

Reducing Impact of Delays using Airspace User-Driven Flight Prioritisation

User Driven Prioritisation Process Validation Simulation and Results

Nadine Pilon, Laurent Guichard
Network Management Research unit
EUROCONTROL Experimental Centre
Brétigny/Orge, France
nadine.pilon@eurocontrol.int,
laurent.guichard@eurocontrol.int

Katherine Cliff
ATM Consultant
Think Research Ltd
Bournemouth, UK
katherine.cliff@think.aero

Abstract— With resumed air traffic growth for a few years now, the European Air Traffic Management Network is about to reach its capacity limits. This growth will continue to generate increasing delays to flights and for passengers. There are two ways to address such increases in delay. One is to strive to augment the capacity. The other is to reduce the impact of the delay on airlines and passengers.

The User Driven Prioritization Process (UDPP) followed the second approach. UDPP provides additional flexibility for airlines within constrained situations where delays occur during the planning phase; this concept allows prioritisation over several flights, beyond the current slot swapping process.

Previous publications introduced the main UDPP principles and early features for airlines that have many flights involved in a constraint generating delays together with, extra flexibility to airspace users with very few flights involved in the same constraint.

This paper reports on the UDPP latest improvements, in particular the new “Margins” feature, and the validation results related to a first integration of UDPP with an Airport Operations Centre. The validation exercise assessed the performance impacts, operational feasibility and human performance aspects of UDPP. The results show that UDPP can reduce the impact of delays on Airspace Users for the additional cost by more than 40% and on passengers’ connections whilst not reducing the performance of the airport.

Keywords- User Driven Prioritisation Process (UDPP), cost of delay, airlines, flexibility, equity, SESAR, KPIs, Real Time Simulation, Validation

I. INTRODUCTION

The steady air traffic growth since 2014, despite the increasing focus on augmenting the capacity of the Air Traffic management system, will probably continue to generate delays to flights and for passengers [11].

An approach has been developed to mitigate increasing delays by reducing the impact of the delay on airlines and passengers [14] as part of a more collaborative management environment. Such collaborative framework, imposed by the European Union Implementing Rules that govern the Air Traffic Management (ATM) Network Management [12], shall involve and take into account the needs and constraints of all

ATM stakeholders, including Airspace Users (AUs), in the resolution of network operational problems.

Today, AUs’ views are not sufficiently represented in case of important delays. Profitability in the air transport industry is very sensitive to cost variations [3]; therefore, AUs would like further flexibility, i.e., the ability of the ATM system to accommodate AUs’ changing business priorities when demand exceeds the available capacity and to reduce the impact of delay during irregular operations. One of the main drivers for AUs’ decisions is the passengers travel needs [14]. AUs look for any possible way to accommodate their passengers’ connections to their best. They are liable for dealing with their transport obligation and for compensation under EU/261 regulation [13].

In the Single European Sky ATM Research program SESAR, AUs have recommended to define a User-Driven Prioritisation Process (UDPP) allowing them to reduce the impact of delays on their operations during planning phases. This process would be an integral part of the collaborative ATM network management framework [15].

The authors have previously addressed early UDPP features Fleet Delay Apportionment (FDA) and Selective Flight Protection (SFP), introducing the notion of Operating Credits to address equity [5]. The use of Credits were explored to address the need for flexibility of the Low Volume Users (less than 6 flights) in a constraint –which most airlines are most of their time, and including Business Aviation- in [6], **Error! Reference source not found.** UDPP research and validation continued on the need for flexibility of commercial airlines with a medium to large volume of flights within a constraint.

This paper reports on the new innovative UDPP features that are now stable: Margins, Fleet Delay Reordering (FDR) and Selective Flight Protection (SFP), and on their validation results when used at an Airport on an arrival constraint. Starting with the need for flexibility to cope with uncertainty on the AUs’ side (Section II), it describes the UDPP solution (Section III) and details the validation experiment along with results (Section IV). The paper concludes with future perspectives (Section V).

II. AIRSPACE USERS' NEED FOR FLEXIBILITY

Airlines are not only operating flights from A to B, they are transporting passengers from A to C via B in a multi-constraint environment. Parameters like airports of origin and destination, aircraft type, crew operating the flight, type rating needed for a specific route or area, and passengers' flows influence drastically AUs' priorities. Even more: priorities evolve within a same day. Constrained airspaces generate restricted en-route slots or arrival times, leading to further delays of already delayed flights.

All these parameters influence daily operations of an airline. As all flights have a different value and this value is evolving with the situation, AUs need:

- To prioritise their flights to reduce reactionary delay impact on the AUs own network;
- Flexibility to adapt the prioritisation according to the evolution of the situation.

Both are key features for AUs to run smoother operations.

