 Metrics for Real Time Simulation – ATS perspective*

# 6 Conclusions

6.1 System performance metrics can be successfully linked to the strategic objectives of an ATM system through the use of a hierarchical top-down approach as follows:

**OBJECTIVES ? PERFORMANCE AREAS ? METRICS**

This requires the identification of Performance Areas. Performance Areas are a breakdown of strategic objectives into areas that can be measured using suitable metrics.

6.2 This approach successfully allows consolidation of metrics identified in a variety of other studies into a single structure (for example a single database). To achieve this, consolidation of the taxonomy used by these studies is also required.

6.3 In order to manage a large number of metrics stored in a single consolidated structure, it is necessary to introduce the concept of perspectives to allow filtering and limiting of the information presented. Both ATS providers and aircraft operators have an interest in measuring improvements in ATM performance. However, there will be differences in the metrics that each would wish to apply. This reflects the different priorities (or perspectives) of ATS providers and aircraft operators.

6.4 The identification of metrics can be further refined to reflect those that are relevant to a specific type of airspace (e.g. airports) or a specific type of ASAS application (e.g. self separation), or a specific type of validation (e.g. fast time simulation).

6.5 To permit 'perspective filtering' requires suitable classification of the metrics themselves. Upon identification, each metric must be assessed for its suitability from all the perspectives that may be considered. This may not always be straightforward, and often may require subjective judgement. However, in cases of difficulty it is not essential to fully identify all perspectives at the outset. The simple rule is that a metric should be considered suitable for any perspective until subsequently decided otherwise. This will ensure that a metric is not incorrectly excluded during any perspective filtering exercise.

6.6 The report presents an analysis of metrics for two example ASAS applications:

- Time based sequencing on approach
- Airborne self separation in en-route airspace

This analysis is based upon the current state of metric classification and this classification may change when subject to wider review and consensus. The analysis of these two applications is believed to be a useful illustration but should therefore not be considered definitive at this stage.

6.7 Human performance metrics can be managed in a similar way provided that certain differences are understood. It is useful to apply a different set of Performance Areas and to recognise that human performance metrics must be applied to specific human tasks.

# 7 References


[1] ASAS Activity 2 Report:
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[3] EUROCONTROL , ATM Strategy for 2000+
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[4] PRC's European ATM Performance Measurement System,
EUROCONTROL, PRU reference document. Edition 1.7, 1 June 1999

[5] INTEGRA Metrics & Methodologies; Safety Metrics Technical Definitions
Version 0.B 25/11/00

[6] ASAS Activity 2 Report:
Initial Validation Framework and Scenario Report
Version 0.1 6 March 2002

[7] Principles of Operation for the use of ASAS
FAA / EUROCONTROL Cooperative R&D. Version 7.1, 19 June 2001

# A List of System Performance Metrics

*The complete listing of System Performance Metrics used in this report is now provided as a separate document.*

## B Top down analysis of System Performance Metrics

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity Access* |
| **Capacity** | | |
| | **Access** | |
| | | *1067* Practical capacity (airport) |
| | | *1057* Availability of airport capacity (unconstrained runway capacity) |
| | | *1058* Availability of airport capacity (peak hour demand) |
| | | *1059* Availability of airspace for military purposes (non-available time) |
| | | *1060* Availability of airspace for military purposes (non-used time) |
| | | *1061* Availability of routes |
| | | *1062* Company preferred routes accepted |
| | | *1063* Availability of airport capacity |
| | | *1064* Movements |
| | | *1012* TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) |
| | | *1066* Saturation capacity (airport) |
| | | *1054* Sector capacity |
| | | *1068* Capacity per sector |
| | | *1069* Sector capacity per hour |
| | | *1070* Sector capacity per unit of time |
| | | *1071* Traffic density |
| | | *1072* ATM restrictions (flow) |
| | | *1074* Missed approaches- non conflict errors |
| | | *1106* Speed- complexity measures |
| | | *1076* Departures |
| | | *1065* Unconstrained runway capacity |
| | | *1037* Impact of system outages |
| | | *1013* Arrival delay (function of departure delays and flight delays) |
| | | *1014* Causes of delay (ATM, aircraft operator, airport) |
| | | *1020* Causes of flight delays |
| | | *1021* ATFM delay |
| | | *1022* ATC delays |
| | | *1023* Ground delays |
| | | *1028* Delay before creation |
| | | *1030* Cancellations due to weather |
| | | *1056* Availability of airport capacity (peak hours) |
| | | *1034* Variations in system performance associated with changes in weather |
| | | *1055* Availability of airspace (access to sectors, preferred routes) |
| | | *1038* Impact of system outages |
| | | *1039* Impact of system outages |

