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SESAR Solution PJ07.02

SPR-INTEROP/OSED

for V2 - Part I

User Driven Prioritisation Process

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UDPP

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15 PJ07-02 UDPP

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 18 grant agreement No 733020 under European Union's Horizon 2020 research and innovation
 19 programme.



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21

22 **Abstract**

23 The current edition of this document describes, in detail, the operational environment (§3.2) and the
 24 operating methods (§3.3) of the new concepts of PJ07 Solution 2 UDPP.

25 The User Driven Prioritisation Process (UDPP) is built to give flexibility to Airspace Users (AUs), i.e.,
 26 the ability of the Air Traffic Management (ATM) system to accommodate AUs' changing business
 27 priorities in particular when delay occurs. Increased flexibility could result in a more cost-efficient
 28 delay management during congested situations, with substantial reductions of operational and cost
 29 impacts for AUs. Equity (in the sense that one AU's prioritisation does not negatively affect
 30 another's) is the main constraint for UDPP.

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157 The SPR/INTEROP-OSED Template includes the following parts:

- 158 • ***SPR/INTEROP-OSED Template – Part I (this volume)***
- 159 • SPR/INTEROP-OSED Template – Part II Safety Assessment Report (SAR)
- 160 • SPR/INTEROP – OSED Template – Part III Security Assessment Report (SeAR)
- 161 • SPR/INTEROP – OSED Template – Part IV Human Performance Assessment Report (HPAR)
- 162 • SPR/INTEROP – OSED Template – Part V Performance Assessment Report (PAR)

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257

1 Executive Summary

258 This document is the Project 07 Solution 02: PJ07-02 Operational Services and Environment
259 Description (OSED) document describing the UDPP solution for SESAR2020 Wave1.

260 UDPP allows AUs' input in ATM Collaborative Decision-Making (CDM) processes primarily used in
261 ATM/Airport Capacity Constrained Situations (CCSs) -and in the future, possibly for AUs to use UDPP
262 for their own business needs. It is applicable in the planning of departure and arrival flights (and in
263 the future possibly in the re-planning during execution). Each AU can provide fleet relative priority
264 information and through a CDM process, request the reprioritisation of their set of flights.

265 The objective for the AU is to optimise their operational costs, reduce the operational impact and
266 improve passenger experience when faced with deteriorated situations. In this ATM constrained
267 situation, UDPP allows AUs to reduce the delay on their important flights, to the detriment of the less
268 important flights, in order to reduce the total impact of delay (this could be called: cost of delay:
269 which is an extra operating cost for the AUs).

270 From the AUs perspective, equity is key. Equity is defined as no negative impact on other AUs (at
271 least a strict minimum impact according to constraints), when an AU implements the prioritisation
272 amongst its flights according to its business needs.

273 This edition of the Interim OSED focuses mainly on the use of UDPP during a congested situation at
274 an arrival Airport when delays are imposed to AUs. This corresponds to the Operational
275 Improvement AUO-0109 "UDPP for Airport constraints". The objective of this part is to reach E-
276 OCVM end-V2 Maturity level at the end of wave1.

277 The integration of UDPP in the Network environment and into the DCB and Airports processes (and
278 in the future for En-Route constraints) is the objective of PJ07-02 in SESAR 2020. It is assumed that
279 the UDPP process could be triggered to allow AUs to propose acceptable solutions for Demand
280 Capacity Balancing (DCB) and Airports through "What-If" scenario calculations using the information
281 available to them. It is also assumed that the UDPP output is used as an initial acceptable solution to
282 the DCB and Airport process. Because UDPP solution will integrate the impact on Network and
283 Airport, it is assumed that a large majority of the UDPP solutions will become the final network
284 solution.

285 The OSED will also include the description of how the concept should be adapted for allowing more
286 access to Low Volume Users in a constraint (LVUC); namely Business and General aviation as well as
287 those airlines who have only a few flights captured in the CCS (e.g. on other Airport than their main
288 one) (AUO-0107 "UDPP for LVUCs").

289 UDPP will contribute to the following Key Performance Areas (KPAs):

- 290 • Flexibility;
- 291 • AU Cost Efficiency;
- 292 • Equity;
- 293 • Predictability; and
- 294 • Punctuality

295

296 The benefits of UDPP for AUs include (but are not limited to) the following:

- 297 • Increased flexibility to recover its fleet schedule times, or with manageable and acceptable
298 impact of delay.
- 299 • Reduced inefficiency (indirect costs to AUs) caused by delay and reactionary delay on
300 Airspace User Operation in CCS (reactionary delay for AU fleet is not a reactionary delay on
301 an Airport).
- 302 • Better punctuality for important flights.
- 303 • The suspension/cancellation- and delay-induced cost for passenger compensation can be
304 reduced—both directly (paying the passenger) and indirectly (rerouting, lodging, etc.)
- 305 • The suspension/cancellation and delay-induced cost for freight can be reduced.
- 306 • Increased access for Low Volume AUs to congested airports (potentially).

307 2 Introduction

308 2.1 Purpose of the document

309 This document provides the requirements specification, covering functional, non-functional, and
310 interface requirements related to SESAR Solution PJ07-02 UDPP.

311 2.2 Scope

312 This OSED for SESAR2020 PJ07-02 describes the concept of UDPP that will be introduced to support
313 the integration of AUs business needs in the ATM system.

314 This OSED covers the following OI steps:

315 **AUO-0109: UDPP for Airport constraints;**

316 User Driven Prioritisation Process (UDPP) running during planning phase, allowing prioritisation
317 coming from AUs to decrease the impact on their fleet in case of an Airport capacity shortfall (eg.
318 Loss of runway throughput). Airports in collaboration with the AUs involved have to come up with
319 a solution to manage the Airport constraint taking into account the network situation if impacted.
320 The ambition in Wave1 is to reach EOCVM end-V2 for this OI, to be ready to start V3.

321 Comment on this OI definition:

322 Some flights could be airborne; some others could be still on-ground. This is especially true for
323 UDPP on Arrival. In this case UDPP has to manage airborne flights in the constraint but also flights
324 not submit to ATFCM measures. UDPP has also to manage flights part of other ATFCM
325 Regulations. With all these management constraints, we can consider that UDPP is integrated in
326 the Network environment.

327 **AUO-0109** started at early V2 (V1), and at the end of Wave 1, it has **reached the V2 maturity**. It is
328 recommended that AUO-0109 transitions to V3 for SESAR2020 Wave 2.

329

330 **AUO-0107: UDPP for Low Volume Airspace Users in a constraint;**

331 Research in SESAR1 allowed elaborating a method considered acceptable by all AUs, which needs
332 further investigation. Research continues in SESAR2020 on an adaptation of UDPP for LVUC. The
333 aim is to establish, using expert judgment, the conditions to allow LVUC to use the same UDPP
334 prioritisation methods as the other AUs.

335 **AUO-0107** has been investigated in Solution PJ.07-02 and the outcome is included in this OSED. A
336 maturity self-assessment has been performed concluding that it is currently at a **maturity of V0**
337 (**early V1**). Further research will take place as part of the **Exploratory Research** programme of
338 SESAR.

339

340 **AUO-0106: UDPP for reprioritising flights during execution;**

341 This OI is not in the scope of Solution PJ.07-02. Removal of the link between the solution and the
342 OI has been requested (CR 03481 “Remove link between AUO-0106 and Solution PJ07.02: Re-

343 prioritising flights during Execution is not part of the scope of solution PJ07.02, hence the need to
 344 remove the link between AUO-0106 and the solution”)

345

346 **AUO-0110: UDPP for network constraints;**

347 This OI Step shall focus on the prioritisation process applied to constraints managed by the
 348 Network Management function. It will address the prioritisation of an AU's group of flights
 349 involved into one or several network constraints (possibly managed by several Flow and/or Local
 350 Traffic Managers, including LTM at Airports). The OI Step shall address as well the integration of
 351 the prioritisation into the reconciliation process in case of multiple constraints.

352 AUO-0110 has been partially addressed, as this concept will apply the already validated methods
 353 of UDPP at one UDPP network constraint managed by the airports in the full delegation mode of
 354 DCB. Several constraints and en-route constraints have not been addressed in SESAR2020 Wave
 355 1.

356

357

358 In the ATM Master Plan, Solution PJ.07-02 is linked to these four OI steps, which represent the needs
 359 expressed by the AUs in UDPP at the end of SESAR1. However, changes to the scope of Solution
 360 PJ.07-02 are not fully reflected in the EATMA portal; PJ07.02 in Wave 1 only focussed on AUO-0109
 361 and addressed partially AUO-0107.

362 AUO-0110 has been partially addressed by the integration of the UDPP process in the Network
 363 environment, but the multi-constraints management part has not been fully addressed.

364 AUO-0110 has not addressed En-route constraints: After consultation with ATM contributors, there
 365 are many other ways to solve En-Route constraints and UDPP will not be used by DCB for solving En-
 366 Route constraints.

367

368 PJ07-02 covers the below OIs with the aim to reach the target maturity levels at the end of
 369 SESAR2020 Wave 1.

OIs	Initial Maturity level	Target Maturity level at the end of Wave 1	OIs description
AUO-0109	Mid-V2 (V1)	End-V2	UDPP for Airport constraints. It is recommended that AUO-0109 transitions to V3 for SESAR2020 Wave 2
AUO-0107	V0	Early-V1 (V0)	UDPP for Low Volume Airspace Users
AUO-0106	V1	Out of scope (CR)	UDPP for reprioritising flights during execution.
AUO-0110	Early-V2 (V1)	Mid-V2 (V1)	UDPP for Network constraints. Partially addressed: UDPP on multi-constraint not fully addressed, UDPP on en-route constraint not addressed.

370

Table 1: PJ07 Solution 02 Maturity levels table

371 2.3 Intended readership

372 This document is aimed at the following stakeholders:

- 373 • the SESAR2020 PJ07, PJ09, PJ04, PJ25 members, including Airspace Users
 374 • the SJU and EUROCONTROL; and
 375 • the transversal PJ19 project;

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379 2.4 Background

380 This document describes the continuation of the development of the UDPP concept that started in
 381 SESAR1 P07.06.02 UDPP and enhanced UDPP concept by integrating stakeholders' comments and
 382 validation results.

383 The UDPP objective is to provide more flexibility to AUs to reorganize their flights in the case of
 384 delays on departure or arrival (including en-route in Wave 2), principally in a Capacity Constrained
 385 Situation (CCS).

386 UDPP allows AUs to mitigate the impact of delays on their business but does not decrease the total
 387 ATFM delay itself. UDPP is not set to replace any ATM organisation to fit the AUs' needs in terms of
 388 optimum Airspace organisation, Airport organisation or optimal trajectory; UDPP allows to limit the
 389 impact on AUs in case of residual congestion.

390 The UDPP concept is designed in an ATM Collaborative Decision-Making (CDM) context and provides
 391 an additional layer of flexibility for AUs compared to UDPP SESAR1 Step 1 (OSED Step 1 V3). UDPP
 392 allows an improved and more efficient management of AUs' fleet in situations of delays.

393 Three different components (features) have been developed for the UDPP concept:

- 394 • Fleet Delay Reordering (FDR);
 395 • Selective Flight Protection (SFP); and
 396 • Margins

397 It should be emphasized that these features do not replace the SESAR1 feature: Enhanced Slot
 398 Swapping, which remains available for an AU if required.

399 2.5 Structure of the document

400 This OSED is structured as follows:

- 401 • **Section 1 Executive Summary:**
- 402 • **Section 2 Introduction:**

403 • **Section 3 Operational Service and Environment Definition:**

404 • **Section 4 Safety, Performance and Interoperability:**

405 • **Section 5 Reference and Applicable Documents:**

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411 **2.6 Glossary of terms**

Term	Definition	Source of the definition
Baseline delay, Baseline Time	Represents the allocated delay to each flight in a constrained situation if no UDPP. It is used as a baseline of the UDPP equity and can be used to benchmark the UDPP concept to identify the concepts' benefits.	
Capacity Constrained Situation (CCS)	A period of time in which the Capacity of an ATFM element (Airspace, Arrival Runway, Departure Runway ...) is reduced. It defines the new capacity constraint due to this condition. In most of the case, this CCS will generate a capacity problem (Hotspot ...) to be managed by Airport/DCB/NM.	
Demand Capacity Balancing (DCB)	Where used in this OSED to convey a role in the UDPP process, the term 'DCB' is intended to be the aggregate group including DCB, Local DCB, Airport, and Network Manager.	
FDR Fleet Delay Reordering	The feature by which using its own allocated slots, an AU can rearrange its fleet, by giving priority values.	
Hotspot	Term used by Network DCB to specify a safety critical area of interest, which generally has a demand that exceeds the available capacity. The Hotspot specifies that the situation has to be managed to decrease the overload. This hotspot could be resolved through delegation to the AUs and triggering UDPP.	
Knock-on delay or	A side effect on subsequent flights due to delay	

Reactionary delay	<p>given to an initial flight(s). The initial delays can be caused by capacity constraints, ATC/Network constraints, airport constraints, but also due to airline constraints (crew, passengers ...).</p> <p>AU reactionary delay take into account all the AU fleet of the day to decrease the impact of the original delay, which is completely different from the Airport reactionary delay who take into account only the impact on the local Airport platform.</p>	
Margin of Manoeuvre	<p>For an AU, it is the maximum delay a flight can take before incurring significant cost (disruption on the cost curve according to delay). It is anticipated that the “significant cost” can be defined differently by each AU, but for the purposes of this example, the cost represents a “spike” that is due to factors such as crew or pilot time-out constraints, or a large number of passengers who miss a connection, curfew, etc.</p> <p>Each time one of the factors is met; another spike in cost is incurred, which represents the end of another Margin of Manoeuvre for the AU.</p>	
Prioritisation	<p>Actions made by the AUs (using the UDPP features SFP, FDR, Slot Swap, Margins) according to the importance of their flights impacted by a Hotspot, based on their business needs.</p>	
Protection/Protect a flight	<p>UDPP Protection is part of the UDPP prioritisation. It is the highest priority given to a flight pushing its operation as closed as possible to the planned off block time. To do this, UDPP applies the SFP algorithm for this flight.</p>	
Ration-By-Effort	<p>The principle by which AUs first have to allocate additional delay to one or more of their flights in order to receive less delay (through protection or prioritisation) on one or more of their flights. This notion is used specially for SFP implementation.</p>	
Scenario	<p>An operational situation, in which, use cases are executed.</p>	
SFP Selective Flight Protection	<p>The feature by which an AU can obtain a desired delay for a flight, even if no ATC slot is available / has been allocated to the AU in question..</p>	
Suspension	<p>ATFM suspension (FLS) is an ETFMS message sent, suspending a flight, which thereafter should not get take-off clearance.</p>	

"Time not After", "Time not Before"	<p>It is the time components of the <u>Margin of Manoeuvre</u>. The feature by which allows a time window to be allocated by an AU to its own flights, as a constraint. This is in order to rearrange the AU sequence.</p>	
UDPP Suspension/Suspend a flight	<p>UDPP Suspension is part of the UDPP prioritisation. It is the lowest priority given to a flight pushing its operation at the end of the problem managed by UDPP.</p> <p>It is not an ATFM suspension, i.e.: an FLS message.</p>	
UDPP Cut-off Time, UDPP Measure Closed time (to AUs modification)	<p>Absolute time defined when the "UDPP Measure" is initiated and specify until when AUs can set priorities/Margins on their flights. Over this time, the last prioritisation given by AUs on their flights are taken as "final UDPP prioritisation" to elaborate final UDPP solution.</p> <p>This time is used only if a flight is not <u>become pre-allocated before</u>: when flights are or become "airborne" (20 to 30 mn before Off-Block or flight considered as out of current regulation rules: coming from out of ECAC area, military flights ...).</p> <p>Finally this UDPP Measure Closed time is used generally for short haul flights with a short flight duration.</p>	
UDPP measure	<p>Term used in this document to trigger the use of UDPP. This can be in a CCS or in 'nominal' situations where demand exceeds capacity for a given period. An Airport/DCB/NM action must be taken to mitigate the situation.</p> <p>Originally, the overloaded situation (called sometime hotspot) does not necessarily contain all the impacted flights relative to the imbalanced situation (because it is not calculated at the beginning). The constraint declaration (CCS) is used to calculate all the impacted flight (all flights having delay) according to the Capacity constraints in a CASA like way (FPFS). Nevertheless, the UDPP measure can be set to a larger time window of even on a window without declared CCS, to allow AU to reorganize flights if needed. Up to the resource owner (e.g. Airport, DCB Network) to allow this delegation, called UDPP measure, in collaboration with AUs.</p>	

	<p>The UDPP measure can also replace a Regulation measure.</p> <p>UDPP generates the same delay than CASA on each flights if no AU input. The total delay of a regulation and a UDPP measure is the same. In a way, a UDPP measure is a regulation where AU can give priority on flights. The mitigation is given by priority from AU, the basis is the delay given by the CASA like part of the UDPP measure.</p> <p>UDPP measure is not only the mitigation part but also the regulation part to avoid overload.</p>	
UDPP Measure freeze input list time	<p>Absolute time when the “UDPP Measure” is closed to new flight insertion in the UDPP Measure (new flight plan). UDPP Measure flights list becomes fixed. If new flights plan are declared, there are put at the end of the “UDPP Measure”.</p> <p>NB: This time normally must be relative to moving time according to flights arriving time in UDPP Measure and not to the “UDPP Measure” starting time. (this must be updated in Wave 2) (ex: 2 hours before the flight arriving in UDPP measure).</p>	
UDPP Priority value	<p>A value given by the Airspace user on a flight (or a specified default value) used by the UDPP function to reorder the flights in the constraint. Values can be: P for Protect, S for suspend, B for keep baseline, or a number from 1 (highest priority) to 999 (lowest priority).</p>	

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Table 2: Glossary of terms

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2.7 List of Acronyms

Acronym	Definition
4D	Four Dimensional
AFUA	Advanced Flexible Use of Airspace
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
AOC	Airline Operations Centre
AOP	Airport Operational Plan

APOC	Airport Operations Centre
APT	Airport
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
AU	Airspace User
BDT	Business Development Trajectory
CASA	Computer-Assisted Slot Allocation (Network Manager slot allocation for regulations)
CCS	Capacity Constrained Situation
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit
CI	Confidence Index
CNS	Communication Navigation and Surveillance
CONOPS	Concept of Operations
CR	Change Request
CTOT	Calculated Take-Off Time
D0	Day 'zero', Day of Operation
D-1	Day 'zero minus one', Day before Operation
DCB	Demand Capacity Balancing
dDCB	Dynamic Demand Capacity Balancing
DFlex	Departure Flexibility
DMAN	Departure Manager
DOD	Detailed Operational Description
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
EIBT	Estimated In Block Time
EOBT	Estimated Off Block Time
E-OCVM	European Operational Concept Validation Methodology
EXE	Exercise
F2F	Face-to-Face

FAB	Functional Airspace Block
FCL	Flexible Credits for Low Volume Users in Constraints (LVUCs)
FDA	Fleet Delay Apportionment
FDR	Fleet Delay Reordering
FIBT	Forecasted In Block Time
FIXM	Flight Information Exchange Model
FMP	Flow Management Position
FMS	Flight Management System
FOBT	Forecasted Off Block Time
FOC	Flight Operations Centre
FSFS / FPFS	First Scheduled First Served / First Planned First Served
HPAR	Human Performance Assessment Report
HSPT	Hot Spot
IBT	In-Block Time
ID	Identifier
INTEROP	Interoperability Requirements
IRS	Interface Requirements Specification
KPA	Key Performance Area
KPI	Key Performance Indicator
LVUC	Low Volume Users in Constraints
MPC	Most Penalising Constraint
MTTT	Minimum Turn-round Time
NEVAC	Network Capacity Evaluation Tool
NM	Network Manager
NMF	Network Manager Function
NOP	Network Operational Plan
OBJ	Objective
OBT	Off-Block Time
OCD	Operational Concept Description
OFA	Operational Focus Areas
OI	Operational Improvement
OPAR	Operational Performance Assessment Report

OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report
PDS	Pre-Departure Sequence
PIRM	Programme Information Reference Model
QoS	Quality of Service
RBE	Ration-By-Effort
RBT	Reference Business Trajectory
RMAN	Runways Manager (first Airport process to organise departure)
RTS	Real-Time Simulation
SAC	Safety Criteria
SAR	Safety Assessment Report
SBT	Shared Business Trajectory
SCN	Scenario
SecAR	Security Assessment Report
SESAR	Single European Sky ATM Research, usually in reference to the European ATM Master Plan
SESAR Programme	The programme that defines the Research and Development activities and Projects for the SJU.
SFP	Selective Flight Protection
SIBT	Scheduled In Block Time (initial Airline schedule)
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme that addresses all activities of the SESAR Joint Undertaking Agency.
SME	Subject Matter Expert
SMT	Shared Mission Trajectory
SOBT	Scheduled Off Block Time (initial Airline schedule)
SPR	Safety and Performance Requirements
STAM	Short-Term ATFCM Measures
SUT	System Under Test
SWIM	System-Wide Information Management
TAD	Technical Architecture Description
TBD	To Be Determined
TMA	Terminal Manoeuvring Area

TS	Technical Specification
TSAT	Target Start-Up Approval Time
TTOT	Target Take-Off Time
TW	Target Window
UC	Use Case
UDPP	User Driven Prioritisation Process
UIBT	User In Block Time (prioritisation given by User)
UOBT	User Off Block Time (prioritisation given by User)
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
V-FOC	Virtual Flight Operation Centre (FOC)
VP	Verification Plan
VR	Verification Report
VS	Verification Strategy
WOC	Wing Operation Centre

414

Table 3: List of acronyms

415 3 Operational Service and Environment 416 Definition

417 3.1 SESAR PJ07 Solution 02: a summary

418 The principal objective of the UDPP solution is to integrate the AUs' needs into the ATM system,
419 especially when delays occur, to decrease the impact of delay on the AUs operation.

420 A basic view of UDPP is that rather than solving the problem by smoothing the traffic in a First
421 Planned First Served (FPFS) manner (with the CASA algorithm), ATM asks the AUs to define a new
422 sequence of flights that better meets their needs when faced with delay. All of the needed
423 coordination and rules -and especially the Equity over the AUs- are defined through the UDPP
424 services.

425 The following three UDPP features allow AUs to manage impact of delays:

- 426 • **FDR Fleet Delay Reordering:** this feature enhances the slot swap feature used today by the
427 AU, by rearranging the sequence of flights of the same AU according to the given priority
428 values.
- 429 • **SFP Selective Flight Protection:** this feature forces the protected flight to be on time, even if
430 there is no direct slot allocated to the AU. It is based on sacrificing an earlier flight to allow
431 this possibility. (to preserve Equity rules)
- 432 • **Margins (“Time not After” and/or “Time not Before”):** a time window is given to a flight by
433 the AU, for the UDPP automation to find the FDR solution automatically. This feature use the
434 combination of the Margin times and the priority value if needed.

435 Note: Whereas FDR and SFP are improved UDPP features following the mid-V2 validation exercises in
436 SESAR, Margins is a new feature responding to AUs' request for more automated support to
437 prioritisation. Therefore, FDR & SFP are aimed to reach end V2. Margins is considered starting V0-V1
438 maturity feature at the beginning and reaching end V2 at end of SESAR2 wave1. A specific Airspace
439 Users workshop will be dedicated to it before the validation exercise with the objective to reach V2
440 at the same level then SFP & FDR.

SESAR Solution ID	SESAR Solution Title	OI ref.	Steps (coming from EATMA)	OI Steps (coming from EATMA)	Title from	OI Step Coverage
		AUO-0109		UDPP for Airport constraints		
"	"	AUO-0107		UDPP for Low Volume Airspace Users	Early V1: Further research of AUO-0107 will take place as part of the Exploratory Research programme of SESAR 2	

				Wave2.
"	"	AUO-0110	UDPP for network constraints	Not fully addressed: AUO-0110 should address several network constraints in Wave 2
"	"	AUO-0106	UDPP for reprioritising flights during execution.	Out of scope (CR)

441

Table 4: SESAR Solution 07-02 Scope and related OI steps

442

High Level CONOPS Requirement ID	High Level CONOPS Requirement	Reference to relevant CONOPS Sections e.g. Operational Scenario applicable to the SESAR Solution
P07-TLOR-01	<p>Optimised Airspace User Operations shall</p> <ul style="list-style-type: none"> • Increase the Airspace Users operational and flight cost efficiency • Increase the Airspace Users flexibility to plan and re-plan a flight; • Contribute to an optimised demand and capacity management; • Enable Airspace Users to optimise their flights integrating all their fleet constraint and business operations. <p>by defining and implementing Trajectory Management processes on AU side that feed into ATM DCB processes that :</p> <ul style="list-style-type: none"> • Integrate the trajectories calculated/planned by the Airspace User throughout the whole lifecycle of the flight; • Integrate the Airspace User defined flight priorities and preferences throughout the whole lifecycle of the flight; • Allow the civil Airspace User to swap slots between eligible flights, • Allow the Airspace User to revise the RBT/RMT <p>While:</p> <ul style="list-style-type: none"> • Support an integrated briefing throughout all flight phases; • Supporting prioritisation and re-prioritisation throughout all flight phases; 	4.9 Operational requirements PJ07 (Top requirements)

	<ul style="list-style-type: none"> • Supporting fleet delay assignment and flight protection; • Supporting AU driven RBT revisions throughout the whole flight execution <p>Integrating civil and military Airspace Users into the Trajectory Management, DCB and UDPP when required.</p>	
P07-TLOR-02	<p>Optimised Airspace User Operations shall:</p> <ul style="list-style-type: none"> • Increase the effectiveness of mission trajectories and flight efficiency ; • Increase the military Airspace Users' mission flight efficiency and safety • Facilitate optimisation of ATM network operations <p>by defining and implementing ATM solutions that :</p> <ul style="list-style-type: none"> • integrates the mission trajectory into the ATM network operating environment throughout the whole ATM lifecycle, integrates SMTs into CDM on the Target Time negotiation when required, enable a Pan-European mission and training planning and enables planning and executing of military training at Pan-European scale <p>facilitates capacity optimisation :</p> <ul style="list-style-type: none"> • Providing enhanced data consistency through the use of a harmonised and improved OAT FPL format and content for military IFR operations • Increasing predictability and awareness on AU demand • Supporting the integration of military operational requirements related to meteorological conditions; • Supporting the integration of military preferences and mission trajectories for DCB processes; • Developing a Pan-European OAT-IFR Transit Service (OATTS); <p>Allowing military Airspace Users to protect RMTs.</p>	4.9 Operational requirements PJ07 (Top requirements)
S07-02-HLOR-01	<p>All types of civil Airspace User shall be able to participate to DCB processes throughout the whole lifecycle of a flight by influencing the allocation of ATM constraint (to a flight) by</p> <ul style="list-style-type: none"> • Protecting individual flights for capacity constrained situations; • Flexibly assign fleet delays for capacity 	4.9.2 High Level Requirements PJ07

	<p>constrained situations;</p> <ul style="list-style-type: none"> • Flexibly re-prioritise flights in case of changing boundary conditions and changing capacity constrained situations; and <p>proposing a flight priority order to NM in case of deteriorated operations.</p>	
S07-02-HLOR-02	<p>UDPP processes shall be as efficient and effective as possible to reach:</p> <ul style="list-style-type: none"> • An optimum trade-off between planning effort and flight operations benefit; • High degree of process automation on AU side to reduce human workload & intervention as much as possible; and <p>Facilitate operational cost efficiency during flight by allowing the planning of optimised trajectories.</p>	4.9.2 High Level Requirements PJ07
Left column		

443

Table 5: Link to CONOPS

444 **3.1.1 Deviations with respect to the SESAR Solution(s) definition**

445 **3.2 Detailed Operational Environment**

446 The UDPP concept definition tries to avoid being stuck in a too futuristic vision of the ATM environment.

448 The majority of the functions described in this document can be implemented in the current environment and in the SESAR2020 environment dealing with trajectory management.

450 **3.2.1 Operational Characteristics**

451 [...]

452 **3.2.2 Roles and Responsibilities**

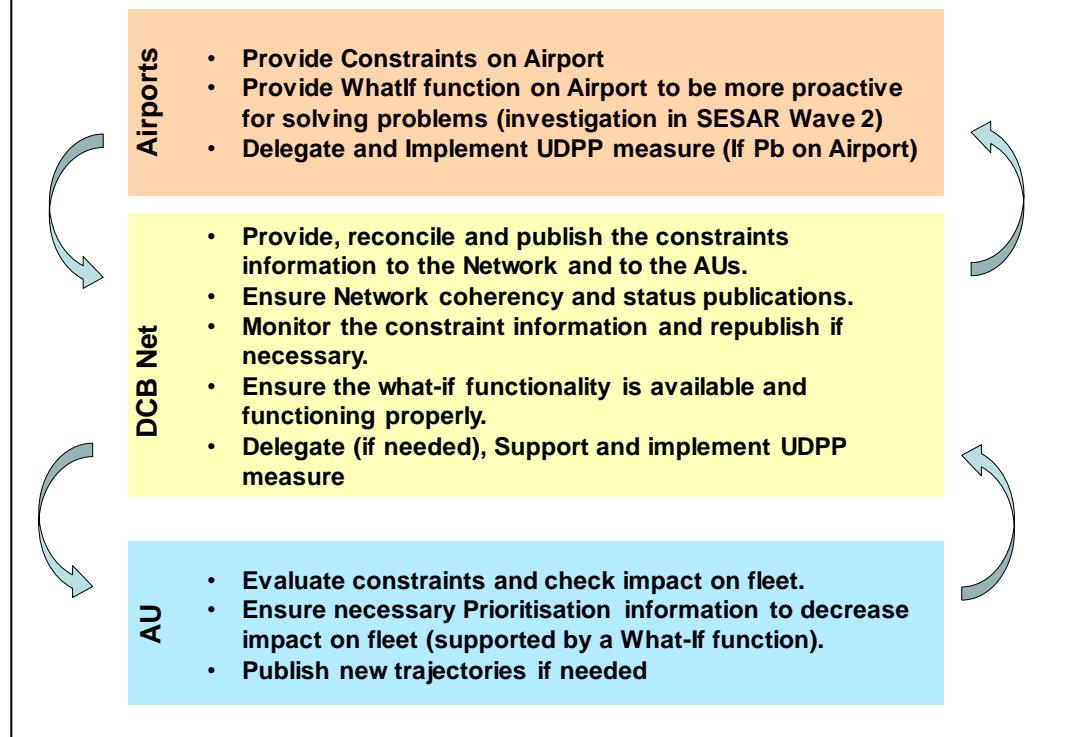
453 The objective of UDPP is to transfer the mitigation of a congested situation from the owner of the resource (for example, the FMP dealing with arrival flights) to the user of the resource (for example, the airlines). The philosophy is to decrease the impact of the problem for the user.

456

457 This section describes the actors involved in the Operational Process(es) / Service(s) and their various responsibilities.

459

Roles and responsibilities from UDPP perspective



460

461

Figure 1: Roles and responsibilities

462 From the AU (UDPP) perspective, there is a unique, single Network representative, called DCB or
 463 dDCB as seen in Table 6 below. Depending on the Airport ANSP local organisation, the different
 464 functions are assumed by different actors named: DCB, dDCB, Local DCB, DCB-Net, Airport-ATC,
 465 Network, Airport-DCB, FMP at Airport. The most important element is that, the different functions
 466 called Network Management Functions (NMF), are supported by one of the actors.

