Intelligent Modelling of the Air Transport Network

Impact of Innovative Prioritisation Strategies on Delay Patterns

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***Abstract*—The SESAR WP-E project NEWO (emerging NEtwork-Wide Effects of inventive Operational approaches in ATM) has explored network-wide performance and delay propagation phenomena in the Air Transport Network linked to specific flight prioritisation strategies. To this end, NEWO has used innovative modelling and simulation techniques by means of a tool conceived for analysing multi-component systems with complex interactions. The tool used, ATM-NEMMO, exploits a mesoscopic approach where probabilistic methods account for Air Transport Network microscopic details without losing the macroscopic and strategic view of the system. This has allowed producing an in-depth analysis of network wide delay performance in different reference scenarios. This paper outlines the methodology that has constituted the basis for analysing network wide impact of flight prioritisation criteria as well as the analysis of the overall research results, combining both the simulation outputs and the feedback from Stakeholders.**

Intelligent Modelling; Delay Performance; Innovative Flight Prioritization Strategies; Network Theory; Air Transport Network

I. INTRODUCTION

The driving principle of NEWO project, in line with SESAR WP-E philosophy, has been to bring into the air transport R&D scene new perspectives that could contribute to improve ATM performance in the future.

NEWO has set the attention on complexity science and on complex networks different than the air transport one to explore some of the still blurry aspects of the Air Transport Network behaviour [1]. The project performed an outlook to gather criteria to prioritise the distribution of elements in a complex network in case of severe capacity shortfall of the network nodes/edges. Rules commonly used in other domains to manage the network to best match the available capacity might be innovative rules applicable to the air transport case [2]. Moreover, the project sought to stimulate the production of innovative operational approaches for prioritisation of departure flights and airline operational strategies.

In this context, innovation might finally come from the generation of deeper knowledge of the impact of certain operational rules or from new applications of existing management approaches [3].

The way NEWO has explored the definition of common and transparent rules for the prioritisation of flights and their translation into new operational approaches has been by means of literature reviews, questionnaires and direct interviews with experts from diverse domains. As for the study of the complex behaviour of the Air Transport Network, NEWO has explored the potential of innovative modelling and simulation techniques through an innovative computational model. The Performance Framework addressed has been oriented to the assessment of network-wide delay performance linked to innovative flight prioritisation criteria.

II. CAPTURING PRIORITISATION STRATEGIES

The air transportation system both in Europe and in the U.S. is highly capacity constrained due to the limited availability of resources on the ground and en-route. The capacity of an airport is dependent on the combined availability of its limiting components, such as runways, aircraft parking positions, gates, passenger terminal throughput. A good management of these areas determines the extent to which the airport can reach its full capacity potential. En-route sectors of airspace also have a limited capacity determined by the maximum workload acceptable for the Air Traffic Controllers (ATCOs). When occasional events occur, either unexpected such as meteorological phenomena and technical failures or predicted in advance such as ATCOs strikes, resource capacity is further reduced.

The challenge for Air Traffic Management and airports is illustrated by the EUROCONTROL Long-Term Forecast: IFR Flight Movements 2008-2030 [4].This forecasts between 16.5 and 22.1 million IFR flight movements in the EUROCONTROL Statistical Reference Area in 2030 - this is between 1.7 and 2.2 times the traffic in 2007 and represents an annual average growth of 2.3%-3.5%. The growth will be distributed unevenly in time and across regions.

The EUROCONTROL forecast also indicates that required capacity at 138 reviewed European airports will increase by 41% in total by 2030, but the demand will exceed the capacity of the airport system by as many as 7.0 million flights. Airport congestion will be a challenge for the quality of service provided by the air transport system. Almost no new airports will be built in Europe, the only expansion possible being with the development of secondary airports.

In the context of ATM, when an imbalance between forecasted traffic and available capacity is detected, it is usually the ATM authority that imposes a regulation, which aims at protecting the potentially overloaded node by imposing delay on some flights. The flights are usually prioritised on a First Planned First Served (FPFS) basis, meaning that the flight which planned to use the resource earlier receives priority on another flight which planned to use it later. In this way delay is imposed without regarding users-preferences, but just on the base of a generally accepted concept of equity among users. The per-minute cost of delay experienced by a flight can vary within a wide range of values depending on several factors. In the case of a single capacitated resource, the FPFS criterion produces an optimal allocation in the case of identical cost of delay values. As soon as different cost weights are introduced for the delayed flights, the FPFS solution is no longer optimal and another system must be employed to guarantee an efficient allocation that minimizes the aggregated cost of delay.