| Objective | Performance Area | Metric |
|---|---|---|
| | *Capacity Access* | |
| | | *1046* Punctuality of arrival |
| | | *1049* Approved approaches |
| | | *1050* Special use airspace access |
| | | *1051* Airport capacity utilisation (average) |
| | | *1052* Airport capacity utilisation (average) |
| | | *1053* Airport capacity |
| | | *1079* Aircraft in sequence |
| | | *1031* Misconnects due to weather |
| | | *1094* Deviation between the requested and flown route (mean lateral deviation) |
| | | *1077* Sector size |
| | | *1110* Traffic density versus FL |
| | | *1108* Delegation instructions |
| | | *1107* Standard instructions |
| | | *1088* Number of flights subject to ATC preferred route |
| | | *1089* Aviation activity not on ATC preferred route |
| | | *1090* Deviation between ATC preferred route and flight plan route |
| | | *1091* Distance between preferred routes and final route |
| | | *1117* Precision approaches |
| | | *1093* Deviation between the requested and flown route (descent) |
| | | *1118* VFR tower services |
| | | *1096* Freedom to change departure time or planned route at short notice (on the ground) |
| | | *1097* Freedom to exchange slots (on the ground) |
| | | *1098* GAT freedom rate |
| | | *1099* Freedom to identify re-routes (on the ground) |
| | | *1100* Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i |
| | | *1102* Level of CDM achieved (in the air) |
| | | *1103* Complexity measures activity variance |
| | | *1104* Altitude- complexity measures |
| | | *1105* Heading- complexity measures |
| | | *1092* Flights able to fly in the requested altitude |
| | | *1128* Disruption caused by unavailability (all critical system) |
| | | *1073* ATM restrictions (average time) |
| | | *1080* Length of sequences |
| | | *1081* Airport capacity |
| | | *1083* Restrictions |
| | | *1084* Restrictions (flights) |
| | | *1085* Restrictions (amount not constrained) |
| | | *1086* Restrictions (impact) |
| | | *1087* Number of ATC preferred routes |
| | | *1111* Global traffic density |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity* |
| | | *Access* |
| | | *1138* ATFM overloads |
| | | *1078* Number of intersecting flight paths |
| | | *1127* Disruption caused by unavailability |
| | | *1126* Time lost due to any component of the ATM system being unavailable (all critical system) |
| | | *1125* Time lost due to any component of the ATM system being unavailable |
| | | *1124* Availability and quality of flight services to the system user |
| | | *1123* Availability and quality of VFR in flight services |
| | | *1122* ATM data processing functionality (routes, meteorological) |
| | | *1121* ATM data processing functionality (track correlation) |
| | | *1120* ATM data processing functionality (conflicts) |
| | | *1119* CNS coverage |
| | | *1193* Information processing load |
| | | *1075* Landings |
| | | *1009* Departure delay (proportion of flights delayed) |
| | | *1008* Departure delay (by total flights) |
| | | *1007* CODA, CFMU reports (departure delays) |
| | | *1002* Causes of delays |
| | | *998* ATC delays |
| | | *1010* Departure delay (by delayed flights) |
| | **Availability** | |
| | | *1102* Level of CDM achieved (in the air) |
| | | *1101* Level of CDM attempted (in the air) |
| | | *1100* Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i |
| | | *1099* Freedom to identify re-routes (on the ground) |
| | | *1098* GAT freedom rate |
| | | *1097* Freedom to exchange slots (on the ground) |
| | | *1096* Freedom to change departure time or planned route at short notice (on the ground) |
| | | *1095* Pilot controller collaboration |
| | | *1094* Deviation between the requested and flown route (mean lateral deviation) |
| | | *1103* Complexity measures activity variance |
| | | *1092* Flights able to fly in the requested altitude |
| | | *1108* Delegation instructions |
| | | *1091* Distance between preferred routes and final route |
| | | *1090* Deviation between ATC preferred route and flight plan route |
| | | *1089* Aviation activity not on ATC preferred route |
| | | *1088* Number of flights subject to ATC preferred route |
| | | *1093* Deviation between the requested and flown route (descent) |
| | | *1117* Precision approaches |
| | | *1127* Disruption caused by unavailability |
| | | *1126* Time lost due to any component of the ATM system being unavailable (all critical system) |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity Availability* |
| | | *1125* Time lost due to any component of the ATM system being unavailable |
| | | *1123* Availability and quality of VFR in flight services |
| | | *1121* ATM data processing functionality (track correlation) |
| | | *1120* ATM data processing functionality (conflicts) |
| | | *1106* Speed- complexity measures |