467 There are three primary processes involved in UDPP. In this context, the actors involved and their
 468 roles and responsibilities are elaborated in Table 6. A brief description of the relationship with
 469 Trajectory Management is described.

470

Actor	Collaborative background process	Initiate the UDPP Process	Implement UDPP solution	Coordinate Trajectory Solution
DCB / dDCB Network	<p>Identify, Evaluate and deliver imbalance to be managed (hotspot ...) and open the possibility to AUs to address it (UDPP delegation to AUs).</p> <p>Monitor the constraints, and update</p>	<p>Ensure UDPP functionality is available and functioning properly.</p> <p>Provide the UDPP environment to the</p>	<p>Ensure the what-if functionality is available and functioning properly (impact assessment).</p> <p>Ensure Published UDPP solution available and</p>	<p>Provide updated information to AU that describes the current delay and sequence for flights based on prioritisation information.</p>

Actor	Collaborative background process	Initiate the UDPP Process	Implement UDPP solution	Coordinate Trajectory Solution
	and publish information as necessary. Maintain the NOP and the AOP/NOP integration	AUs.	effective.	
Airspace User	Ensure eFPL information has been sent to the Network to manage traffic properly Evaluate options provided by DCB and dDCB and provide feedback on the most favourable course of action.	Ensure prioritisation information has been put in the eFPL if needed (FF-ICE field: <i>within fleet priority</i>)	Evaluate the constraint information and make UDPP prioritisation for flights in the constraint if needed.	Submit updated SBTs based on UDPP time calculated with prioritisation information.
Low Volume User in Constraint	Ensure necessary prioritisation information has been applied to the SBT to be included in DCB and dDCB option generation. Evaluate options provided by DCB and dDCB and provide feedback on the most favourable course of action.	Ensure necessary prioritisation information has been applied to the eFPL if needed (FF-ICE field: <i>within fleet priority</i>)	Evaluate the constraint information and make UDPP prioritisation for flights in the constraint if needed.	Submit updated SBTs based on UDPP time calculated with prioritisation information.
Airport	The Airport determines Airport capacity limitations and publishes the constraints characteristics and updates the plan through the AOP or through the Network representative. Assumes the role of Airport landside and airside and update the plan through the APOC-AOP.	Publish and maintain Airport constraints when needed. Allow AU to mitigate the delay impact with UDPP.	Evaluate and publish through AOP/NOP the impact of new time given by UDPP prioritisation. Through the Network	Update time information (Taxiing ...) when necessary. To be noted that taxi times can be overwritten by AU in eFPL

Actor	Collaborative background process	Initiate the UDPP Process	Implement UDPP solution	Coordinate Trajectory Solution
	Ensure good coordination with the Network specially with an appropriate AOP/NOP integration			

471 **Table 6: UDPP Actors Roles and Responsibilities for each Process**

472

473 **3.2.3 Technical Characteristics**

474 For use, a UDPP service (server) is required to handle the UDPP functions. It integrates all of the rules
 475 and functions needed to issue new times to flights according to the Priorities and Margins given by
 476 the AUs, in order to manage the constraint. This UDPP service is the interface between the AU, the
 477 Network, and the Airport. This service shall also protect AUs to exposure of confidential data that
 478 maybe used to produce these new times.

479 **3.2.4 Applicable standards and regulations**

480

Standard Name	Standard Description	Standard Enabler	Comment
Use Case (NOV-5)	UDPP Delegation in the SBT Elaboration process		

481

482 **3.3 Detailed Operating Method**483 **3.3.1 Previous Operating Method**

484 In the current operating environment, AU input and control is very limited. Planning and sequencing
 485 is performed on a First-Plan-First-Served basis (CASA), both under normal and abnormal conditions.
 486 The current operating method, planning, sequencing, and flow management are only using time-
 487 dimensional control to balance capacity and demand without airspace users interventions. Flow
 488 management is performed by means of regulations and slot-delay. A-CDM provides the AU with a
 489 possible dialogue with the airport.

490 Today, all actions on traffic and measures of the efficiency of the ATM organisation are done through
 491 the measurement of the delay, but nothing is done to decrease the impact of delay to AUs.

492 STAMs are based on eliminating overload, based on traffic overload and complexity. Many of STAMs
 493 are solved by Flight Level Capping in the current method, but equity is not managed, and the notion
 494 of flight value for the Airspace user is not taken into account. Nevertheless, in many cases, in light
 495 overloaded situations, targeting only flight creating the problem gives efficient solution instead of
 496 creating a blanket regulation.

497

498 Current ATM paradigm based on delay only.

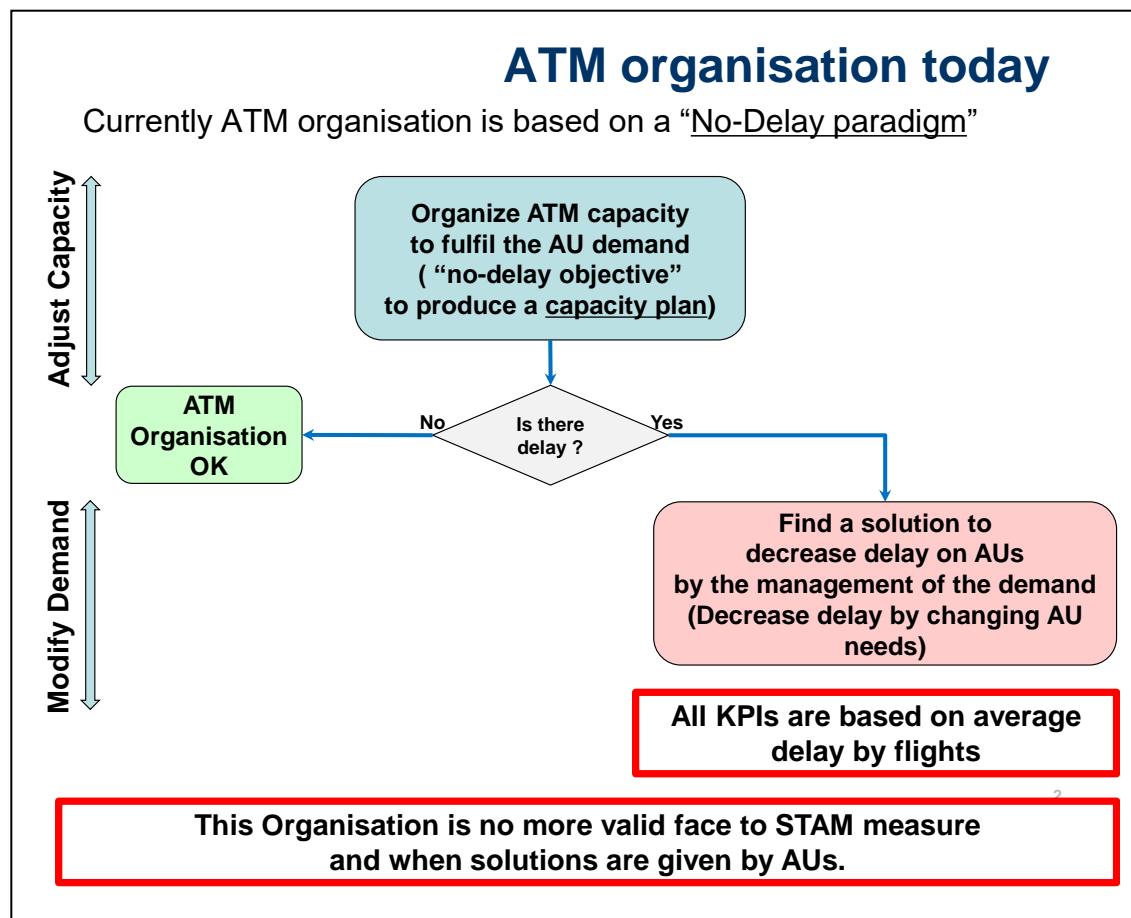
499 Today all of the actions put in place to solve capacity problems are based on reducing the flight delay over the network. This delay management concept is not taking into account the impact of the delay to the AUs. The current delay management does not take into account impact of each flight and the rotational impact therein, nor the costs associated to this line of flying, nor of the impacts to passenger experience.

500
501
502
503
504 The ATM paradigm is based on two organisational loops managed by the DCB network:

- 505
506
507
508
509
510
- The first one is based on the best organisation of the capacity resources faced by the original demand in terms of traffic: the capacity Loop.
 - The second one appears when there is residual overload to manage the traffic safely. In this case, a traffic solution based on eliminating overload is chosen. Traffic Regulations: generating delay on flights to smooth the traffic, STAMs: rerouting or delay some flights at shorter term..

511 Currently, no measurement is done on the impact of this delay on airlines or passengers.

512 Today if airlines give or update its flights to find a solution to mitigate the overload situation, no 513 specific measurement is done to quantify the cost of these actions.



514

515 **Figure 2: Current ATM organisation**

516

517 To be noted that the SESAR1 UDPP slot swapping is not part of this document because it is not touch
 518 by this new concept. Current deployed UDPP slot swapping is still available and can be used in
 519 addition to this new concept because it is used at the last moment on departure to swap flights and
 520 not in planning.

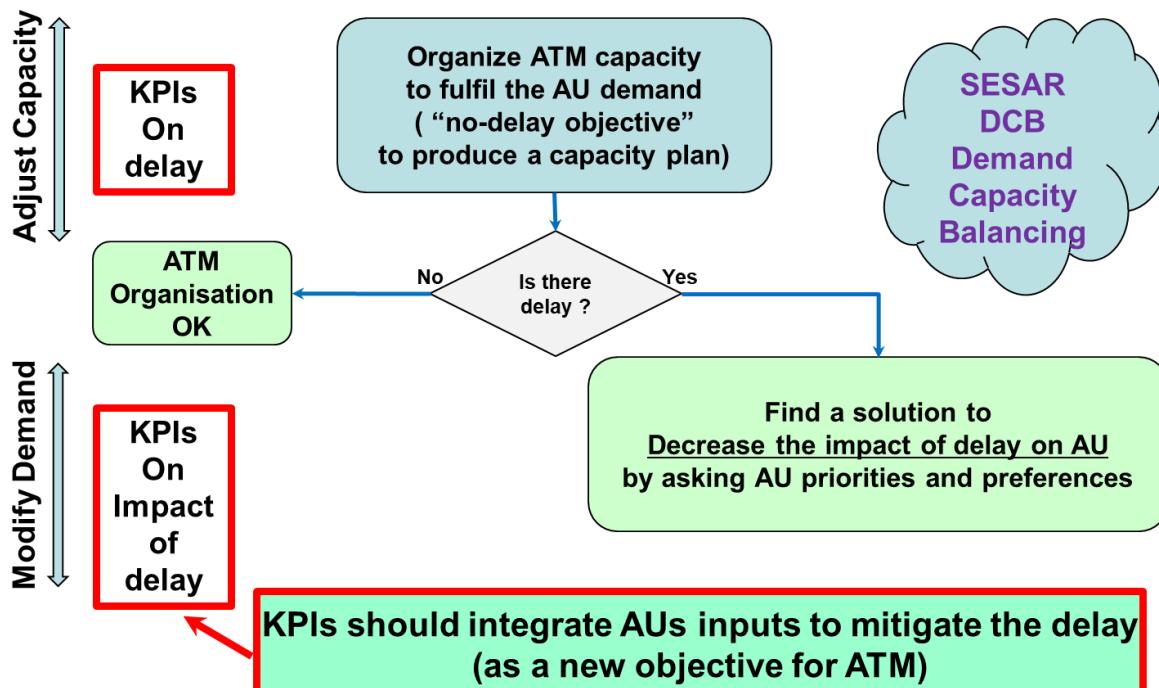
521 **3.3.2 New SESAR Operating Method**

522 The new method is based on asking AUs to provide how to decrease the impact of an overloaded
 523 capacity problem.

524 After DCB initially try to balance demand and available capacity, should there still be a delay, the
 525 objective is to ask the AU to mitigate the delay, in order to decrease the impact on their operations.

ATM paradigm evolution integrating AUs need

ATM organisation is based on **Impact delay management paradigm**



526

527 **Figure 3: ATM paradigm including AUs to solve problems**

528

529

530 **3.3.2.1 From Delay management to Cost Management and Improve Passenger Experience**

531 Only managing traffic through delay, including reactionary delay, overlooks that:

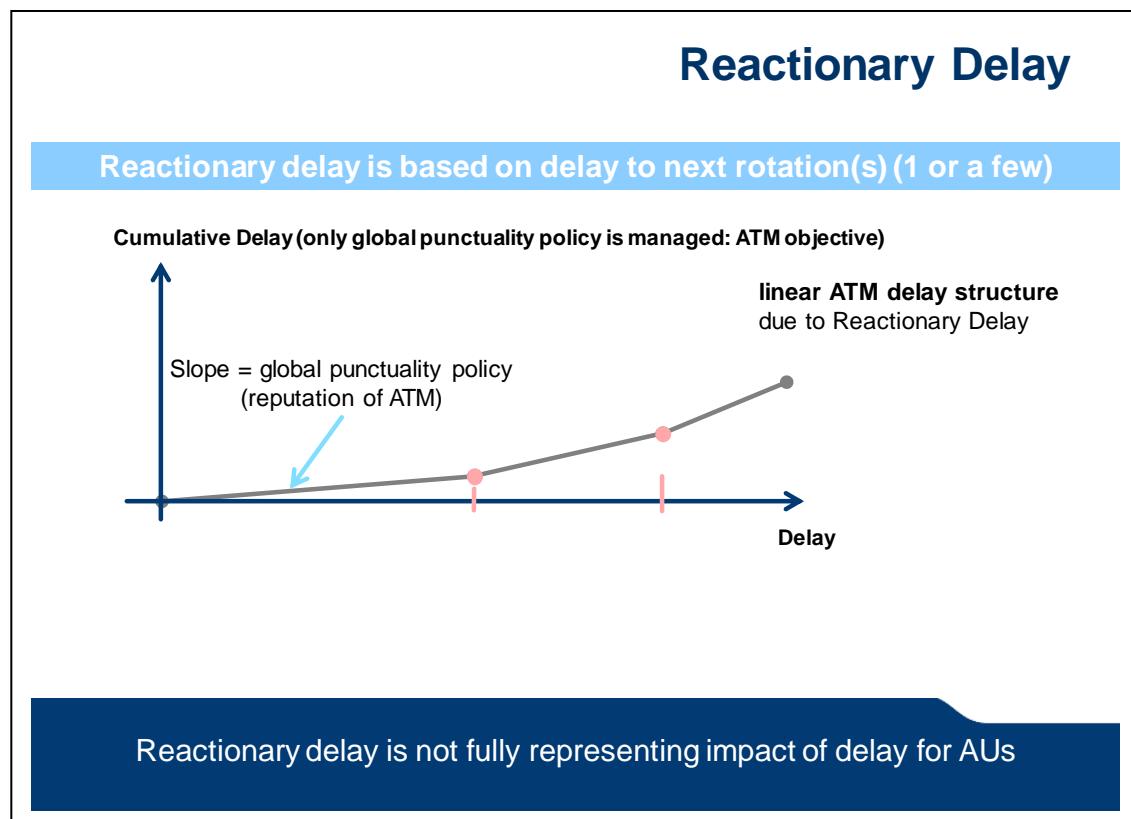
- 533 • The impact of delay is not the same depending on the number of passengers inside the aircraft
 534 and the type of flight;
 535 • There is a specific passenger flow (PAX Flow) including transit passengers that connect to other
 536 flights;
 537 • Curfew constraints (hard and PPR requirements), that are usually known in advance;
 538 • Operating crew have duty flight time limitation (FTL) constraints;
 539 • Planned maintenance requirements have significant operational impacts;
 540 • Commercial / reputational impacts that are unique to each airline's business model;
 541 • VIP on board (airline reputation possible issue),
 542 • Issue with cargo (for example live stocks on board),
 543 • Protection after diversion, medical emergency, religious reason....
 544 • Delay is not the only way to manage impact on AUs.

545 **3.3.2.1.1 Reactionary delay management**

546 Managing ATFM delay through Airport reactionary delay is an initial step to decrease the overall
 547 ATFM delay but it is still an action to decrease the delay itself. It does not necessarily fulfill the
 548 impact of delay especially on the AU's fleet. E.g. increasing delay on a flight, even if the next rotation
 549 is impacted, could have less impact than on a flight with no reactionary delay that has a significant
 550 impact given that passengers in transit may miss their next flight.

551 Even more, Airport reactionary delay approach can be counterproductive for an AU HUB operation,
 552 because fleet organisation / timetable is based on passenger flow as well as aircraft rotation.

553



554

555

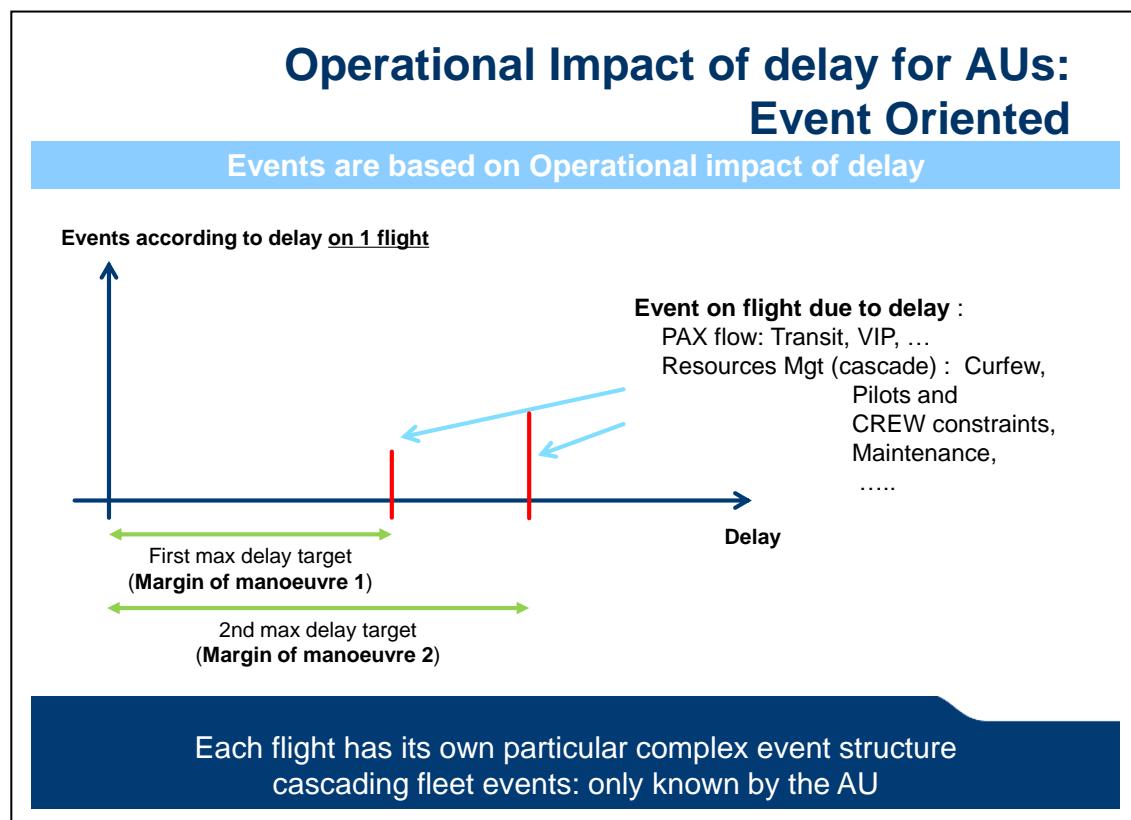
Figure 4: Reactionary delay in ATM

556 Reactionary delay does integrate many elements involved in the impact of delay on the AU's fleet,
 557 but only manages the delay on the next flight operated by the same aircraft.

558 **3.3.2.1.2 AU event oriented management**

559 The Operational cell in the AU are faced, every day for a large number of their flights, to solve the
 560 problem of managing delay in real time to avoid big impacts on their entire fleet. A solution for a
 561 flight is not taken only by managing the flight itself or the next rotation, but according to the full lines
 562 of flying, which can impact into the following day (s).

563 Major elements, taken as the driver of action, are based on losing a time window to operate flights.
 564 These time windows are based on events occurring if these windows are not respected.



565

Figure 5: Operational Impact of delay for AUs

566

568 **3.3.2.1.3 AU Cost management**

569 According to the different tools available on the different FOC of the different airlines, evaluating
 570 possible solutions face to delay could be a difficult task that experienced organizations can handle
 571 (experienced dispatchers ...). Comparing different options and scenarios to decrease the impact of
 572 delay is driven by the operational cost impact off the delay on the fleet (sometime integrating
 573 operational changes until D+2). Cost is the common denominator of the impact to evaluate different
 574 kind of solutions. The cost is not always easily quantifiable to allow comparisons or easy decision

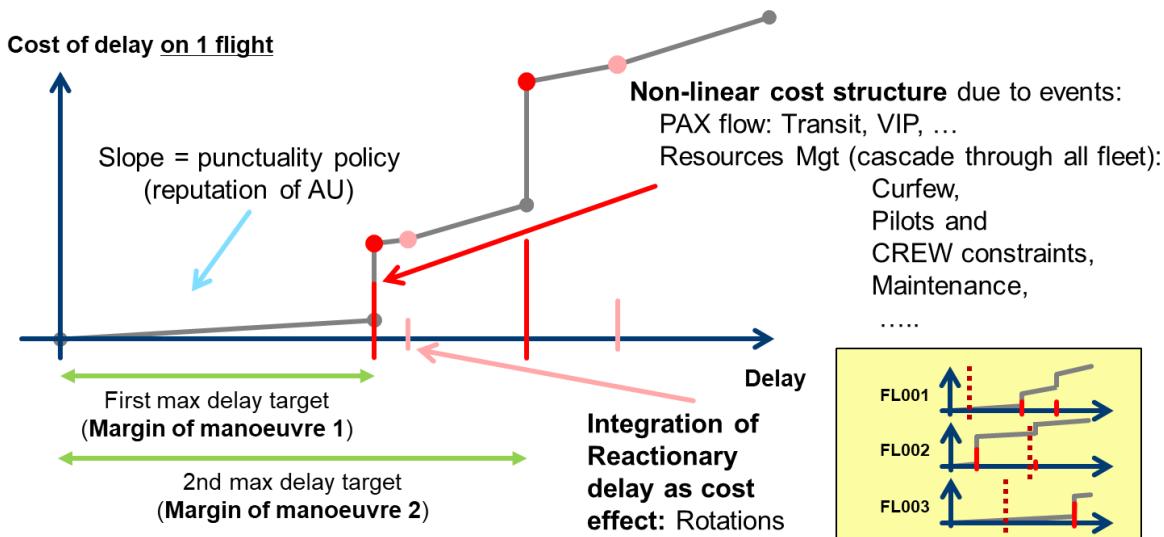
575 making when faced with complex situations and AU reputational value is not easy to judge. However,
 576 a cost approach is proposed integrating all the relevant elements to calculate a cost value for delay.

577 Operational cost of delay, including punctuality reputation, is one of the most efficient ways to
 578 compare solutions, but as it is not mandatory to use UDPP, a conventional approach is of course
 579 allows. Whilst no mandatory method is applied to UDPP, UDPP priority values are always used to give
 580 the best solution. No mandatory method to be applied to the UDPP prioritisation is foreseen because
 581 priority management is an internal airspace user business. However, UDPP priority values are always
 582 used to give the best solution according to the priority values given.

583 In some OCC, and according to FOC, we cannot speak directly about Cost management or operational
 584 cost. The dispatcher does not have this info, and only uses his operational knowledge and experience
 585 about his network and fleet. His main goal is just to reduce big delay on particular flights to avoid
 586 disruptive situation (curfew, crew time and maintenance are the main reasons). However, these
 587 impacts are de facto linked to the cost.

Operational Cost of delay for Airspace Users ?

AU: Impossible to Act on delay → Act on Operational Cost of the delay



Each flight has its own particular complex cost structure including fleet rotation impacts: usually only known by the AU

588

589

590

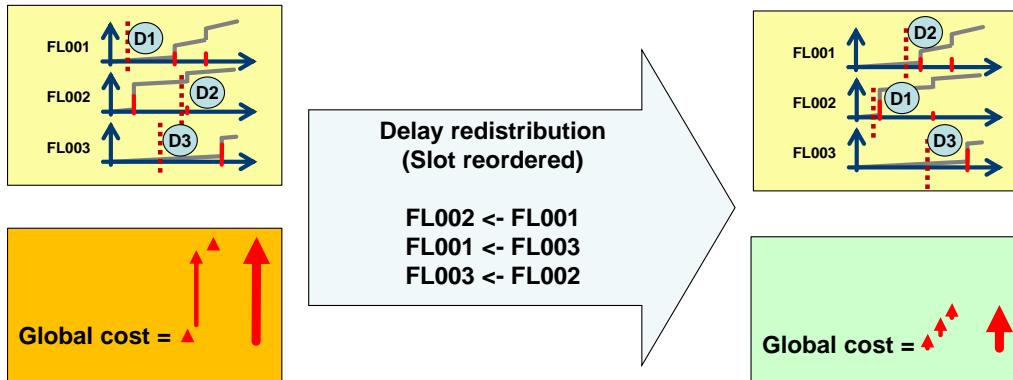
591 A very simple example is given above to illustrate that reordering flights can decrease the impact of
 592 delay.

593

Figure 6: Operational cost of delay for AUs

Operational Cost of delay for Airspace Users ?

AU: reorganize Flight according to Operational Cost of the Delay



Each flight has its own particular complex cost structure
only known by the AU

594

595

Figure 7: Operational Cost of delay reordered

596 Imbalanced situation is delegated to UDPP to be solved.

3.3.2.2 The UDPP delegation and UDPP measure

598 If an imbalance situation is detected by DCB and has to be solved, according to the overcapacity
599 characteristic and situation, a different kind of measure can be applied:

- 600 • A STAMs can be apply for small overloads, to reduce the impact on Network (few flights are
601 moving)
- 602 • An ATFCM Regulation can be applied for heavy overloads, involving all flights in the
603 regulation area. This type of measure could be solved also by a UDPP measure with less
604 impact on AUs.
- 605 • A UDPP measure: whatever the type of overload, it is delegated to the AUs to provide their
606 operational solution. This is achieved through the UDPP rules and processes.

607

608 The UDPP delegation is the term used in this document to trigger the use of UDPP in a specific area
609 of interest resulting in traffic crossing a Capacity Constrained Situation or a normal Capacity
610 situation, which has a demand that exceeds the available capacity. This UDPP delegation becomes an
611 active "UDPP measure" to manage the imbalance.

612 To mitigate the imbalanced situation, an Airport or NM/DCB action must be taken.

613 A hotspot declaration could issue a UDPP measure to solve an imbalanced situation.

614 Originally, the imbalance, or the hotspot, does not necessarily define all the impacted flights relative
 615 to the situation (because the effect of the imbalance is not known initially: e.g. no idea of the
 616 recovery period). When the UDPP measure is created, the different constraint declarations (CCS) are
 617 used to calculate all the impacted flights (all flights having delay) according to the Capacity
 618 constraints in a CASA like way (FPFS), and then, all the flights touched by the constraints are involved
 619 in the UDPP measure.

620 Nevertheless, a UDPP measure can be set to a larger time window than the calculated one generated
 621 by the impacted flights, or on a window with any CCS declared, to allow AU to reorganize flights if
 622 needed. It is up to the resource owner (e.g. Airport) to define this “UDPP measure” in collaboration
 623 with AUs.

624

625 3.3.2.3 The UDPP prioritization

626 The UDPP concept is based on minimising the impact of delay to AUs.

627 The main objective for an AU is to mitigate and reduce the impact of delay on their operational fleet
 628 until flights, or lines of flights are back on schedule (which may be D+2 or longer).

629 AUs expect UDPP prioritisation to be robust and efficient. The main element is to have a confidence
 630 of the result over the time until execution, with the minimum variability on it, to stabilize as soon as
 631 possible the arrival or departure time of the flights.

632 This implies that:

- 633 • the knowledge of the problem: the constraint, have a good degrees of stability
- 634 • The result of the UDPP prioritisation has a good stability over time.

635 From a generic approach view, UDPP could be seen as a tool to manage scarce resources, in the case
 636 of exceeding demand, by integrating AUs’ needs to the solution.

637 The UDPP function receives all of the priorities from all of the AUs involved in a declared capacity
 638 problem, and the UDPP function generates the AUs’ preferred sequence of flights for its fleet during
 639 this particular problem.

640 The objective of the prioritisation algorithm is to have a new reordered list of flight in the UDPP
 641 measure that best feed the AU expectation.

642 All AU will not necessarily use UDPP; therefore, those not using UDPP will receive baseline slots as
 643 defined in a CASA regulation.

644 Important statement:

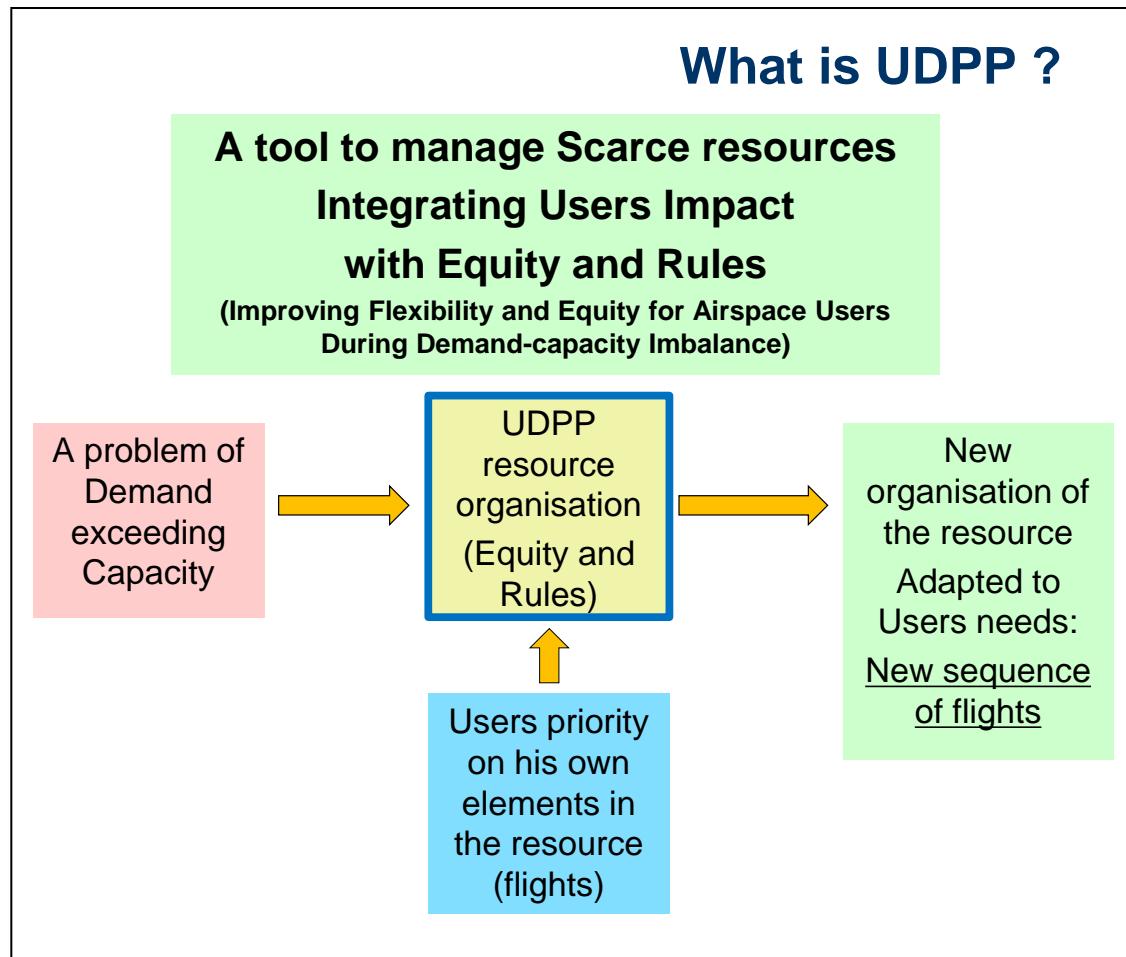
645 To facilitate UDPP, a number of techniques are used (FDR, SFP, Margins). The values given by the AU
 646 (priority values / margins) are strictly relative to the UDPP measure and specific to each AU. These
 647 priority values cannot be used outside this defined environment and represent nothing more than a
 648 way to reorder the flight in the constraints.

