Reducing Impact of Delays using Airspace User-Driven Flight Prioritisation

User Driven Prioritisation Process Validation Simulation and Results

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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.**

This paper reports on research that followed the second approach. The User Driven Prioritization Process (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, in a set of features that can be combined by the users when appropriate.

Based on validation assessing the performance impacts, operational feasibility and human performance aspects of UDPP, the paper reports on UDPP reducing the impact of delays on Airspace Users on 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, 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 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 presented these challenges introducing the UDPP concepts to address the problem [5]; this paper reports on new innovative UDPP concept features: Margins, Fleet Delay Reordering (FDR) and Selective Flight Protection (SFP). It describes the need for flexibility to cope with uncertainty on the AUs' side (Section II), the UDPP solution (Section III) and details of the validation experiment conducted 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

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 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.

Thus, the cost structure of a flight is typically not linear. For any delay, the AU's reputation could be harmed. It has been recognised by AUs that flights often have some tolerance to delay (i.e., margins). Although a minute of delay always has a cost, 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 Figure1.

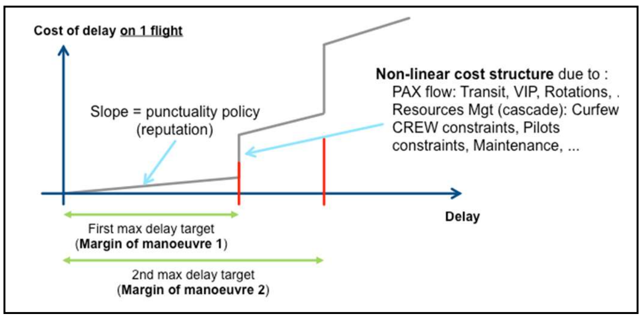

Figure 1: Typical cost-delay model profile per flight

Each flight has its own 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- [7], [8] -, 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 the Network Manager (NM) and ariports and Collaborative Decision Making between airports and airlines such as DFlex [10].

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

In response to the need for increased flexibility with equity in ATM, the UDPP concept includes several innovative features [5][6] allowing AUs to exchange flight positions and redistribute total delay among several of their own flights: by reprioritizing delayed flights in a capacity constraint during the planning phase, the cost/impact of delay can be reduced.

Building on Figure1, Figure 2 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. For example, FL002 has a medium delay that may include the costs associated to the potential knock-on effect caused by a certain amount of delay allocated to that flight.

The benefits of giving flexibility to the AU by transferring the delay between its flights by exchanging positions in the sequence and how it reduces the overall cost to the AU are shown in Figure 2.

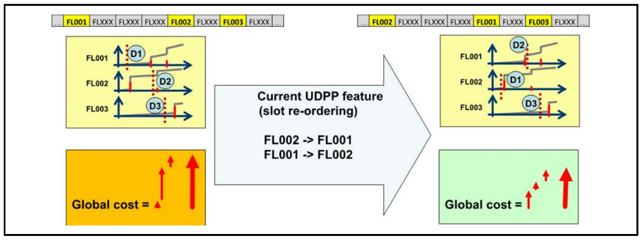

Figure 2: UDPP flexibility for the optimisation of AU impact of delay

UDPP features include FDR and SFP and a new feature requested by AUs, the Margins that are described below.

1) FDR – Fleet Delay Reordering

FDR is a prioritisation feature based on the slot swapping process. The AU can reorder its flights within the UDPP Measure using only their own slots by assigning a priority value on each flight. However, flights cannot be given a slot that is before their original time prior to the UDPP Measure.

2) SFP – Selective Flight Protection

SFP is a prioritisation feature 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 to its scheduled slot whilst improving the other AUs flights in between.

3) Margins with priority values

This feature allows assigning “time windows” to each flight in combination with the SFP and FDR features, reflecting the AU’s internal constraints and therefore it remains stable even when the ATM environment change. Margins on flights can be given by two time values:

- Time not after: specifies a time for the flight that cannot be later than the given value.
- Time not before: specifies a time for the flight that cannot be earlier than the given value.

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 FPFS 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) [18] which provides a framework to support collaborative validation of operational concepts through research and development (R&D) to implementation and operations.

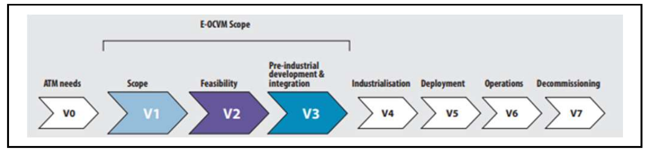

Figure 3: Concept lifecycle model [18]

SESAR2020 Wave 1 aimed to validate the UDPP solution to an E-OCVM V2 maturity where the operational feasibility is assessed. The transition into V3, integration and pre-industrial development is foreseen for SESAR2020 Wave 2.