| | | *1118* VFR tower services |
| | | *1104* Altitude- complexity measures |
| | | *1111* Global traffic density |
| | | *1110* Traffic density versus FL |
| | | *1083* Restrictions |
| | | *1107* Standard instructions |
| | | *1087* Number of ATC preferred routes |
| | | *1105* Heading- complexity measures |
| | | *1119* CNS coverage |
| | | *1014* Causes of delay (ATM, aircraft operator, airport) |
| | | *1045* Taxi-out variation (variability in arrival delay) |
| | | *1044* Taxi-in variation (variability in arrival delay) |
| | | *1035* Variation in the ATM system as experienced by the user |
| | | *1033* Variations in system performance associated with changes in weather |
| | | *1023* Ground delays |
| | | *1022* ATC delays |
| | | *1085* Restrictions (amount not constrained) |
| | | *1020* Causes of flight delays |
| | | *1057* Availability of airport capacity (unconstrained runway capacity) |
| | | *1013* Arrival delay (function of departure delays and flight delays) |
| | | *1012* TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) |
| | | *1007* CODA, CFMU reports (departure delays) |
| | | *1004* CFMU delay (peak) |
| | | *1002* Causes of delays |
| | | *997* Taxi-out delay |
| | | *996* Taxi-in delay |
| | | *1021* ATFM delay |
| | | *1065* Unconstrained runway capacity |
| | | *1128* Disruption caused by unavailability (all critical system) |
| | | *1084* Restrictions (flights) |
| | | *1124* Availability and quality of flight services to the system user |
| | | *1081* Airport capacity |
| | | *1080* Length of sequences |
| | | *1079* Aircraft in sequence |
| | | *1073* ATM restrictions (average time) |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity Availability* |
| | | *1055* Availability of airspace (access to sectors, preferred routes) |
| | | *1066* Saturation capacity (airport) |
| | | *1056* Availability of airport capacity (peak hours) |
| | | *1063* Availability of airport capacity |
| | | *1062* Company preferred routes accepted |
| | | *1061* Availability of routes |
| | | *1060* Availability of airspace for military purposes (non-used time) |
| | | *1059* Availability of airspace for military purposes (non-available time) |
| | | *1058* Availability of airport capacity (peak hour demand) |
| | | *1086* Restrictions (impact) |
| | | *1072* ATM restrictions (flow) |
| | | *1122* ATM data processing functionality (routes, meteorological) |
| | | *1130* Communication delay |
| | | *1131* Number of communication delays |
| | | *1132* Voice frequency- communication activity |
| | | *1133* Voice duration communication activity |
| | | *1134* Messages exchanged |
| | | *1135* Frequency occupancy |
| | | *1193* Information processing load |
| | | *1129* Number of hold/turn delays |
| | **Delay** | |
| | | *1109* Distance difference |
| | | *1114* Initial trajectory length |
| | | *1115* Real trajectory length |
| | | *1116* Length increase |
| | | *1125* Time lost due to any component of the ATM system being unavailable |
| | | *1098* GAT freedom rate |
| | | *1127* Disruption caused by unavailability |
| | | *1086* Restrictions (impact) |
| | | *1126* Time lost due to any component of the ATM system being unavailable (all critical system) |
| | | *1094* Deviation between the requested and flown route (mean lateral deviation) |
| | | *1093* Deviation between the requested and flown route (descent) |
| | | *1092* Flights able to fly in the requested altitude |
| | | *1128* Disruption caused by unavailability (all critical system) |
| | | *1090* Deviation between ATC preferred route and flight plan route |
| | | *1011* Flight delay (delays on the ground before take-off, in the air, on the floor after landing) |
| | | *1085* Restrictions (amount not constrained) |
| | | *1084* Restrictions (flights) |
| | | *1083* Restrictions |
| | | *1091* Distance between preferred routes and final route |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity Delay* |
| | | *1006* CODA delay (most affected traffic) |
| | | *996* Taxi-in delay |
| | | *997* Taxi-out delay |
| | | *998* ATC delays |
| | | *999* Total delay |
| | | *1000* Flights delayed |
| | | *1001* Average delay |
| | | *1002* Causes of delays |
| | | *1003* CFMU delay (overall) |
| | | *1131* Number of communication delays |
| | | *1005* CODA delay (overall) |
| | | *1129* Number of hold/turn delays |
| | | *1007* CODA, CFMU reports (departure delays) |
| | | *1008* Departure delay (by total flights) |
| | | *1009* Departure delay (proportion of flights delayed) |
| | | *1010* Departure delay (by delayed flights) |
| | | *1056* Availability of airport capacity (peak hours) |
| | | *1193* Information processing load |
| | | *1081* Airport capacity |
| | | *1130* Communication delay |
| | | *1004* CFMU delay (peak) |
| | | *1020* Causes of flight delays |