A. Cost of Delay: Passengers and Operations

Although ATM policy making traditionally use a linear cost of delay based on thorough analyses of overall yearly airlines costs [17], in day-to-day operations dispatchers make decisions (such as prioritisation) based on event-driven costs that define their margins of manoeuvre. Delays never affect an AU's entire fleet with the same consequences on operations.

Depending on the situation, costs are differently distributed for each flight. As soon as the first connecting passengers risks to miss their outbound flights, delay costs surge. The same occurs if crew gets out of duty time or if the aircraft rotation delays the next scheduled flight. Delay costs dramatically increase if a night curfew is reached as all passengers will need hotel accommodation and compensation and the flight cannot be operated as scheduled.

Although a minute of delay always has a cost, it has been recognised by AUs that flights often have some tolerance to delay (i.e., margins), and this cost can often be considered as marginal in practice, provided that the delay is not bigger than the more constraining operational margins. This gives several margins of manoeuvre, as described in Figure 1.

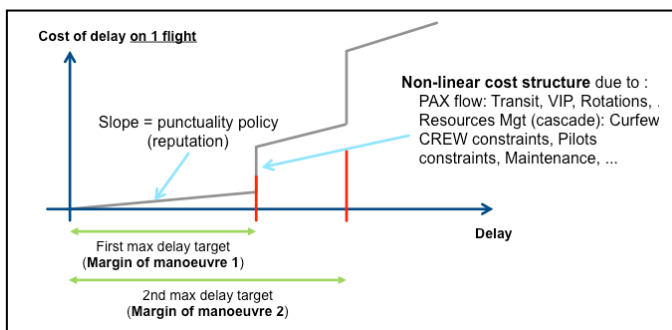


Figure 1: Typical cost-delay model profile per flight

Each flight has its own not linear complex cost structure, which is only known by the AU. If a flight is delayed so that an

important milestone or constraint cannot be fulfilled, a larger negative impact on AU's operational costs may be the consequence.

III. USER-DRIVEN PRIORITISATION IN ATM

A. Current ATFM Operations

Air traffic operations are planned in a large multi-actor framework that allows the preparation of appropriate resources by all actors in ATM.

During the planning phase a few hours before a potential demand-capacity imbalance is foreseen with a certain level of confidence, the European Network Air Traffic Flow Management Function (ATFM) authority activates a regulation scenario and issues 'ATFM slots' for the constrained airspace.

These slots will apply a tactical time-based separation between flights in order to maintain safety and smooth management of air traffic flows and sector/airport capacities [1], [2]. The allocation of these slots to flights imposes delays on flights before their departure, attributed to flights on a first planned first served (FPFS) basis.

From an ATFM view, the FPFS policy preserves equity as all flights are being treated with the same rule. Therefore it is widely accepted both by ATFM operators -because it minimizes the total delay in the ATFM regulation- [8][7] -, and by AUs -because it preserves the original sequence of flights-. However, FPFS does not consider the different impacts of allocated delay on the flights' operational costs.

Today there is some flexibility for AUs, although it is limited and challenging within the tight reaction timeframe and the situation complexity. Available options include: ATFM slot swapping -enhanced in UDPP [9] - allows AUs to exchange positions between only two flights involved in the same regulation; cancelling flights which negatively impacts AU and passengers; delaying a flight which shifts the problem; airframe swapping which is frequently used; phone calls to NM and airports; and Collaborative Decision Making between airports and airlines - in which UDPP contributed to Departure Flexibility, DFlex [10], allows swapping schedule times between flights in the pre-departure sequence.

B. Improving Performance for AUs

The need for flexibility corresponds to a performance improvement of the ATM system, and new areas have to be explored:

- Flexibility for the AUs is the possibility to react to the imposed ATFM delays, that create additional costs and operational issues for the airlines and passengers, according to their business needs;
- For AUs, allowing flexibility to all is considered acceptable only if this has no negative impact on other AUs' flights. For example, equity insures that for each individual flight not participating in UDPP, there is no increase of delay.

SESAR sets a performance framework that includes Flexibility and Equity: these are the main drivers for the definition of the UDPP concept.

C. The User-Driven Prioritisation Process - UDPP

The UDPP concept aims to reduce the impact of delays on operational costs. It includes several innovative features allowing each AU to exchange its flight positions and redistribute its total delay among several of its own flights: by prioritizing delayed flights in a capacity constraint during the planning phase, the cost/impact of delay can be reduced, as shown in Figure 2.