A. Past Validation Exercises

Further to the V3 validation of the Enhanced Slot Swapping and the DFlex demonstration [10], a complete prioritisation scheme was elaborated with AUs in SESAR 1

The previous validation exercise in SESAR 1 [8] performed an early V2 human-in-the-loop exercise measuring the utility and impacts of applying the UDPP prioritisation methods Fleet Delay Apportionment (FDA) and SFP for departure during the planning phase at Collaborative Decision Making (CDM)-airports.

Taking into consideration the results and conclusions from the past validation exercise, the solution addressing UDPP in SESAR2020 Wave 1 incorporated the following recommendations from SESAR 1:

- The FDA and SFP features of UDPP were revised to the above described FDR and SFP features. These features distribute the delay across the fleet more evenly and ensure that equity is maintained.
- The Margins with priority values feature was implemented.
- The validation exercise in SESAR2020 Wave 1 addressed the use of UDPP 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 and Scope

The validation exercise was joint with Total Airport Management using 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. This 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). RTS allows a human-in-the-loop experience of the UDPP system by operational experts in a relatively controlled and repeatable environment [18]. 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 APOC. 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:

- An INNOVE platform emulates the ATFCM system with NM functionalities including B2B services.
- A 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.
- A 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.
- An APOC system simulates the runway and ground movements at the airport. Airport actors were able to create the UDPP Measure and monitor the performance indicators at the airport and to change the stand allocation planning.

UDPP was the only option available to the participants in order to solve their issues. 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 FPFS is used, as today.

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 were compared to the outcomes from the reference scenarios in order to validate the impacts of UDPP.

Validation Scenario Events

Six validation scenarios were written where specific events occurred causing 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 even that lasts for a couple of hours in the afternoon causing curfew issues.

These scenario events vary in length and severity in order to be able to measure the 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 (HP);
- 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

AUC is expected to produce the most benefits from UDPP. 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 to use 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– where costs occur per passenger per minute dependent on the duration of the flight and the amount of delay.

The passenger flow model is crucial 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 based on the flight lengths defined by expert judgement.

EU261 is not included in the cost model (except Duty of Care) 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 disruption to the passenger 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 that the solution scenario recovered 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 CASA-like 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 used for the results of the percentage 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	25th Percentile	Median	75th 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 amount of additional cost. On average, AUs were able to recover 58.2% of the additional costs imposed by the ATFM delays. The 'Maximum' cost saving was 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 the additional cost recovered by the airline type and UDPP feature are shown in figure 4.

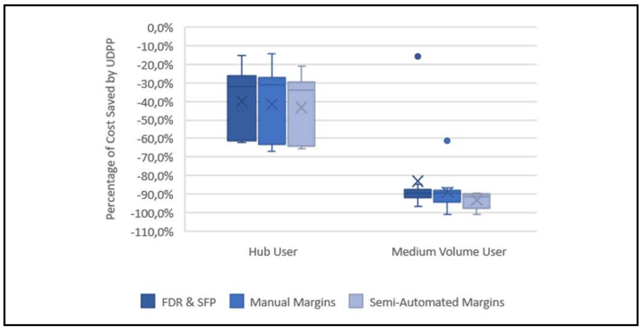

Figure 4: Spread of the percentage of additional costs recovered by UDPP per airline type and UDPP feature

The results show that the participants using all UDPP features are always able to reduce the additional costs imposed by ATFCM delays. The results show that MVUs were able to recover more of the additional costs, this is due to the number of constraints each airline model needs to address. MVUs have less constraints to consider as they do not have passenger connections; therefore, the focus for MVUs was on mitigating curfew violations.

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 developed passenger flow model defined by expert judgement as shown in TABLE II. as a percentage of the 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**	**25th Percentile**	**Median**	**75th 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

The participating airlines use UDPP to their benefit; therefore, equity is measured by assessing the impact on the non-participating airlines.

The non-participating airlines 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 6.

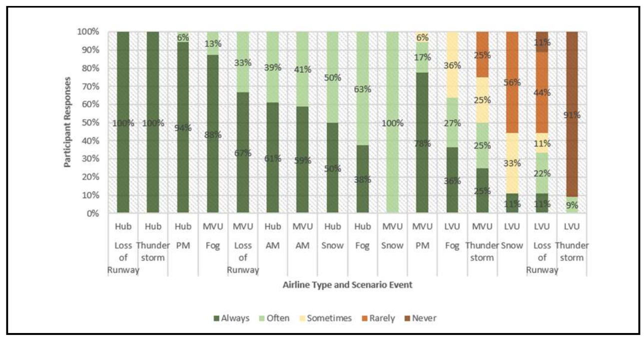

Figure 6: Opportunity to use UDPP per airline type and scenario event.

