Complexity in the Optimisation of ATM Performance Metrics

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ABSTRACT

Today's motivation for autonomous systems research stems out of the fact that networked environments have reached a level of complexity and heterogeneity that make their control and management by solely human administrators more and more difficult. The optimisation of performance metrics for the air traffic management system, like in other networked system, has become more complex with increasing number of flights, capacity constraints, environmental factors and safety regulations. It is anticipated that a new structure of planning layers and the introduction of higher levels of automation will reduce complexity and will optimise the performance metrics of the air traffic management system. This paper discusses the complexity of optimising air traffic management performance metrics and proposes a way forward based on higher levels of automation.

Categories and Subject Descriptors

J.2 [**Physical Sciences and Engineering**]: *Aerospace.*

General Terms

Performance, Experimentation.

Keywords

Performance metrics, Optimisation, ATM

INTRODUCTION

The intention of the airspace user is to execute an individual flight with its business trajectory. Due to the multiplicity of these trajectories and limited resources like airspace and airport capacity, it is not possible to achieve the original intention of the airspace users for all of these flights. A compromise has to be found to optimise the execution of all flights as close as possible to the original intentions. To achieve that, the SESAR Concept of Operations [7] is performance driven, process oriented,

trajectory based and founded on a system wide information management.

SESAR have defined Trajectory Management as the process by which the Business or Mission trajectory of the aircraft is planned, agreed and revised. This is to be achieved through Collaborative Decision Making (CDM) processes between airspace users (Aircraft Operators) and Air Traffic Management (ATM) service providers (ANSP, Airports) or directly between pilots and controllers during the execution phase when time does not permit CDM.

Collaborative decision making in the SESAR concept means sharing of information as well as acting on the shared information. Decisions are made on the basis of common situational awareness and consequently an improved understanding of the network effects of the decisions.

Layered planning is proposed as the way of conceiving a CDM based ATM Network as it supports the implementation of work sharing schemes that permit the intervention of adequate actors at the right place and the right time where unpredictable events create the need for changes to Mission or Business trajectories. Under the proposed new dispensation of ATM the following planning layers are envisioned (see Figure 1)
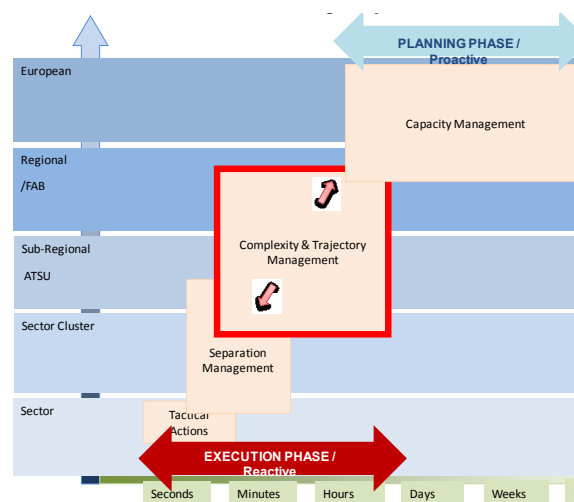

Figure 1: ATM Planning Layers

Layered planning will support the paradigm shift from an airspace-based environment to a trajectory-based environment and concurrently the reduction in the need for tactical intervention as the result of the action of strategic planning layers in the optimisation process. To arrive at this, a critical evaluation of the performance framework of ATM would be necessary. The performance framework will aid in defining the roles and functions of the planning layers.

SESAR and NextGen vision of the future ATM System (network, technologies, and procedures) is that it should facilitate the increasing multidimensional air transport demand safely and efficiently, be guided and driven by a performance framework addressing quality of service, societal needs and other areas, and in which safety is a paramount and continually improving Key Performance Area (KPA) [3 5 6]. KPA are a way of categorising performance subjects related to high level ambitions and expectations. In compliance with ICAO specification SESAR has defined 11 KPAs. These KPAs are Capacity, Cost-Effectiveness, Efficiency, Flexibility, Predictability, Safety, Security, Environmental Sustainability, Access and Equity, Participation, Interoperability. These have been further categorised into High, medium and low visibility areas based on their scope (represented in Figure 2). The definition of the 11 KPAs and the above mentioned categories are as provided in [3].