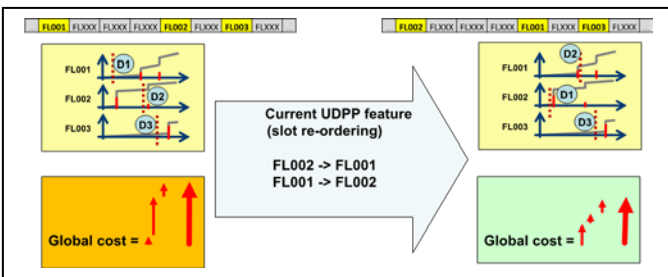


Figure 2: UDPP flexibility for the optimisation of AU impact of delay

Building on Figure 1, it shows three flights of the same AU that are impacted differently by delay. Each flight has a different position in the sequence and a different cost structure, either in the size of its delay margins and/or in the magnitude of the impact of delay. Transferring the delay between its flights by exchanging positions in the sequence reduces the overall cost to the AU.

The UDPP innovative features include FDR and SFP simplified from SESAR1 –operating credits are no longer needed-, and the Margins, a new feature requested by AUs to automatically find the best position of each flight.

1) FDR – Fleet Delay Reordering

FDR is similar to slot swapping involving more than two flights. The AU can reorder its flights within the constraint using only its own slots by assigning a priority value on each flight. The automation uses the priority to put flights in the best position, but not before the original schedule.

2) SFP – Selective Flight Protection

SFP allows to protect the schedule of a specific flight (Pflight) even when there is no direct slot allocated to the AU at this schedule time. To do so, the AU must have a minimum of one slot before the original schedule of the protected flight. This earlier flight is moved to a later slot and the protected flight is moved forward to its schedule. Flights of the other AUs in between the protected schedule and the earlier flight moved backwards are improved.

3) Margins with priority values

When many flights are involved, flights prioritisation becomes a very complex task for AUs and automation is needed. The Margins allows assigning “time windows” -Time not before and Time not after- to each flight in combination

with the SFP and FDR features, reflecting the AU’s internal constraints and remaining stable when the ATM environment changes. The position of the flights with Margins is automatically optimised.

The AU can use Margins, SFP or FDR only, or a combination of the three features. A simple hierarchy of features manages all of the UDPP prioritisation possibilities: 1) SFP: “Pflights”, 2) Margins: flights with a defined Margin time and corresponding priority, 3) FDR: flights with no Margins.

D. Launching UDPP in the ATM Collaborative Framework

During a Capacity Constraint Situation (CCS), to avoid large impacts of delay to the AU, a “UDPP measure” will be put in place in coordination between the local actors and NM instead of a standard regulation.

The UDPP Measure starts with the same PFPS approach as a Standard Regulation Measure to calculate the baseline delay for each flight. Then, it opens a semi-automated coordination time window -until a cut-off time- during which AUs rearrange their own flights in their slots to decrease the impact on the fleet of the day, supported by a What-If function.

IV. UDPP VALIDATION

Validation is an iterative process by which the fitness for purpose of a new system or operational concept being developed is established. SESAR follows the European Operational Concept Validation Methodology (E-OCVM) [4] which provides a framework to support collaborative validation of operational concepts through research and development (R&D) to implementation and operations.

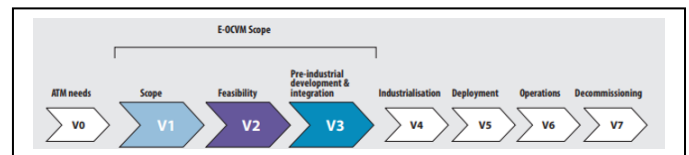


Figure 3: Concept lifecycle model [4]

SESAR2020 Wave 1 aimed to validate UDPP to an E-OCVM V2 maturity where operational feasibility is assessed.

A. Past Validation Exercises

Beyond slot swapping and DFlex, SESAR 1 introduced a prioritisation concept with FDA and SFP. An early V2 human-in-the-loop exercise [7] measured the utility and impacts of applying the UDPP features for departures during the planning phase at Collaborative Decision Making (CDM)-airport.

The following recommendations were implemented:

- FDA and SFP were revised to the above described FDR and SFP features that distribute the delay across the fleet more evenly and ensure that equity is maintained.
- The Margins with priority values feature was implemented.
- UDPP was validated for arrival capacity constraints as these are the most frequent delays.
- The cost-delay profiles have been modified to include rules for the cost-delay model and passenger flow model

that have been determined by expert judgement, in order to provide more realistic results.

B. SESAR2020 Wave 1 Validation Exercise Description

The validation exercise used UDPP for arrivals at a congested airport managed by the APOC (Airport Operations Centre) which represents the command and control system for collaborative airport performance management and decision making, including both landside and airside. The exercise addressed the operational feasibility and performance of UDPP from the perspective of the AUs and addressed the integration of the UDPP collaboration processes with Airports.

1) Validation Environment

a) Validation Technique

This experiment has been conducted through Real Time Simulations (RTS) that allows a human-in-the-loop experience of the UDPP system by operational experts in a relatively controlled and repeatable environment [4]. In total 51 runs were simulated; 23 runs involving the APOC.