The first project Workshop on 'Innovative Operational Approaches in ATM' provided an occasion to deepen into the strengths and weaknesses of very diverse strategies for prioritizing flights or elements in the Air Transport Network.

Experts from different fields of knowledge such as logistics, complexity science and ATM discussed about how the air transport system could better deal with the complexity of interrelations of its elements with the aim of efficiently performing distribution of passengers and cargo. The discussions led to the identification of a set of promising flight prioritisation strategies and different reference scenarios to be tested in.

The prioritisation criteria were classified into categories by looking at the potential impact of their implementation. The list of most promising prioritisation criteria that were eventually selected amongst all the identified ones were the following:

- Priority for those flights that fly to airports with higher number of outgoing flights;
- Priority for those flights that fly to airports with lower number of outgoing flights;
- Priority for those flights flying to more congested airports;
- Priority for those flights flying to less congested airports;
- Priority for the airlines with hub & spoke structure over airlines with point to point structure;
- Priority for the last flight of the day;
- Priority for the flight with higher number of subsequent flight legs;
- Priority for those flights with longer turnaround time at next airport;
- Priority for those flights with shorter turnaround time at next airport;
- Priority on random basis;
- Priority for those flights flying to less central destination;
- Priority for those flights connecting different communities.

III. Modelling Approach

The tool used for the implementation of the scenarios and for the simulations' performance, ATM-NEMMO, exploits a mesoscopic approach where probabilistic methods account for Air Transport Network microscopic details, without losing the macroscopic and strategic view of the system. This state-of-the-art tool features:

- Dynamic graphs, generated from traffic data input, where non-fixed network structure and dynamic rules are inter-related;
- Incorporation of "noise" in the behaviour of elements (non-determinism), as a way for modelling uncertainty;
- Links between elements beyond the network topology, reproducing actual delay propagation phenomena and emergent behaviour generation;
- Flexibility for implementation of diverse behavioural rules and innovative network management strategies.

A. *Network Nodes and Structure*

The tool reproduces a reduced set of nodes (airports and airspace high density areas) of the European Air Transport Network. The advantages in terms of computational tractability of modelling a simplified network are direct. It is an assumption common to most models of real networks that modelling in an explicit manner only the main nodes provides representative results of network performance. As discussed in [5], many empirical complex networks have a skeleton, implying that for developing a dynamical model of an empirical complex network it is enough to simulate only its skeleton, not requiring simulation on (or even knowledge of) the full network.

The selection of the nodes comprises the main 133 European airports: those handling 90% of total traffic. The rest of nodes are represented in an aggregated manner. There are five nodes called 'AREA' nodes that integrate departures from/ arrivals to airports outside European Civil Aviation Conference (ECAC) area, grouped by geographical areas. These AREA nodes are points in the limits of the grid that represent the ECAC area. One node 'OTHER' integrates departures from/ arrivals to airports not included in main ECAC set of airports (secondary airports).

An undisturbed run, meaning that there is no uncertainty and all flights are executed according to planned schedule, is used to compute the hourly aircraft density and to detect volumes with maximum hourly aircraft density over a defined Density Percentile.

For each node, nominal capacity reflects the actual capacity of the airport at each Time Step, whereas predicted capacity is used to simulate inaccuracies on the information available in the network about the actual capacity of the nodes. The parameter Time Step (TStep) indicates, in minutes, the time interval used by the model for executing the algorithms. Finally, the model creates a Network Operations Plan (NOP), derived from the input traffic sample which defines the network structure.

B. Traffic Growth and Flight Links

To simulate the increase of network congestion level in a long-term scenario (e.g. 2050), traffic growth samples are generated by the model from the original traffic input. The flights from the input traffic sample are replicated at different times and the airport capacity is updated according to direct inputs to the model.

In case the traffic sample used does not include aircraft registration (i.e. the unique alphanumeric string identifying a civil aircraft); the model includes an algorithm to create links between flights using the same aircraft. This is the case when using a traffic growth scenario. The model links flights within the same airline taking into account a minimum stopover time. This function is crucial to reproduce propagation phenomena derived from traffic execution.

C. Modelling Uncertainty

Internal disturbances account for all the potential sources of uncertainty internal to the air transport system: turnaround process of aircraft at airports, taxi and flight duration variability, etc.

Disturbances are related to failures of systems or equipment, human errors, unplanned occurrences, small changes in environmental conditions, etc. They were modelled as aggregated parameters whose values were obtained from a statistical analysis of delay data. In the case of the turnaround, for instance, a fixed rotation time was defined (considered as the minimum turnaround time required for each type of aircraft being modelled) and variability was included as a stochastic variable added to the fixed rotation time. This variable follows a probability distribution defined in line with available statistics of actual variability (or primary delays) of turn-around time at airports.