| | | *1029* Diversions due to weather |
| | | *1028* Delay before creation |
| | | *1027* Duration increase |
| | | *1026* Real trajectory duration |
| | | *1025* Initial trajectory duration |
| | | *1024* Record of time |
| | | *1023* Ground delays |
| | | *1058* Availability of airport capacity (peak hour demand) |
| | | *1021* ATFM delay |
| | | *1037* Impact of system outages |
| | | *1019* Flight delay |
| | | *1018* Capacity management (traffic variation) |
| | | *1017* Capacity management (target variation) |
| | | *1016* Capacity management (index) |
| | | *1015* Relationship among delay, traffic volume and capacity |
| | | *1014* Causes of delay (ATM, aircraft operator, airport) |
| | | *1013* Arrival delay (function of departure delays and flight delays) |
| | | *1012* TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity Delay* |
| | | *1022* ATC delays |
| | | *1046* Punctuality of arrival |
| | | *1073* ATM restrictions (average time) |
| | | *1072* ATM restrictions (flow) |
| | | *1057* Availability of airport capacity (unconstrained runway capacity) |
| | | *1054* Sector capacity |
| | | *1053* Airport capacity |
| | | *1052* Airport capacity utilisation (average) |
| | | *1051* Airport capacity utilisation (average) |
| | | *1034* Variations in system performance associated with changes in weather |
| | | *1047* Anticipated delay |
| | | *1036* Variation in the ATM system as experienced by the user |
| | | *1045* Taxi-out variation (variability in arrival delay) |
| | | *1044* Taxi-in variation (variability in arrival delay) |
| | | *1043* Causes (arrival delay) |
| | | *1042* Components (arrival delay) |
| | | *1041* Standard deviation |
| | | *1039* Impact of system outages |
| | | *1038* Impact of system outages |
| | | *1074* Missed approaches- non conflict errors |
| | | *1048* Cancel flight- instantaneous aircraft count |
| | **Equity** | |
| | | *1145* Equity of the planning functions |
| | | *1146* Equity of the planning functions (expenditure) |
| | | *1143* Multiple flights |
| | | *1193* Information processing load |
| | | *1002* Causes of delays |
| | | *1144* Equity of treatment of all airspace users within and between all classes of user |
| | | *1142* Ghost flights |
| | | *1141* Flights with delay compensation |
| | | *1140* Flights not adhering to ATFM slots |
| | | *1139* ATFM underdeliveries |
| | | *1137* ATFM exempted flights |
| | | *1136* ATFM equity |
| | | *1085* Restrictions (amount not constrained) |
| | | *1050* Special use airspace access |
| | | *1041* Standard deviation |
| | | *1009* Departure delay (proportion of flights delayed) |
| | | *1006* CODA delay (most affected traffic) |
| | | *1138* ATFM overloads |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity* |
| | | *Flexibility* |
| | **Flexibility** | |
| | | *1015* Relationship among delay, traffic volume and capacity |
| | | *1052* Airport capacity utilisation (average) |
| | | *1051* Airport capacity utilisation (average) |
| | | *1037* Impact of system outages |
| | | *1036* Variation in the ATM system as experienced by the user |
| | | *1033* Variations in system performance associated with changes in weather |
| | | *1032* Variations in system performance associated with changes in weather |
| | | *1029* Diversions due to weather |
| | | *1021* ATFM delay |
| | | *1020* Causes of flight delays |
| | | *1007* CODA, CFMU reports (departure delays) |
| | | *1017* Capacity management (target variation) |
| | | *1006* CODA delay (most affected traffic) |
| | | *1053* Airport capacity |
| | | *1018* Capacity management (traffic variation) |
| | | *1111* Global traffic density |
| | | *1099* Freedom to identify re-routes (on the ground) |
| | | *1100* Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i |
| | | *1101* Level of CDM attempted (in the air) |
| | | *1102* Level of CDM achieved (in the air) |
| | | *1103* Complexity measures activity variance |
| | | *1104* Altitude- complexity measures |
| | | *1105* Heading- complexity measures |
| | | *1106* Speed- complexity measures |
| | | *1107* Standard instructions |
| | | *1108* Delegation instructions |
| | | *1098* GAT freedom rate |
| | | *1110* Traffic density versus FL |
| | | *1138* ATFM overloads |
| | | *1112* Traffic density versus range |
| | | *1113* Heading distribution |
| | | *1114* Initial trajectory length |
| | | *1115* Real trajectory length |
| | | *1116* Length increase |
| | | *1139* ATFM underdeliveries |
| | | *1141* Flights with delay compensation |
| | | *1142* Ghost flights |
| | | *1193* Information processing load |
| | | *998* ATC delays |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity Flexibility* |
| | | *1054* Sector capacity |
| | | *1109* Distance difference |
| | | *1056* Availability of airport capacity (peak hours) |