A randomised experimental design was performed during the validation exercise in order to allow for maximum subjective feedback from participants having exposure to all roles. This is where a random combination of factors and levels were performed per run.

b) Operational Environment

The validation exercise simulated in multiple arrival CCSs at Paris Charles de Gaulle airport where a UDPP Measure was triggered by the Airport. The airlines then applied UDPP prioritisation for arrival flights during the planning phase.

These prioritisations were then sent to the regional ATFM system which feeds the ATM network with the current information. The airport receives the new flight times, updated from the UDPP solution.

The exercise connected four systems/tools to emulate the behaviour and interaction with each stakeholder concerned:

- INNOVE platform emulates the ATFCM system with NM functionalities including B2B services.
- FOC system replicates a simplified Flight Operations Centre (FOC) interface for the flight dispatcher. This is where the participants allocate their UDPP priorities and/or margins. This system also contains a set of rules for the passenger flow model and to produce cost-delay profiles for each flight.
- UDPP Server system receives the prioritisations from the AUs and calculates the new sequence of flights within the UDPP Measure. It then sends this back to the AU during a “what-if” and to the network when the AU publishes their prioritisation.
- APOC system simulates the runway and ground movements at the airport. APOC actors were able to create the UDPP Measure, monitor the airport performance indicators and change the stand allocation planning.

UDPP was the only option available to the participants in order to solve their constraints. Other options available in real-life operations were not used in the validation exercise.

c) Roles and Actors

Six airlines were involved in the validation of UDPP providing operational experts to participate in the exercise: Air France, Swiss, EL AL, Air Baltic, HOP!, and Transavia.

Each participant operated a FOC position for an airline as a flight dispatcher to manage a set of flights within the UDPP Measure. The validation exercise had positions available for: a Hub airline with a base at the impacted airport, a prominent proportion of flights and passenger connections; a Medium Volume User (MVU)/Low-Cost airline with a large number of flights in the UDPP Measure; and Low Volume Users (LVU) with 6 or less flights in the UDPP Measure.

SESAR European Airports Consortium (SEAC) provided Airport operational experts to participate in the exercise to operate the APOC in terms of creating the UDPP Measure, stand planning, performance monitoring and liaising with the airlines.

d) Validation Scenarios

Reference Scenario

The reference scenarios calculated the baseline delays and costs from a regulation where PFPS is used prior to any prioritization (UDPP) actions.

Solution Scenario

During the solution scenarios, the participants applied UDPP features; FDR and SFP, Manual Margins and Semi-Automated Margins. The outcomes from introducing these UDPP solutions are compared to the outcomes from the reference scenarios in order to validate the impacts of UDPP in terms of performance and operational feasibility.

Validation Scenario Events

Six validation scenarios have been written where specific events occurred which cause CCSs at airports.

- Fog – a capacity constraint known well in advance that is foreseen to last a long time then evolves to be less severe and shorter in duration than expected;
- Loss of Runway – a constant, stable event known in advance with a low capacity reduction lasting all day;
- Thunderstorm – a severe event known in advance lasting a short period of time;
- Snow – a forecasted event whose impact becomes a lot greater than expected and affects the whole day;
- Morning (Airport Capacity) – a stable event that lasts for a couple of hours in the morning;
- Afternoon (Airport Capacity) – a stable event that lasts for a couple of hours in the afternoon causing curfew issues.

These scenario events vary in length and severity in order to measure feasibility and performance of UDPP in various CCSs.

2) Validation Objectives

The objectives of the validation exercise were:

- To identify the UDPP performance benefits and drawbacks, in terms of:
 - Airspace-User-Cost-Efficiency (AUC), measured by the overall direct operating costs (as calculated by the cost model) and the number of missed passenger connections (as calculated by the passenger flow model);
 - Equity, measured by the total delay for non-participating AUs within the UDPP Measure;
 - Flexibility, measured by the opportunity to use UDPP (subjective feedback) and the number of flights with a change in the sequence within the UDPP Measure;
- To understand how UDPP affects human performance;
- To determine whether the UDPP features are useable, acceptable and efficient;
- To assess the feasibility of integrating UDPP with APOC processes using NM B2B services.

3) Cost-Delay Model

Most UDPP benefits are expected in AUC. Therefore, it was important that an accurate cost-delay model and passenger-flow model were developed for the validation exercise in the FOC tool to measure costs, passenger connections and to drive realistic decisions for allocating UDPP priorities.