The model features two main functionalities accounting for the realistic simulation of air transport: the processes 'UNBALANCE TRAFFIC' and 'CAPACITY CHECK'. The second one is described in detail in heading "D. Implementation of Routing Rules". The process named 'UNBALANCE TRAFFIC' introduced the uncertainty of demand. The reason to include this process was to reflect changes in schedule that occurs in the medium/short-term planning phases, i.e. before the day of operations or execution phase. These changes are motivated by increased availability of accurate weather predictions, traffic demand, Air Navigation Service Providers (ANSPs) and airport capacities, etc. The changes considered in the model were particularised in flight cancellations, appearances of new flights and changes in Estimated Take-Off Time (ETOT). The consequence was an unbalanced traffic demand with regards to capacity as input for the execution phase, during which tactical Demand and Capacity Balance (DCB) measures (such as ground delay) were applied to adapt demand to the available capacity.

D. Implementation of Routing Rules

The operational context of the simulation was a one-day operations mixed picture (short-term planning phase), where some flights are in the planning phase and some flights are already in execution. Once the data are loaded for a particular day, the simulation starts one hour before the day of operations. At each Time Step, the model computes all the sub-processes shown in the model flowcharts in Figures 1, 2 and 4.

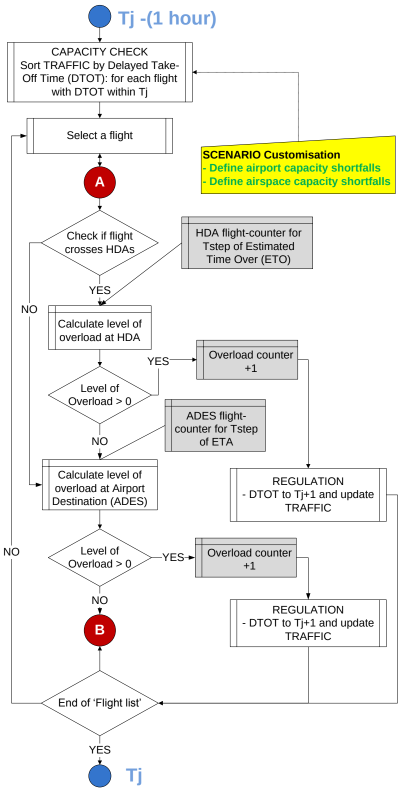

Figure 1. Model Flowchart for Tj-1 hour.

At Tj-1 hour it is performed the first capacity check for flights departing within Tj (see Figure 1). The 'CAPACITY CHECK' process checks that predicted capacity at destination airports is enough to respond to the planned demand of flights departing within Tj. The different checks performed lead to impose, in case of need, regulation in the form of on-ground delays.

The departure 'CAPACITY CHECK' performed at Tj (the TStep of operation in the day of operations) is the final check to clear for take-off the flights planned for departure within Tj. The process is similar to that performed one hour in advance A-B process in Figure 1), with the addition of a cross-check for each flight of arrival delay of the previous flight using the same aircraft. If the Actual Time of Arrival (ATA) of previous flight plus a defined Minimum Rotation Time (MRT) is later than the Delayed Take-Off Time (DTOT), then, the flight is regulated on-ground and a Reactionary Delay Counter is increased.