649 Concerning the UDPP Margins approach:

650 Currently UDPP Margins are defined only in the framework of UDPP, which guarantee the equity and
 651 the security of the associated AU data.

652 In future work (no defined in wave 1), Margins could have an important value to manage the ATM,
 653 but first, data protection, security issues and equity must be clearly studied.

654



655

656 **Figure 8: What is UDPP?**

657

658 **3.3.2.3.1 Introduction of the UDPP features.**

659 The UDPP feature can be used, by each AU that has more than one planned flight to enter into the
 660 congested period, when a UDDP measure is published.

661 The common aim of the UDDP algorithm is that, regardless of any actions performed by the AUs, the
 662 equity aspect is maintained.

663 The UDPP Prioritization must cover all the possible needs for an AU to rearrange the list of their
 664 flights. To enable broad usage of UDPP features, a number of parameters have been defined and are
 665 described in the following chapters.

666

667 UDPP features are originally based on the extension of the Slot Swap capability validated in SESAR1
 668 Step 1, which is currently under deployment.

669 UDPP concept is based on three features:

- 670 • **FDR**: a prioritisation feature only based on the generalisation of the slot swap extension
- 671 • **SFP**: a specific prioritisation feature to force flight times into a time window even if there is
 672 no AU slot available for it.
- 673 • **Margins**: a feature to manage time windows associated to each flight.

674 **3.3.2.3.2 Equity in UDPP**

675 The notion of equity is fully integrated in the UDPP concept. All AUs claim to have an equitable
 676 solution to the problem of delay.

677 Today the FPFS method is widely accepted by AU to be fair and equitable as it preserves the original
 678 sequence of flights. In ATFM operations it is accepted as it minimizes the total delay by using
 679 available resources at 100% of the declared capacity

680 Equity in UDPP is implemented in a way that one AU's prioritisation does not negatively affect
 681 another AU.

682 To ensure equity, each AU's total delay shall remain the same, if no flight is suspended (explained in
 683 3.3.2.3.3).

684 Equity in UDPP is managed and measured by two criteria:

- 685 • by comparing, the sum of the baseline delay obtained by the equitable algorithm (FPFS) on
 686 the AU flights (defined as an initial ATFM delay) with the result of the UDPP algorithm,
- 687 • and by the fact that whatever the time position in the sequence the cumulative delay of the
 688 solution is always equal or greater than the cumulative delay of the baseline delay for the AU
 689 (issue from the CASA like algorithm: FPFS). In other words, the AU cannot take a slot if it does
 690 not give one at or before the slot they want to take. This is especially important for SFP to
 691 manage Protected flights.

692 **3.3.2.3.3 UDPP FDR feature**

693 The FDR feature is based on enhanced slot swapping validated in SESAR 1.

694 According to the slot assigned to each flight of an AU, FDR gives the possibility for the AU to assign its
 695 own list of flights to each slot given by the FPFS slot list. In particular, the flight the AU is interested
 696 to decrease the impact of the delay on its fleet can be “swapped” with another flight from its fleet.
 697 For this, the AU can put a priority value on each flight to be reordered.

698 FDR priority values can be set to:

- 699 - A priority number from 1 (highest priority) to 999 (lowest priority) to give flights a
 700 relative ranking number (up to the AU to choose the range of priority to apply. This range
 701 can be decided according to the way and the AU internal tool used to manage the UDPP

702 measure. E.g.: this priority value could be a ranking value over all the AU flights within
 703 the UDPP measure).

- "L" Lowest priority flight of the AU: specifies the AU's lowest priority flight(s) whatever the value given to its other flights (could be seen as the 1000 priority value). The flight will take the last slot of the AU.
- "B" Baseline priority: specifies to keep the baseline delay of the flight as the current target delay.
- "S" to suspend a flight: specifies that the flight will no longer be in the middle of the UDPP measure, up to the AU to take a decision concerning this flight (cancellation, diversion, rerouting ...). It becomes the least important flights of the UDPP measure, and the flight will be allocated after the last not suspended flights of the UDPP measure.

713

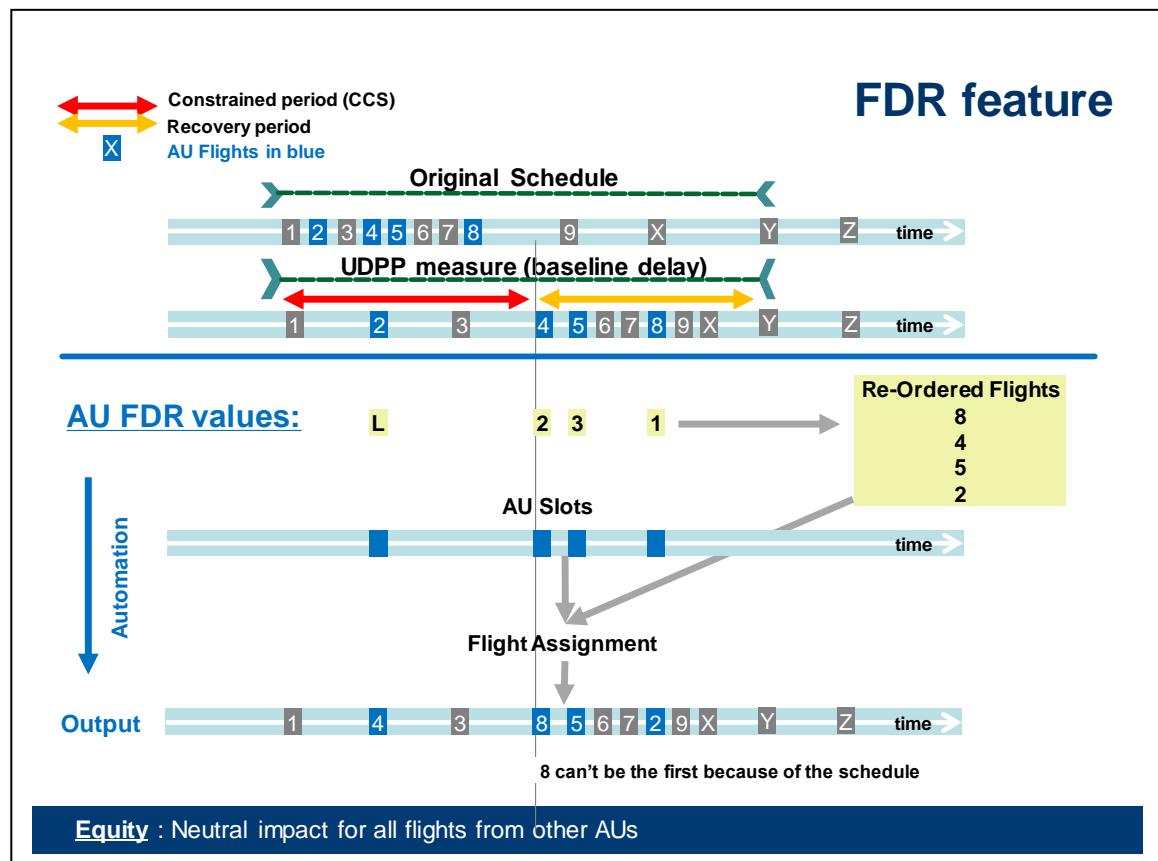
714 To avoid giving priorities to all the flights in the UDPP measure, the AU can set a default priority value
 715 to be taken if no priority is given to a flight.

716 Generally, two priority values can be considered to have default values:

- The "B" value is given as an default value if the AU wants to limit the number of changes of flights, in this case the reordering is apply only on flights with a priority value.
- The value 5 is given as a default value, if the AU has decided to use priority from 1 to 9 only (or 50 for using priority from 1 to 99). This default value allows flights with no priority to be part of the reordering as middle priority flight.
- Other values are allowed according to each AU's specific way of managing priorities on flights.

724 Note that if no suspended priority value is used ("S"), because FDR is based on slot swapping, there is
 725 no impact on other flights from other AUs and the sum of delay for each AU is the same without or
 726 with priority values.

727 The specific suspended priority value allows the AU to take advantage of this action to create a better situation for him, for its other flights. At the same time, because a suspended flight is allocated to an available slot after the last flight of the UDPP measure, it can be considered that the UDPP Measure is decreased and all of the AUs will benefit from this action.



731

732

Figure 9: example of FDR

733 **3.3.2.3.4 UDPP SFP feature**

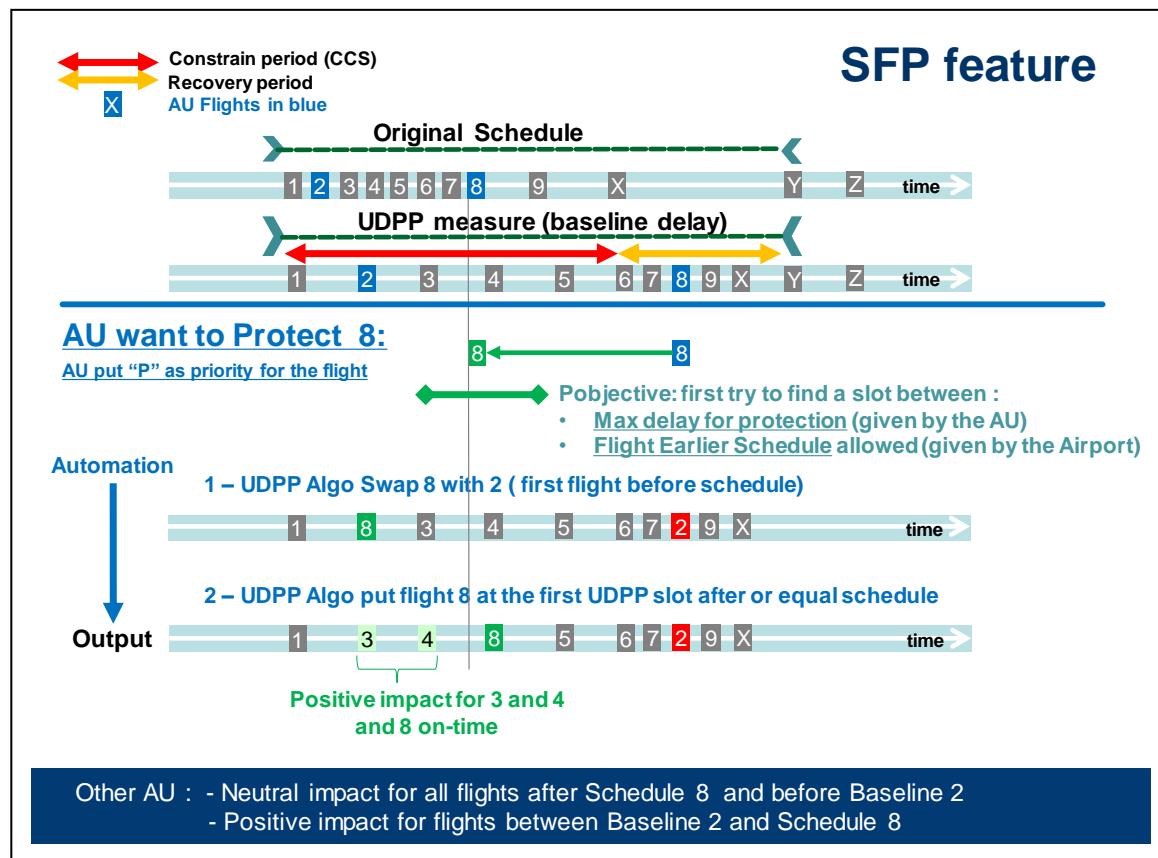
734 The SFP feature is the specific priority value "P" (for protect) to give to the AU the possibility to
 735 protect the schedule of a flight (Pflight) even if there is no direct current slot allocated to the AU.

736 To do so the AU must have, a minimum of one slot before the original schedule of the protected
 737 flight (within a window: called the Pobjective) to not affect other AUs negatively from its action.

738 If an AU places a P on a flight, the UDPP algorithm, first tried to find an AU slot within the Pobjective
 739 time window. If no slot is available at the Pobjective time window, the algorithm finds the first
 740 available slot earlier then the flight's schedule. When a slot is found, the AU's flight with this current
 741 slot is swapped to in the actual slot of the Pflight and the Pflight is allocated to its new slot closer to
 742 the original Schedule.

743 Note that:

- 744 • If a slot is available within the Pobjective, the solution is identical to a flight with a FDR value
 745 of 1 (or 0, ensuring that it's a higher than any 'priority 1 already assigned) .
- 746 • If no slot is available within the Pobjective, no negative impact is generated to the other AUs
 747 but positive impact may be experienced.



748

749

Figure 10: example of SFP

750 The Pobjective of a Pflight is given by two parameters:

- The MaxDelayProtection: this AU parameter gives the maximum delay acceptable for a Pflight according to its schedule time: (e.g. 5mn or 10mn). This parameter, defined by the AU, and applicable to all its Pflights, can be changed dynamically to adjust AU objectives on Pflights.
- The HotspotFlightEarlierSchedule: this airport parameter (common to all AUs) gives the maximum early departure or arrival delay buffer allowed by the airport to manage flights. (e.g. 5mn = 5minutes before schedule is allowed)

758 Note that, if margins are specified for a Pflight, Margins are taken in replacement of these two
759 Pobjective parameters (above) if they are compatible (see 3.3.2.3.5).

760 3.3.2.3.5 UDPP Margins feature

761 Margins on flights provide the AU with the possibility to express time constraints on certain flights
762 with time values, as per below. Currently, a specific algorithm has been developed named "Margin"
763 to allow the possibility of such feature.

764 Margins on flights can be given by two values:

- "Time not After": specifies a time by which the flight is requested not to be later than the value indicated.

- 767 • “Time not Before”: specifies a time by which the flight is requested not to be earlier than the
768 value indicated.

769 The objective of the algorithm is to rearrange flights automatically according to these time
770 constraints using the AU's own slots (similar to FDR, but not based on priority values, but based on
771 time values).

772 Within the 'Margin' algorithm, a priority value can be allocated on flights where the margin has been
773 set. This priority value can then be used in tandem with the time values indicated in Margins and is
774 used when not all the margin values can be met, in this case the highest priority Margin (Prio = 1) is
775 matched first etc.... Another way to see this priority value is to allow it according to the importance
776 of the cost or lack of resource generated by going over this margin.

777 For example a flight with a “Time not After” with a priority=1 will be managed first, and then, have its
778 ‘Time not After’ objective realized. Then a flight with a “Time not After” with priority=6 will be
779 managed after and its ‘Time not After’ objective will not be necessarily realized if the available AU
780 slot cannot give it.

781 Providing Margins is not mandatory on flights, if no Margin value is given on a flight, the flight is
782 managed as a FDR flights (using only the priority value or the default one if priority is also not given
783 for this flight).

784 **3.3.2.3.6 Margins on Protected flights**

785 The protection of a flight does not necessarily mean that the flight will be on time (even with a
786 Pobjective given by a small window representing the On-time Objective).

787 The AU can, if required, protect a flight within a time window by defining Margins.

788 If margins are defined for a specific Pflight, the Margins replace the time value of the Pobjective:

- 789 • If a “Time Not After” is given to a protected flight, this time replaces the upper Pobjective
790 time (normally set by Schedule + MaxDelayProtection).
- 791 • If a “Time Not Before” is given to a protected flight, this time replaces the lower Pobjective
792 time (normally set by Schedule – HotspotFlightEarlierSchedule).

793 Only one of the two Margins could be given.

794 The algorithm checks that:

- 795 • The Time Not After could not be earlier than the schedule.
- 796 • The Time Not Before could not be earlier than the Schedule - HotspotFlightEarlierSchedule.
- 797 • The Time Not After >= Time Not Before

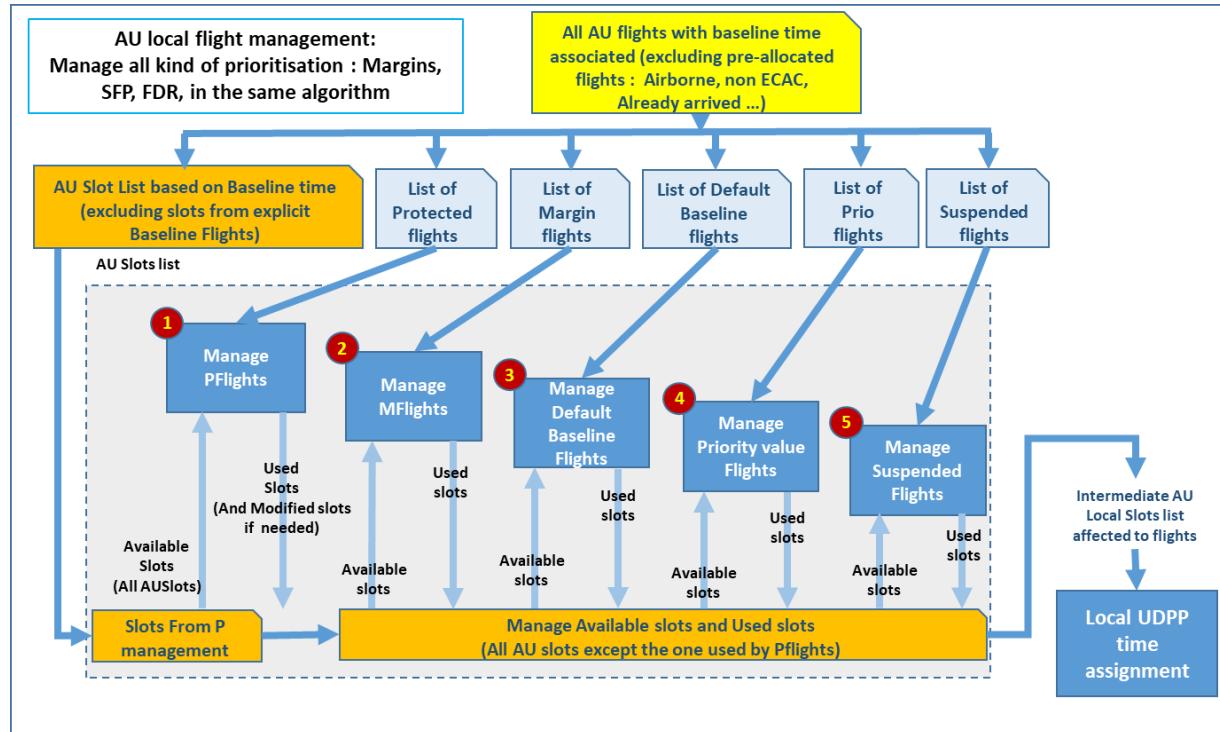
798

799 **3.3.2.3.7 FDR, SFP and Margin are mixed in the same priority value approach**

800 All the UDPP features are managed through a single algorithm, allowing the AU to use a mix of the
801 different possibilities to organize his fleet.

802 The algorithm manages the flights in the following order:

- 803 1. Manage Protected flights (flight with a "P" as priority value)
 804 2. Manage Margin flights (flight with a "time not after" value without a "P" as priority)
 805 3. Manage default Baseline flights (flight with No Margins values, no priority value, and
 806 when the defaults priority is "B")
 807 4. Manage flights with priority value (flights with a priority value 1 to 999 or "L" (= to 1000)
 808 with no Time not after)
 809 5. Manage Suspended flights (flights with a "S" as priority value)



810

811 Figure 11: Management organisation of the flights

812

813 3.3.2.3.8 AU inputs: different ways of thinking

814

815 AUs have a number of different options when mitigating the impact of delay on their fleet.

816 No specific features is mandatory, the objective is to allow AUs a large possibility to interact with the
 817 UDPP algorithm according to their own capability, configuration, model and tools.

818 Whilst the use of the different UDPP techniques / solutions is not mandatory, the objective is to
 819 allow AUs the possibility to interact with the UDPP algorithm through the use of these techniques in
 820 order to reduce the impact of delay.

821 Some example are defined here.

- 822 • Usage of default value: the default value is apply when no priority is given to a flight.

823 This default value can be set by AU to “B”: in this case, only flights with a priority value are
 824 part of the re-ordering. This way of setting priorities limits the number of changes for the AU
 825 flights, but also limits the number of possibilities to find a solution.

826 If the default value is set to a number (e.g. 5), all flights in the UDPP measure are rearranged
 827 and the delay is distributed over all the AU flights.

828 N.B.: “B” can be specifically set to a flight if the AU wants to exclude the flight from the
 829 reordering: keep Baseline as a solution.

830 • Usage of the “Protect” priority:

831 Generally, “P” is used for important flights to allow them to be “on time” even if no slot is
 832 available for the AU. This can cause extra overall delay by pushing lowest priority flights later
 833 in the sequence. To be noted that starting by using priority 1 for this flight could be helpful
 834 for rearranging the sequence without impacting the overall delay.

835 On the other hand, using 'P' with margins, could increase the possibility of finding a solution.

836 • Usage of Suspend “S” or Lowest “L” priority

837 “S” is foreseen to be used only when the impact of pushing a flight completely outside of the
 838 UDPP measure is beneficial to the AU.

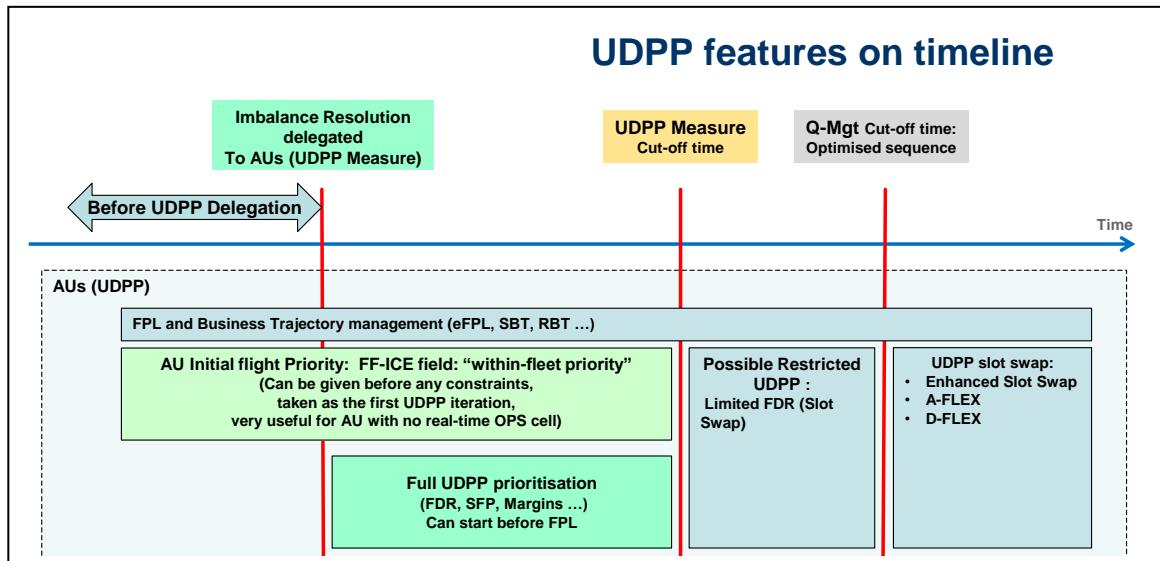
839 Otherwise, use “L” for lowest priority flights. The flights will be assigned in the last slot of the
 840 AU.

841

842 **3.3.2.3.9 UDPP features timeline**

843 UDPP can be considered a consolidation of different processes and features: FDR, SFP, Margins, but
 844 also Extended Slot Swap developed in SESAR1 Step1 environment.

845 The different features can be used depending on the magnitude, and type, of problem that the AU is
 846 trying to mitigate.



847

848

Figure 12: UDPP features on timeline

3.3.2.3.10 UDPP mapping on ATM

The objective of the paragraph is to show where, when and with which type of problem UDPP can be used and has a good benefit.

Tree major types of data are used to segregate the use of UDPP. Form each type, a number / value is used and can be defined as follow:

- The severity of the problem:
 - Large impact on AUs (large delay, large duration): Regulation, DCB big hotspot
 - Large to small impact on AU (delay and duration consistent): DCB hotspot
 - Small impact (low delay, rerouting, or optimisation needed): Optispot, STAM
 - No problem: but optimisation can be still needed
- The anticipation time to the problem:
 - Long term – before other optimisation
 - Start other optimisation – before execution (define the Cut-Off time)
 - During execution
- Where the problem occurs:
 - Airport Departure
 - Airport Arrival
 - En-route

867

868

869

870

871 The following table shows the value of UDPP:

UDPP features on timeline: UDPP Mapping

		UDPP solution Cut-off time			
Severity	Where	Long term planning: Before other optimisation	Medium term planning: Before other optimisations	Short term planning: With other optimisations	During execution
Large Impact: - Regulation, Large Hotspot	Apt Dep	UDPP	UDPP	X	X
	Apt Arr	UDPP	UDPP	X	UDPP(*)
	En-route	UDPP	UDPP	X	UDPP
Small Impact: - No regulation: Hotspot , Optispot , STAM	Apt Dep	APT (UDPP)	APT (UDPP)	APT	X
	Apt Arr	APT (UDPP)	APT (AIMA) (UDPP)	APT (AIMA) (UDPP)	APT (AIMA)
	En-route	X	Preferences & Prio	Preferences & Prio	Preferences & Prio
No Impact: - No delay but optimisation needed	Apt Dep	UDPP Always running	UDPP Always running	APT	X
	Apt Arr	UDPP Always running	UDPP Always running	APT	APT
	En-route	X	X	X	X

UDPP

UDPP defined and validated

UDPP

(*) In a UDPP measure, the flights already in execution are allocated first, according to their estimated time in the measure and not according to prioritization. And then, the available slots are allocated to the flights on ground using UDPP prioritization.

UDPP

UDPP can be used but not a lot of added value;
After consultation with ATM contributors, there are many other ways to solve en-route constraints (STAM, re-routing ...) and UDPP will not be used by DCB for solving en-route constraints.

UDPP

UDPP can be used but not defined

872

873

Table 7: UDPP features on timeline

874

3.3.2.4 Time parameters and timeline

3.3.2.4.1 Time reference and Arrival Schedule time

877 For the passenger, the arrival time (scheduled in-block time: SIBT) represents the 'contractual
 878 obligation' between themselves and the airline to arrive no later than this time. However today, the
 879 SIBT is not of real value at ATM level due to volatility in flight planning (route selection / wind
 880 component etc...) and there remains a mismatch between "airport runway slot allocation" and
 881 commercial need.

882 In many cases, the SIBT is overestimated and is based on performance of the city pair / flight number
 883 in previous seasons. This is not considered abuse, but the AU will base its schedule to deliver the
 884 passengers as per the 'contract'. This provides uncertainty at ATM level. Complexity is further added
 885 due to that, on occasion, some airport slots are oversold.

886 At level 3 coordinated airports, the SIBTs are checked for consistency against the airport slot.

887 When comparing scheduled arrival and departure times, it is observed that in many cases the
 888 minimum turnaround time (MTTT) cannot be respected. This is particularly relevant when flights on a
 889 given day are operating with extended block times.

890 Today nothing is done to check all of the validity of the arrival Schedule, and this schedule is not used
 891 to organize the ATM.

892 A good approach, allowing ATM operations that are more robust, will be to check the arrival
 893 schedule by the airport and the ATM in order to be in coherence with ATM actors.

894 **3.3.2.4.2 UDPP Cut-off time: UDPP measure close time**

895 The UDPP cut-off time is the time after which prioritisation values from the AU's can no longer be
 896 accepted.

897 Before this time, when an AU prioritizes its flights and submits them, the new sequence of flights is
 898 calculated and maintained, integrating the modification into the network.

899 The UDPP cut-off time is specified when the UDPP delegation is decided, which corresponds to the
 900 publication of the UDPP managed hotspot.

901 The time value is given by the owner of the resource (e.g.; Airport; probably under the APOC
 902 coordination) according to the uncertainty of the situation and the characteristics of the different
 903 components influencing the final sequence.

904 The components influencing the value of the cut-off time are linked to different optimisation tools
 905 used to manage the airport, these components are:

- 906 • Starting time of the runway optimisation;
- 907 • Arrival manager (AMAN);
- 908 • Departure Manager (DMAN), Pre-departure sequence;
- 909 • DCB Airport;
- 910 • ...

911 After a specific Workshop with Airspace Users, Airports and DCB experts, some elements have been
 912 clarified.

913 When a UDPP measure is applied on the airport of arrival, the allocation of CTOT from the departure
 914 airports means that there is no cut-off time required from the airport perspective (the CTOT provides

915 a natural 'stop'). From a DCB perspective, should there be a need for a DCB en-route action, a cut-off
 916 time must be defined to allow DCB to manage the measure effectively.

917 **3.3.2.4.3 UDPP Time for freezing flights input**

918 A UDPP measure can be published a long time in advance, using the AU schedules as the basis for the
 919 demand. However, if published too far in advance, the full demand may not be evident, as all flight
 920 plans may not yet be filed.

921 The UDPP time for freezing flights is defined and published at the same time as the notification for
 922 the UDDP measures.

923 The UDPP time for freezing flights is specified when the UDPP function stops integrating new flight
 924 plans in the UDPP measure. After this time, new flight plans would be set at the end of the calculated
 925 hotspot.

926 The time value for freezing flights is given by the owner of the resource (e.g.; Airport; probably under
 927 APOC coordination) according to the uncertainty of the traffic, the situation and the characteristic of
 928 the different components influencing the final sequence, as defined for UDPP cut-off time.

929 UDPP extended Slot Swap (ESS) is a particular case that could be allowed without any freezing time
 930 because it's not used in the same way that FDR and SFP and Margin.