A workshop with the AUs addressed the assumptions, rules and the values for the cost-delay model and for the passenger-flow model based on expert judgement. The defined cost-delay model generates costs based on the following constraints:

- Duty of care – where costs occur per passenger dependent on the amount of time delayed (over 2 hours or 6 hours) or whether the passenger requires to stay overnight;
- Strict curfew restrictions (arrival and departures) – where costs occur per passenger with an overnight cost and per aircraft dependent on the size of the aircraft;
- Transferring passengers – treated the same as duty of care costs;
- Overhead cost as an operating cost that is not passenger centric – where costs occur per passenger per minute dependent on the duration of the flight and the amount of delay.

The passenger flow model is a crucial model development as this is highly correlated to the cost of delays. The aircraft load is generated randomly from the range of 75% to 90% of aircraft capacity, defined by expert judgement. From these passengers, a proportion of transferring passengers and minimum connection times have been defined through expert judgement.

EU261 is not included in the cost model as it assumes that EU261 does not apply due to all scenarios having an ATFM cause. The cost-delay model also assumes that delaying a flight further via UDPP is classified as ATFM delay.

The cost-delay model could impact the results as it does not include all constraints, such as: crew duty time, maintenance schedules, cancellations, diversions, future value.

C. Validation Results

The results from the validation exercise will be presented in terms of the performance and feasibility of UDPP for the AUs and for the APOC.

1) Airspace Users Performance

a) Performance Impacts

The performance impacts of introducing UDPP are compared to the FPFS algorithm used today are presented in this section measured by AUC, equity and flexibility.

Airspace User Cost Efficiency

The ATFM delays impose additional operating costs to AUs and cause disruptions to the passengers flow. It is expected that UDPP will help to recover the operating costs and increase the AUC. The results from the validation exercise of the average percentage of additional cost recovered are shown in TABLE I. A negative value indicates a recovery of additional cost.

A perfect operation according to the airline schedule would have zero delays. However, in the real operating world there is additional noise in the network that causes delays and costs prior to the CCS disruption; this is the Standard Cost ($C_{Standard}$).

Once the CCS is triggered, the FPFS algorithm imposes the ATFM delays and the additional operating costs to the AUs. The total operating cost when the CCS is triggered is the Reference Cost ($C_{Reference}$).

The Solution cost ($C_{Solution}$) is the operating cost after UDPP has been applied.

These two costs contain the Standard Cost; therefore, to understand the benefits of UDPP, the difference between the solution and reference cost is found as a percentage of the Reference Cost not including the Standard cost. Equation (1) shows the calculation of the % of additional cost recovered.

$$(C_{Solution} - C_{Reference}) / (C_{Reference} - C_{Standard}) \quad (1)$$

TABLE I. OVERALL AVERAGE ADDITIONAL COST SAVINGS

AVG Total Additional Costs	AVG	SD	MIN	25 th Percentile	Median	75 th Percentile	MAX
€121K	-58.2%	30.0%	-2.6%	-31.0%	-61.2%	-89.5%	-124.4%

The results show that UDPP always reduces the additional cost. On average, AUs could recover 58.2% of the additional costs. (The ‘Maximum’ cost saving above 100% indicates that 100% of the additional costs were recovered and a further amount from the existing Standard Cost due to optimisation).

The spread of additional cost recovered are shown in figure 4 show that the participants using all UDPP features are always able to reduce the additional costs imposed by ATFCM delays.

MVU during the simulation were defined as an airline with a large proportion of flights within the UDPP Measure, although not as many as the Hub and without passenger connections (low cost carrier/point-to-point models). The results show that MVUs were able to recover more of the additional costs, this is due to the fact that MVUs have less constraints to consider as they do not have passenger connections and they focused on mitigating curfew violations.

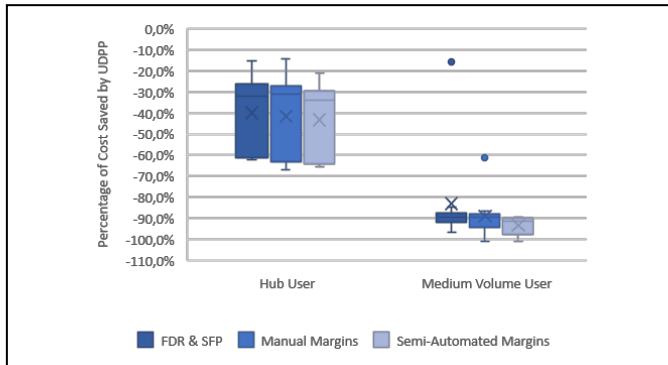


Figure 4: Spread of the percentage of additional costs recovered by UDPP per airline type and UDPP feature

As part of the impact of delay, the AUC is also determined by passenger transfers and passenger satisfaction. The validation captured the results of the passenger transfers according to the passenger flow model as shown in TABLE II. as a percentage of the additional passenger connections recovered. A negative value shows that there is a positive impact and more passengers made a successful connection.