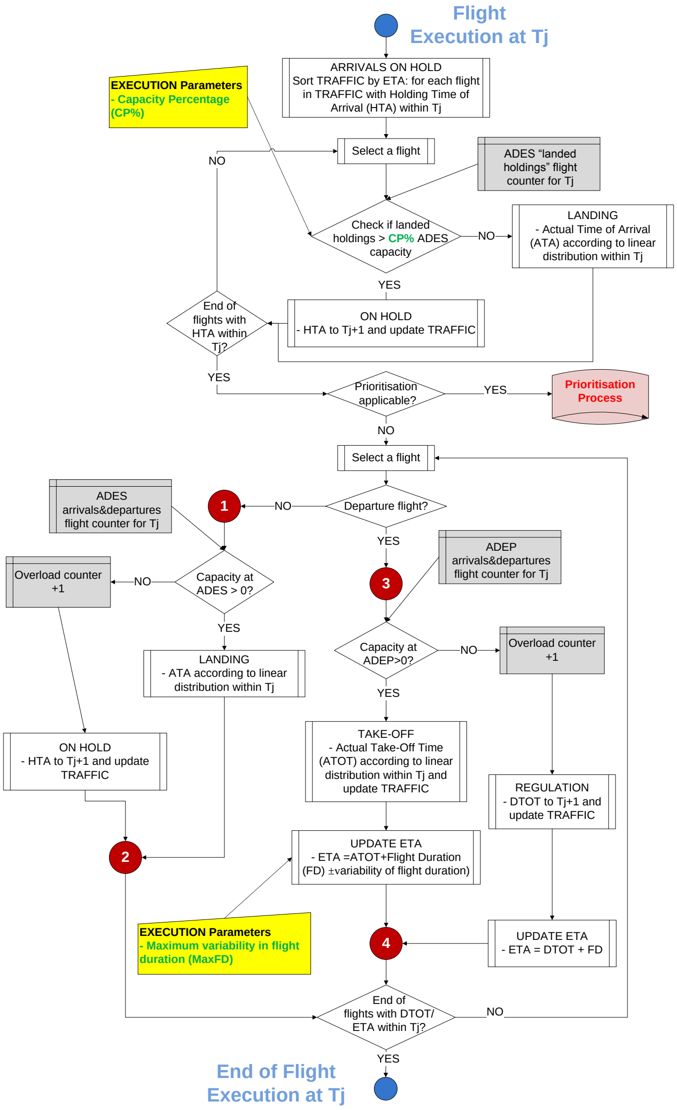

Figure 2. Model Flowchart for Flight Execution at Tj.

Execution of flights at Tj (see Figure 4) starts processing first arrival flights on hold at Destination Airport (ADES). The process lands all flights on hold by order of Estimated Time of Arrival (ETA) (which, given the modelling framework, is equivalent to landing first flights that have been on hold for longer time). Up to a Capacity Percentage (CP%) of ADES capacity is reserved for landing holdings.

E. Modelling Flight Prioritisation Strategies

The defined flight prioritisation strategies were modelled by plugging-in specific algorithms in the flight execution flow of the model. Figure 4 shows the flowchart that corresponds to the Prioritisation module in Figure 3. The model computes the characteristics of flights and/or destination airports that determine the level of priority of each flight, so that they can be sorted out according to the defined criteria. Examples explored in the present research were based on giving priority to flights to more/less congested airports, to airlines with hub&spoke route structure over point to point, or to flights with the higher number of subsequent flight legs.

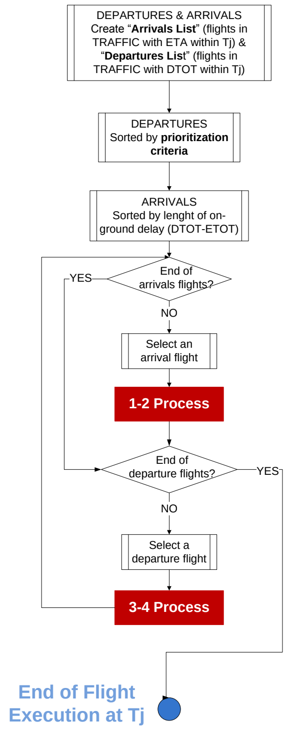

Figure 3. Prioritisation Criteria for Departure Flights.

IV. Simulation Results

The network-wide effects of the different prioritisation strategies were analysed through five different scenarios (explained below).The indicators used to assess the network performance are:

- 'EFF.ECAC.PI1' - Percentage of flights departing on time
- 'EFF.ECAC.PI2' - Average departure delay per flight (in minutes)
- 'PRED.ECAC.PI2' - Average departure delay of delayed departure flights (in minutes)

The input traffic sample was one-day ECAC traffic sample composed of 27658 flights. The sample included the following data for each flight: Callsign, Actual Take Off Time (ATOT), Actual Off Block Time (AOBT), Departure Airport (ADEP), Destination Airport (ADES), Duration, Registration, Equipment, Type of Flight (regular/charter), Type of aircraft.

The simulation results of each Modelling Scenario were as follows:

A. *Impact of Individual Prioritisation Criteria on the Network Stability (Scenario 1)*

It comprehended the simulation of the selected prioritisation criteria individually to analyse their effectiveness in terms of network efficiency in comparison to the baseline First Come First Serve (FCFS) situation. To ensure representativeness of results, different exercises were conducted combining each prioritisation criteria together with the current traffic and the presence or not of the unexpected events or external disturbances. The results are analysed either at global (through histograms representing the 24 hours of the day) and at local level (for the top 20 delay-affected airports according to CODA)

Figure 4 shows one hour average values of the indicator "Percentage of flights departing on time" are showed. The 'x' axis is representing the one hour time intervals and 'y' axis represents the percentage of flights. In this exercise the criteria 1 and 8 are being compared with FCFS. The scenario is characterised by current traffic level and an external disturbance affecting Holland, Belgium and Luxemburg airspace (temporary capacity restrictions).