It is generally accepted that continuous performance management shall remain the ultimate tool to assessing the state of the future ATM system. It is however essential to not only look at this assessment at a global level but locally to examine the impact any change has on every structure within the system.

Figure 2: Key performance areas in SESAR (ICAO Compliant)

To measure the KPAs, Key performance Indicators (KPIs) are to be used. KPI is the quantitative expression of actual progress in achieving performance objectives i.e. Current/past performance, expected future performance. Since indicators support objectives, they should not be defined without having a specific performance objective in mind. Indicators are not often directly measured. They are calculated from supporting metrics according to clearly defined formulas, e.g. cost-per-flight-indicator = Sum(cost)/Sum(flights). Performance measurement is therefore done through the collection of data for the supporting metrics."

PERFORMANCE METRICS

Metric is a standard definition of any measurable quantity. However, for this research work, performance metrics shall be the focus point. Performance metric can be said to be a standard definition of a measurable quantity that indicates some aspect of performance of the said system. Performance metrics should exhibit certain characteristics to be valuable and practical. These metrics should:

- Be measurable (or able to be determined from other measurements).
- Have a clear definition, including boundaries of the measurements.
- Indicate progress toward a performance area.
- Answer specific questions about the performance.

Performance metrics should be consistent with the performance objective and performance targets of the system. They should be compatible with existing and future ATM system as well as meet the expectations of the set goals (KPA). Performance metrics should be able to measure and track progress toward the Key Performance Area. An example of how these terms are related is shown in Figure 3 (*source: Eurocontrol*)
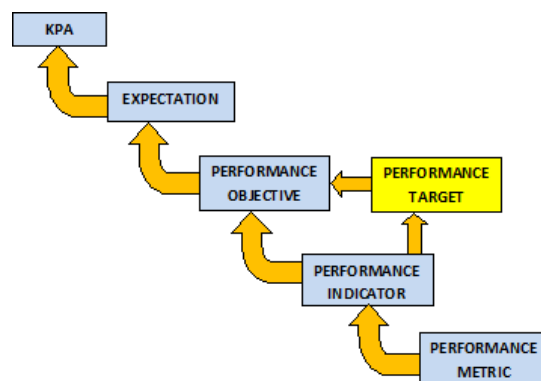
Figure 3: Relationship between Performance Metric, KPI (performance Objective) and KPA

THE CHALLENGE

In the future ATM system several performance metrics have been proposed to measure the KPI in order to achieve the set goals. As performance management is relevant to the success of the future ATM system policy makers, designers, Airport officials, Airlines operators, ANSPs, researchers and other stakeholders shall rely extensively on metrics for assessment. Considering the structure and size of ATM, the task of defining or choosing metrics might

prove to be complex. One form of confusion or complexity is that as there are no defined general methods for data processing, it might differ from region to region which shall make and comparison or compilation difficult.

In [1] a joint focus group by airlines defines a number of performance metrics for ATS with relevance to airline business. It proposes similar KPA as established in the performance management framework of SESAR and NextGen [3 6] but advocates for different KPI and metrics to assess the performance of the KPA. This shows that the audience the performance analysis is to be prepared for is a factor that is worth considering when selecting performance metrics.

Other questions that also need to be attended to include; how much data is needed for meaningful analysis and does it make any difference how much data is available on which to base model performance estimates? This is to identify if conclusive assessment can only be made over long period of data acquisition or on a short term. This could prove helpful for in real-time assessment which is an idea that supports continuous assessment.

What effect does weather conditions have on the metrics output? The performance analysis might not represent the exact situation in the advent of bad weather conditions.

What if we want at least to avoid the worst-performing selection metrics? What if the objective is not optimal performance, but simply robust performance across several metrics? Because the metrics measures a KPI does not necessarily mean it should be used.