931 **3.3.2.4.4 UDPP max anticipation schedule delay**

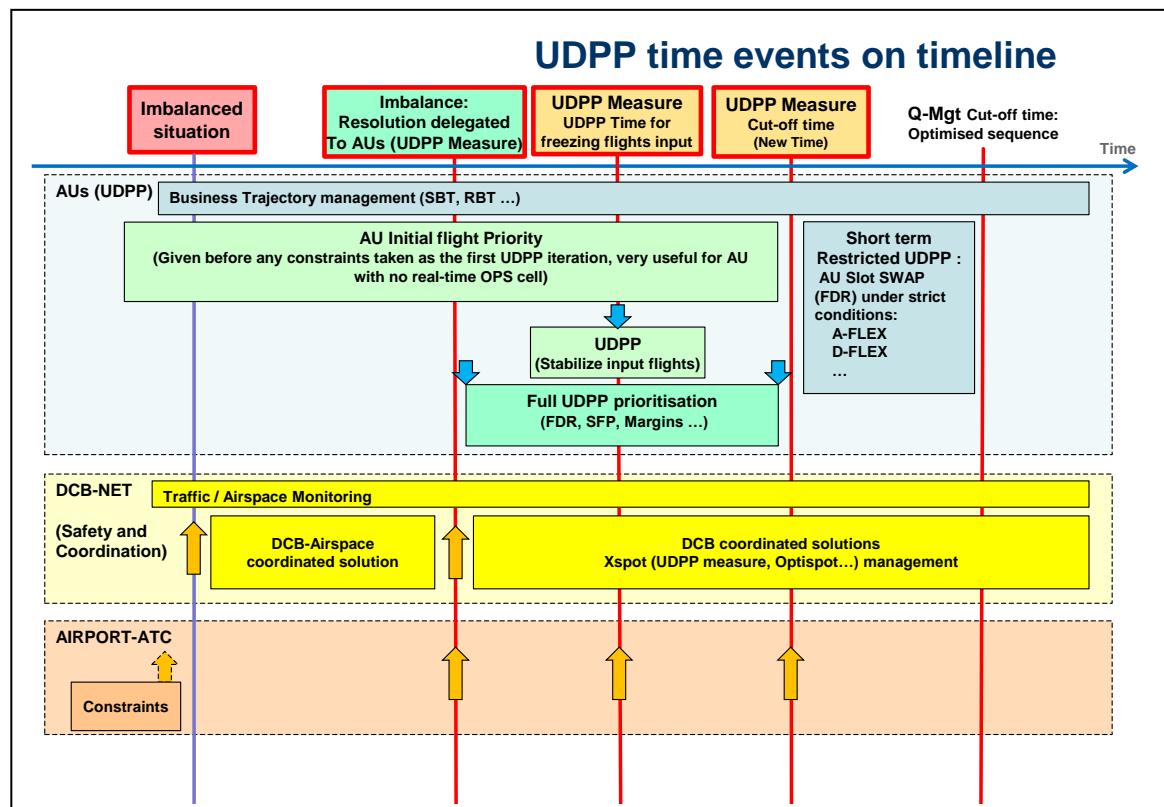
932 This value gives the maximum anticipated delay for each reference flight time (e.g. 10mn) that the
 933 UDPP feature is able to give to a flight to rearrange the sequence.

934 During a UDPP measure, this value gives the possibility to the AU to arrive earlier according to the
 935 flight reference time (schedule) and the prioritisation, in a manageable way.

936 This value gives room for optimisation of resource (e.g. runway throughput).

937 This value is decided and published by airport, in coordination with the AUs.

938 **3.3.2.4.5 Summary of UDPP Time events on timeline**



939

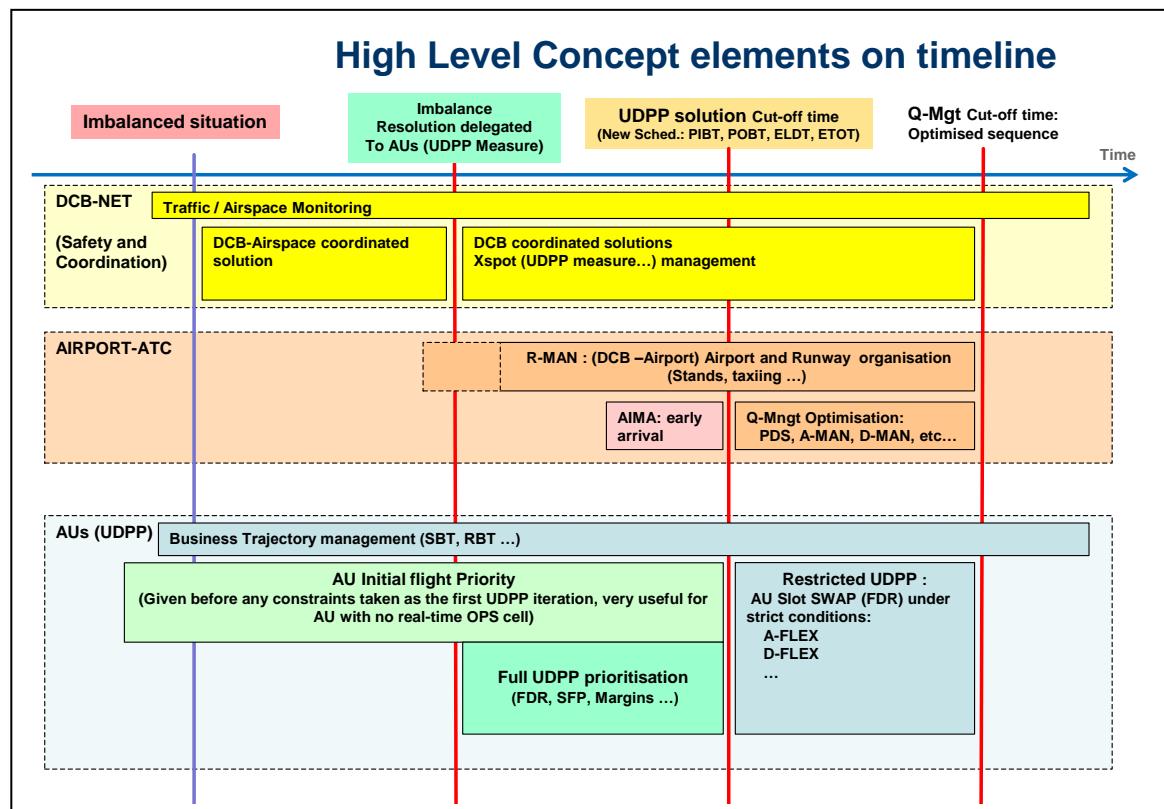
940

Figure 13: UDPP Time Events on timeline

941

3.3.2.4.6 UDPP over ATM actors timeline

943



944

Figure 14: High-level concept elements on timeline

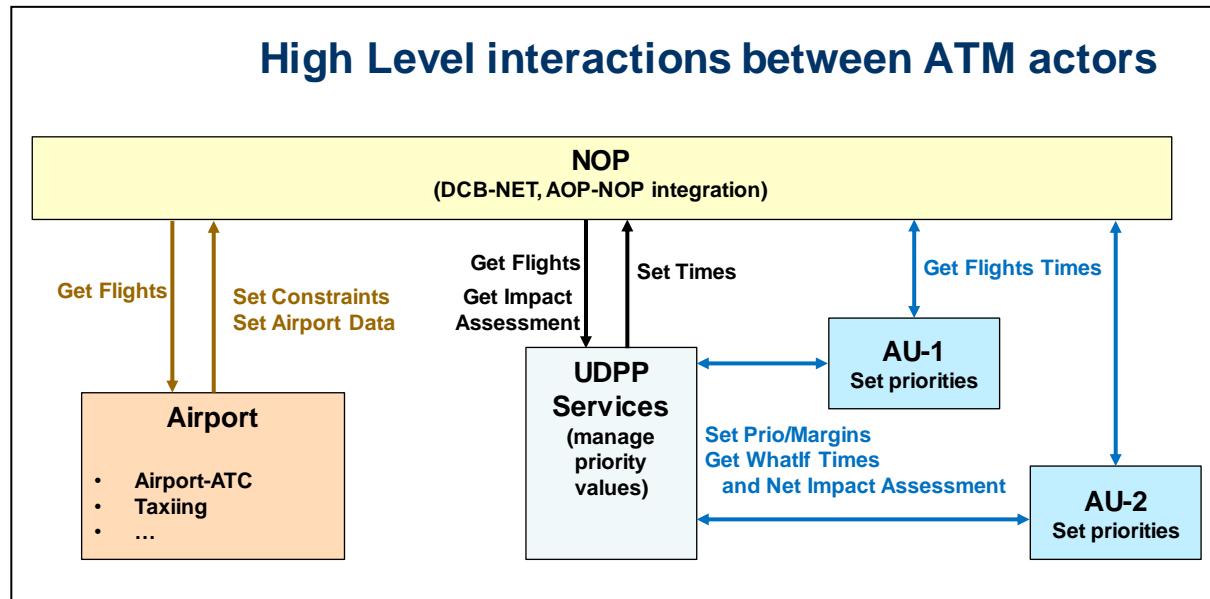
945

947 3.3.2.5 Concept view of interactions between ATM actors

948 This graph represents a simple concept view of the interactions between ATM actors in the
949 framework of UDPP.

950 It should be noted that impact assessment given to AUs when prioritizing flights through the UDPP
951 service, is supported by the DCB actor (linked to the Net status) integrating AOP data through the
952 AOP/NOP integration capability. The AOP/NOP integration is under the responsibility of the DCB
953 actor.

954



955

Figure 15: Concept view of interactions between ATM actors

957

958 3.3.2.6 Time management: UDPP priorities, AU Preferences and DCB STAMs

959 Today, to solve a capacity problem, the majority of the features defined, and other features currently
 960 under deployment, are based on time management without integrating the AU needs.

961 These time solutions are based on:

- 962 • CTOT to manage the take off time, and/or
 963 • TTA, to manage the arrival time.

964 DCB STAM functionality availability: Today if a TTA or/and CTOT is already defined on a flight, it
 965 indicates that, due to a constraint, the flight has already been treated as such to manage the DCB
 966 constraint. In this case, the FMP must try to avoid using this flight for STAM actions, which generate a
 967 double penalization for this flight (delay + Level-Cap for example). Nevertheless, if this flight is
 968 absolutely needed for solving the problem, the FMP must try to avoid changing the flight arrival time,
 969 to 'not disturb' an already managed organisation. In this case, a light STAM level cap is possible to
 970 apply.

971 If User Preferences are allowed to manage STAM, the same constraint is preferred when time
 972 constraint is applied on arrival (not changing arrival time) but User Preferences can be used if
 973 compatible.

974 UDPP prioritisation is a Measure to manage a specific constraint. This measure involves the AU giving
 975 their preferred solution, which is less impacting than the standard FPFS delay.

976 Today UDPP priorities are not visible outside the UDPP server and are specific to the problem and
 977 relative to the AU flights only (relative priority). These priority values will not be accessible until they
 978 are outside of the UDPP server, and until a clear view on the equity principle related to the use of the
 979 value is clearly defined.

980 **3.3.2.7 UDPP investigation: Absolut priority (E-OCVM V1)**

981 Absolute priority (A-PRIORI) is a VO concept that complements the Enhanced DCB framework defined
 982 in PJ09S03 OSED. During Wave1, no clear solution has been identified for having and indicators (A-
 983 PRIORI) to compare flights between different AUs to support DCB identifying candidate flights for
 984 short-term ATFM measures (STAM).

985 After investigations, the A-PRIORI concept has been stopped, showing that extracting elements from
 986 the current available data could not give relevant element to set an Absolut priority value.

987 A-PRIORI concept has been investigated by PJ07S01 as a continuity of the User Preference mechanism
 988 and finally has been called "Priority Flight". This "Priority Flight" information is given by AUs as extra
 989 input when needed.

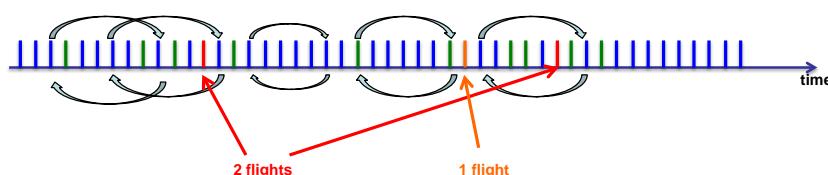
990 **3.3.2.8 UDPP investigation: Low Volume Users in Constraint (E-OCVM V1)**

991 This particular concept is in maturity level1 and has to be further developed in order to become a
 992 reality'. It will not be part of the human in the loop validation exercises in wave 1.

993 AUs should be able to use UDPP even if there are very few flights in the constraint. However, some
 994 AUs would want to participate but have limited flexibility due to the low volume of their operations
 995 (the so-called LVUCs, i.e., Low Volume Users in Constraint). See Figure 16 to find an illustration of the
 996 problem of access for LVUCs and the need to develop a new UDPP feature to give flexibility for
 997 adapting their operations to the changing operational environment, thus increasing the
 998 opportunities for LVUCs to mitigate disruptions and minimise their costs in the event of congestion
 999 problems that trigger UDPP measures.

1000 It is key from the point of view of 'access and equity', to find a new feature that allows the LVUCs to
 1001 participate in the UDPP mechanism. To be accepted, such feature must show evidence, under the
 1002 consideration of realistic operational scenarios, that the equity is preserved in the long term, i.e., no
 1003 significant impact is caused on other AUs at the end of the reference period, e.g., 1 year.

- How to give **flexibility** to Low Volume Users in Constraint (**LVUCs**), i.e., AUs with a few flights (e.g., 3 or less), while preserving **equity** for the rest of the AUs?



1004

1005 **Figure 16: Illustration of the need to give access and flexibility to LVUCs**

1006

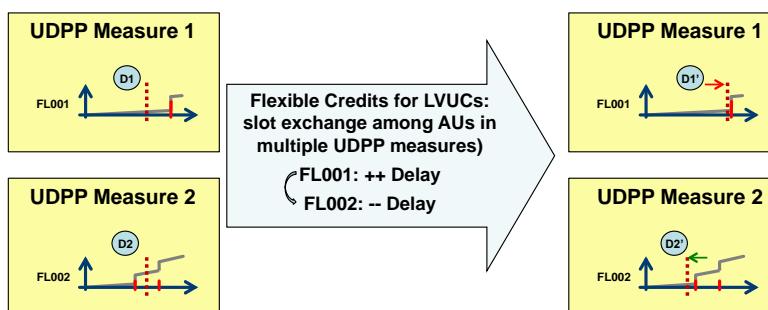
1007 The **Flexible Credits for LVUCs (FCL)** is a new UDPP feature built upon the existing collaborative
 1008 decision-making mechanisms that would allow the LVUCs to participate in the re-allocation of slots. It
 1009 aims to provide enhanced flexibility to the AUs for re-distributing delays among their flights with
 1010 **Delay Credits (DCs)**, a virtual currency without monetary value. The most relevant characteristic of
 1011 the FCL mechanism is that LVUCs can accumulate credits in a particular UDPP measure by accepting
 1012 extra delay in some flights, and such credits can be used in other UDPP measures (occurring in

1013 different time), compensating the LVUCs for their current and previous efforts that benefit other
 1014 AUs. LVUCs can decide at any moment if credits are fully or partially transferred from one UDPP
 1015 measure to another, or alternatively they are used in the same UDPP measure (in the cases in which
 1016 the LVUC has more than one flight in a UDPP measure). Business aviation operators usually have few
 1017 flights involved in a given UDPP measure, so they will benefit greatly from the introduction of this
 1018 new mechanism.

1019 It is expected that LVUCs will accept more delay in those flights with delay allocated far from their
 1020 operational margins (i.e., relatively low cost of delay in the current situation), thus giving the margins
 1021 on behalf of other AUs, in exchange of credits. These credits will be used in future UDPP measures to
 1022 reduce their overall costs when one or more of theirs flights are impacted severely by delay.

1023 For example, consider the illustration case in Figure 17 in which a LVUC only has one flight (FL001) in
 1024 UDPP measure 1 and one flight (FL002) in UDPP measure 2. In either of the two cases the LVUC
 1025 cannot improve his situation (i.e., reduce the cost impact of delay) even if access is given to him to
 1026 the current Enhanced Slot Swapping, FDR or SFP features. However, with FCL the AU could have an
 1027 access to UDPP and could substantially improve his situation. Note that in this example the flight
 1028 FL001 has a certain amount of delay (D_1) that could be increased, due to the operational margins
 1029 available, with relatively low impact in terms of cost. Accepting the extra delay D'_1 ($D'_1 > D_1$) the AU
 1030 is giving his position and reducing the delay (positive impact) to other AUs between the original and
 1031 the new sequence position. The AU can then be rewarded for this, with an amount of delay credits
 1032 proportional to extra delay accepted (in this document 1 DC = 1 minute of delay). In UDPP Measure 2
 1033 the LVUC could use the credits available from UDPP Measure 1, because in this example the flight
 1034 FL002 has an amount of delay D_2 that has an important impact in terms of costs for the LVUC. After
 1035 using part or full of the credits available, the AU can reduce the delay for that flight from D_2 to D'_2
 1036 ($D'_2 < D_2$), which is an amount of delay within the operational margins available for that flight, and
 1037 therefore with marginal cost of delay. The AUs in between the baseline and the new position are
 1038 impacted negatively, but with just one position in the sequence. Typically, it means 3 minutes or less
 1039 of extra delay, which can be considered as a negligible impact if the total allocated delay to a flight is
 1040 within its operational margins (see in Appendix B the simulations results and other evidence that
 1041 supports such sentence).

Advanced UDPP features are needed to give access to LVUCs



1042
 1043 **Figure 17: Illustration of an LVUC exchanging delay and credits between two UDPP Measures**
 1044

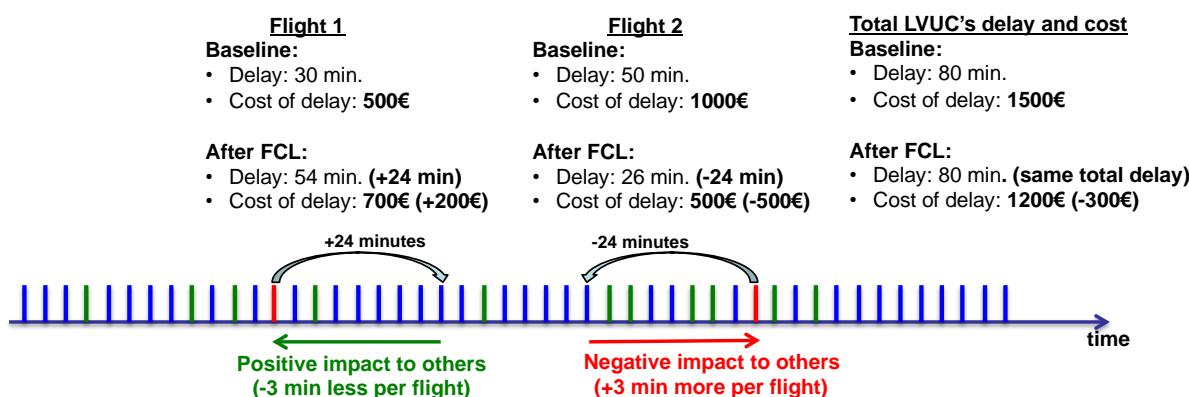
1045 It is expected that the impact on these flights will be always negligible (LVUCs requests will be cross-
 1046 checked against the operational margins of impacted AUs before accepting them), and that the extra
 1047 costs for other AUs will be compensated in the long-term by the positive impacts received when

1048 LVUCs are giving their positions and by having access to the rest of UDPP features (e.g., FDR/SFP) to
 1049 which LVUCs cannot have real access. The final goal of including LVUCs is to ensure a higher level of
 1050 equity by increasing the access to all the operators irrespective to their volume of operations.

1051 In addition, the consideration of an AU as a LVUC may change in different UDPP measures according
 1052 to the circumstances; therefore, even large airlines can be often¹ considered as LVUCs in many UDPP
 1053 measures (typically in UDPP Measures triggered at airports in which they only operate a few flights).
 1054 The access to FCL and LVUC rules to any AU –in those UDPP Measures in which the AU can be
 1055 considered as LVUC– can increase even further the acceptability of some circumstantial degree of
 1056 inequity in favour of the LVUCs in individual UDPP Measures.

1057 Another example is illustrated in Figure 18. The sequence in the example is dominated in number of
 1058 flight and slots by two AUs (non-LVUCs). These AUs are represented in the figure by sticks coloured in
 1059 green and blue, whereas an LVUC has been represented with two flights identified in the sequence
 1060 with orange colour. The example illustrates how the LVUC can reduce in this specific scenario the
 1061 total impact of delay (costs) by increasing +24 minutes the delay of flight 1 to obtain 24 delay credits
 1062 and reducing the delay of flight 2 by giving the 24 credits gotten previously. In this example, a 20% of
 1063 cost reduction could be achieved, due to the non-linear relationship between the fleet cost structure
 1064 and delay. The impact to other flights is considered negligible (3 minutes of extra delay per flight, if
 1065 impacted).

1066



1067

1068 **Figure 18: Illustration of an LVUC exchanging delay and credits in the same UDPP Measure**

1069

1070 Note that, in addition to FCL, LVUCs could sometimes have access to FDR/SFP features by grouping
 1071 together in a voluntarily basis and operating as a single operator through a virtual flight operation
 1072 centre (V-FOC). Such approach would respect equity out of the V-FOC (i.e., LVUCs could exchange
 1073 their own slots without generating impact to others), but two major questions should be addressed
 1074 in future research to guarantee that the access to LVUCs through V-FOCs is effective in practice: a)

¹ See in Appendix B the statistical evidence that supports such sentence.

1075 how often a set of LVUCs would be willing or will be able² to make a group to form a V-FOC; b)
 1076 whether such mechanism is flexible enough, e.g., if all the LVUCs in a V-FOC want to reduce their
 1077 delay; and c) how the equity can be preserved within the VFOC over the time. Such last question is an
 1078 internal private aspect of the AUs grouping in a V-FOC, but if a pragmatic way of coordination for AUs
 1079 in a V-FOC is not foreseen, the concept of V-FOC could not work in practice and thus the actual
 1080 access supposedly given to LVUCs would be not effective.

1081 In conclusion:

- 1082 1. **FCL could be recommended as a mechanism to give access for LVUCs to UDPP.** FCL can
 1083 provide high flexibility to LVUCs and according to the evidence (see Appendix B), the equity
 1084 could be controlled by fine-tuning the set of rules that limit the number of flights in a UDPP
 1085 measure and the maximum negative impact on time allowed per flight (MNIT).
- 1086 2. **FCL is compatible and can co-exist with the FDR and SFP features** (in which LVUCs have little
 1087 flexibility). LVUCs could be constrained if the impact generated by their actions in FCL could
 1088 have a large impact on other AUs, e.g., if the operational time constraints of other AUs flights
 1089 cannot be fulfilled as a consequence of a FCL prioritisation. FCL could also coexist with other
 1090 ways to give access to LVUCs, such as the concept of V-FOCs.
- 1091 3. **All the AUs could have access to FCL when they can be considered LVUCs at any particular
 1092 UDPP measure**, which occurs quite often daily and therefore it could have a large positive
 1093 impact on the flexibility and cost-efficiency of all the AUs. Special rules may apply for AUs
 1094 that always are LVUCs (e.g., business aviation).
- 1095 4. **FCL may generate little and controlled inequities momentarily** in form of negligible
 1096 impact/extraneous delay received in some flights, which is justified by the need to give access to
 1097 LVUCs to UDPP. Non-LVUCs in a UDPP Measure should have **benefits from participating in
 1098 FDR and SFP that are expected to be larger** than the negligible impacts potentially
 1099 occasioned circumstantially to them by the LVUCs that use FCL. In addition, **increasing the
 1100 flexibility of LVUCs in turn will benefit to all the AUs**, since all the AUs may be LVUCs in
 1101 some UDPP Measures.
- 1102 5. **Further research is needed** (current concept is in V1) to fully understand how to adapt the
 1103 system to have a good balance between the benefits received by the AUs when they have
 1104 access to UDPP and the efforts and negative impacts that are necessarily tolerable to
 1105 guarantee the equity and to increase the flexibility for all the participants.

1106

1107 3.3.2.9 Use Cases

1108 UDPP is described through a single Use case, integrated in the DCB processes.

1109 DCB processes are based on Use cases defined in the DCB OSED (see PJ09.03 OSED
 1110 document, and will not be described in this document).

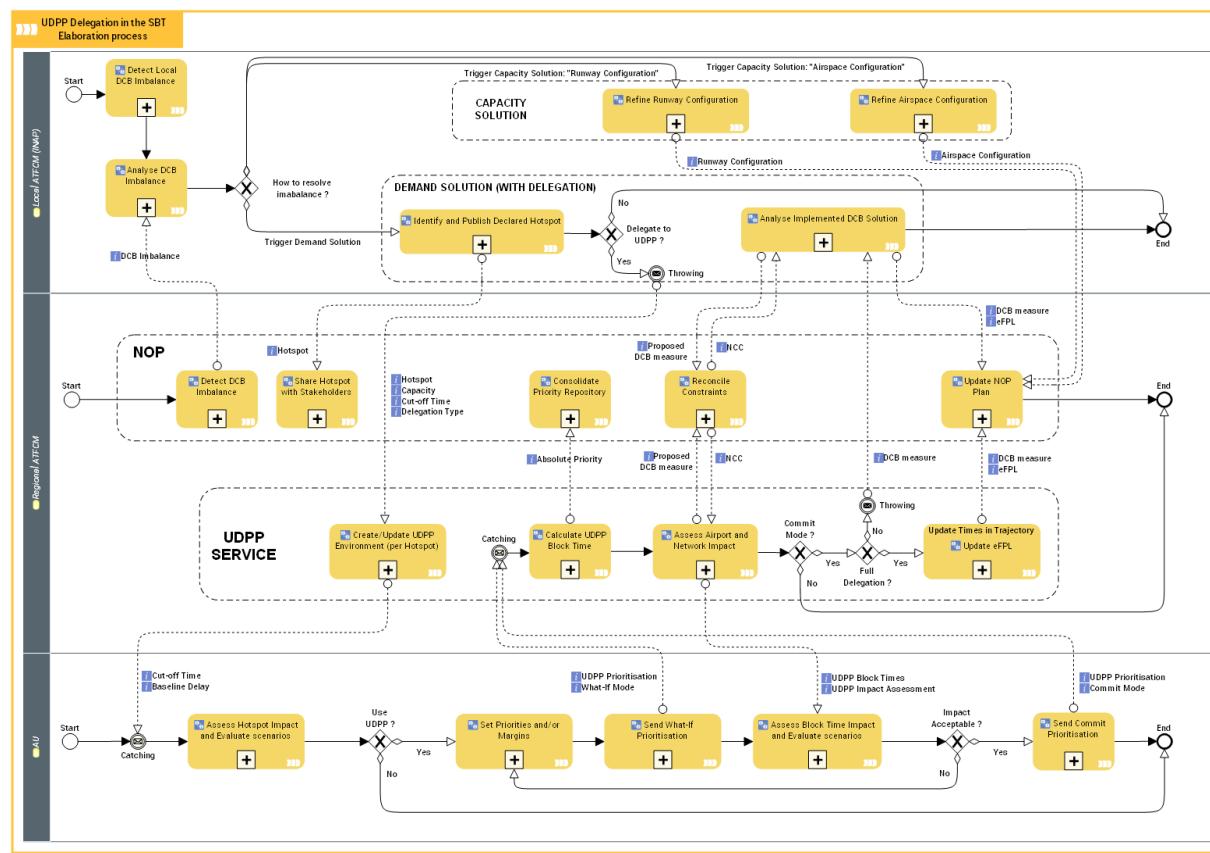
² Note that the Access via V-FOC would be not always possible, e.g., if there is only 1 LVUC in the UDPP Measure

1111 PJ09.03 OSED reference: Chap 3.5.2.9.1 the Collaborative process, specifically the Chap
 1112 3.5.2.9.1.[2 and 3] dealing with the description of the DCB Collaborative Workflow for
 1113 Hotspot Arrival Management using TTA prepared in the SBT Elaboration process with APOC
 1114 [full and limited] delegation.

1115 The description of the relationship between Regional ATFCM and Local ATFCM is also
 1116 defined in the DCB OSED Chap 3.5.2.9.1: The Collaborative process. It is synthetized here
 1117 from the UDPP point of view, to understand the global context and the UDPP integration and
 1118 behaviour.

1119 Only relations with UDPP services and AU are described.

1120



1121

Figure 19: Use case 1 - UDPP delegation in the SBT elaboration process

1122 The Integration of the UDPP process is based on SESAR2020 PJ09.3 (DCB) definition on
 1123 process interactions. The different type of delegation and modus operandi between local
 1124 and regional ATFCM is defined in the PJ09.3 OSED as basis of coordination between the ATM
 1125 Actors in the S2020 vision. For more details, see PJ09.3 OSED: Chap 3.5.2.9.1 The
 1126 Collaborative Framework Process.

1127
 1128 In this Use case definition, all the part above the UDPP SERVICE container is part of PJ04.2 or
 1129 PJ09.3 definition. There have been defined here to make and understand the links between

1130 the 3 entities. These parts have to be defined in PJ04.2 or PJ09.2 and managed as
 1131 assumptions in PJ07.2 (UDPP).

1132 The Integration of the UDPP process is based on the following high-level steps:

- 1133 • Detection of imbalance (DCB)
- 1134 • DCB create a UDPP measure (DCB with Local ATFCM: part of Airport): delegation is
 1135 given to the UDPP service to manage the imbalance
- 1136 • The UDPP service manages the UDPP measure, and allows what-if and publishes
 1137 according to AUs prioritizations and kind of delegation.
- 1138 • The AU is alerted by the Network if a UDPP measure concern them
- 1139 • AU prioritises their flights to decrease the impact of the delay according to their
 1140 business model and operations (AU).
- 1141 • The UDPP service manages the new sequence and issues times according to the
 1142 prioritisations made by the AU. It returns the Network impact to the AUs based on
 1143 this new sequence. This impact assessment is based upon the implementation of the
 1144 data exchanges foreseen between PJ09.03 and PJ04.02. If no impact is observed at
 1145 Airport level, then only the Network impact is considered and passed back to the AU
 1146 during the prioritisation process.
- 1147 • The UDPP service publishes a new sequence and times organisation to the Network
 1148 according to the type of delegation (full delegation, partial delegation).

1149

1150 Description of UDPP nodes:

1151 The DCB service (Network: no need to make the distinction between local and regional
 1152 ATFCM: it is a DCB internal organisation):

- 1153 • DCB (or the responsible body to delegate) allows the delegation to AUs of an
 1154 imbalance problem and set a UDPP measure with the delegation characteristics: Cut-
 1155 off times, delegation type ...)
- 1156 • DCB integrates UDPP solution according to the delegation type.

1157 The UDPP service:

- 1158 • The UDPP service is instantiated when a UDPP measure is created. Once created, the
 1159 characteristic of the measure is given: the different cut-off times, the problem to
 1160 solve, and delegation type. The UDPP service obtains all required data from the
 1161 Network to manage the UDPP measure (capacity constraints, impacted flights) and
 1162 create a new sequence (CASA like) to evaluate the impact and publishes delay.

- 1163 • If flights have already priority values through extended flight plans (FF-ICE field:
1164 within fleet priority), UDPP services considers them and publishes the new sequence
1165 to the network accordingly.
- 1166 • AU asks UDPP service to consider the new delay and sequence according to the
1167 prioritisation given to it, in what-if or commit mode.
- 1168 • The UDPP service checks the impact of the new delay / sequence to the Network
1169 (and Airport, as defined) and returns this impact assessment result back to the AU.
- 1170 • When AU sends Commit prioritizations, according to the delegation mode, the UDPP
1171 service sends back to DCB the new sequence and times for implementation (partial
1172 delegation) or implements directly the UDPP solution in full delegation mode.

1173 The AU actors:

- 1174 • The AU asks to the Network if a UDPP measure concern them.
- 1175 • If a UDPP measure exists, AU gets all the measure characteristics and the subsequent
1176 operational impacts / delays to their flights.
- 1177 • If the AU wishes to use UDPP to decrease the impact of the CCS, they give their
1178 priorities and margins to their flights and call the UDPP service to obtain new delay
1179 and the impact on the Network.
- 1180 • AU can use what-if scenarios to evaluate the new impact.
- 1181 • When the new delay / sequence is acceptable to the AU, they can then submit their
1182 finalized prioritisation to become effective in the Network.

1183

1184 Activities description :

1185 The colors in the following table highlight the status of the activity:

- 1186 • In black: non UDPP activity currently defined in the relevant project and used
1187 by UDPP
- 1188 • In blue: UDPP activity defined in this document
- 1189 • In red: Activity out of the scope of UDPP or not defined in other relevant
1190 project.