When looking at the results provided by the tool, it is clear that for all time intervals FCFS criterion presented best performance in terms of punctuality at network level.

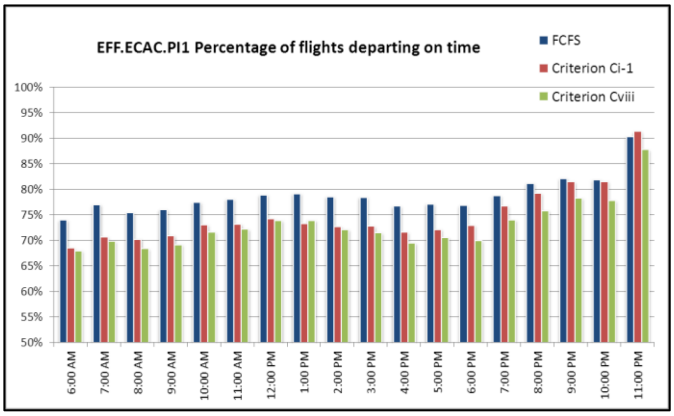

Figure 4. Comparison between FCFS and other criteria (Scenario 1)

Table I represents the average values for the same indicator at the European top 20 airports, applying the same prioritisation criteria, traffic level and external disturbance than Figure 4. Paying attention to local aspects, the results presented slight improvements when making comparisons between FCFS and the prioritisation criteria under study.

TABLE I. LOCAL EFFECTS ON EUROPEAN TOP 20 AIRPORTS

	FCFS		Criterion Ci-1 (to airports with higher nb of outgoing flights)		Criterion Cviii (random)	
Departure Airport by ICAO CODE	% flights departing on time	Av. Dep. Delay per flight	% flights departing on time	Av. Dep. Delay per flight	% flights departing on time	Av. Dep. Delay per flight
LEMD	80,35%	6,93	74,55%	8,11	75,54%	7,88
LPPT	57,33%	6,13	55,70%	6,24	58,71%	6,63
LEPA	60,03%	11,83	57,25%	7,26	55,16%	7,74
EGCC	56,44%	5,11	53,24%	5,65	53,27%	5,71
LFPG	79,92%	7,06	75,89%	7,82	75,55%	7,79
EGGW	63,04%	5,75	62,88%	6,91	59,77%	6,32
LEAL	64,97%	5,21	60,55%	6,21	61,13%	5,86
EDDF	73,08%	6,58	68,53%	7,51	69,01%	7,30
LEMG	63,51%	5,69	58,21%	6,74	59,46%	6,56
LIRF	66,67%	5,85	68,83%	6,04	66,57%	6,86
EGKK	55,92%	5,20	52,38%	6,05	52,68%	5,94
EGLL	76,76%	6,75	71,78%	7,89	72,24%	7,73
LEBL	75,58%	7,09	71,06%	8,04	69,15%	8,49
EHAM	75,49%	7,25	70,92%	8,12	69,53%	8,43
LHBP	55,99%	5,08	49,71%	5,64	53,42%	5,73
EDDM	73,90%	9,72	69,19%	8,59	69,22%	8,89
LIML	73,03%	6,69	66,55%	6,85	69,05%	7,55
LFMN	70,03%	6,18	68,06%	6,36	65,56%	7,22
LFPO	57,22%	4,90	53,04%	5,84	55,04%	5,25
EPWA	67,11%	5,72	62,77%	6,70	63,31%	6,67

After analysing efficiency, capacity and predictability network and local indicators, the results suggested that none of the selected prioritisation criteria improves the situation at global level with respect to the FCFS basis under any of the generic scenarios. The propagation of delays, appearance of overloads at airports not directly impacted by external disturbances and other undesirable network effects were not better absorbed when applying the specific criteria instead of FCFS. In few cases slight improvements were detected at airport level in specific timeframes. This opened the door for further research to analyse if any of the criteria could improve problematic hours at local level, which would require the local switch on/off of criteria at specific times and the study of which timeframe is the most efficient in terms of reducing undesirable effects.

B. *Relation between Network Stability and Equity (Scenario 2)*

This scenario was designed to investigate how giving priority to airlines' interests provides the best impact in terms of network stability. Figure 5 shows the algorithm that was formulated to assign priority to each flight by summing up points related to airline driven criteria and points grouped around network general concerns. Both parts of the equation where given relative weight according to the value of the parameter "alpha" (α).

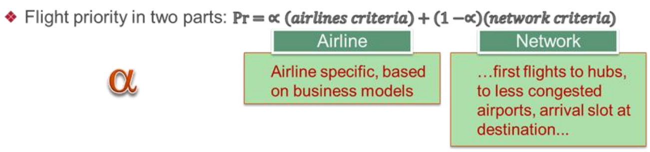

Figure 5. Algorithm for Analysis of Airlines and Network Driven Criteria.