TABLE II. OVERALL AVERAGE RECOVERY OF PASSENGER CONNECTIONS

Total Passengers	AVG	SD	MIN	25 th Percentile	Median	75 th Percentile	MAX
4597	-2.1%	2.3%	-11.0%	-2.5%	-1.4%	-0.6%	0.7%

The results show that passenger connections were improved by an average of 2.1%. The 'Maximum' value shows that there was an occurrence where the number of successful passenger connection decreased. This arose in only two runs from 51 runs where the scenario events caused curfew issues and the main priority for the AU was to reduce the number of curfew violations. Respecting the curfews benefits the passengers as it guarantees that they will arrive at their destinations and flights are less likely to be cancelled; this is not reflected in the passenger connection results.

Equity

Equity was measured by assessing the impact on the non-participating airlines, that should not be negatively impacted when using UDPP. TABLE III compares the impacts of the non-participating flight following UDPP prioritisations by the percentage of (%) flights that improved (have less delay); flights that worsened (have more delay); and flights that are neutral (delay remains the same).

TABLE III. OVERALL AVERAGE PERCENTAGE OF NON-PARTICIPATING FLIGHTS WITH AN IMPACT FROM UDPP

Number of Flights	% Improved Flights	% Improved Flights >=5 minutes	% Improved Flights >=15 minutes	% Worsened Flights	% Neutral Flights
114	7,8%	2,3%	0,1%	0,0%	92,2%

The results show that equity is respected as the delay of any non-participating flights did not worsen. UDPP provides benefits for the non-participating airlines shown by the percentage of the flights that received an improvement in slots. A very small percentage of flights had a large improvement where the slot changes by 5 minutes or greater.

Flexibility

When the UDPP Measure was triggered, flexibility was measured by participants' responses on the opportunity they had to use UDPP to solve their issues as shown Figure 5. The results show that Hub and MVUs have the most opportunities to utilise UDPP due to the number of flights that are present within every constraint. The sample size of the respondents varies from a minimum of three responses to 18 responses with an average of nine responses per airline type and scenario event. This is due to the randomised experimental design performed during the validation exercise in order to allow for maximum subjective feedback from participants having exposure to all roles. This is where a random combination of factors and levels were performed per run.

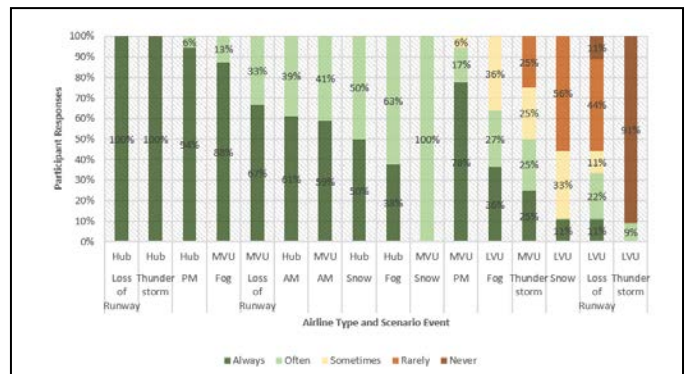


Figure 5: Opportunity to use UDPP per airline type and scenario event

Responses to other questions on flexibility and debriefings suggest that AUs find that UDPP provides additional flexibility.

Current flexibility options for AUs including slot swapping, allow airlines to only swap two flights at a time. Often AUs wish to redistribute the delays and impacts across many of their flights, not only two flights. UDPP allows more flexibility to the AUs as they are able to influence the slots of more than just two flights. The average percentage of flights that are impacted by UDPP in comparison to the flights position in the slot list in a PFPS regulation is shown in TABLE IV.

TABLE IV. AVERAGE PERCENTAGE OF FLIGHTS WITHIN THE UDPP MEASURE THAT HAVE A CHANGE FROM THE BASELINE SLOT

Flights within UDPP Measure	% Flights with Change	% of Flights with Priority	%Flights with Change \geq 5 minutes	%Flights with Change \geq 15 minutes	%Flights with Change \geq 30 minutes
302	27%	10%	15%	8%	5%

The results show that on average only 8% of the flights within the UDPP Measure show a large change from the baseline slot allocated by the FFS algorithm, of which 0.1% are non-participating users according to TABLE III.

b) Human Performance

Human Performance (HP) was assessed in terms of system acceptability, workload, situational awareness and trust.

All assessments of the impact on HP exceeded the minimum requirements, showing positive impacts. Participants provided feedback that the UDPP features are clear, acceptable and that the users have a high level of trust in the UDPP features. The workload was considered to be tolerable and acceptable and situational awareness achieved very high ratings.

c) Operational Feasibility

The participants provided their expert opinion on the usability and acceptability of each specific UDPP features, shown in Figure 6. Majority of the responses agree that each function is acceptable and usable. Semi-Automated Margins received only positive responses suggesting that it is the most acceptable solution in an operational sense.