| | | *1140* Flights not adhering to ATFM slots |
| | | *1097* Freedom to exchange slots (on the ground) |
| | | *1060* Availability of airspace for military purposes (non-used time) |
| | | *1061* Availability of routes |
| | | *1072* ATM restrictions (flow) |
| | | *1073* ATM restrictions (average time) |
| | | *1077* Sector size |
| | | *1078* Number of intersecting flight paths |
| | | *1081* Airport capacity |
| | | *1083* Restrictions |
| | | *1084* Restrictions (flights) |
| | | *1085* Restrictions (amount not constrained) |
| | | *1092* Flights able to fly in the requested altitude |
| | | *1095* Pilot controller collaboration |
| | | *1062* Company preferred routes accepted |
| | | *1086* Restrictions (impact) |
| | | *1094* Deviation between the requested and flown route (mean lateral deviation) |
| | | *1096* Freedom to change departure time or planned route at short notice (on the ground) |
| | | *1093* Deviation between the requested and flown route (descent) |
| | | *1091* Distance between preferred routes and final route |
| | | *1090* Deviation between ATC preferred route and flight plan route |
| | | *1089* Aviation activity not on ATC preferred route |
| | | *1088* Number of flights subject to ATC preferred route |
| | | *1087* Number of ATC preferred routes |
| | **Predictability** | |
| | | *1143* Multiple flights |
| | | *1193* Information processing load |
| | | *1022* ATC delays |
| | | *1036* Variation in the ATM system as experienced by the user |
| | | *1142* Ghost flights |
| | | *1035* Variation in the ATM system as experienced by the user |
| | | *1034* Variations in system performance associated with changes in weather |
| | | *1033* Variations in system performance associated with changes in weather |
| | | *1139* ATFM underdeliveries |
| | | *1037* Impact of system outages |
| | | *1032* Variations in system performance associated with changes in weather |
| | | *1031* Misconnects due to weather |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Capacity* |
| | | *Predictability* |
| | | *1030* Cancellations due to weather |
| | | *1023* Ground delays |
| | | *1013* Arrival delay (function of departure delays and flight delays) |
| | | *1128* Disruption caused by unavailability (all critical system) |
| | | *1048* Cancel flight- instantaneous aircraft count |
| | | *1010* Departure delay (by delayed flights) |
| | | *1008* Departure delay (by total flights) |
| | | *1009* Departure delay (proportion of flights delayed) |
| | | *1029* Diversions due to weather |
| | | *1056* Availability of airport capacity (peak hours) |
| | | *1040* Anticipated delay |
| | | *1039* Impact of system outages |
| | | *998* ATC delays |
| | | *1041* Standard deviation |
| | | *1042* Components (arrival delay) |
| | | *1043* Causes (arrival delay) |
| | | *1044* Taxi-in variation (variability in arrival delay) |
| | | *1045* Taxi-out variation (variability in arrival delay) |
| | | *1057* Availability of airport capacity (unconstrained runway capacity) |
| | | *1047* Anticipated delay |
| | | *1127* Disruption caused by unavailability |
| | | *1058* Availability of airport capacity (peak hour demand) |
| | | *1064* Movements |
| | | *1074* Missed approaches- non conflict errors |
| | | *1092* Flights able to fly in the requested altitude |
| | | *1093* Deviation between the requested and flown route (descent) |
| | | *1094* Deviation between the requested and flown route (mean lateral deviation) |
| | | *1125* Time lost due to any component of the ATM system being unavailable |
| | | *1126* Time lost due to any component of the ATM system being unavailable (all critical system) |
| | | *1038* Impact of system outages |
| | | *1046* Punctuality of arrival |
| **Efficiency** | | |
| | **Cost effectiveness** | |
| | | *1099* Freedom to identify re-routes (on the ground) |
| | | *1022* ATC delays |
| | | *1146* Equity of the planning functions (expenditure) |
| | | *1098* GAT freedom rate |
| | | *1073* ATM restrictions (average time) |
| | | *1072* ATM restrictions (flow) |
| | | *1067* Practical capacity (airport) |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Efficiency* |
| | | *Cost effectiveness* |
| | | *1066* Saturation capacity (airport) |
| | | *1065* Unconstrained runway capacity |
| | | *1184* ATS productivity |
| | | *1023* Ground delays |
| | | *1185* Unit costs of en-route service |
| | | *1021* ATFM delay |
| | | *1020* Causes of flight delays |
| | | *16* Total service charges |
| | | *15* Route ATM charges |
| | | *11* Efficiency of routing service |
| | | *10* Efficiency of route structure |
| | | *9* Efficiency of actual route flown |
| | | *1062* Company preferred routes accepted |
| | | *1187* Delay costs to airlines |
| | | *1188* User operation costs |