In Figures 6 and 7 the values of "Average departure delay per flight" and "Average delay of delayed departures" indicators are showed for α=0.25 and α=1.

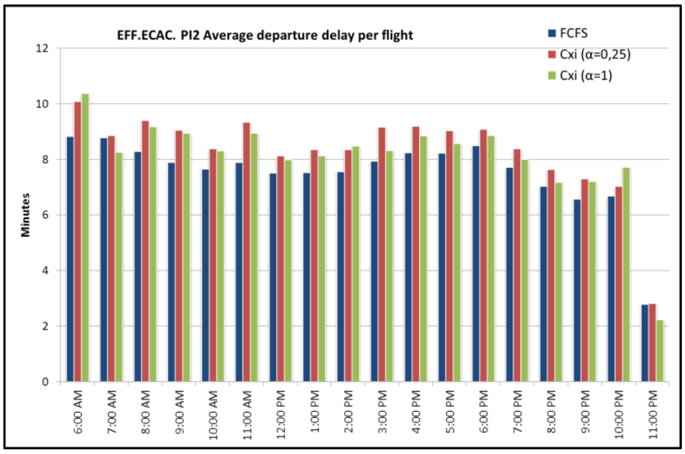

Figure 6. FCFS vs. other criteria for EFF.ECAC. PI2 - Scenario 2

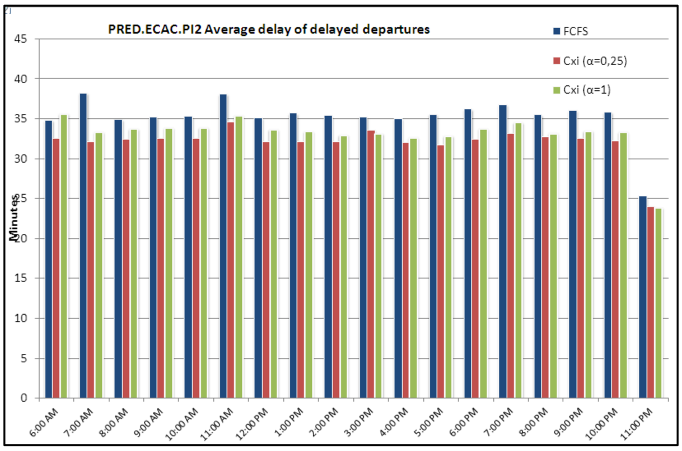

Figure 7. FCFS vs. other criteria for PRED.ECAC. PI2 - Scenario 2

In this scenario, the simulations clearly showed that the best network performance results were obtained with alpha closer to one, meaning that what is good for airlines might be also good for the network, since airline performance relies on network performance.

It must be highlighted that the scenario design lacked direct input from airlines, and therefore although the results were promising, better targeted scenarios should be studied. It was also concluded the need for further exploring if what is good for one particular airline or for a set of airlines operating at the airport where a local problem arise, might also be good for the whole network, and might, in the end, penalise other airlines.

C. Airlines Interests as a Black Box (Scenario 3)

With the aim of translating the "airline" part of the equation mentioned in the previous scenario into numerical values, it was used a random function instead of a detailed list of priority criteria and punctuations, assuming that airline business is a black box for the network manager.

Figures 8 and 9 show the results obtained for the same set of indicators used in Scenario 2.