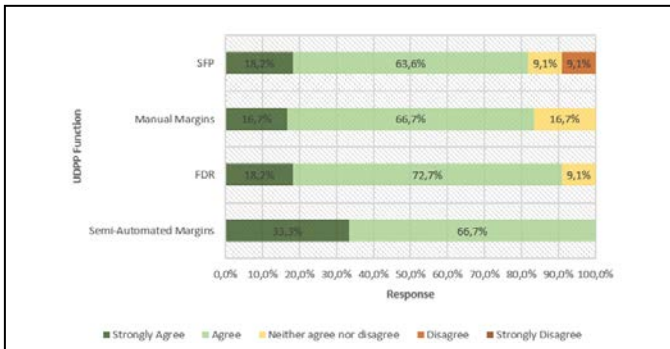


Figure 6: User Acceptance of each UDPP feature

2) Airport Performance and Integration

During the exercise, the APOC triggered UDPP at the start of each run and the participants using the stand allocation process were not aware of the actions performed by AUs on their flights with UDPP. The participants could only see variability in the traffic, not knowing which was due to UDPP. For airports, the effects of UDPP should be negligible as there is already a lot of noise and disruption in actual operations: UDPP would be a small part of the larger noise.

The performance of the airport was measured by the total delay at the airport. The results of the analysis show that UDPP reduced delay for arrivals. In some cases, off-block delay was increased although to the benefit of an increased departure flow,

decreased risk of cancellations and increase in passenger connectivity, or to airlines “sacrificing” flights in order to minimise the impact of delay.

Verbal exchanges of information from airports about the stand changes to certain flights were disclosed to airlines and they checked these changes against their priorities. Observations of these verbal exchanges showed that the airports did not touch any flights of importance to the airlines, therefore the stand changes did not degrade the benefits for airlines and passengers. The common goal of both stakeholders is to ensure passenger connectivity and UDPP is expected to provide these benefits.

Airport participants agreed that integrating UDPP improves pro-active CDM with AUs and that further exchange about priorities would be beneficial. Participants noted that the workload of the stand planner seemed to increase, although still at a tolerable level.

Finally, Airports and AUs agreed that UDPP would be an advantage for operations, as airports and NM would receive less requests from airlines and less last minute changes, therefore, creating a more stable plan.

3) ECAC-wide performance assessment

A performance assessment was performed extrapolating the results ECAC-wide. It assumes that a UDPP Measure could be triggered every year 120 times at each of the 15 airports identified as problematic, and that only the major airline of that airport will perform UDPP actions. Therefore, assuming that UDPP Measures could occur 1,800 times a year within the ECAC network. These assumptions have been taken from expert judgement and the analysis of the current slot swapping, arrival regulations and the results from the validation exercise.

The extrapolation used 40% as the amount of additional costs due to delay recovered for participating airlines. 40% is the average cost savings per airline type from the validation exercise, equating to €50K cost recovery per UDPP Measure.

These assumptions calculating that €90M ECAC wide could be saved with 1,800 UDPP Measures per year each saving €50K were used as inputs into the Cost Benefit Analysis that took a conservative hypothesis on the deployment date. Figure 7 shows the results with a positive return of investment within only 6 to 7 years. These results, however, do not take into consideration the network effects of UDPP.

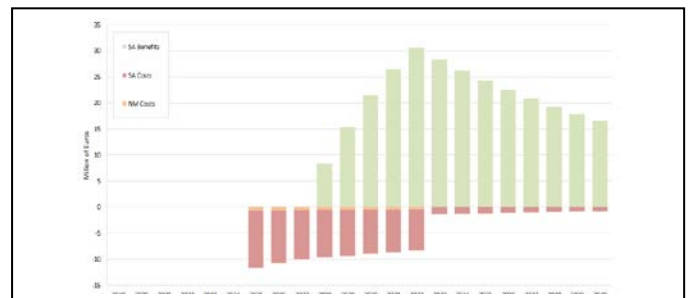


Figure 7: Annual investments and benefits for Network Management and Scheduled Aviation

4) Limitations of Validation Results

The validation results of the feasibility and performance of UDPP are promising, despite the following limitations:

- The measurements were assessed at only one airport, whereas there are more than 400 airports in ECAC.
- Only one-day's traffic was assessed. Constraints at airports differ from day-to-day and season-to-season.
- Participants did not have all tools and options available, such as airframe swapping, which may have exaggerated the use and benefits of UDPP.
- The cost-delay model did not include all constraints that produce costs and aid decision making for the allocation of UDPP prioritisations, such as crew duty time.