Activity	Description
Analyse DCB Imbalance	[DOD 7.2 modelling] The Local Traffic Manager and/or the Flow Manager analyse the demand versus the given resources and capabilities in his area, in order to foresee the resulting problems.
Analyse Implemented DCB	The Local Traffic Manager and/or the Flow Manager monitors the

Solution	proper execution of the DCB plan to resolve the hotspot and take additional measures in case of plan deviation of necessary
Assess Airport and Network Impact	The UDPP service assesses the impact of the new prioritisation to the network by running a network what-if in the NOP. If What-If NOP does not exist the impact on network will be visible only after submit by the AU.
Assess Block Time Impact and Evaluate scenarios	AU assesses the output of the what-if of their prioritisation to take decision to implement or not. If not AU can modify the prioritisation and run a what-if again
Assess Hotspot Impact and Evaluate scenarios	AU assesses the impact of the delay to their fleet within a UDPP measure to take decision to prioritise their flight or not
Calculate UDPP Block Time	This UDPP central function, convert priority to new delay, according to all AU prioritization values and equity rules.
Consolidate Priority Repository	DCB activity
Create/Update UDPP Environment (per Hotspot)	Create the UDPP measure according to the traffic and the constraints on the element to manage: e.g. get all traffic arriving in Airport, apply the constraints, and generate de delay to the corresponding flights. This Activity maintains also the different flight delay according to the possible evolution of the constraints or the evolution of the traffic.
Detect DCB Imbalance	The Local Traffic Manager and/or the Flow Manager monitor the balance between demand and capacity in real time by analysing entry and occupancy counts and associated workload values, and comparing them respectively with situational traffic capacity values and occupancy traffic monitoring values.
Detect Local DCB Imbalance	The Flow Manager (INAP) function analyses the local imbalance figures (complexity,).
Identify and Publish Declared Hotspot	Identify DCB imbalances that need to be monitored and/or resolved by creating and publishing a corresponding hotspot.
Reconcile Constraints	This function collects the planned DCB constraints from local NMF actors and provide the Network Consolidated Constraints (NCC) aiming at reconciling the interfering local constraints.
Refine Airspace Configuration	DAC activity
Refine Runway Configuration	Airport activity
Send Commit Prioritisation	When AU are OK with the prioritisation he has put in place, AU can submit it to the Network
Send What-If Prioritisation	AU can run a What-if to evaluate the result of a prioritization.
Set Priorities and/or Margins	AU can set prioritisation to their flights to decrease the impact of the delay (SFP, FDR, Margins)
Share Hotspot with Stakeholders	The local hotspots are collected by the Collaborative NOP and accessible by NMF actors
Update eFPL	UDPP send new time for flights within the UDPP measure.
Update NOP Plan	The dDCB/DCB solutions descriptions and their intended use are updated and published in the NOP.

1192

3.3.3 Differences between new and previous Operating Methods

Activities (in EATMA) that are impacted by the SESAR Solution	Current Operating Method	New Operating Method
	Manage Hotspot	UDPP measure are part of the possible solution to manage imbalance/hotspot
In Airport	Airport apply only regulation to manage overloaded situation	Airport can delegate to AU through UDPP measure the management of the overload in coordination with DCB
AU	Not possible to deal with impact of delay	AU can rearrange their flight sequence to decrease impact of delay on their fleet.

1193

Table 8: Difference between new and previous Operating Method

1194 **4 Safety, Performance and Interoperability Requirements (SPR-INTEROP)**

1195

1196 **4.1 UDPP enablers form other projects**

1197 This sub-chapter of the document define enablers from other Project/Process needed to start the
1198 UDPP function. Without these elements, UDPP could not exist because a “UDPP measure” cannot be
1199 created.

1200 The DCB (PJ09) through a local NMF has to delegate to UDPP (the AUs) the resolution of an
1201 imbalance and then a UDPP measure can be declared.

1202 **4.2 Operational Requirements**

1203 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OLOC.0001
Title	NMF (local ATFCM) delegate imbalance resolution to UDPP
Requirement	DCB shall allow AUs to mitigate a Capacity Constraint Situation through UDPP functions
Status	<In progress>
Rationale	In order to decrease the impact of a capacity problem causing delays, APT or NM actor through a NMF function can allow AU to mitigate the situation with UDPP
Category	<Operational>

1204

1205 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Create/Update UDPP environment
<ALLOCATED_TO>	<Allocate To>	PJ09.03
<ALLOCATED_TO>	<role>	Local ATFCM (INAP)
<ALLOCATED_TO>	<Sub-Operating Environment>	DCB_Env

1206

1207 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OLOC.0002
Title	Decision to Trigger UDPP
Requirement	A collaborative procedure involving both the Airports and the AUs shall be established for deciding when to trigger a UDPP event.
Status	<In progress>
Rationale	Both actors have different views of the situation and therefore, may have different opinions on whether UDPP would be a useful situation.

Category	<Operational>
----------	---------------

1208

1209 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Create/Update UDPP environment
<ALLOCATED_TO>	<Allocate To>	PJ04.02
<ALLOCATED_TO>	<role>	Local ATFCM (INAP)
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1210

1211 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OLOC.0003
Title	Airport can define constraints (CCS) on its runways
Requirement	The NMF shall allow Airports to set constraints (declare a Capacity Constraint Situation) on its runways
Status	<In progress>
Rationale	In order to define a capacity problem (CCS) Airport must have the possibility to define constraints on their resources (currently only Runway capacity). NB: the concept could be extended to other Airport resources like terminal, de-icing bay
Category	<Operational>

1212

1213 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Create/Update UDPP environment
<ALLOCATED_TO>	<Allocate To>	PJ04.02
<ALLOCATED_TO>	<role>	Local ATFCM (INAP)
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1214

1215 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OLOC.0004
Title	Identify overloaded areas
Requirement	DCB shall identify the overloaded areas with the help of Airports through

	the NMF.
Status	<In progress>
Rationale	In order to define a regulation or a UDPP measure a DCB NM Function must identify the imbalanced area to be managed.
Category	<Operational>

1216

1217 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Create/Update UDPP environment
<ALLOCATED_TO>	<Allocate To>	PJ09.03
<ALLOCATED_TO>	<role>	Local ATFCM (INAP)
<ALLOCATED_TO>	<Sub-Operating Environment>	DCB_Env

1218

1219 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OREG.0001
Title	UDPP functions are available for AUs to prioritise flights
Requirement	A UDPP Centralized function shall build a new sequence according to AU prioritisation.
Status	<In progress>
Rationale	The UDPP function is operating to allow AUs to manage their fleet in face of capacity problem. An assumption has been done that a DCB actor (FMP or Airport) initiate the UDPP process from a Capacity constrained Situation.
Category	<Operational>

1220

1221 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Create/Update UDPP environment
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	NOP_Env

1222

1223 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OREG.0002
Title	A UDPP communication link is available to each AU if needed
Requirement	A private UDPP communication link shall be available to AUs to perform UDPP prioritisations privately
Status	<In progress>
Rationale	UDPP link shall be available to AUs to prioritise their flights in a safe

	manner, avoiding publication of sensitive information to other AUs. AUs Priorities and Margins must stay private.
Category	<Operational>

1224

1225 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Create/Update UDPP environment
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	NOP_Env

1226

1227 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OREG.0003
Title	NMF allow What-If on flights
Requirement	NMF shall allow the UDPP function to assess the impact of changing the departure or arrival time to flights through a what-if function
Status	<In progress>
Rationale	In order to avoid possible instability and to be proactive in the solution to stabilize the fleet and ATFM organisation, a NMF what-if function can be available to show the impact of the AU prioritisation.
Category	<Operational>

1228

1229 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Assess Airport and Network impact
<ALLOCATED_TO>	<Allocate To>	PJ09.03
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	NOP_Env

1230

1231 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OREG.0004
Title	DCB through the NMF shall allow the integration of the result of UDPP as a mitigation to manage a capacity reduction
Requirement	DCB through a NMF shall allow the integration of the result of UDPP as mitigation for the management of a capacity reduction
Status	<In progress>
Rationale	In order to take into account AUs needs to mitigate delays, DCB shall integrate the output of the UDPP function.
Category	<Operational>

1232

1233 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Update NOP plan
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	NOP_Env

1234

1235 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OSVC.0001
Title	UDPP creates and maintains the UDPP environment (Delay on flights)
Requirement	The UDPP function shall create and maintain the UDPP environment to permit AUs prioritisation according to the possible variability of the Network
Status	<In progress>
Rationale	A UDPP set of functions shall be available and maintained to allow AU to operationally make flight prioritisation.
Category	<Operational>

1236

1237 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Delegate hotspot resolution to UDPP
<ALLOCATED_TO>	<Allocate To>	PJ09.03
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	UDPP_Funct_Env

1238

1239 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OSVC.0002
Title	UDPP Calculate UDPP block Time
Requirement	The UDPP function shall calculate new Block times according to the AUs prioritisation values and the current Network data
Status	<In progress>
Rationale	A UDPP function must manage the flight prioritisations of all the AUs in a constraint (CCS) and produce a new sequence of flight with new time accordingly.
Category	<Operational>

1240

1241 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	UDPP_Funct_Env

1242

1243 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OSVC.0003
Title	Flight Cut-Off Time for prioritisation
Requirement	Within a UDPP measure, a flight can be (re-)prioritized only if it's not pre-allocated: Non-ECAC, ATFCM Exempt, Airborne, if the current time is too late to modify the departure time (TSAT-30min)
Status	<In progress>
Rationale	Airports must have enough time in order to react to the changes to optimise the operations at the arrival airport.
Category	<Operational>

1244

1245 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	UDPP_Funct_Env

1246

1247 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OSVC.0004
Title	UDPP assesses the new time impacts on the network
Requirement	The UDPP function shall assess through NMF the impact of the new flight times issued from the new calculation of delay based on prioritisation
Status	<In progress>
Rationale	UDPP function must transmit to AUs the Network impact of a new sequence organisation. E.g. If a flight with the new time is entering in another regulation, the most penalized time is given to this flight and highlighted to the AU to decide or not to change the prioritization.
Category	<Operational>

1248

1249 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02

<ALLOCATED_TO>	<Activity>	Assess Airport and Network impact
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	UDPP_Funct_Env

1250

1251 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OSVC.0005
Title	UDPP submit a new block Time corresponding to AUs priorities
Requirement	UDPP shall submit to the Network a new block Time corresponding to the AU Prioritisation
Status	<In progress>
Rationale	In order to apply flight prioritisation to the network, the UDPP function shall produce new times for flights and a NMF function shall update the Network time for these flights (submit the AU needs to the network).
Category	<Operational>

1252

1253 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Update eFPL
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	UDPP_Funct_Env

1254

1255 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OAUF.0001
Title	AU assess the impact of delay on their fleet
Requirement	The AUs shall have the possibility to check the impact of delays on their all fleet of the day and possibly the day after in case of curfew problem
Status	<In progress>
Rationale	In order to decrease the impact of delay on AU fleet, the AU must have the possibility to evaluate the impact of delay for flights in constraints over the whole fleet.
Category	<Operational>

1256

1257 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Assess measure impact and evaluate scenario
<ALLOCATED_TO>	<Allocate To>	PJ07.02

<ALLOCATED_TO>	<role>	AU
<ALLOCATED_TO>	<Sub-Operating Environment>	FOC_Env

1258

1259 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OAUF.0002
Title	AU set priorities and/or Margins on flights
Requirement	The AUs shall have the possibility to allocate Priorities and/or Margins on flights if needed
Status	<In progress>
Rationale	AU shall have a tool to allocate priorities and/or margins on flights within a UDPP measure.
Category	<Operational>

1260

1261 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Set Priorities and/or Margins
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	AU
<ALLOCATED_TO>	<Sub-Operating Environment>	FOC_Env

1262

1263 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OAUF.0003
Title	AU can send what-if to UDPP services
Requirement	The AU shall have the possibility to send what-ifs to UDPP services to evaluate the result and impact of the prioritisation
Status	<In progress>
Rationale	To test and evaluate the impact of new prioritisations the AU shall have the possibility to send a What-If to the UDPP services.
Category	<Operational>

1264

1265 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Send What-If prioritisation
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	AU
<ALLOCATED_TO>	<Sub-Operating Environment>	FOC_Env

1266

1267 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OAUF.0004
Title	AU assess the new block time impacts on their fleet
Requirement	The AU shall have the possibility to assess the result of a prioritisation over its fleet
Status	<In progress>
Rationale	To evaluate the impact of a new prioritisation the AU shall have the possibility to check the result of a UDPP what-if function.
Category	<Operational>

1268

1269 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Assess block time impact and evaluate scenario
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	AU
<ALLOCATED_TO>	<Sub-Operating Environment>	FOC_Env

1270

1271 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OAUF.0005
Title	AU can submit the prioritisation to Network
Requirement	The AU shall have the possibility to submit the prioritisation to the Network to be implemented as new block time.
Status	<In progress>
Rationale	AUs shall have a tool to submit the prioritisation values given to flights in a UDPP measure.
Category	<Operational>

1272

1273 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Send Submit Prioritisation
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	AU
<ALLOCATED_TO>	<Sub-Operating Environment>	FOC_Env

1274

1275 [REQ]

[REQ]Identifier	REQ-07.02-OPS-OSVC.0006
Title	UDPP calculates UDPP block Time for non UDPP participating AUs
Requirement	The UDPP function shall calculate a flight block times in the same manner than the Network Manager CASA (called in UDPP CASA like

	algorithm) and assign it on flight of AUs who do not use UDPP (Equity).
Status	<In progress>
Rationale	A UDPP function must manage the flights of AUs who do not participate in UDPP. Delays assigned to Non-participating AUs flights must be calculated in the same manner than the Network Manager CASA: (FPFS algorithm used by Network Manager for slot allocation on regulations), because this algorithm is considered as equitable by AUs. Whatever the UDPP prioritisation given by the AUs, other AUs who not participate in UDPP must not be impacted negatively by priorities (Equity). The total delay of the problem must stay the same (optimal use of the runway throughput in planning).
Category	<Operational>

1276

1277 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	UDPP_Funct_Env

1278

Table 9: REQuirement capture layout

1280 **4.3 SPR**

1281 **4.3.1 Safety Requirements for UDPP**

1282 After having carried out the Safety Assessment (see PJ07.02 OSED part II - SAR), no Safety
1283 Requirements have been derived at this stage.

1284 Nevertheless, a Safety Issue (Ref. IO01, see PJ07.02 OSED part II – SAR) remains open that will need
1285 to be resolved during the next phases of the solution.

1286

1287 **4.3.2 Performance Requirements for UDPP**

1288 The following performance requirement define the need in term of:

1289 1. Capacity: CAPA

1290 2. Punctuality: PUN1

1291 3. Predictability: PRED

1292 4. Cost effectiveness: COST

1293 5. Flexibility: FLEX

1294 6. Human Performance: HUMP

1295 7. Fuel efficiency: Not applicable but predictability help decreasing used fuel.

1296 8. Equity: EQUI

1297 9. Safety: SAFT

1298

1299 [REQ]

[REQ]Identifier	REQ-07.02-OPS-CAPA.0001
Title	Airport Runway throughput
Requirement	The UDPP function shall not decrease the runway throughput
Status	<In progress>
Rationale	AU prioritisation must not negatively impact the runway throughput of the airport when the UDPP measure is put in place
Category	<Performance>

1300

1301 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1302

1303 [REQ]

[REQ]Identifier	REQ-07.02-OPS-PUN1.0001
Title	Punctuality on Airport
Requirement	The punctuality on airport within a UDPP measure shall be increased by an average of 0,245%
Status	<In progress>
Rationale	Punctuality on airport is defined differently according to the size of the airport : - Very large= 0.089% - Large=0.074% - Medium=0.052% - Small=0,03%
Category	<Performance>

1304

1305 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM

<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1306

1307 [REQ]

[REQ]Identifier	REQ-07.02-OPS-PRED.0001
Title	Predictability of flights
Requirement	Flights within a UDPP measure shall be more predictable
Status	<In progress>
Rationale	Flight within a UDPP measure are managed better by the fact that they have an arrival target time (TT) and are part of a measure well known by the Airspace User. Currently these TT are imposed by NM (the regulation) without any AU possibilities to adapt. Currently when a flight take-off, pilot ask to reduce the delay because it is not adapted and cost a lot for the Airline. With UDPP, AUs have adapted all the fleet to take into account the constraint and we hope that changing the planning in execution will be less mandatory for the Airline than in current situation.
Category	<Performance>

1308

1309 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1310

1311 [REQ]

[REQ]Identifier	REQ-07.02-OPS-COST.0001
Title	Cost effectiveness of the UDPP solution
Requirement	Prioritisation shall decrease the cost of the delay for the AU
Status	<In progress>
Rationale	When a UDPP measure is defined, the delays allocated to the flights in the measure impact the entire fleet such as missed passenger connections. This impact to the fleet is the Cost of the delay to the AU. In order to decrease this cost of delay, AUs will make prioritisations on the flights within in the measure.
Category	<Performance>

1312

1313 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1314

1315 [REQ]

[REQ]Identifier	REQ-07.02-OPS-FLEX.0001
Title	Flexibility for AU to prioritize flights
Requirement	The UDPP function shall give the AU a higher degree of flexibility
Status	<In progress>

Rationale	UDPP functions and interface have to give to the AU the possibility to rearrange their fleet according to their needs. UDPP do not have to impose a way to manage the flights. The UDPP functions must be useful for all kind of AU (regular, low cost ...) and open enough to implement different AU working methods. Whatever the way AUs make prioritisation, a set of algorithm manages the equity and the final sequence.
Category	<Performance>

1316

1317 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1318

1319 [REQ]

[REQ]Identifier	REQ-07.02-OPS-HUMP.0001
Title	What-if response time
Requirement	The UDPP functions shall provide the response to What -if within limited time (10 sec).
Status	<In progress>
Rationale	AU must be able to evaluate the impact on their fleet via what- if function in due time to evaluate the effect of the prioritisation on each flight. This mean that the new time for each flight must be available to evaluate the prioritisation and decide to change the prioritisation or to Submit it.
Category	<Human Performance>

1320

1321 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1322 [REQ]

[REQ]Identifier	REQ-07.02-OPS-HUMP.0002
Title	Submit response time
Requirement	The UDPP functions shall provide the response to Submit within limited time (10 sec).
Status	<In progress>
Rationale	Au must be able to evaluate the impact on their fleet via Submit function in due time. This mean that the new time for each flight must be available to confirm that the prioritisation has been taken as new AU wishes.
Category	<Human Performance>

1323

1324 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1325

1326 [REQ]

[REQ]Identifier	REQ-07.02-OPS-EQUI.0001
Title	Equity between AUs

Requirement	The UDPP function shall generate an equitable solution between AUs
Status	<In progress>
Rationale	Equity is a Key factor from the AU perspective to have a common solution in face of situations generating delays.
Category	<Performance>

1327

1328 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Calculate UDPP block time
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Very large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Large APT
<ALLOCATED_TO>	<Sub-Operating Environment>	Medium APT

1329

1330

1331 [REQ]

[REQ]Identifier	REQ-07.02-OPS-SAFT.0001
Title	Impact of several coexisting UDPP measures
Requirement	The validation activities shall check whether the implementation of several co-existing UDPP measures at ECAC level do not affect significantly the stability of the Network, and if positive, the adequate mitigations shall be designed
Status	<In progress>
Rationale	In order to ensure that the implementation of several UDPP measures in the same timeframe does not lead to any safety risk, additional validation activities need to be performed to analyse the impact. Depending on the outcomes, adequate mitigations shall be designed to maintain safety at acceptable level.

Category	<Safety>
----------	----------

1332

1333 [REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ07.02
<ALLOCATED_TO>	<Activity>	Update eFPL Update NOP Plan
<ALLOCATED_TO>	<Allocate To>	PJ07.02
<ALLOCATED_TO>	<role>	Regional ATFCM
<ALLOCATED_TO>	<Sub-Operating Environment>	Network

1334

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1339 4.4 INTEROP

Identifier	Name	Issuer	Intended Addressees	Information Element	Involved Operational Activities	Op	Sys
IER-07.02-OPS-AUI.0001	UDPPMeasure_FlightsBaselineDelay	Regional ATFCM	AU	Create/Update UDPP Environment (per Hotspot) o--> Catching	UC-01	Baseline Delay	
IER-07.02-OPS-AUI.0002	UDPPMeasure_Cut-offTime	Regional ATFCM	AU	Create/Update UDPP Environment (per Hotspot) o--> Catching	UC-01	Cut-off Time	
IER-07.02-OPS-AUO.0001	UDPPPrioritisation_PriorityOnFlightsInWhat-If	AU	Regional ATFCM	Send What-If Prioritisation o--> Catching	UC-01	UDPP Prioritisation in What-If mode	

IER-07-OPS-AUI.0003	UDPPP Prioritisation_NewTimes	Regional ATFCM	AU	Assess Airport and Network Impact o--> Assess Block Time Impact and Evaluate scenarios	UC-01	UDPP Block Times	
IER-07-OPS-AUI.0004	UDPPP Prioritisation_Impact	Regional ATFCM	AU	Assess Airport and Network Impact o--> Assess Block Time Impact and Evaluate scenarios	UC-01	UDPP Impact Assessment	
IER-07-OPS-AUO.0002	UDPPP Prioritisation_PriorityOnFlightsInSubmit	AU	Regional ATFCM	Send Commit Prioritisation o--> Catching	UC-01	UDPP Prioritisation in Submit Mode	
IER-07-OPS-UDPI.0001	UDPP Measure_LocationAndFlights	Local ATFCM (INAP)	Regional ATFCM	Throwing o--> Create/Update UDPP Environment (per Hotspot)	UC-01	Hotspot	
IER-07-OPS-UDPI.0002	UDPP Measure_Capacity	Local ATFCM (INAP)	Regional ATFCM	Throwing o--> Create/Update UDPP Environment (per Hotspot)	UC-01	Capacity	
IER-07-OPS-UDPI.0003	UDPP Measure_Cut-offTime	Local ATFCM (INAP)	Regional ATFCM	Throwing o--> Create/Update UDPP Environment (per Hotspot)	UC-01	Cut-off Time	
IER-07-OPS-UDPI.0004	UDPP Measure_DelagationType	Local ATFCM (INAP)	Regional ATFCM	Throwing o--> Create/Update UDPP Environment (per Hotspot)	UC-01	Delegation Type	

1340

1341

Identifier	Name	Issuer	Intended Addressees	Information Element	Involved Operational Activities	Op	Sys
IER-07-OPS-UDPO.0001	UDPP Measure_NewTimesProposition	Regional ATFCM	Regional ATFCM	Assess Airport and Network Impact o--> Reconcile Constraints	UC-01	Proposed DCB measure	
IER-07-OPS-UDPI.0005	UDPP Measure_NewTimesImpact	Regional ATFCM	Regional ATFCM	Reconcile Constraints o--> Assess Airport and Network Impact	UC-01	NCC	

IER-07.02-OPS-UDPO.0002	UDPPMeasure_SolutionInPartialDelegation	Local ATFCM (INAP)	Regional ATFCM	Analyse Implemented DCB Solution o--> Update NOP Plan	UC-01	Agreed DCB measure	ATFMMeasure
IER-07.02-OPS-UDPO.0003	UDPPMeasure_SolutionInFullDelegation	Regional ATFCM	Local ATFCM (INAP)	Throwing o--> Analyse Implemented DCB Solution	UC-01	Agreed DCB measure	ATFMMeasure
IER-07.02-OPS-UDPO.0004	UDPPMeasure_SolutionInFullDelagation_eFPL	Regional ATFCM	Regional ATFCM	Update Times in Trajectory o--> Update NOP Plan	UC-01	eFPL	

1342

1343 5 References and Applicable Documents

1344 Content Integration

1345 [1] B.04.01 D138 EATMA Guidance Material

1346 [2] EATMA Community pages

1347 [3] SESAR ATM Lexicon

1348 Content Development

1349 [4] B4.2 D106 Transition Concept of Operations SESAR 2020

1350 System and Service Development

1351 [5] 08.01.01 D52: SWIM Foundation v2

1352 [6] 08.01.01 D49: SWIM Compliance Criteria

1353 [7] 08.01.03 D47: AIRM v4.1.0

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1403 **Appendix A Cost and Benefit Mechanisms**

1404

1 Stakeholders identification and Expectations

1405

Stakeholder	Involvement	Why it matters to stakeholder
Airlines (Airspace users)	Act on flight on UDPP measure	Reduce the Impact on Fleet when ATFCM delay occur
Airport (APOC)	Assess new sequence and implement it.	Integrate new sequence in Airport management (including Impact assessment for what-if)
Network	Delegate imbalance solution to AU through UDPP	Allow delegation, produce impact assessment of UDPP solution and implement it.

1407

Table 10: Stakeholder's expectations

1408

[...]

1409 2 Benefits mechanisms

1410 Notes:

1411 The corresponding descriptions matching the numbers are:

- 1412 1. UDPP prioritization acts on the schedule only, and does not attempt to interfere with ATC optimization of the traffic. ATC will be at liberty to rearrange the arrival (or departure) sequence as it sees fit, hence a horizontal green arrow. However, in theory at least, prioritizing flights at an airport with two or more arrival runways (or departure runways) could lead to extra loading of one of the runways, and under-loading of another if flights cannot change their assigned runways, which might reduce runway throughput. The effect could be slight, if noticeable at all, and could be investigated in a live trial or a detailed airport simulation. (Note, no deterioration in runway throughput was reported in the DFlex live trial in SESAR 1.)
- 1421 2. The Airport's costs are calculated by the total delay. As UDPP should not create any differences in the total delay of the DCB measure, it should not affect the airport's total delay. However, due to the schedule disruption, there could be knock-on effects for departures, although the effect, if noticeable, is probably very slight. This is not foreseen as it is expected that an Airspace user will try to reduce the delay between flights with shorter turnaround times, ensuring that the flights do not depart later.
- 1427 3. It is anticipated that AUs will prioritise flights with shorter turnaround times that cause a knock-on effect throughout the rotation leading to the departures becoming delayed. This leads to higher costs for both the Airport and the Airspace Users. This knock-on effect is the aircrafts next leg departure delay which is anticipated to reduce by a small amount as this is not the primary factor in the decision making and cost calculations.
- 1432 4a. AUs using the SFP UDPP feature will experience a modest improvement in punctuality because these flights will be put back on schedule. Some of these flights may still be delayed by ATC if operationally necessary.
- 1435 4b. FDR will have no or little effect on punctuality because an AU will only be swapping his flights amongst his own slots in the UDPP Measure; few flights will have the opportunity to be put back on schedule.
- 1438 5a. Non-participating AUs will not experience any increased total delay because the AUs that use UDPP either swap their own allocated slots or produce positive impacts on total delay when using SFP due to the AU sacrificing one of its own flights. Shown by UDPP algorithm testing for equity, see Appendix B in the VALR [54].
- 1442 5b. AUs using the SFP UDPP feature will experience a modest increased total delay as a flight is sacrificed and gains more delay in order to protect the schedule time of another flight of higher priority. However, other airspace users will experience a small reduction in total delay in compensation because the total delay for the hotspot will not change.
- 1446 5c. Any airspace user using FDR will not experience a change to their total delay because FDR only allows flights to be changed amongst an airspace user's allocated slots in the sequence.
- 1448 6. The total amount of delay within the UDPP Measure will not change and it is only rearranging flights within the available slots provided through the CASA algorithm.

- 1450 7a. Direct costs (fuel, crew time, airport fees, passenger service costs, maintenance, navigation charges...) will reduce. Each flight has its own unique cost-delay curve. By rebalancing delay with UDPP an airspace user can minimize the total cost of additional delay incurred from ATFCM delay and its knock-on effect on the schedule. Indirect costs such as infrastructure, training and staffing will probably increase, but are expected to be small in comparison to savings on direct costs. Indirect costs are estimated in the CBA [59].
- 1451
1452
1453
1454
1455
- 1456 7b. UDPP prioritization provides airspace users with another means to react to the imposed ATFCM delays, increasing flexibility. This should be reflected in the cost savings for the airspace user.
- 1457
1458
- 1459 8. UDPP prioritization provides AUs with another means to react to the imposed ATFCM delay and the knock-on effects to the airspace users' schedule. Part of flexibility for airspace users is getting what they have asked for, but this will be limited by constraints from airports and the wider network. A resequencing that is fully accepted by ATC is indicative of good flexibility for airspace users.
- 1460
1461
1462
1463
- 1464 9 and 10 have not been measured for Wave 1 and must be measured during Wave 2 for the scope of V3 Maturity as integration.
- 1465
- 1466 9. The network's airspace capacity will be unaffected by UDPP because UDPP prioritization will be moderated/constrained by constraints imposed by ATC and the Network Manager. Besides, given most flights depart and arrive on schedule, UDPP is likely to be applied to very few flights, so the whole network impact could be very slight, if any at all.
- 1467
1468
1469
- 1470 10. Overloading the TMA could lead to a situation in which the intended 4D trajectories of two or more airborne aircraft are in conflict – a pre-existing hazard. So, a pre-existing hazard which can and will be addressed by the project, hence a white horizontal arrow.
- 1471
1472
- 1473

1474 3 Costs mechanisms

1475 The costs mechanisms for UDPP are defined in the CBA document:

- 1476 • SESAR PJ07S02 UDPP OSED

1477 This CBA document describes the costs and the benefits associated to the deployment of UDPP concept, as described in this OSED, across ECAC. Details of areas for further development and improvement in V3 are provided.

1480 A summary of the discounted values (actualisation across years) is shown in the following graph:

1481 To be noted that AUs stakeholders are defined in the eATM Portal by :

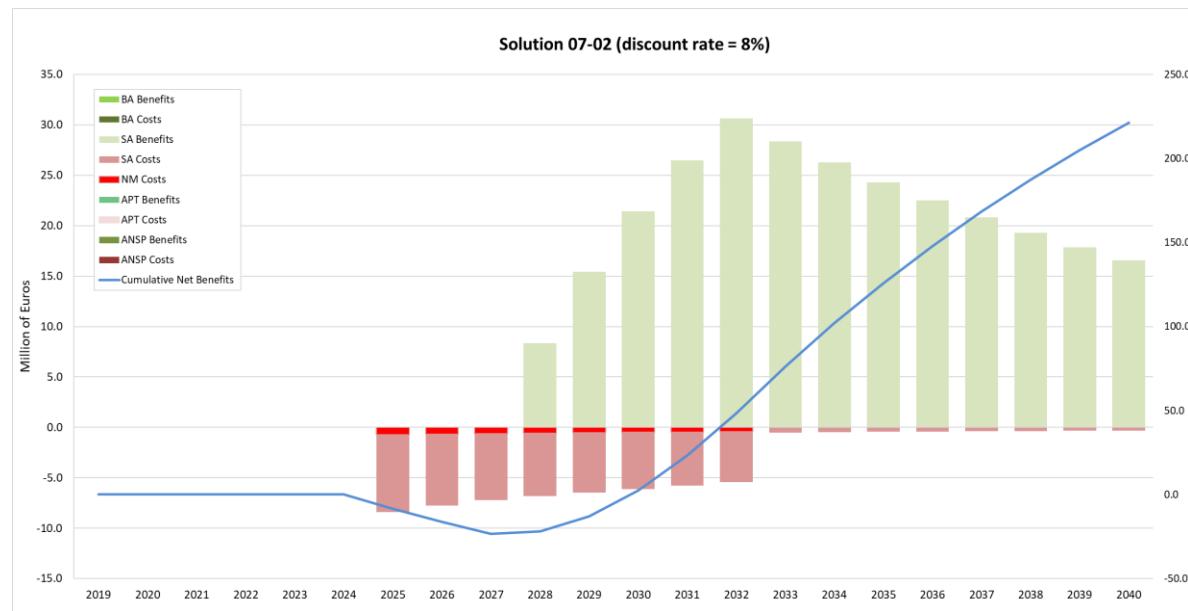
- 1482 • SA: Civil Schedule Aviation
 1483 • BA: Business Aviation

2019-2040					
Discounted	NPV (M€)	Costs (discounted)	Benefits (discounted)	Discount rate	Discounted
ANSP	0.0	0.0	0.0	8%	
APT	0.0	0.0	0.0	8%	
NM	-4.5	4.5	0.0	8%	
BA	0.0	0.0	0.0	8%	
SA	225.8	52.6	278.4	8%	
Overall	221.3	57.2	278.4		

1484 Table 11: Discounted CBA results (per stakeholder and overall)

1485

1486



1487

1488 **Figure 20: Annual Investment Levels and Benefits (Discounted)**

1489

1490 **Appendix B UDPP algorithms description**

1491 1 Introduction

1492 UDPP is a set of AU functions to mitigate delay from AU perspective.

1493

1494 The objective of the AUs, in case of major delay, is to reduce the impact of the delay on their fleet.

1495 To do this, a set of UDPP algorithms has been specified and produced to generate a new time to be
1496 assigned to AUs flights from priorities and/or margins input coming from AUs, and implementing
1497 equity and rules to support efficient coordination.