There is a strong indication that, if these metrics are not standardized, the choice of the metrics might not depict the exact state of the system or vary from one region to the other thereby giving false overall performance information. Metrics might be optimum for analysis in one case and inappropriate in another case. All these and keeping in mind that improvement in ATM is a continuous process and that more KPI are bound to be introduced requiring defining metrics for them, the research seek to provide consistency in how performance metrics are determined and reported. Real-world considerations make evaluation more complicated than might be generally assumed. Performance metrics may change over time, may not be known, may be difficult to simulate, or may be numerous. In this research work shall also examine uncertain evaluation by providing experimental answers to two questions:

1. What selection metrics yield the highest performance across commonly applied evaluation metrics?

2. What is the effect of the number of data points available for making model selection judgments where the ultimate evaluation metric may be unknown?

APPROACH

As a first step, information about performance evaluation from our own experience, literature reviews, current practices, and expert workshops was gathered. This review in conjunction with questionnaires sent to some ATM partners to assess the veracity of diversity in performance assessment provided the results in Table 1.

All the information was assessed based on description of the KPI and consolidated. After analysing the data, it was discovered that from the data so far collected, the performance metrics for measuring the KPI were about double the number of KPI. This might even increase as contributors from the survey are from different Aeronautical industries and service providers and are responding to the questionnaires based on their industrial interest. Some of the KPA has so far not yielded any results from the research and survey so far.

KPA	KPI	Metrics
Capacity	5	10
Cost-effectiveness	9	26
Efficiency	18	35
Flexibility	7	15
Predictability	5	9
Safety	3	10
Security	-	-
Environment	13	21
Access and Equity	23	36
Participation	-	-
Interoperability	-	-

Table 1: Available Metrics and KPI from Literature and survey

A data base on KPI and metrics is in the making as more survey results and information are being compiled.

The next stage after compilation of the data will be to categorise the accumulated data (performance metrics) in terms of the different actors or usability. Figure 4 represent the different categories.
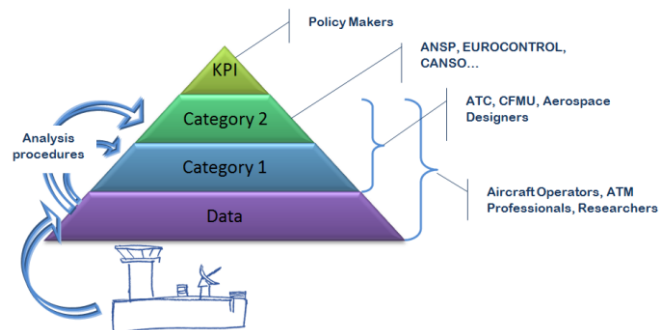
Figure 4: Overview of ATM Performance Evaluation

Category 2 provides a high level view of ATM performance and can be derived from monthly and annual data. Category 1 metrics provides a detailed breakdown of the metrics and typically requires daily, hourly or sub-hourly measurements. Performance indicators are above category 2 metrics, and they aggregate complex information to show planning level trends toward achieving the KPA.

FUTURE WORKS

Decision tree shall be used to develop a performance metrics selection model. The model will select the best performance metrics based on purpose, audience, data frequency, calculation time and available data. The decision tree model is explained in [4].

A convention will be adopted as to normalize performance with respect to various metrics. Normalization is necessary in order to compare directly metrics with different measurement scales. The metrics will be normalized to values in [0; 1] where 0 represents the baseline performance of classifying all instances with the most frequent class in the data, and 1 corresponds to the best performance of any model developed in the lab on that data.

EXPECTED RESULTS

The purpose of this procedure will be to establish a standard method for monitoring and reporting on the ATM performance. The performance metrics determined here will be compared against other benchmarks to evaluate performance and verify that performance targets have been achieved. Some of the analysis will include:

- Compare performance with the design intent.

- Compare performance with other set standards like future forecast.

- Evaluate performance in terms of weather or other factors.

- Establish long-term performance records that enable monitoring trends in ATM performance.

This procedure will include definitions of the performance metrics obtained and detailed steps for quantifying performance.

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