| | | *1186* Delay costs to passengers |
| | | *1100* Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i |
| | **Delay** | |
| | | *1027* Duration increase |
| | | *1019* Flight delay |
| | | *1020* Causes of flight delays |
| | | *1042* Components (arrival delay) |
| | | *1041* Standard deviation |
| | | *1039* Impact of system outages |
| | | *1038* Impact of system outages |
| | | *1037* Impact of system outages |
| | | *1036* Variation in the ATM system as experienced by the user |
| | | *1034* Variations in system performance associated with changes in weather |
| | | *1028* Delay before creation |
| | | *1026* Real trajectory duration |
| | | *1025* Initial trajectory duration |
| | | *1024* Record of time |
| | | *1023* Ground delays |
| | | *1022* ATC delays |
| | | *1021* ATFM delay |
| | | *1093* Deviation between the requested and flown route (descent) |
| | | *1043* Causes (arrival delay) |
| | | *1029* Diversions due to weather |
| | | *1116* Length increase |
| | | *1091* Distance between preferred routes and final route |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Efficiency* |
| | | *Delay* |
| | | *1018* Capacity management (traffic variation) |
| | | *1092* Flights able to fly in the requested altitude |
| | | *999* Total delay |
| | | *1094* Deviation between the requested and flown route (mean lateral deviation) |
| | | *1098* GAT freedom rate |
| | | *1109* Distance difference |
| | | *1086* Restrictions (impact) |
| | | *1115* Real trajectory length |
| | | *1085* Restrictions (amount not constrained) |
| | | *1125* Time lost due to any component of the ATM system being unavailable |
| | | *1126* Time lost due to any component of the ATM system being unavailable (all critical system) |
| | | *1127* Disruption caused by unavailability |
| | | *1128* Disruption caused by unavailability (all critical system) |
| | | *1129* Number of hold/turn delays |
| | | *1130* Communication delay |
| | | *1131* Number of communication delays |
| | | *1114* Initial trajectory length |
| | | *1057* Availability of airport capacity (unconstrained runway capacity) |
| | | *1045* Taxi-out variation (variability in arrival delay) |
| | | *1046* Punctuality of arrival |
| | | *1047* Anticipated delay |
| | | *1048* Cancel flight- instantaneous aircraft count |
| | | *1051* Airport capacity utilisation (average) |
| | | *1052* Airport capacity utilisation (average) |
| | | *1053* Airport capacity |
| | | *1090* Deviation between ATC preferred route and flight plan route |
| | | *1056* Availability of airport capacity (peak hours) |
| | | *1044* Taxi-in variation (variability in arrival delay) |
| | | *1058* Availability of airport capacity (peak hour demand) |
| | | *1072* ATM restrictions (flow) |
| | | *1073* ATM restrictions (average time) |
| | | *1074* Missed approaches- non conflict errors |
| | | *1081* Airport capacity |
| | | *1083* Restrictions |
| | | *1084* Restrictions (flights) |
| | | *1054* Sector capacity |
| | | *1000* Flights delayed |
| | | *1193* Information processing load |
| | | *1017* Capacity management (target variation) |
| | | *1001* Average delay |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Efficiency* |
| | | *Delay* |
| | | *996* Taxi-in delay |
| | | *998* ATC delays |
| | | *1002* Causes of delays |
| | | *1003* CFMU delay (overall) |
| | | *1004* CFMU delay (peak) |
| | | *1005* CODA delay (overall) |
| | | *1006* CODA delay (most affected traffic) |
| | | *1013* Arrival delay (function of departure delays and flight delays) |
| | | *997* Taxi-out delay |
| | | *1007* CODA, CFMU reports (departure delays) |
| | | *1015* Relationship among delay, traffic volume and capacity |
| | | *1014* Causes of delay (ATM, aircraft operator, airport) |
| | | *1016* Capacity management (index) |
| | | *1012* TMA delay (between the arrival fix and the touch-down: holding, radar vectoring) |
| | | *1011* Flight delay (delays on the ground before take-off, in the air, on the floor after landing) |
| | | *1010* Departure delay (by delayed flights) |
| | | *1009* Departure delay (proportion of flights delayed) |
| | | *1008* Departure delay (by total flights) |
| | **Flight efficiency** | |
| | | *1098* GAT freedom rate |
| | | *1021* ATFM delay |
| | | *1072* ATM restrictions (flow) |
| | | *1067* Practical capacity (airport) |
| | | *1065* Unconstrained runway capacity |
| | | *1073* ATM restrictions (average time) |
| | | *1020* Causes of flight delays |
| | | *14* Route fuel average |
| | | *11* Efficiency of routing service |
| | | *9* Efficiency of actual route flown |
| | | *1100* Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i |
| | | *1066* Saturation capacity (airport) |
| | | *10* Efficiency of route structure |
| | | *1022* ATC delays |
| **Environment** | | |