1498

1499 The objective of the UDPP algorithm is to give the best solution for the given problem according to
1500 the inputs of the AUs: all the UDPP algorithms must always generate a solution; there is no blocking
1501 point to stop the UDPP time generation.

1502

1503 The concept description of the AU tools, SFP, FDR and Margins is written in this OSED.

1504

1505

1506 This document describes the different algorithms to implement the UDPP functions.

1507

1508 2 Definitions

1509 Slot Definition in UDPP:

1510 Currently in UDPP, we use the term Slot because UDPP manages flights like a NM regulation, except
 1511 that, instead of using CASA to give the time solution, the flight reordering is managed by the UDPP
 1512 server (the entity who regroup all the UDPP functions) and a new UDPP time is given relative to the
 1513 priorities given by AUs.

1514 Today, UDPP Slots define only a time without a time window around like normal CASA Slot.

1515 Future investigation will be done to add to this UDPP time an appropriate time Window. This
 1516 investigation will be done in wave 2 when UDPP functionalities will be integrated in the NM system.

1517

1518 Baseline time (Baseline Slots List), Baseline delay:

1519 Time assigned to a flight by the CASA-like algorithm (First Schedule First Planned). This time is
 1520 calculated by the UDPP server according to the Capacity definition on the Resource to manage (e.g.
 1521 Runway) and the planned flights on it. Values are saved in the Baseline Slot List.
 1522 Baseline Delay is [BaselineTime – Flight Reference time= generally ScheduleTime)

1523

1524 Flight Reference time:

1525 Currently the Reference time is the schedule time of the flight, but according to Airport Runways
 1526 management style, sometime the flight Schedule is ignored and only current situation is managed.

1527 In this kind of Airport, the Reference time could be the current flight time when “UDPP Measure” is
 1528 created.

1529 In this document, we can use Schedule time instead of Reference time because it is the standard
 1530 definition of the Reference time.

1531

1532 AU Intermediate Local Slots List:

1533 Intermediate Slot list generated by the Ranking Method, because the Baseline Slot List can be
 1534 updated by the management of the Protected flights (Pflights)

1535

1536 AU Local Slots List:

1537 AU can manage only its own slot list. The AU Local Slots List is the time given on each AU flights after
 1538 AU prioritisation method (selected by AU) by conversion of AU input priority and settings,
 1539 implementing Equity, using only flights of the AU. This Local Slots list has to be merge with all the
 1540 other AUs flights to have the final UDPP solution: the UDPP Slot list.

1541

1542 UDPP Slots List:

1543 Final result of UDPP, merging all AU Local Slot Lists.

1544

1545 Airborne flights:

1546 Used to specify flights not available for prioritisation: keep the current time as target UDPP Slot.

1547

1548 Terminated flights:

1549 Flight already landed (no way to change anything in term of prioritisation), excluded from lists.

1550

1551 CCS (Capacity Constraint Situation):1552 Definition of the constraints on the resource, (e.g.; the runway capacity constraints: could be a stair
1553 given by more than one consecutive constraint...)

1554

1555 UDPP Measure:

1556 The set of flights concerned by a Capacity Constraint Situation (delay is given on each flight).

1557

1558 HotspotFlightEarlierSchedule:1559 Early time departure or time arrival authorised by the Airport and accepted by the AUs, to be used by
1560 UDPP algorithms. This value is an authorized negative delay given in minutes relative to the Flight
1561 Reference time (Schedule). This value also implies that AU must be ready to accept this earlier time.

1562

1563 Hotspot time for freezing Input flight list (late filler):1564 Time when the “UDPP Measure” is closed to flights insertion, AU flights list becomes fixed; if any,
1565 new flights are put at the end of the “UDPP Measure”. NB: This time normally must be relative to
1566 flights and not to “UDPP Measure” (through a moving window).

1567

1568 Hotspot Closed time (to AUs modification):1569 Absolute time relative to the “UDPP Measure” until AUs can set priorities on their flights, over this
1570 time, the last priorities given by AUs to their flights are taken as “UDPP Measure” solution.

1571

1572 Pflight:

1573 Flight with “P” priority: Protected Priority (highest priority for the AU).

1574

1575 Psolution:1576 It's the local time solution of a Pflight. This time could be slightly changed when merging all AUs
1577 flights or by the optimisation (merge function)

1578

1579 Sflight:1580 Flight with “S” priority: Suspended Priority (lowest priority of the “UDPP Measure”: flight(s)
1581 candidate(s) for Cancellation).

1582

1583 Lflight:1584 Flight with “L” priority: Lowest Priority (lowest priority of all flights of the Airline in the “UDPP
1585 Measure”). if several Lflights are set, Lflights are managed in their baseline time order.

1586

1587 Bflight:1588 “Baseline” priority: keep baseline delay as target time for UDPP algorithms (this time could be earlier
1589 according to resource optimisation). Two kind of Bflight are possible:

1590 Explicit Bflight: a B priority value is given for this specific flight by the AU

1591 Default Bflight: no specific priority is given for this flight, but a B priority is given as the Default
1592 priority value.

1593

1594 3 General UDPP algorithm view

1595 The UDPP Algorithms are composed by 3 consecutive steps:

1596 **1) The Baseline Slot Allocation** using Resource constraint definition (CCS, all flights concerned ...) to
 1597 generate Baseline Slot Allocation (CASA-like Algorithm).

1598 **2) The local AU flights management** uses AU input flight priorities (priorities and/or margins) and
 1599 settings, implementing Equity, to generate a new AU local Slot List for each AU flights inside the
 1600 "UDPP Measure" (based only on the local AU flights). Basically convert AU Prioritization in Time to be
 1601 merge with all AUs flights.

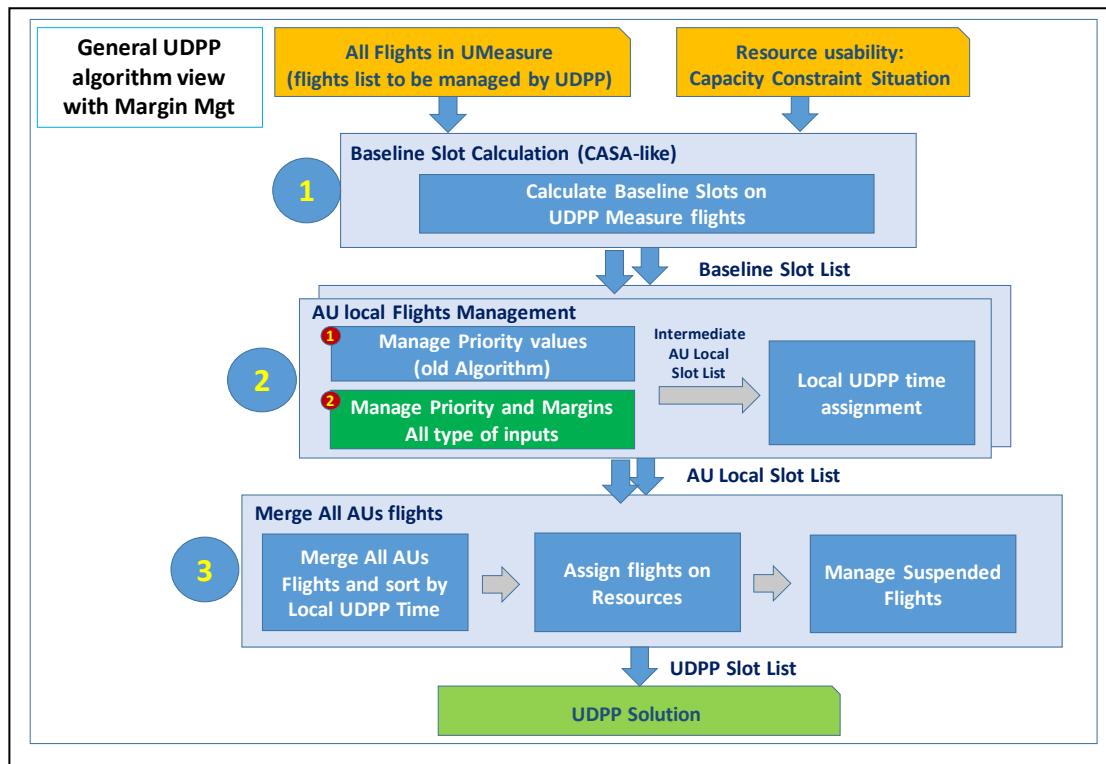
1602 **3) The merge of all AUs Flights:** In the "UDPP Measure", each AU can send its priorities
 1603 independently one from each other. To generate the What-If or Submit sequence adapted to the
 1604 specificity and dynamicity of the CCS, the merge function integrates all AU local prioritisation given at
 1605 the different time.

1606 To be noted that when one AU send its prioritisation, all AU flights in the UDPP Measure are
 1607 recalculated according to the last current status of all flights integrating last flights prioritisation, to
 1608 have always an up-to-date solution for all flights.

1609

1610 This algorithm structure organisation has been elaborated to manage Protected flights and
 1611 Suspended flights that could generate possible changes of the Initial Slot List produced by the
 1612 Baseline Slot Allocation.

1613 According to Holes created in the Baseline Slot list by the Suspended flights and the possible re-
 1614 arrangement of the Slot time due to Protected flights, a final recalculation of an Optimum UDPP slot
 1615 list is mandatory to avoid loss of runway throughput.



1616

1617 Figure 21: General UDPP algorithm view

1618 4 Global and AU algorithm parameters

1619 A set of parameters is defined to allow UDPP algorithms to be tuned to the Airport characteristics
 1620 and tuned to the specific needs of the AU.

1621 4.1 Global Airport Parameters (applied to all AUs):

- 1622 - Hotspot time for freezing Input flight list (late filler):
 1623 Time when the “UDPP Measure” is closed to flights insertion of its schedule time (e.g.
 1624 could be in the middle of the “UDPP Measure”). Slot list could change according to the
 1625 dynamicity of the situation but new flights (late fillers) are pushed at the end of the
 1626 “UDPP Measure”, in this case, the end of the “UDPP Measure” is modified. NB: This time
 1627 could normally be relative to flights and not to the “UDPP Measure” starting time
 1628 (through a moving window) but to give priority to flight already planned, only flights
 1629 using empty slots inside of the current UDPP measure can be inserted in the middle of
 1630 the sequence.
 - 1631 - Hotspot Closed time (to AUs modification):
 1632 Time until AUs can set priorities; over this time, the last priorities given by AUs are taken
 1633 as “UDPP Measure” solution.
 - 1634 - Hotspot Flight Earlier Schedule:
 1635 This parameter specifies the early Departure/Arrival anticipation buffer in minutes,
 1636 subtracted from Reference Time (e.g. 5min before Schedule Time). It defines the
 1637 maximum early departure / arrival time an AU can match._NB: currently the NM ATFCM
 1638 functions do not allow negative delay; this could cause a sub-optimisation the resource
 1639 (Runway) by the fact that a flight could not take an earlier slot if possible.
- 1640 [Rule_1] The “HotspotFlightEarlierSchedule” parameter is used for managing Pflights in AU local
 1641 ranking model but also in the Merge function to optimize the resource (Runway).
 1642 This parameter is used in combination with the *Time Window For Protection* (see next
 1643 paragraph)
- 1644 [Rule_2] “HotspotFlightEarlierSchedule” is also used for managing all prioritized Flights in the
 1645 Merge function, for resource (runway) optimisation.
- 1646 [Rule_3] UDPP Suspended After last flight for Merge: This parameter specifies the way the
 1647 Suspended flights are allocated in the final Merge function:
 - 1648 ○ If yes, the Suspended flights are pushed after the last non-Suspended flight of all the
 1649 AUs.
 - 1650 ○ If No, Suspended flight could be allocated in the middle of the “UDPP Measure”
 1651 where there is a sufficient time slot to host it.

1652 4.2 Parameters Specific to each AU (defined by AU and can be 1653 dynamically changed)

- 1654 - Default Priority Value: it is the value taken as default Priority, when no priority is
1655 specified for an AU flight.
- 1656 - Max delay for Protection (MaxDelayProtection):
1657 The “MaxDelayProtection” parameter specifies the maximum delay (based on Reference
1658 Time) to manage Protected flights.
1659 This parameter is used for the *Time Window For Protection*: Pobjective (see next
1660 parameters).
- 1661 **[Rule_4]** Time Window for Protection (called Pobjective):
1662 the default Time Window for Protection is defined by [Reference Time –
1663 HotspotFlightEarlierSchedule, Reference Time + _MaxDelayProtection].
- 1664 **[Rule_5]** If a Margin value is specified for this flight, The Margins values “Time Not Before”
1665 and/or “Time Not After”, overwrite the default Pobjective
- 1666 **[Rule_6]** A Protected flight has first to find a solution inside its Time Window. In this case, there is
1667 no impact on overall delay of the Airline because an AU slot is used. If more than one
1668 flight is in this time window (Pobjective), the flight with the later time in the window is
1669 taken to limit the impact on the others AU flights.
- 1670 - Local Ranking model: AU can dynamically apply a ranking model: Priorities only (1) or
1671 Priority and Margins (2) to manage their flights with UDPP.

1672 5 UDPP Algorithms

1673 5.1 The CASA-like time calculation on constrained resources

1674 Input:

1675 All flights that could concern the “UDPP Measure” extracted from NM according to the resource to
1676 manage.

1677 The CCS who defines the minimum size of the “UDPP Measure” (the “UDPP Measure” could not start
1678 after the beginning of the CCS and could not stop before the end of the CCS).

1679 According to the traffic on the CCS, the “UDPP Measure” could start before the CCS if residual delay
1680 before creating the CCS, and end after the CCS to manage the recovery period.

1681 If the CCS impact and the CCS itself is disjunctive (no times in common: this could exist for a CCS with
1682 a rate of 0):

- 1683 • starting time of “UDPP Measure” is the earliest time between the 2 starting times (CCS and
1684 CCS impact)
- 1685 • ending time of “UDPP Measure” is the latest time of the 2 ending times (CCS and CCS impact)
- 1686 • NB: this rule also cover the previous rule but the first rule stay defined to clarify the
1687 definition.
- 1688 • Side effect on that:

1689 We could have some empty slots in the baseline sequence that can be used by AUs when
1690 making prioritisation. In this case, we can see differences between total delay from
1691 baseline time and total delay of What-If (less total delay with UDPP).

1692 Output:

- 1693 • Baseline Slot List (All Flights in the “UDPP Measure”). Currently the size of the slot is not
1694 defined yet and used in UDPP. It will be studied later one.

1695

1696 Objective:

- 1697 • This algorithm (CASA-like algorithm) generates the baseline delay on Schedule/Reference
1698 Departure / Arrival Time or any constraint to manage flights affected by the Capacity
1699 Constraint Situation.
- 1700 • This part of the UDPP server, creates the “UDPP Measure” with associated baseline delay
1701 relative to the reference time (baseline time) on each flight by allocating flight on resources
1702 (runway) according to their current capacity definition including the CCS characteristics.

1703

1704 Capacity Constraint Situation (CCS) example:

1705 Normal Capa = 60 (flights/hours) --> minimum time between 2 flights = 1 minute.

1706 From 6:00 to 7:59 Capacity = 30 --> minimum time of 2 minutes between 2 flights.

- 1707 From 8:00 to 9:59 Capacity = 45 --> minimum time of 1 minute and 20 seconds between 2 flights.
- 1708 Etc....
- 1709 N.B. Pre-allocated flights (airborne flights, non ECAC flights, terminated flights ...) are forced to their
1710 current time (like in CASA).
- 1711 [Rule_7] Due to the CCS, All flights are allocated to a slot and have a baseline time. A “UDPP
1712 Measure” is automatically created by UDPP around the constraints, starting by the first
1713 flight with “a delay (delay different to 0)” and ending just before the first flight after the
1714 CCS starting with “0 delay”, this includes the recovery period. The UDPP Measure can
1715 start before the beginning of the CCS due to existing delay not previously managed.
1716 The “UDPP Measure” ‘could be’ manually adjusted by the owner of the resource, only by
1717 adjusting the CCS time starting and finishing because the CCS period is the minimum
1718 period of the “UDPP Measure”. This period is always checked and published manually by
1719 the owner of the resource and become the “UDPP Measure”.
1720
- 1721 “UDPP Measure” Dynamicity:
- 1722 A time is given to freeze flights entering in the “UDPP Measure”, called “Hotspot time for
1723 freezing Input flight list” (like in CASA - e.g. 2h before “UDPP Measure”). When the Freezing
1724 time is passed, no more flights can be added inside the “UDPP Measure” except if there are
1725 empty slots available, new flights are pushed at the end of the “UDPP Measure” and the
1726 “UDPP Measure” is extended. These new flights can be managed by the AU as the others,
1727 only the Baseline Slot Time is at the end of the “UDPP Measure”. In this case, flights are not
1728 excluded from the AU priority management.
- 1729 Before this freeze time, new flights can be added inside the “UDPP Measure” according to
1730 their Reference time (Schedule or Current)
- 1731 The Content of the “UDPP Measure” is always updated when an AU send a flight
1732 prioritisation. This “UDPP Measure” must reflect the up-to-date status of all the flights and
1733 CCS especially when time run and some flight become pre-allocated.
- 1734
- 1735 UDPP global Delay Calculation for network KPI (to be developed later):
- 1736 When UDPP delay is mitigated by Airlines, a new method to calculate Network delays must
1737 be issued to take into account the AUs wishes: flights with High priority must have less delay
1738 than flight with Low priority. A new formula for delay calculation must be issued taking into
1739 consideration a ponderation factor due to AU prioritisation. AU prioritisation must be taken
1740 as a new demand from AUs face to the CCS problem.
- 1741
- 1742 NB: The “Baseline time” (baseline slot allocation) is relative to the flight reference time taken as
1743 initial condition (Schedule or Current time). According to the specificity of the different Airport, the
1744 UDPP can be specially tuned to cope with this specificity: the Reference time could be the Schedule
1745 time or the current value of the time when the “UDPP Measure” is created. In this case, the Baseline

1746 Slot list takes current situation as reference. The schedule time can still be used to specify the
 1747 minimum time to be allowed to flights (with HotspotFlightEarlierSchedule subtracted if defined). But
 1748 this possibility is not managed by NM ATFCM because the schedule is ignored.

1749 **5.2 The AU local flight management: local ranking models + time 1750 assignment**

1751 The ranking models are basically the 2 models of prioritisation used by UDPP: ("Priority only",
 1752 "Priority and Margins) and a re-assignment of the flights on the available slots, but due to the
 1753 management of the Protected flights and the Suspended flights, they are a bit more elaborated to
 1754 adapt the solution to the AU needs.

1755 **Input:**

- 1756 • AU flights
- 1757 • Baseline Slot List for the AU,
- 1758 • Priority values (including flights margins if any) for each flight
- 1759 • and the AU parameters (Default Priority Value and Max delay for Protection)

1760
 1761 **Output:**

1762 AU Local Slots List

1763 **Objective:**

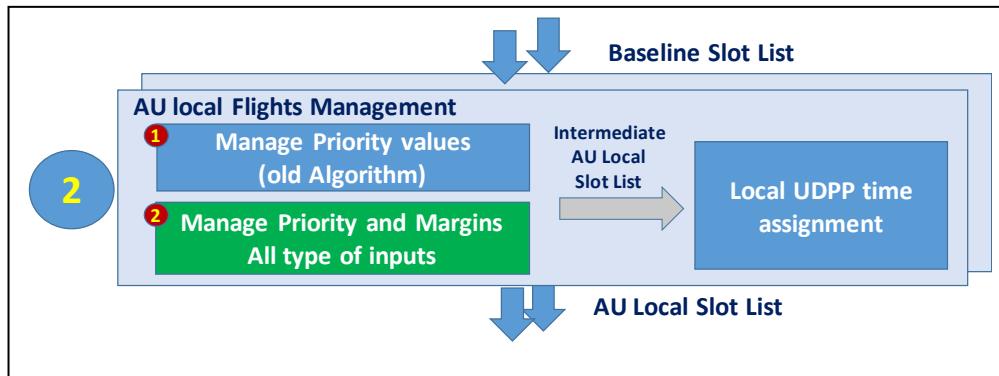
1764 Convert AU Priority values to new time for AU flights according to parameters and equity.

1765

1766 The objective of this local part, specific to each AU, is to generate a new local time for each flight (AU
 1767 Local Slot List) according to input given by the AU (priority values, margins values, ranking model)
 1768 and equity rules. This is basically based on using allocated AU Baseline Slots (baseline time generated
 1769 by the CASA-like Algorithm) to rearrange the flights in a more convenient and efficient sequence for
 1770 the AU.

1771

1772



1773 Figure 22: AU local flight management

1774

1775 The AU local flight management is split into 2 consecutive parts:

1776 1. **The Local Ranking algorithm:** based on AU input priority values and/or input margins and
1777 parameters.1778 The objective of this part is to translate the Priority inputs values (made of integers, letters, margins)
1779 into an AU flight list sorted according to the need of the AU, and an intermediate AU Slot List (with
1780 times) possibly modified by the management of the Pflights.1781 2. **The Time Assignment** of flights on intermediate AU Local Slots (the local slot list times could be
1782 modified by the Pflight management).1783 According to the type of Algorithm selected by the AU, when the AU calls the function What-If or
1784 Submit, the AU local flight management runs the selected Algorithm to manage its own flights.

1785 1. The “Priority only” ranking model: uses only the input priority values entered by the AU

1786 2. The “Priority and Margins” ranking model: uses the input priority values to manage flights
1787 but using also the input Margins as time target. This Algorithm type regroup all the possibility
1788 to manage flight in one model.1789 [Rule_8] Flights in AU Slots list containing flights with airborne and terminated status are excluded
1790 from the ranking methods but must be still visible for AU and UDPP functions.1791

5.2.1 The Local Ranking models

1792

5.2.1.1 The “Priority only” model

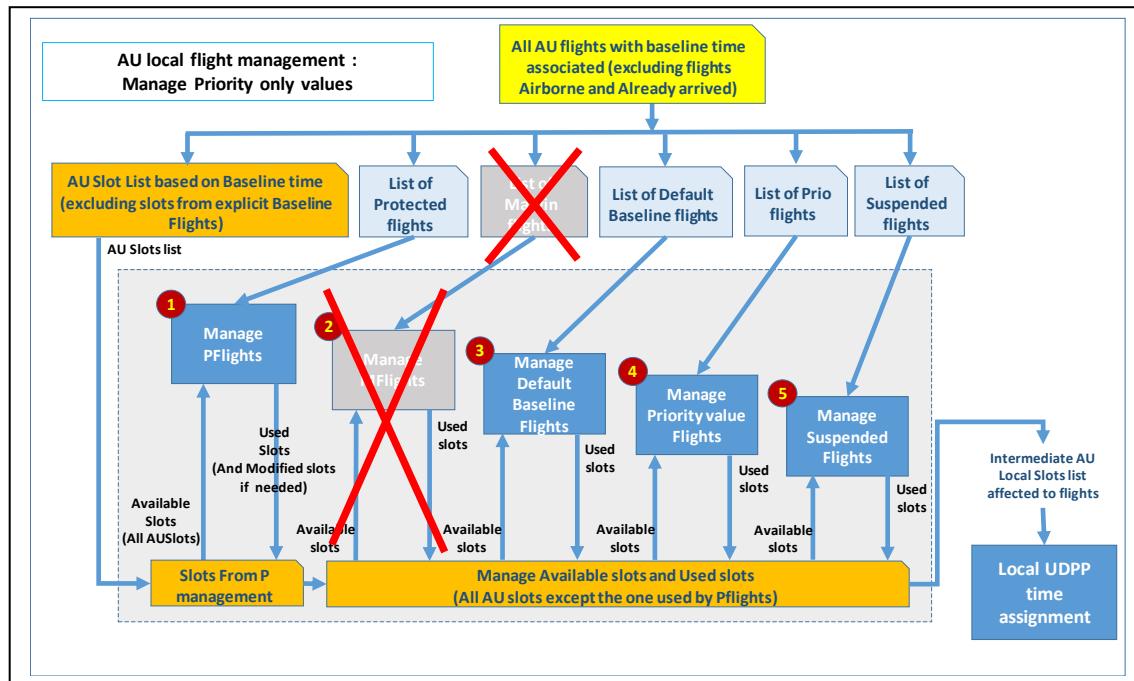
1793 To be noted that this “Priority only” algorithm is still defined in this document because it can be used
1794 as a Ranking model but it is replaced by the “Priority and Margins” model who merge all kind of
1795 prioritisation. There is no difference between “Priority only” outputs and “Priority and Margins”
1796 outputs if no Margins are defined for flights.

1797

1798 The definition of this model is done on the “Priority and Margins” model chapter. The difference is
1799 that the management for the Margin flights is not done for “Priority only”.

1800

1801



1802

Figure 23: Ranking Model: Priority Only

5.2.1.2 The “Priority and Margin” model

The ‘Priority and Margin’ model of algorithm manage all type of priorities: SFP, FDR and Margins with or without a priority value.

1806

1807 UDPP priority values can be:

- “P” to Protect a flight: very important AU flight(s) (Pflight), to be as closed as possible of the Margins if defined or the Reference time if not (see 4.2)
- A priority number from 1 (highest priority) to 999 (lowest priority) (Nflight) to give flights a relative ranking number.
- “L” Lowest priority flight: to specify the AU lowest priority flight(s) (Lflight) whatever the value given to its other flights (could be seen as the priority value = 1000)
- “B” for Baseline: (Bflight) to keep Baseline delay of the flight as the target time.
- “S” to UDPP Suspend a flight (Sflight): this flight becomes the less important flight of the “UDPP Measure”, it a candidate to avoid “UDPP Measure” or to be cancelled later on.

1817 A Margin value can be given on flights:

- “Time Not After” (TNA) specify the latest time to be given to a flight
- “Time not Before” (TNB) specify the earliest time to be given to a flight

1820

1821 To be noted that, according to the current status of the flight and the clock, a dynamic value of TNB and TNA is calculated to drive the possible local slot allocation (see 5.2.1.3 Dynamic Management of Time Not Before and Time Not After).

1824

1825 A combination of Priority and Margin is possible and give a large amount of possibility to the AUs to
 1826 give constraints to the UDPP algorithm to have a slot corresponding to the UDPP rules and AU
 1827 constraints. This combination allows representing the cost/delay curve of a flight: Time Not After
 1828 (TNA) is the time constraint not to exceed and the Priority is relative to the extra cost if exceed.

1829

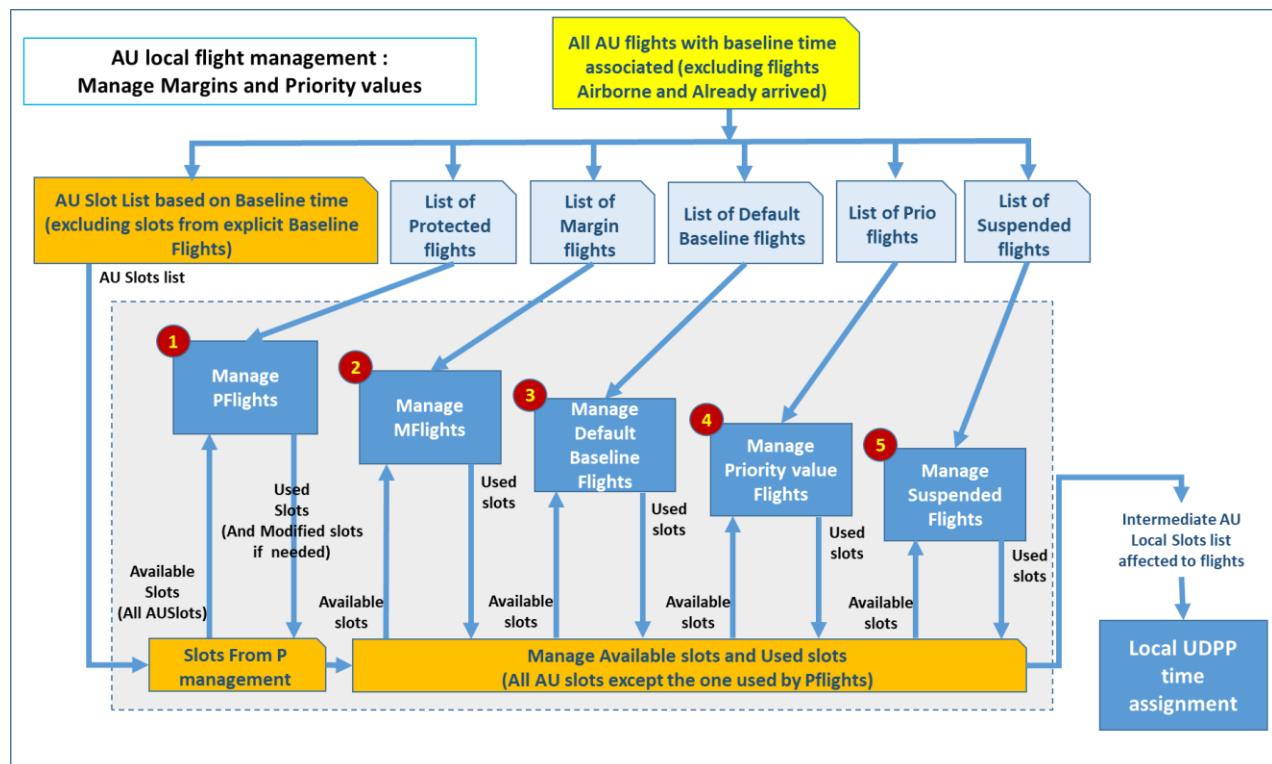
1830 To implement this model, the Management of the different flights generates a list of flights to be
 1831 given to the Local UDPP time assignment.

1832 The local flight management for this algorithm is based on 5 steps organised in the following order:

- 1833 1. the management of the Protected flights (Pflights), then
- 1834 2. the management of the Margin flights (Mflights), then
- 1835 3. the management of the default Baseline flights (dBflights), then
- 1836 4. the management of priority flights (numbers and 'L') (Nflights), then
- 1837 5. the management of the Suspended flights (Sflights).