The results show that Hub and MVUs have the most opportunity 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 the randomised experimental design.

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 impact for many of their flights, not only two flights. TABLE IV. shows the average percentage of flights that are impacted by UDPP.

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 >=|5| minutes**	**%Flights with Change >=|15| minutes**	**%Flights with Change >=|30| minutes**
302	27%	10%	15%	8%	5%

The results show that UDPP provides more flexibility to the AUs as they are able to influence the slots of more than just two flights. On average, only 8% of the flights within the UDPP Measure show a large change from the baseline slot allocated by the CASA-like algorithm, of which 0.1% are non-participating users according to TABLE III.

b) Human Performance

HP was assessed in the areas: system acceptability, workload, situational awareness and trust.

All assessments of the impact on HP areas when using UDPP exceeded the minimum requirements showing positive impacts. The 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 7.

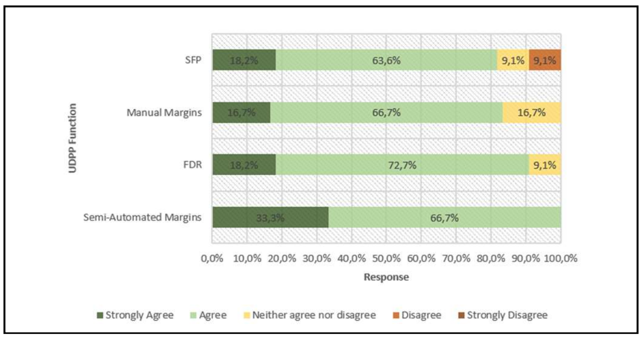

Figure 7: User Acceptance of each UDPP feature

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.

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 an increase in passenger connectivity. This increase in off-block delay may also be due to the 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.

Subjective feedback from the airport participants agreed that the UDPP integration improves pro-active CDM with AUs and it may be possible that further exchange about priorities would take place. The participants provided feedback that the workload of the stand planner seemed to increase, although the workload was deemed to be 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 the15 identified problematic airports where 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 day slot swapping, arrival regulations and the results from the validation exercise.

The extrapolation used a conservative assumption for the improvement of passenger experience and AUC, 40% as the amount of additional costs due to delay recovered for participating airlines. 40% is the average of the average cost savings per airline type from the validation exercise, equating to €50k cost recovery per UDPP Measure.

These assumptions were used as inputs into the Cost Benefit Analysis (CBA) that took a conservative hypothesis on the deployment date. The results indicated a positive return of investment within only 6 to 7 years as shown in figure 8.

Figure 8: Annual investments and benefits for Network Management andScheduled Aviation (SA)

These results, however, do not take into consideration the network effects on UDPP.

4) Limitations of Validation Results

The validation results of the feasibility and performance of UDPP are promising; however, the following limitations should be considered:

- 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 differ from day-to-day and from season-to-season at the same airport.
- 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

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.

For AUs, each UDPP feature is useable, desirable, feasible and acceptable in operations, although airlines would need support for the allocation of priorities/margins to flights when there are a lot of flights. Performance results show that more flexibility brings more cost efficiency for AUs and increases the number of successful connections by passengers, whilst respecting equity. In particular, users with fewer constraints to consider in the decision making were able to recover the most costs; LVUs with the current features are less likely to be able to use UDPP and further research into LVUs should be continued to ensure flexibility for all airline types. Currently, the metrics for flexibility and equity within the SESAR performance framework are immature; further metrics for flexibility could include the rate of acceptance for UDPP solutions.

For airports, airlines and passengers are their clients and UDPP is expected to provide benefits to both clients. The common goal of the AUs and airports is to ensure passenger connectivity. These benefits contribute to the performance of the airport.

UDPP for airport constraints has reached V2 from the perspective of AU operational feasibility. It is recommended that it should transition to V3 of the lifecycle phase [18]. Future validation of the UDPP concept should focus on the integration of UDPP into the wider network. The next steps in future research will be to assess the impacts of multiple UDPP Measures in the network and the stability of the network through Fast Time Simulations and to integrate UDPP as a part of the collaborative network management framework. The performance impacts of UDPP should particularly focus on passenger metrics which is recommended to be included in the performance framework.

The deployment of UDPP suggested in the CBA is a conservative assumption. Deployment could be introduced earlier by an incremental approach for example implementing at a local level, provided that UDPP is feasible with the network efforts and the performance of the network is not degraded.

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