| | **Environment regulation** | |
| | | *18* Adherence to noise abatement procedures |
| | **Flight efficiency** | |
| | | *1066* Saturation capacity (airport) |
| | | *1100* Ability of an airspace user to alter speed or alter route laterally or vertically during a flight (i |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Environment* |
| | | *Flight efficiency* |
| | | *1022* ATC delays |
| | | *1073* ATM restrictions (average time) |
| | | *1067* Practical capacity (airport) |
| | | *1098* GAT freedom rate |
| | | *1065* Unconstrained runway capacity |
| | | *9* Efficiency of actual route flown |
| | | *10* Efficiency of route structure |
| | | *11* Efficiency of routing service |
| | | *14* Route fuel average |
| | | *1020* Causes of flight delays |
| | | *1021* ATFM delay |
| | | *1072* ATM restrictions (flow) |
| **Safety** | | |
| | **Safety** | |
| | | *964* Airspace conflict frequency cumulative duration variable |
| | | *963* Airspace conflict frequency variable |
| | | *962* Aircraft proximity index variable |
| | | *961* Between sector conflict frequency cumulative duration variable |
| | | *960* Between sector conflict frequency variable |
| | | *959* Parallel conflict frequency cumulative duration variable |
| | | *965* Conflict alerts |
| | | *957* The cumulative duration of longitudinal conflicts |
| | | *973* Vertical separation (feet)- Conflicts |
| | | *958* Parallel conflict frequency variable |
| | | *966* Vertical separation |
| | | *967* Closest point-of-approach |
| | | *968* Slant range miss distance- measure of aircraft separation |
| | | *969* Blunders and associated conflicts |
| | | *970* Blundering aircraft and the next aircraft receiving a path change message |
| | | *956* Primary conflict measure for aircraft that are on final approaches and are in trail of one another |
| | | *972* Horizontal separation (miles)- Conflicts |
| | | *948* Alerting mechanism failures (Failure time) |
| | | *974* Number of non-solved conflicts |
| | | *975* Number of missed resolutions |
| | | *976* Number of conflicts with missed resolution attempt |
| | | *971* Deviation (feet, L-left, R-right), MX (maximum deviation in feet) |
| | | *945* Alerting mechanism failures (ACAS failures) |
| | | *1120* ATM data processing functionality (conflicts) |
| | | *977* Number of class 1 resolutions |
| | | *940* Accident risk probability |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Safety* |
| | | *Safety* |
| | | *939* ATM ratio (accidents, serious incidents and other incidents) |
| | | *938* Priori identification of potential hazards related to the implementation of any operational or techn |
| | | *937* Priori identification of potential hazards related to the implementation of any operational or techn |
| | | *941* Air-misses per flight |
| | | *936* Posteriori measure of actual hazards (air-air, air-ground, ground-ground, other incidents) |
| | | *942* Air-misses per flown distance |
| | | *950* A/G communication accessibility |
| | | *944* Contingency measures |
| | | *955* User specifiable conflict, cumulative duration and terminal variable |
| | | *946* Alerting mechanism failures (STCA failures) |
| | | *947* Alerting mechanism failures (ACAS/STCA reliability) |
| | | *949* Operational errors |
| | | *951* Standard conflict en-route variable |
| | | *952* Standard conflict duration variable |
| | | *953* Standard conflict terminal variable |
| | | *935* Posteriori measure of actual hazards (air-air, air-ground, ground-ground, other serious incidents) |
| | | *954* Standard conflict cumulative duration variable |
| | | *934* Posteriori measure of actual hazards (air-air, air-ground, ground-ground, other accidents) |
| | | *943* Air-misses per flown hour |
| | | *1126* Time lost due to any component of the ATM system being unavailable (all critical system) |
| | | *1103* Complexity measures activity variance |
| | | *978* Number of class 2 resolutions |
| | | *1117* Precision approaches |
| | | *1118* VFR tower services |
| | | *1121* ATM data processing functionality (track correlation) |
| | | *1122* ATM data processing functionality (routes, meteorological) |
| | | *1123* Availability and quality of VFR in flight services |
| | | *1049* Approved approaches |
| | | *1125* Time lost due to any component of the ATM system being unavailable |
| | | *1112* Traffic density versus range |
| | | *1129* Number of hold/turn delays |
| | | *1130* Communication delay |
| | | *1131* Number of communication delays |
| | | *1138* ATFM overloads |
| | | *1194* Propensity |
| | | *1195* Resilience |
| | | *933* Incidents (separation infringements) |
| | | *1124* Availability and quality of flight services to the system user |
| | | *985* Detected "convergence" conflicts versus FL |
| | | *979* Number of lateral resolutions |