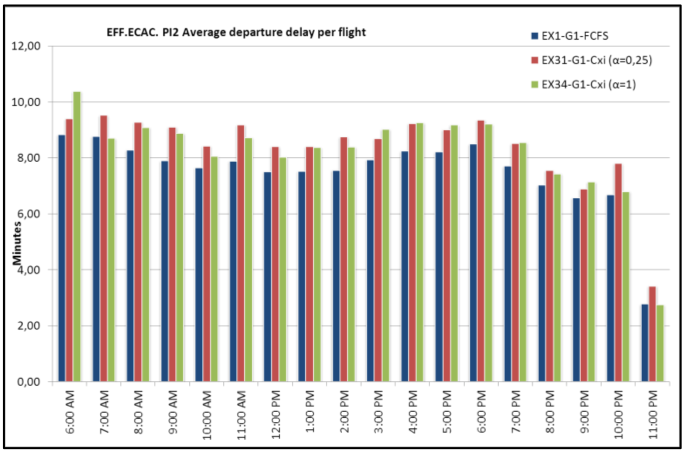

Figure 8. FCFS vs. other criteria for EFF.ECAC. PI2 - Scenario 3

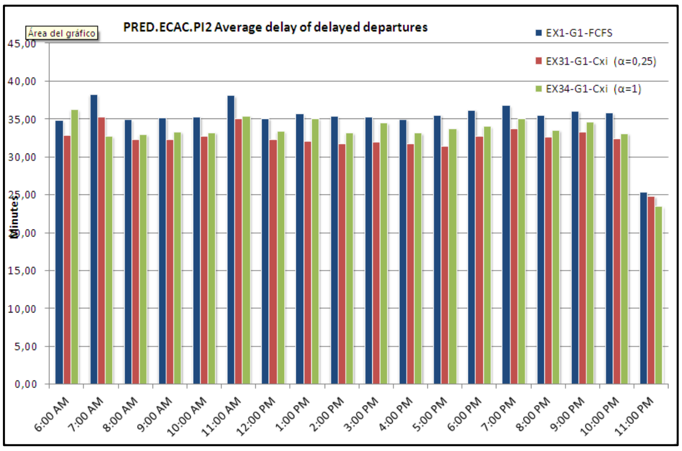

Figure 9. FCFS vs. other criteria for PRED.ECAC. PI2 - Scenario 3

Similarly to what was obtained in Scenario 2, giving less weight to network-driven prioritisation criteria provided better network performance. Even though this was not expected, the results were oriented to this direction for all the cases. Again there were very different performance responses between time intervals, suggesting that, for optimising the network management, the application of criteria should be restricted to specific airports at specific timeframes.

D. Network Critical Load Analysis (Scenario4)

In this scenario, an innovative analysis was conducted to observe the performance of some prioritisation criteria under heavily congested circumstances. The network critical load, defined as the traffic density beyond which jamming or overload appears at the nodes, was used as an indicator of the influence of network routing rules on behaviour.

For this assessment, three traffic growth levels were considered according to an algorithm defined based on Challenge of Growth 2008 expectations [6]. See Table II. At the same time, future airport capacities were also estimated, using as reference the Estimated Capacity Data provided by Airport Corner[i] for specific airports. These traffic growth levels and only the 'most promising prioritisation criteria' according to the results of the previous scenarios were simulated.

TABLE II. TRAFFIC GROWTH EXERCISES

Exercise	Traffic Growth	Capacity Growth
4.1	33%	20%
4.2	66%	32%
4.3	100%	40%

The results shown in Figure 10 depict a situation that became unstable in the central hours of the day.

The indicators turned to worse for the selected 'most promising prioritisation criteria' under study with regard to FCFS basis, showing high delay queues and calling for flight regulation in most of the cases. However an improvement on average delays was observed at the end of the simulation exercise for 1.3 and 1.6 traffic levels that might imply a potential recovery of the system. It could be therefore stated that the application of certain prioritisation criteria for long periods of time (22 hours) might improve the negative effects of the network and absorbs the systems delays.

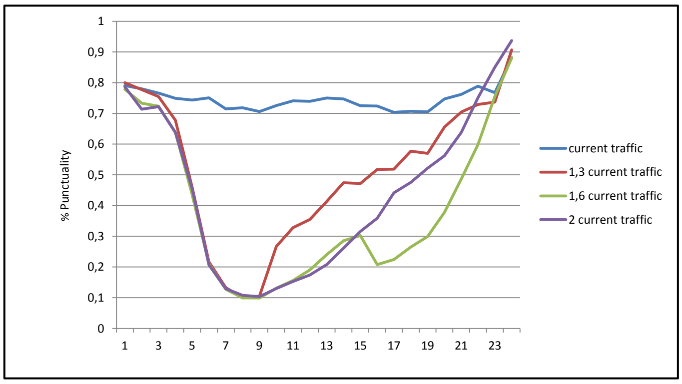

Figure 10. Comparison between different traffic levels

E. *Most Capable Best Served*

One of the key enablers in SESAR and NextGen capabilities is the advanced onboard equipage of the aircraft, and it seems implicit that the usage of this equipment would provide the equipped aircrafts an advantage over the non-equipped ones in an environment that allows enhanced operations.

Assuming a long transition phase until the aircraft, ground systems and staff evolve from today's operations to a future "better equipped" world, the implementation of advanced capabilities in the airlines is considered to be gradual.

The aim of this scenario was to evaluate if during this transition phase, rewarding operationally the equipped airlines, e.g.: giving departure precedence to the aircrafts, produces any effect on the network performance.