1838

1839 The description of the Local AU flight management is graphically explained in the following figure.



1840

1841

1842 **Figure 24: Local flight management: Priority and Margins**

1843

1844

1845

1846 **5.2.1.2.1 Step 1 - Manage Protected flights (Pflight) (with Margins or not)**

1847 The objective of this part is to assign a slot to the Protected flights using 'Time not After' and 'Time
1848 not Before' if defined for this Pflight.

1849 A Pflight is defined by the fact that its priority is "P" with Margin or not.

1850

1851 [Rule_9] The Pflights have a particular priority, which corresponds to the highest priority of the
1852 fleet "P".

1853 [Rule_10] To find a time for the Protected flights, the first objective is to find a local slot "close to
1854 their schedule" in the AU Baseline Slot List to fulfil the "Pobjective" (defined hereafter)
1855 for these flights.

1856 [Rule_11] The AU slots used to find a Pflight solution are All AU Local Slots, including default
1857 Bflights (refer to Default Priority Value parameter) but excluding AU Explicit Bflights as
1858 well as Airborne and Terminated flights.

1859 [Rule_12] Pobjective of a flight is given by 2 parameters or Margin if defined:

- 1860 ○ The MaxDelayProtection: this AU parameter gives the maximum delay acceptable for
1861 a Pflight according to its schedule time: (e.g. 5mn or 10mn). This parameter, defined
1862 by the AU, can be changed dynamically to adjust AU objectives on Pflights.

- 1863 ○ The HotspotFlightEarlierSchedule: this Airport parameter (common to all AUs) gives
1864 the maximum early departure / early arrival buffer subtracted to Schedule Time of all
1865 AU Pflights: (e.g. 5mn)

1866 Pobjective: find a slot time inside the Time Window for Protection [Reference Time –
1867 HotspotFlightEarlierSchedule, Reference Time + MaxDelayProtection]

1868

1869 Protection Algorithm (for Pflights):

1870 The Management of the Protected Flight algorithm is the first algorithm applied for the "Priority and
1871 Margins" algorithm model when the What-If or Submit button is pressed.

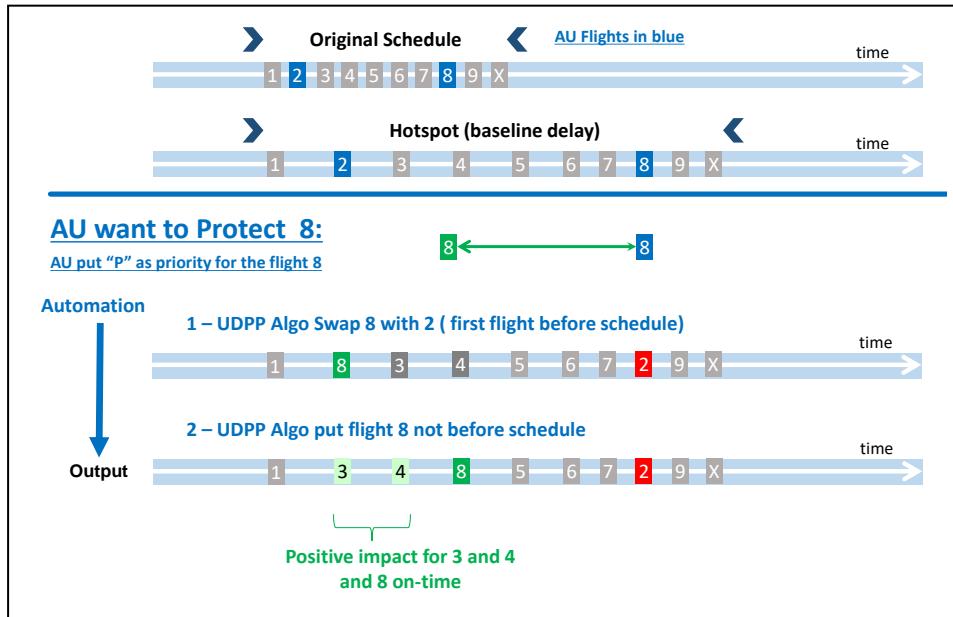
1872 It's based on 2 steps:

1873 [Rule_13] Find an already defined AU Local Slot matching Pobjective (defined above), allocated to a
1874 AU flight with a priority lower than Pflight.
1875 If found: the Psolution is the Slot of the flight found.

1876 [Rule_14] If no Pobjective solution is found:

- 1877 a. Find the first AU slot before the Schedule of the Pflight with a priority different of P.
- 1878 b. If a AU slot target exists, change the Slot of the targeted flight by the Slot of the
1879 Pflight and gives to the Pflight its Reference Time. This produces an Intermediate
1880 Local Slot List.
- 1881 c. If the targeted flight has an Default Priority of B, its priority is not touched. Except the
1882 Pflights, all the other AU flights will be managed in the next phases according to their
1883 priority and margins including default B priority.

1884



1885

Figure 25: Pflight management example

1886

1887 This function is described as follow:

- 1888 • Get all Pflights to be managed (The possible slot list is given by all AU slots excluding explicit
1889 Bflights)
- 1890 • Sort flights by 'Time not After' then 'Baseline time' if same 'Time not After' (if no 'Time not
1891 After' is specified the implicit value (for Pflights) = Reference time + Max delay for
1892 protection)
- 1893 • Manage Pflights: finding solution between 'Time not After' and 'Time not Before'
1894 (Pobjective) when a solution is found :
 - 1895 1) Update the UDPP Intermediate time of the Pflights (assign a slot to the Pflight :
1896 could be the one on the Pobjective, or a created one at the 'Time not After' value if
1897 no flight in Pobjective) and
 - 1898 2) update slots of the target flight if necessary (the other flights taken to manage the
1899 Pflights).

1900 The Pflight must be assigned in the same order than their 'Time not After' value if the
1901 schedule is appropriate. If not, reorder them.

1902 To be noted that, if more than 1 Protected flight is defined, because the algorithm start
1903 managing Pflight looking from the closest earlier flight, it is possible that the order of Pflights,
1904 at the end of the management, are not respected (earlier Pflight must have a time earlier
1905 than a later one). Because the algorithm use an earlier available slot to solve its Pobjective,
1906 the slot become more and more earlier to find the solution and then later Pflight has an
1907 earlier solution. This is clearly visible if many Pflights are defined.

1908 This can be solved by rearranging the slots of the Pflights by sorting them by 'Time not After'
1909 which is part of the Pobjective (assuming that if no 'Time not After' is given the time value is :
1910 the Reference time + Max delay for protection).

1911

1912 NB: this Pflights Management can change the slot assigned to the AU if no Pobjective solution is
 1913 found for a Pflight. This new slot list (with increase value of the sum of delay) is the one taken to
 1914 manage the others flights.

1915 **5.2.1.2.2 Step 2 - Manage Margin flights**

1916 Margin flights are defined by the fact that there is for the flight, a '**Time not After**' value given but h
 1917 AU and **its priority value is not P** (otherwise it's a Pflight). If no value is given on 'Time not After'
 1918 field, it's not an Mflight, if a P is given on priority value, it's a Pflight whatever the content of the
 1919 'Time not After' field.

1920 There is no default Margin for an Mflight. If there is no 'Time not After' value, the flight is **NOT** a
 1921 Mflight and is managed according to its priority value or default priority value.

1922 The Margin 'Time not After' and the Priority value are used to manage the Margin flights. If no
 1923 priority is given, the defaults priority value is taken (defined by AU in the interface as defaults priority
 1924 and also used to manage priority only flights). For Margin management, if the **defaults priority value**
 1925 given is **Baseline, the priority assign to the Mflight** is considered as **lowest priority ('L')**. This
 1926 because default B for a Mflight is declared less importance than a real priority value (it's considered
 1927 that flight will have a cost less important to manage than others if delay go over its 'Time not After').

1928

1929 The candidate Slot for the Margin flights can be found on all the available slot of the AU **except the**
 1930 **one already assigned to the Pflights** and the one **with an explicit B value** (explicit Baseline priority
 1931 value given on a flight).

1932 The Margin flights are assigned to slots in the same order then their priority value and 'Time not
 1933 After' value, using the 'Time not After' as time objective to be not over (use the latest time slot
 1934 before being over the 'Time not After'). For flights with, same priority value, same time not after, the
 1935 order must be as the baseline time. In other word, the list of Mflights is sorted by : 1) Priority values
 1936 (including default one) then 2) if same priority by 'Time not After' then 3) if same priority and 'Time
 1937 not After', the Baseline time.

1938 If it's not possible to fulfil the Margin as define by the 'Time not After': first an earliest available slot
 1939 must be assign to the Mflight, respecting the fact that the flight already assigned must not have a
 1940 degraded slot (earlier slot but not later) which is given by the priority rule; an second a slot later if no
 1941 possibility earlier.

1942

1943 In algorithm language:

- 1944 • Get all flights to be managed: Margin flights (All AU flights in the UDPP measure with 'Time
 1945 Not After' value except Pflights, and explicit B flights).
- 1946 • The assignment will be done on the list of available slots for the AU (to be share with Margin
 1947 and not Margin flights) except the slot already used by the Pflights.
- 1948 • Sort Margin flights by 'Priority' then 'Time not After', then 'Baseline time'
- 1949 • On each Margin flights, call the **Function "Manage Time Solution"** to assign a slot to Margin
 1950 flights (see function description after)

1952 **5.2.1.2.3 Step 3 - Manage the Default Baseline flights (dBflights)**

1953 The objective of this part is to assign a slot to the defaults baseline flights (dBflight).

1954 Default Baseline flights are defined by the fact that 1) the default priority value is set to 'B', 2) and
 1955 the flight has no priority value and no Margin.

1956 The objective is to assign to these flights a slot closest to their Baseline time value.

1957 The slot assignment of the baseline flight is done in the same way than the Margin flights, minimizing
 1958 the degradation of the already assigned flights (Margin flights).

1959 The objective is to:

- 1960 • Assign **default B flights** to the closest slot (not degrading Mflight slots) of their Baseline
 1961 time. This is done by calling the **Function “Manage Time Solution”** exactly in the same
 1962 way than Margin flights, but with target time = to the Baseline time of the flight (instead
 1963 of the ‘Time not After’ for Mflights).

1964

1965 **5.2.1.2.4 Step 4 - Manage the priority value flights (Nflights)**

1966 Nflights are defined by the fact that they have no Margins defined on its and not "P" and not "S" as
 1967 priority value. Lflights are part of Nflights management but with a priority = to 1000.

1968 The objective is to rearrange the sequence of the flight according to priority given by the AU. It is
 1969 implemented by sorting AU flights by priority then by Baseline time. This ordered list is used to assign
 1970 slots in the remaining AU Local slots of the AU.

1971 This priority value could be specifically given for the flight or given by the default one.

1972 The first part of this algorithm is to get all the AU flights to be used for this step; All AU flights except
 1973 the one previously assigned: Pflights, Mflights, and dBflights and the Sflights.

1974 Then sort flights by priority then Baseline times: Lflights the Lowest priority (priority = 1000).

1975

- 1976 • Then Assign **Nflights** on remaining slots in the ordered list on empty slots (not before its
 1977 Reference time of course).
 1978 • If a flight could not be assigned on an empty slot due to its reference time, use the same
 1979 function then for the Margin flights: **Function “Manage Time Solution”** but with a target
 1980 time value at the end of the “UDPP Measure”. In this case fill the empty slot by the end of
 1981 local slot list.

1982

1983 **5.2.1.2.5 Step 5 - Manage the Suspended flights**

1984 The assignment of the Suspended flights (Sflights) is done in this step by giving to these flights the
 1985 time of the end of the hotspot (set its local UDPP time to the end of the UDPP Measure). The real
 1986 Time will be given at the end of the Merge phase see part (3) of the graphic of the General UDPP
 1987 algorithm view.

1988

1989 **5.2.1.3 Dynamic Management of Time Not Before and Time Not After**

1990 The management of TNA and TNB could be generalised to each flight of all the AUs. This 2 values
 1991 become times constraint to assign flights to the right slot.

1992 These values are not necessary issued by the Margin field TNB and TNA given by the AU but
 1993 calculated according to the status of the flight and the type of priority given on it.

1994 The calculation is done in 3 steps, 1) The calculation of the status of the flights, 2) the static value of
 1995 the TNB and TNA and then 3) the validity of TNA according to the status of the flight.

1) Status of the flight:

1997 The status of a flight, is given by the current time, and determines if the flight is pre-allocated
 1998 (already airborne ...) or not. This status is expressed by "Max prioritisation time" and given by the
 1999 formula:

2000 $(\text{MaxPrioritisationTime} = \text{CTOT} + \text{Flight duration} + 20\text{mn}) > \text{Current time}$

2001 If the current time is earlier then the MaxPrioritisationTime, then the flight must be considered
 2002 as pre-allocated at its current CTOT.

2) Static value of TNB and TNA:

2004 TNB = Margin TNB value TNB if exist

2005 or Reference time – EarlyScheduleTime for Pflights

2006 or Reference time for others flights

2007 TNA = Margin TN value if exist

2008 or end of UDPP measure

2009

3) Validity of TNB and TNA value:

2011 Final TNB = latest time between (TNB, MaxPrioritisationTime): according to the current time,
 2012 MaxPrioritisationTime can replace the reference time to calculate the UDPP output.

2013 Final TNA = earliest time between (TNA, end of the UDPP measure)

2014

2015 The dynamic approach of the TNA and TNB avoid giving impossible solution to flights.

5.2.1.4 Generic functions to manage flight position

5.2.1.4.1 Function - Manage Time Solution

2018 The objective of this function is to assign a slot close or earlier to the flight 'Time not After', with
 2019 minimum impact on previously assigned slots.

2020 This function has, as input, the flight to manage and its 'Time not After' objective associated.

2021 It uses the slots list, with already assigned flights.

2022 1st Try to assigned slot with equal or earlier objective, by calling first Function: Manage Solution
 2023 Earlier.

2024 2nd If no Earlier slot solution is possible, assign first later available slot.

2025

2026 **5.2.1.4.2 Function - Manage Solution Earlier**

2027 This function called by 'Manage Time Solution', try to find an **equal or earlier slot** to be assigned to a
2028 flight.

2029 For that, this function loops from the target slot of the desired slot to the 1st slot of the list (earliest).

2030 And Call the Function: Move flight Earlier

2031 And Return the slot assigned if succeed or a negative value if not possible

2032 **5.2.1.4.3 Function – Move Flight Earlier**

2033 This function is **the heart of the Margin management**. It's a recursive function to find a slot earlier by
2034 pushing already used slots according to their possibilities.

2035 In algorithm language:

- 2036 • Loop until an earlier slot has to be tested: An earlier slot has to be tested if the target slot is
2037 used, and the flight to move, to free it, is blocked according to its schedule.

2038 • Try to assign to the target flights the target slot time (target time is the one before going
2039 over the Margin 'Time not After').

2040 • If the slot is empty (slot not already used) gives it to the target flights. This end the
2041 function.

2042 • If the slot is already used:
2043 Test if possible to shift already assign flights on it to earlier slot, to free the slot (because
2044 previously assign flight must have an earlier slot) by calling **Function: Move flight**
2045 **Earlier** (itself on flight using the slot). This is the recursive call of this function.

2046 If the shift is possible, assign the target flight to the target slot and return the free slot.

2047 By this, all the movable flights (driven by the level of recursively) shift the other
2048 flights needed to make it free (done by finishing the recursive call of the function).

2049 If the shift is not possible (no slot available before, or time too early according to
2050 reference time (schedule)), return a negative value corresponding to the blocking
2051 target slot.

2052 For information: the management of the shift flights earlier (make the slot free) is implemented
2053 by a recursive call to shift all the already affected flights with the test of the possible shift. This
2054 recursive function returns the value of the shift to be done or the fact that it is not possible. The
2055 real shift is done by the calling function (itself but recursively before) when the result is positive
2056 and gives the slot to be shift. A shift of a flight could be done if the reference time is earlier or
2057 equal to the target time to shift. To be noted that the fact that if a flight in the slot list is not
2058 shiftable, does mean that an earlier flight cannot be taken as target slot to fulfil the Time not
2059 After of the flight to assign.

2060

2061 **5.2.2 Local Flight Time Assignment**

2062 **Input:**

2063 AU Intermediate Local Slots List

2064 AU sorted flight List (by ranking algorithm)

2065 Priority values (to manage Sflights)

2066 AU parameters (Max delay for Protection)

2067

2068 **Output:**

2069 AU Local Slots List

2070

2071 **Objective:**

2072 The objective of this final local part is to calculate AU Local Slot time to be used later as an input of
 2073 the merging function integrating all AUs inputs. NB: Airborne and terminated flights keep the same
 2074 current time in slot list.

2075 The previous “Local ranking method” phase (previous chapter) gives a priority sorted AU Flight list,
 2076 and a AU Slot list.

2077 The Local Flight Time Assignment puts all AU sorted flights in the AU Slot list (could be changed by
 2078 Pflights management).

2079

2080 **Synopsis:**

2081 Loop on all flights in sorted AU flight list (given by the selected ranking method)

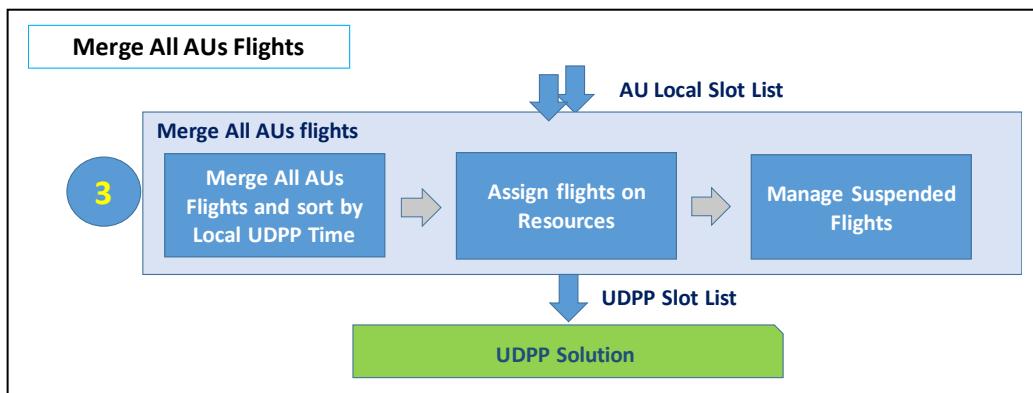
2082 **[Rule_15]** If the flight is a Sflight, the time assigned to it corresponds to the End Of “UDPP
 2083 Measure” minus 5 seconds to be sure that the flight will be managed as a flight inside the
 2084 “UDPP Measure” (it’s an intermediate solution, the final real time will be given in the
 2085 merge function because it depends on the other Suspended flights from the other AUs
 2086 and possible holes in the final sequence).

2087 **[Rule_16]** Else Assign the first available AU Time Slot equal or after the Psolution for Pflights and
 2088 the flight schedule for the others. To be noted that “HotspotFlightEarlierSchedule” time
 2089 has been used for Psolution and not used here for the local solution because the
 2090 objective is not to optimise the resource at this stage.

2091 End Loop

2092 **5.3 The Merge function**

2093 The Merge function is triggered by the Local Slot assignment done at each AU WhatIf or Commit
 2094 demand. It’s the last step to generate UDPP slot times.



2095 Figure 26: Merge function and Absolute Priority

2096

2097 **Input:**

2098 AU Local Slots List of All the AUs

2099 Priority values of all the flights (to manage Sflights)

2100

2101 **Output:**

2102 Final UDPP Solution = UDPP Slot List.

2103

2104 **Objective:**

2105 The objective of this function is to merge the local AU Assigned time of all flights from all AUs (given
 2106 by the previous phase). All Sflights will be first excluded from this merge and re-introduced after all
 2107 other flights.

2108

2109 **[Rule_17]** The merge function performs the following actions:

2110 Sort all AU “UDPP Measure” flights by the AU Local Time Slot (if same Assigned Time
 2111 then ordered by the Baseline Slot Time), ignoring the Suspended flights (Sflights).

2112 **[Rule_18]** Assigned each flight on the managed resource (e.g. runway) in an optimum way: make
 2113 the same Slot allocation than the one performed to create the Baseline Slot List (CASA-
 2114 like algorithm) but instead of taking flights Reference (Schedule) as input, take All AUs
 2115 Local Slot List, and Ignoring first all Suspended flights, but also using
 2116 HotspotFlightEarlierSchedule as possible departure time (to optimise the resource) (see
 2117 after).

2118 **[Rule_19]** Apply the following rules optimisation:

2119 Use the HotspotFlightEarlierSchedule on all flights to optimise the resource (e.g. runway
 2120 throughput): get a slot later or equal than [Schedule time - HotspotFlightEarlierSchedule]
 2121 nb: This optimisation is based on the usability of the resources given by the different
 2122 constraints provided by the resource owner (CCS).

2123 **[Rule_20]** Then assign Suspended flights (sorted by Baseline Time):

2124 First Sort Sflights by Baseline time then, 2 options are possible and are actually
 2125 implemented waiting for AUs feedbacks:

- 2126 ○ Starting from the beginning of the “UDPP Measure”, and where there is a hole in
 the sequence (available time to add a flight: enough time before and after a
 possible slot), put the Sflight, and loop until no more Sflight to assign (some Sflights
 could be out of the “UDPP Measure”).
- 2130 ○ Starting from the last assigned flight in the “UDPP Measure” and continue the
 Merge with the Suspended flights Sflight, not touching existing flight time even out
 of the “UDPP Measure” (some Sflights could be out of the “UDPP Measure”).

2134 **Appendix C Flexible Credits for Low Volume Users in**
2135 **Constraint (FCL) – E-OCVM V1**

2136

2137 This appendix presents in detail the FCL mechanism proposed, together with some evidence that
2138 support the concept description and the business case.

2139

1 FCL design criteria

2140 The following bullet points are the most significant design criteria that have been introduced in the
 2141 FCL feature (most of them requirements or recommendations given by AUs):

- 2142 • FCL should be based on the use of credits and incorporate the principles and rules of UDPP
- 2143 • Possibility to use credits obtained in the past at any future UDPP Measure (for LVUCs)
- 2144 • Continuous model in terms of delay management (avoid drastic efforts)
- 2145 • Rewards and charges should be accurately measured and be proportional to the positive and
 2146 negative impact generated to others (to preserve equity)
- 2147 • Take into account the compatibility of the different AUs prioritisations
- 2148 • Should allow LVUCs optimising the impact/cost of delay
- 2149 • Make it compatible and coexistent with the mainstream UDPP, i.e., FDR and SFP features (in
 2150 which LVUCs have little flexibility).

2151

2 FCL rules to preserve equity under high flexibility conditions

In FCL high flexibility is given to an LVUCs to minimise its own global delay costs, i.e., the LVUC has full freedom to transfer its total *baseline delay* (i.e., initial ATFM delay) among its flights and to exchange freely flight sequence positions with other AUs only being subject to two particular equity constraints: 1) AU's total baseline delay cannot be reduced, and 2) the Maximum Negative Impact of Time (MNIT) for individual flights in a UDPP Measure must be respected.

The main rules of FCL are defined as:

1. Any AU with a given number of flights (3 or less is considered as an initial proposal) in a UDPP Measure is considered as LVUC in the context of such a UDPP Measure (note: perhaps other criteria might be used to determine whether an AU is an LVUC in a given UDPP Measure, e.g., the AUs' share of flights in the UDPP Measure, but such a concept requires further research);
2. Any LVUC in a UDPP measure can save credits obtained by increasing the delay in some flights (thus giving better sequence positions to other AUs) and used them in that particular UDPP measure or keep them to use such credits in future UDPP measures;
3. Any LVUC in a UDPP measure can use Leftover Operational Credits (LOCs) obtained in the past to protect flights in the current UDPP measure; LOCs could be weighted up to take into account the differences of the UDPP measures in terms of duration and severity, so that the equity among AUs can be preserved (out of the scope of this research);
4. LVUCs can request any⁴ target place in the sequence (e.g., corresponding to the optimal delay allocation for that flight), irrespective of where and when the efforts were done to obtain the credits (note that this rule is significantly different from SFP that requires the efforts to take place in a sooner position in the sequence);
5. The AUs' total delay at the end of the reference period (e.g., 1 year) must be the same (more or less, in practice) as the baseline delay (delay without UDPP, e.g., FPFS).
6. The Maximum Negative Impact of Time (MNIT) represents the maximum minutes of additional delay that LVUCs can cause to a flight of another AUs. LVUCs might be unable to protect and reduce the delay for a particular flight if the MNIT has been reached for any of the flights it affects.
7. All the requests will be sorted by the requested time and will be integrated in the sequence in FIFO order and minimising the impact to others. No empty positions should be found in the sequence (compression) and requests that could generate impact greater than MNIT will be allocated the nearest feasible solution.

2185

⁴ Note that this rule applies for LVUCs, which, by definition, are expected to have less flexibility than other AUs. It may occur that in a particular hotspot the only flight available for a suspension could be in positions after the one that is tactically important for the LVUC.

2186 3 Assumptions and principles of the 2187 mechanism

2188 The proposed method is based on the following assumptions:

- 2189 • All transactions of credits and slots exchanges will be done through the Airport or DCB
2190 triggering the UDPP mechanism, which will act as a broker and supervisor.
 - 2191 • AUs must be consistent and accept any consequence derived from their own decisions.
 - 2192 • Regarding the NM and the FCL system, one minute of delay will be considered as having the
2193 same⁵ 'value' for all the flights (i.e., 1 minute delay = 1 DC).
 - 2194 • No negative delays are allowed during the slot re-allocation (this could be relaxed later, but
2195 for the moment this assumption is taken for the sake of simplification).
 - 2196 • No uncertainty associated with the new slot allocations planned during UDPP is considered
2197 (i.e., Confidence Index = 1).
 - 2198 • Having credits is useful and positive for the AUs since they provide flexibility to adapt the
2199 operations to changing and unforeseen conditions. AUs must contribute to the network with
2200 something in exchange, e.g., assuming extra delays for some flights under a regulation, i.e.,
2201 giving their sequence positions to other AUs.
 - 2202 • No loss of value or expiry of credits is currently considered (although this may be reviewed
2203 later).
 - 2204 • AUs are able to and have the necessary information (e.g., historical records) to make
2205 decisions involving different UDPP measures over the time, thus making a
2206 stochastic/probabilistic management of delay and management of impact of delay.
 - 2207 • The FCL decisions should be made and supervised carefully by expert human operators that
2208 will ensure the stability of the system and the application of good practice (i.e., automation
2209 shall be only provided to support human decision-making and control).
 - 2210 • If an AU sends no sequence position request for a given participating flight, it is assumed that
2211 it is willing to take advantage of any delay reduction opportunity for such flight⁶.
 - 2212 • FCL can coexist with the FDR and SFP features that would be used by non-LVUC operators.
 - 2213 • Special care should be taken when extending the validity of the credits through different
2214 UDPP measures, as the severity, duration or the flights involved are different in each
2215 situation. Hence, the credits should not have the same value in all UDPP measures. This is out
2216 of the scope of this research, but in future research an equivalence factor could be
2217 developed to update the number of credits to transfer credits from one UDPP measure to
-

⁵ To have more control on equity aspects, future research may consider different value of delay depending on the position in the sequence and the level of delay already allocated to such position.

⁶ This assumption is consistent with the assumptions behind the compression algorithm detailed in [39].

2218 another, being equitable for the AUs involved, e.g., associating the number of credits given
2219 or requested according to the amount of delay associated to the positions released or taken.
2220

2221 4 Initial proposal benefits and limitations

2222 The properties and advantages of FCL compared to SFP are detailed below:

- 2223 • The use of Delay Credits (DCs) is simple and versatile.
- 2224 • FCL allows several methods to obtain credits, not limited to suspending flights (e.g.
2225 supporting extra delay in exchange of credits). This may enhance the flexibility for all users,
2226 since AUs can now decide to protect flights not necessarily on-time, but just reducing the
2227 delay to the desired level (between zero and BD). More flexible delay management and cost
2228 management are available for the LVUCs.
- 2229 • The same can be said of suspensions: AUs do not necessarily need to send a flight to the last
2230 slot position of their flights or at the end of the sequence (*maximum delay*), but can rather
2231 decide any other slot in between which already generates positive externalities to some AUs
2232 and the flight is rewarded accordingly. Also, it increases the efficiency, since AUs can take
2233 into account the non-linear cost functions of delay of a particular flight and be more precise
2234 with the amount of delay that should be applied to optimise the relationship between
2235 sacrifice and reward.
- 2236 • The positive and negative impacts to each user are precisely quantified and registered every
2237 time there is a slot change.
- 2238 • The 'rewards' and 'charges' (in the form of credits) are applied to the AUs accordingly (and
2239 exactly) to the positive and negative externalities generated to the other users. In particular
2240 an AU will be rewarded by his efforts according to the extra delay accepted for some flights
2241 (positive externalities given to the other AUs) and will be charged according to the delay
2242 reductions in some other flights (negative externalities to others), so the two effects are
2243 compensated and neutralised proportionally.
- 2244 • Global scope (generalised time-space usage) is better, since the value of credits can be
2245 directly applied to different UDPP measures. AUs can now distribute their assigned delay
2246 among their actual and future flights taking into consideration the (private) cost and revenue
2247 functions (actual or expected) for each particular flight, thus giving flexibility to AUs to
2248 optimize the delay management with a long-term perspective.
- 2249 • FCL is compatible with current FDR and SFP mechanisms (although further research must be
2250 conducted to further validate this).
- 2251 • FCL offers a high degree of flexibility to set the close-out ('respond-by') time of the market,
2252 and also offers the capability of AUs to change their decisions of participation/non-
2253 participation at the beginning of each negotiation cycle.
- 2254 • FCL mechanism has been designed to be simple and easy to manage by human experts (with
2255 the help of decision support tools).

2256 5 Body of evidence

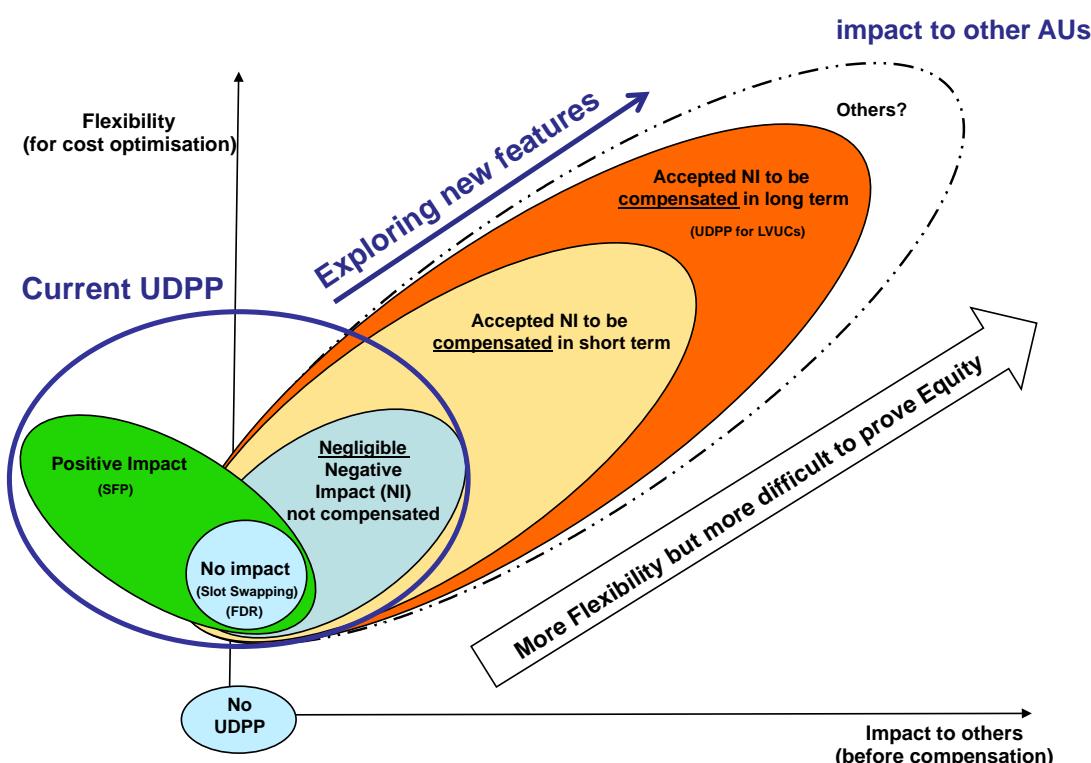
2257 To guarantee equity over the time all the AUs should receive, at the end of a reference period,
 2258 proportional levels of ATFM delay minutes as well as proportional flexibility levels that will allow
 2259 them to adapt their operations and minimise their impact of delay in the event of capacity
 2260 constrained situations.