| Objective | Performance Area | Metric |
|---|---|---|
| | | *Safety* |
| | | *Safety* |
| | | *980* Number of vertical resolutions |
| | | *981* Number of aircraft taken into account for a resolution |
| | | *982* Resolution complexity |
| | | *1119* CNS coverage |
| | | *984* Number of illegal vertical exit |
| | | *1035* Variation in the ATM system as experienced by the user |
| | | *986* Total number of detected conflicts in ADS-B range versus FL |
| | | *987* Simultaneously detected conflicts in ADS-B range per aircraft versus FL |
| | | *995* Time before induced conflicts resolution |
| | | *983* Number of illegal horizontal exit |
| | | *1032* Variations in system performance associated with changes in weather |
| | | *988* Active conflict resolution versus flight level |
| | | *994* Number of induced conflicts |
| | | *993* Cluster density versus size, expressed in number of conflicts |
| | | *992* Cluster density versus size, expressed in number of aircraft |
| | | *991* Time between active resolutions |
| | | *990* Time between conflict resolution and beginning times |
| | | *989* Time between a conflict detection and resolution |
| **Security/Defence** | | |
| | **Civil-military co-operation** | |
| | | *1183* Number of refused military access requests |
| | **Military access** | |
| | | *1059* Availability of airspace for military purposes (non-available time) |
| | | *1060* Availability of airspace for military purposes (non-used time) |
| | | *1183* Number of refused military access requests |
| | **Security of air transport** | |
| | | *1189* Time taken to identify an abnormal deviation from expected flight behaviour |
| | | *1190* Time taken to identify a false ADS-B type target |
| | | *1191* Time taken to notify a false ADS-B type target |

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## Report documentation page

| | | | |
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10a. Abstract

This report constitutes the main delivarable of Work Package 2 of the CARE ASAS Activity 2 work programme.The purpose of the report is to analyse System Performance Metrics relevant to ATM and identify those that shall form the basis of the Validation Framework for ASAS applications.

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