V. CONCLUSIONS AND FUTURE WORK

For AUs, each UDPP feature is useable, desirable, feasible and acceptable in operations, although airlines would need support from automation for the allocation of priorities/margins to flights when there are a lot of flights. Performance results show that, whilst respecting equity, more flexibility brings more cost efficiency for AUs with 40 % reduction on average of the additional cost of delays, and increases the number of successful connections for passengers. In particular, users with fewer constraints to consider in the decision making (MVUs) were able to recover the most costs; LVUs were able to use UDPP with the current features, although not consistently.

For airports, although looking at stand allocation covered a limited range of the Total Airport Management, the initial results looked acceptable to APOC participants. Furthermore, airlines and passengers are airports' clients and UDPP is expected to provide benefits to both clients. The common goal of the AUs and airports is to ensure passenger connectivity, and from that perspective UDPP benefits would contribute to the airport Quality of Service.

The paper suggests that the SESAR performance framework for measuring the impacts of UDPP on flexibility and equity is not fully mature; further metrics for flexibility should include the rate of acceptance for UDPP prioritisations, as well as the rate of opportunities to use UDPP in ATM. With passengers as the clients of air transport, passenger experience metrics should be included into the performance framework.

UDPP for airport constraints has completed V2 maturity according to the E-OCVM [4] from the perspective of AU operational feasibility and will transition to V3.

UDPP aims to reduce the impact of delays, not the delay itself. The validation results of the feasibility and performance benefits of UDPP are promising. Future research will assess the

impacts of multiple UDPP Measures on the network stability through Fast Time Simulations, and address the integration of UDPP into Network Management Collaborative processes with local and regional ATM actors at airports and with NM in contexts closer-to-operations.

ACKNOWLEDGMENTS

The authors want to acknowledge the valuable contributions to this paper from Leo VAN DER HOORN, Laurent CROUZARD, Kris DELCOURTE (EUROCONTROL), Marie CARRE (SWISS International Air Lines) and the participants of the validation exercise.

REFERENCES

- [1] A. Cook. (Ed.) European Air Traffic Management: Principles, Practice and Research. Ashgate, 2008.
- [2] EUROCONTROL, "ATFCM Users Manual", Ed. 21, 2017
- [3] A.J.M Castro, A.P. Rocha and E. Oliveira, "A new approach to disruption management in airline operations control", AGIFORS/SSP, 2014.
- [4] European Operational Concept Validation Methodology (E-OCVM) - 3.0 Volume 1, 2010
- [5] N. Pilon, S. Ruiz, A. Bujor, A. Cook & L. Castelli, "Improved flexibility and equity for airspace users during demand-capacity imbalance - an introduction to the user-driven prioritisation process", Sixth SESAR Innovation Days, Delft, Netherlands, 2016
- [6] Sergio Ruiz, Laurent Guichard and Nadine Pilon, EUROCONTROL Experimental Centre, "Optimal Delay Allocation under High Flexibility Conditions during Demand-Capacity Imbalance: A theoretical approach to show the potential of the User Driven Prioritization Process", SESAR Innovation Days, Belgrade, 2017
- [7] Sergio Ruiz, Laurent Guichard, Nadine Pilon and Kris Delcourte, EUROCONTROL Experimental Centre, "A New Air Traffic Flow Management User-Driven Prioritisation Process for Low Volume Operator in Constraint: Simulations and Results," Journal of Advanced Transportation, vol. 2019, Article ID 1208279, 21 pages, 2019. <http://downloads.hindawi.com/journals/jat/2019/1208279.pdf>
- [8] SESAR P.07.06.04. UDPP Step 2 V1 Validation Report, 2016
- [9] SESAR P.07.06.04. UDPP Step 1 V3 Validation Report, 2014
- [10] SESAR P.02.03. DFLEX Demonstration Report, 2014
- [11] EUROCONTROL, "European Aviation in 2040 - Challenges of Growth" (Edition 2), 2018
- [12] EU No 677/2011, Commission Regulation (EU) No 677/2011 of 7 July 2011 laying down detailed rules for the implementation of air traffic management (ATM) network functions and amending Regulation (EU) No 691/2010, <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ>
- [13] EU 261, Regulation (EC) No 261/2004 of the European Parliament and of the Council, 11th February 2004, <http://data.europa.eu/eli/reg/2004/261/oj>
- [14] AMADEUS, "Passengers first, Rethinking irregular operations", 2013
- [15] SESAR Definition Phase D3, "The ATM Target Concept" V2.0, 2007
- [16] M. Ball, C. Barnhart, G. Nemhauser, A. Odoni, "Air Transportation: irregular Operations and Control", 2006
- [17] University of Westminster, "European airline delay cost reference values" - Updated and extended values. Ed. 4.1, 20