For doing that, and in absence of real "equipment" data from the initial traffic sample, four exercises representing this "step- by- step" introduction of equipment were selected:

a) Exercise 1: all the "Hub and Spoke" airlines have 20% of their flights labeled as "capable"

b) Exercise 2 : half of the "Hub and Spoke" airlines have 50% of their flights labeled as "capable", the other half have 20% of their flights labeled as "capable"

c) Exercise 3: half of the "Hub and Spoke" airlines have 80% of their flights labeled as "capable", the other half have 20% of their flights labeled as "capable"

d) Exercise 4: half of the "Hub and Spoke" airlines have 80% of their flights labeled as "capable", the other half have 50% of their flights labeled as "capable"

According to the results, the application of departure precedence to capable flights did not represent an improvement to the situation at a global level, but it has to be taken into account that the four chosen exercises only represent a gap from 10% to 35% of capable flights,. The conclusion for higher percentages of capable flights should be confirmed in further simulations. From a "capable" airline point of view, the conclusion derived from the simulation could be interpreted the other way around: To give precedence to capable flights, which means an advantage at local level for the airline, has not harmful effect for the global network behaviour, this could be an argument for justify an investment in more advanced equipage. Taking advantage of these simulations, other aspects like identifying certain airports as most suitable for capable flights or calculating the indicators per airline, could be explored.

F. *Statistical Analysis*

The results presented in this paper have been statistically analysed based on Kolmogorov-Smirnov and Shapiro-Wilk methods, with the objective of validating the simulations data quality. The analysis has been conducted using the software package SPSS Statistics. Figure 11 shows the reference values in both methods for a sample of three simulation exercises comparison within Scenario 1. Figure 11 shows the histograms, as provided by SPSS tool, for each of the three exercises, depicting the bell-shaped distributions and indicating mean, standard deviation and number of values analysed.

NORMAL TESTS

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistical Data	gl	Sig.	Statistical Data	gl	Sig.
Ex1_G1_FCFS	,043	184	,200*	,995	184	,732
EX10_G1_Cii_1	,042	184	,200*	,994	184	,692
EX20_G1_Cvi_1	,034	184	,200*	,990	184	,241

The entire criterions follow a normal distribution.

The SPSS tool provides the histograms below that show the bell-shaped distributions for each criterion, with indication of mean, standard deviation and number of values analysed.

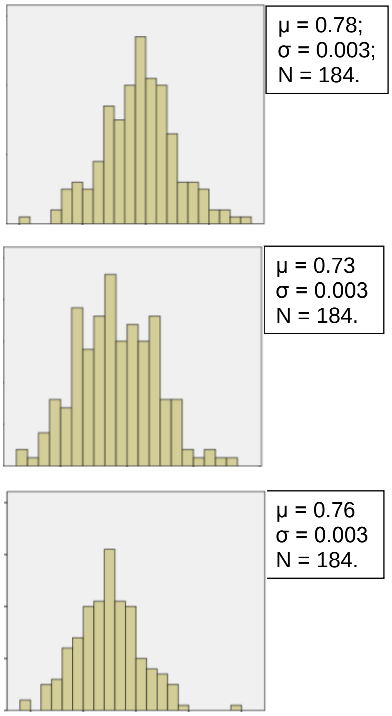

Figure 11. Example of Data Statistical Analysis

V. DISCUSSION

The expected rapid increase of traffic in European and worldwide airspace will challenge the current structure of the ATM system. The most critical aspect of this challenge is how to face the problem of airspace capacity limitation by ensuring high levels of efficiency together with the highest standards of safety.

Project simulation results have provided a better perception of the way forward for studying the impact of expected operational changes in the future Air Transport Network in terms of deepening in the analysis of the network response to specific local stimuli, i.e. integrating as much as possible the Airport – Collaborative Decision Making (A-CDM) concept in the model by the integration of more milestones at airports.

Simulating longer periods of time (2 or 3 days operation) will permit to observe if network effects are softened or propagated delays absorbed, when sufficient time has elapsed since the occurrence of an external disturbance.

The set of promising prioritisation strategies gathered during the identification phase and the whole set of simulation results remain as a useful repository for future projects picking up the baton of the flight prioritisation challenge.

In fact, from SESAR and NextGen they are spurring fresh interest from business aircraft operators to upgrade their systems since this improvement on their equipage level will address operational benefits for the aircraft/airlines; beyond the mandates, operators are coming to see the operational benefits these advanced avionics systems can provide.

The prioritisation challenge that better represents the intent of optimizing the efficiency of airspace operations is the Most Capable Best Served (MCBS) criterion; although project preliminary results on this matter are not conclusive enough to arrive at any firm conclusion, it is quite clear that the research work on prioritisation should be focused on this way.

A better understanding of the plan for progressively improving both airlines' aircraft equipage levels and ANSPs systems will clearly have a significant impact on the planning of future MCBS scenario for network wide impact assessment.

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