2261 This chapter shows and discusses the early evidence found during the research conducted. The
 2262 purpose is to proof that a UDPP feature enabled for LVUCs, e.g. FCL, is equitable for all the AUs in the
 2263 long-term (e.g., after 1 year). Proof of equity is fundamental to generate commitment from all ATM
 2264 actors to proceed with implementation of new UDPP features.

2265 Part of the research conducted in this project has been published as a paper in the SESAR Innovation
 2266 Days 2017 conference [38]. As explained in the paper, generating proof of equity for UDPP
 2267 mechanisms that allow the exchange of slots between AUs over the time is largely complex; see
 2268 Figure 27.

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2270



2271
 2272 **Figure 27: Conceptual map of Flexibility versus Equity**

2273

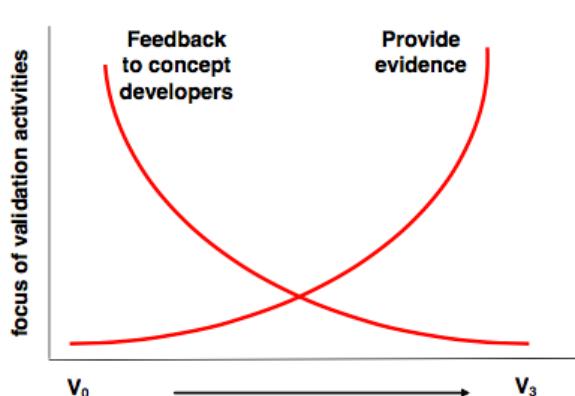
2274 5.1 Techniques used for the generation of evidence

2275 The FCL concept is at V0 maturity (identification of ATM needs and definition of strategic objectives),
 2276 although some V1 validation exercises were conducted in previous research. In this sense, FCL should

2277 be considered close to V1 gate, at least in many aspects. Therefore, it could be argued that FCL is in
 2278 between the maturity levels V0 and V1.

2279 According to E-OCVM [24] the purpose of validation activities at early maturity stages are oriented to
 2280 the collection of feedback and requirements to further develop and refine the FCL concept, and
 2281 progressively deliver more and more evidence of the feasibility and impact benefit of the concept;
 2282 see Figure 28. Taking this into account, this document provides **evidence for V0** (establishment and
 2283 quantification of the need for change) **and for V1** (operational technical solution, logical architecture,
 2284 identification of research needs and validation strategy aspects), although **some early evidence is**
 2285 **also provided through fast time simulations for V2 and V3 maturity levels** (V2: feasibility of the FCL
 2286 mechanism; and V3: system integration of the many de-centralised AUs' decision-making processes).

2287 The approach followed in this research takes as inputs the knowledge generated in the literature
 2288 review, discussion with experts, fast time simulations and validation exercises via expert judgement
 2289 and builds a new set of evidence, this time more focused on addressing some of the
 2290 recommendations and requirements requested by the AUs for the LVUCs mechanism during the
 2291 validation exercises.



2292
 2293 **Figure 28: Focus of validation activities at different maturity levels. Source: E-OCVM v3.0 guide**

2294

2295 The potential implications of introducing high flexibility subject to equity will be discussed via the
 2296 **theoretical analysis of the User Delay Optimisation Model (UDOM)**, a simplified mathematical
 2297 framework developed in the context of this research to capture the complex relationships between
 2298 time, cost of operations and the flexible and equitable allocation of slots and delay. Two different
 2299 degrees of equitable flexibility have been explored: a) the equity condition must be fulfilled at each
 2300 single UDPP measure; and, b) equity requirements can be fulfilled after many UDPP measures in a
 2301 long-term period (e.g., one year). Section 5.2 summarises the outcomes achieved with such analytical
 2302 approach.

2303 At V0 stage the identification of the ATM problems and needs is also fundamental for the business
 2304 case to take the GO/NO-GO to further pre-industrial research. For this reason a **quantitative**
 2305 **characterisation of the hotspots (potential UDPP measures) and LVUCs has been conducted,**
 2306 **through the statistical analysis of historical data records**, with the purpose to answer questions such
 2307 as: how often the AUs are affected by regulations and hotspots, how many and how often LVUCs are
 2308 affected by delay in hotspots, how often the AUs could be considered LVUCs in different hotspots,
 2309 and how many LVUCs can be found in a typical hotspot, among others. Section 5.3 shows the most
 2310 relevant results and outcomes of such data mining process.

2311 **Expert Judgement** has been included in the concept, taking advantage of the PJ07 expert panel
 2312 activities in where the early results and work-in-progress were presented and discussed with AUs.
 2313 The mathematical framework and its outcomes have been also reviewed by independent scientific
 2314 experts before acceptance of the paper in the SID 2017 conference and during the presentation of
 2315 the paper in the conference held in Belgrado, Serbia. The feedback and outcomes of the expert
 2316 judgement have been included in each of the following sections, and will be explicitly mentioned
 2317 where relevant.

2318 Finally, a simplified prototype has been implemented to analyse some use cases and perform some
 2319 simulations (**fast-time simulations analysis**). The prototype includes the possibility to process and
 2320 analyse simplified but quite realistic scenarios, to emulate the LVUCs decision-making (in a simplified
 2321 scenario their optimal requests can be calculated with UDOM), to merge the different requests, and
 2322 to analyse the impact of the 'emulated gaming' on performance (cost of delay, flexibility, equity, and
 2323 equity over the time).

2324

2325 **5.2 Analysis of the concept through the User Delay Optimisation
 2326 Model (UDOM)**

2327 This section summarises the main observations and conclusions after the analytical assessment of an
 2328 hypothetical case in which high flexible conditions are given to an AU (typically an LVUC) only subject
 2329 to a unique constraint of equity: the AU cannot reduce his total baseline delay. The paper is
 2330 therefore analysing one of the most fundamental properties of CFL, i.e., the free usage/exchange of
 2331 slots by part of an AU in a single UDPP measure or across multiple UDPP measures (over the time).
 2332 The full paper content [38] can be downloaded at:

2333 http://www.sesarju.eu/sites/default/files/documents/sid/2017/SIDs_2017_paper_75.pdf

2334 The paper analysed the UDOM context with a wider and more abstract perspective, i.e., not limiting
 2335 the potential usage of high flexibility conditions to LVUCs. In this section however, only the results
 2336 applicable to the potential utilisation of the FCL mechanism by part of LVUCs are presented.

2337 With the utilisation of UDOM to analyse the high flexibility conditions constrained by equity, the
 2338 dominant strategies of the AUs can be anticipated. The most relevant observations and conclusions
 2339 are the following:

- 2340 a) Under high flexible conditions constrained by equity a **LVUC can minimise his costs** by
 2341 transferring delay among their flights (either in the short term or in the long term), while his
 2342 total baseline delay remains the same at the end of the reference period.
- 2343 b) The equity constraint forces the LVUC to increase delay (and related costs) in some flights,
 2344 which ensures an **efficient utilisation of the slots taken by a LVUC**, and the **avoidance of the
 2345 free-riding problem**.
- 2346 c) Under equity constraints a LVUC will find trade-off solutions for the distribution of the delay
 2347 among his flights. This implies the existence of an **optimal level of delay** (typically greater
 2348 than zero) for each of his flights.
- 2349 d) In contrast with the today's 'no-delay paradigm', the minimisation of fleet costs under **CFL
 2350 rules will lead to increasing the delay for some flights**, and not necessarily for the 'less
 2351 important' ones, e.g., an 'important' flight could receive 20 minutes of extra delay, if its
 2352 baseline delay is 15 minutes and it has a delay tolerance of 40 minutes.

- 2353 e) A specific position in the sequence shall be requested by a LVUC for each flight of his fleet
 2354 such that the delay allocated to such flight will coincide with the optimal 'target' delay.
- 2355 f) LVUCs can compute their optimal delay for their future flights using UDOM adapted to
 2356 stochastic optimisation. This adaptation requires taking into consideration the probability
 2357 for each future flight of being affected by a UDPP measure, and the expected delay in each
 2358 situation. It must be pointed out that some AUs confirmed during the expert judgement
 2359 sessions that they typically have access to historical records and statistics of operations,
 2360 and that they could use such information for cost optimisation. Also note that such
 2361 stochastic optimisation is necessary for LVUCs that only operate one flight in a UDPP
 2362 measure.
- 2363 g) For some flights the LVUC will like to reduce their delay, thus taking positions from the flights
 2364 before in the sequence, and increasing their delay. The delay increased per flight of other
 2365 AUs (negative impact) will be equal to the size in minutes of each position in the sequence.
- 2366 h) If the number of LVUCs is not too large, the impact to others might be considered negligible
 2367 (which is congruent with the results of the validation exercise conducted in the past with
 2368 expert panels, although further research and validation must be done).
- 2369 i) If MNIT = 0 is ruled, the equity condition could increase flexibility in the system, because the
 2370 LVUCs are forced to offer positions to other AUs, thus reducing their delay and neutralising
 2371 potential negative impacts of other flights using FCL and reducing their delay ("Equity creates
 2372 market"). This fact is also true when MNIT > 0; in such a case, the flexibility introduced by the
 2373 definition of MNIT > 0 is enhanced by the equity constraint.
- 2374 j) Smooth coordination among AUs might be possible with a reduced set of simple UDPP rules
 2375 and constraints.
- 2376 k) AUs could be just focused on optimising their own operations (thus fulfilling one important
 2377 system requirement from AUs)

2378 5.3 Data analysis for the characterisation of LVUCs and hotspots

2379 The purpose of the historical data analysis is to characterise the 'problem' of LVUCs in real
 2380 operations, in order to generate evidence that should be useful to develop the business case of the
 2381 FCL or any other potential UDPP feature aimed at giving access to LVUCs.

2382 The specific data-mining tasks were addressing the following research interests:

- 2383 • To identify how often AUs might be LVUCs
- 2384 • To identify how often we can find LVUCs in ATFM regulations/hotspots
- 2385 • To analyse how the delay is today spread among AUs
- 2386 • To discuss with the AUs about what could be an acceptable equity target for UDPP for LVUCs
 2387 (objective validation criteria)
- 2388 • To develop further the rules for FCL on the basis of the data mining results and start
 2389 discussing about the potential integration with the 'normal' UDPP, i.e., FDR and SFP.

2390

2391 Next bullet list describes the data used for the analysis:

- 2392 • Data from **DDR2** (historical records)
- 2393 • **Only arrival** regulations
- 2394 • **20 AIRACs** ($20 \times 28 = 560$ days), **from Jan 2016 to Jul 2017**
- 2395 • **Some data adjustments were done** to recode HOP! that was labelled as XXX ('unkown') but
2396 whose two-letter code (AF) could be used to identify it.
- 2397 • A total of 19000 arrival regulations were analysed (**34 'arrival' regulations in average per**
2398 **day**)
- 2399 • **Some limitations were identified** after contrasting the results of the data analysis with the
2400 AUs, limitations that are commented in Section 6 but **it is expected that these limitations**
2401 **should not imply significant differences with regards the results presented** in this section.

2402 Table 12 describes the characteristics of a statistically typical hotspot. The most relevant results
2403 possibly are that **hotspots occur every day during daylight hours (all day) at many airports** in the
2404 network, typically affecting more to the major ECAC airports that held the 90% of the traffic. **Delay**
2405 **affects all the AUs more or less evenly** with an average of 22 min., while **the 40% of the times the**
2406 **delay will be larger than 40 min., and a 5% of flights will have more than 60 min.** delay. In most of
2407 the hotspots there is a **large presence of LVUCs (around 75% of AUs in a typical hotspot)**. Finally, in
2408 around the 85% of the cases in which an AU have flights in a hotspot, the AU may have 3 or less
2409 flights (thus **AUs can be considered as LVUC in the 85% of the hotspots**). Figure 29 to Figure 43 show
2410 the evidence.

Hotspot characteristic	Description of a 'typical hotspot'	Evidence
Period	<ul style="list-style-type: none"> Significant number of hotspots every day at any season Peaks in summer and Christmas More often in weekends, but common every day Within 5.30-20.00 (with more intensity within 10.00 and 16.00) 	Figure 29 Figure 30 Figure 31 Figure 32
Duration	<ul style="list-style-type: none"> 3 h in average (typical variance: between 2 h and 4 h) 	Figure 33 Figure 34
Reason	The three most important factors are: <ul style="list-style-type: none"> Airport capacity Weather ATC capacity 	Figure 35 Figure 36
Impact on AUs	<ul style="list-style-type: none"> It affects more often to major operators and airports (which altogether held the 90% of the traffic) Avg. delay per AU: 22 min. The 40% of flights have more than 40 min. of delay A 5% of the flights have more than 60 min. of delay AUs are impacted more or less evenly (equity) 	Figure 37 Figure 38 Figure 39

Number of AUs and Flexibility Potential	<p>A typical regulation affects to 9 different AUs (typical dispersion between 4 and 12 different AUs), with the following number of flights:</p> <ul style="list-style-type: none"> • 6 AUs with 1 flight • 1 AU with 2 flights • 1 AU with 3 up to 6 flights • 1 with more than 6 flights <p>All AUs could be considered LVUCs (3 flights or less) in around 85% of the hotspots in which they have some flights affected</p>	Errore. L'origine riferimento non è stata trovata.
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Table 12: Description of a statically typical hotspot

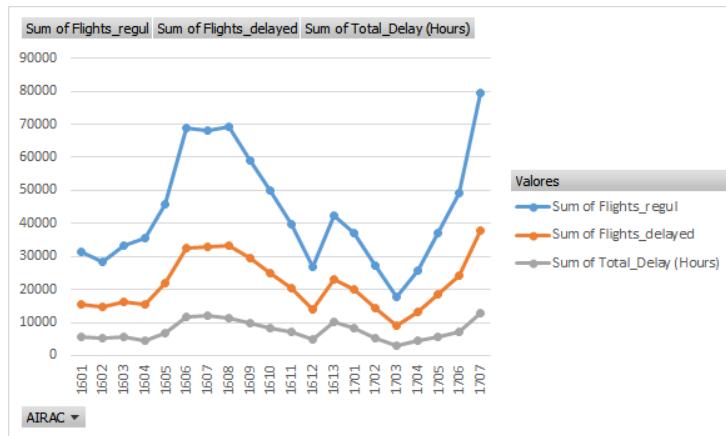
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Figure 29: Evolution of flights regulated, flights delayed and total delay (in hours) in 20 AIRACs

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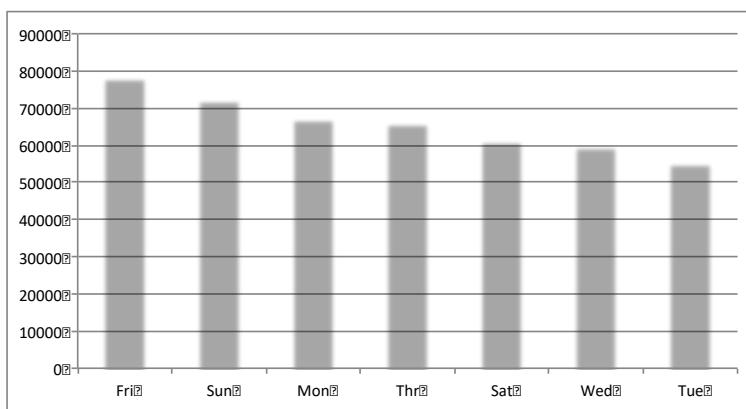


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**Figure 30: Distribution of hotspots per weekday**

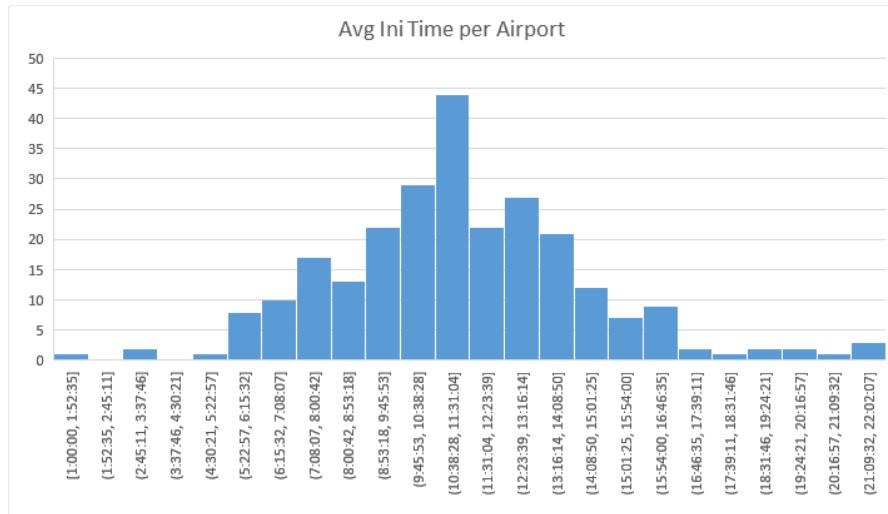


Figure 31: Histogram of initial times per regulation

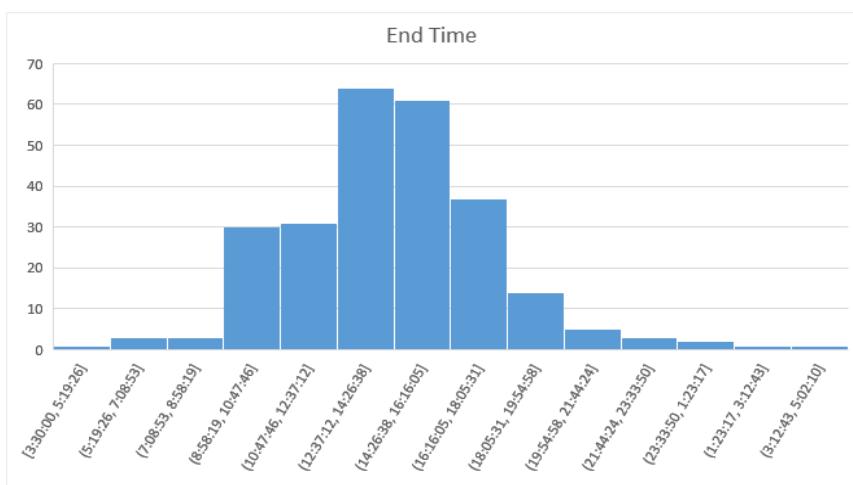
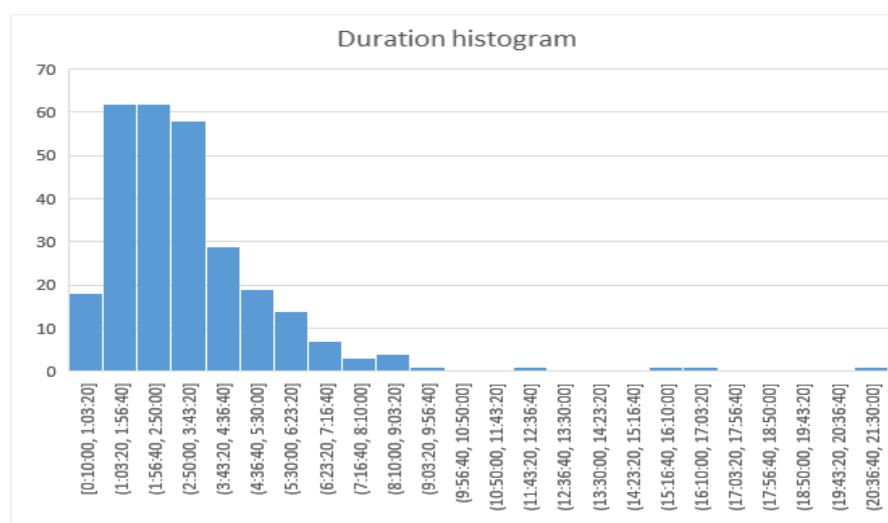


Figure 32: Histogram of end times per regulation



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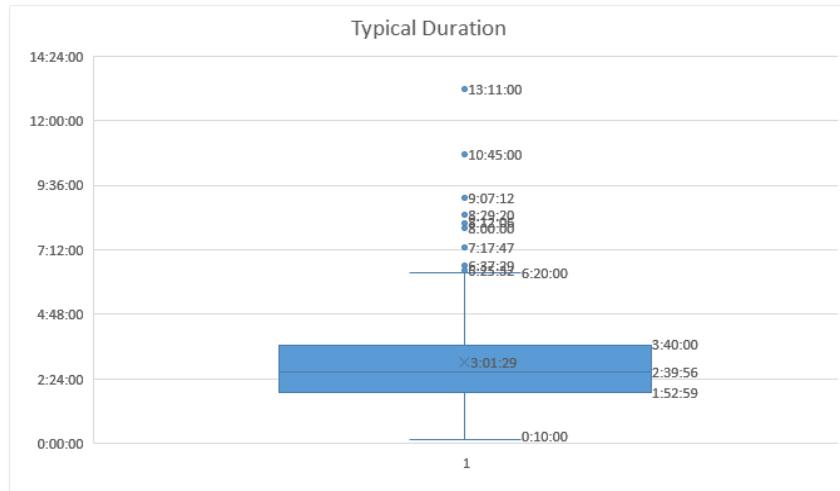
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Figure 33: Histogram of regulation durations

2429



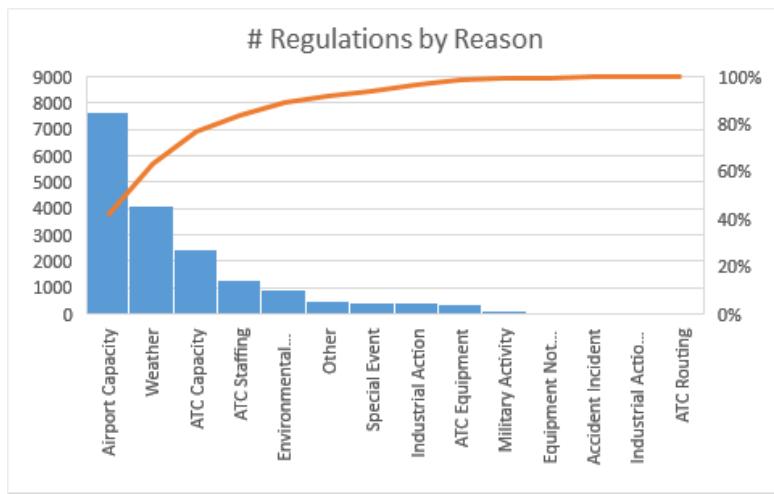
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Figure 34: Statistical characterisation (box diagram) of regulation durations

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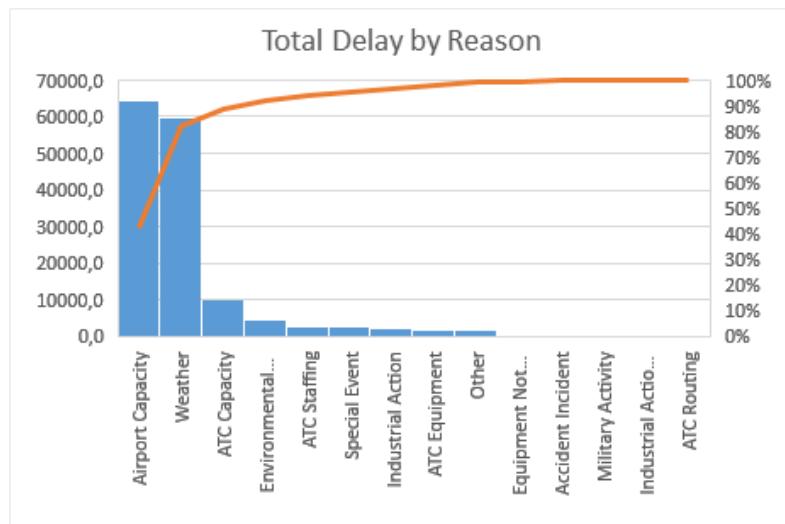


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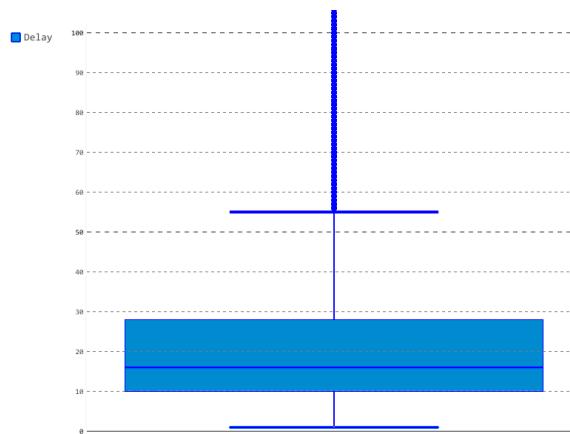
Figure 35: Number of regulations by reason

**Figure 36: Total delay by reason**

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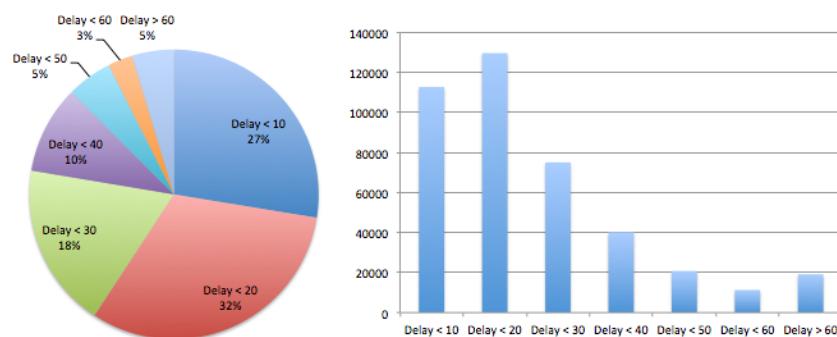
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**Figure 37: Statistical characterisation (box diagram) of delay**

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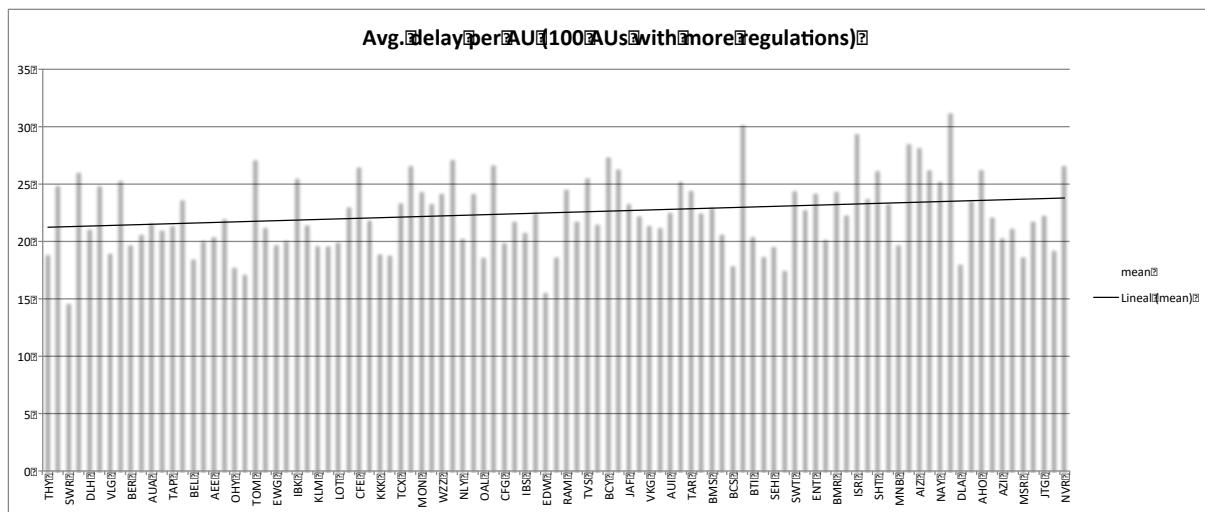
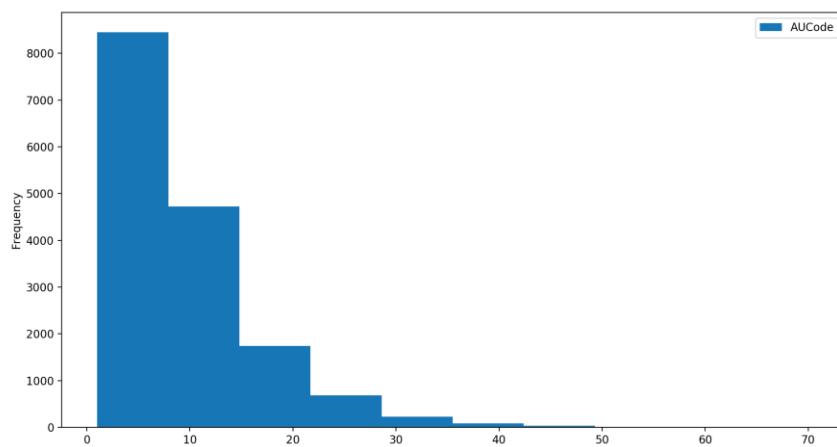
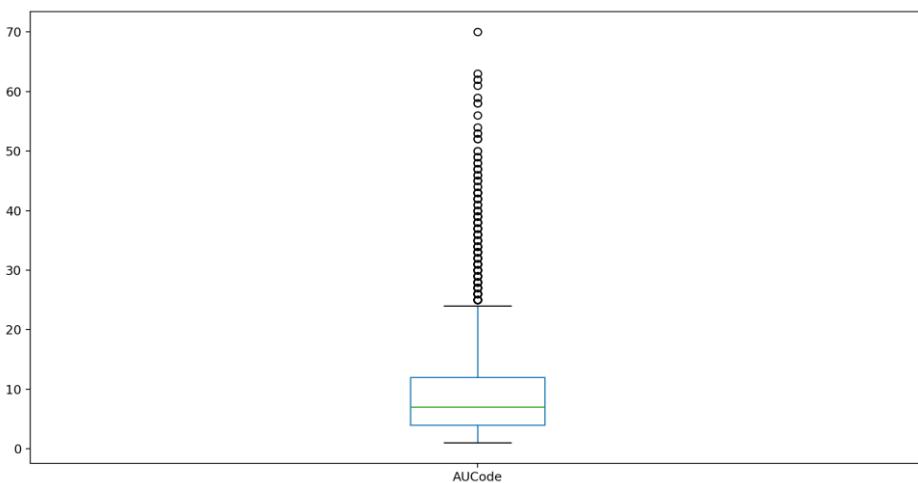
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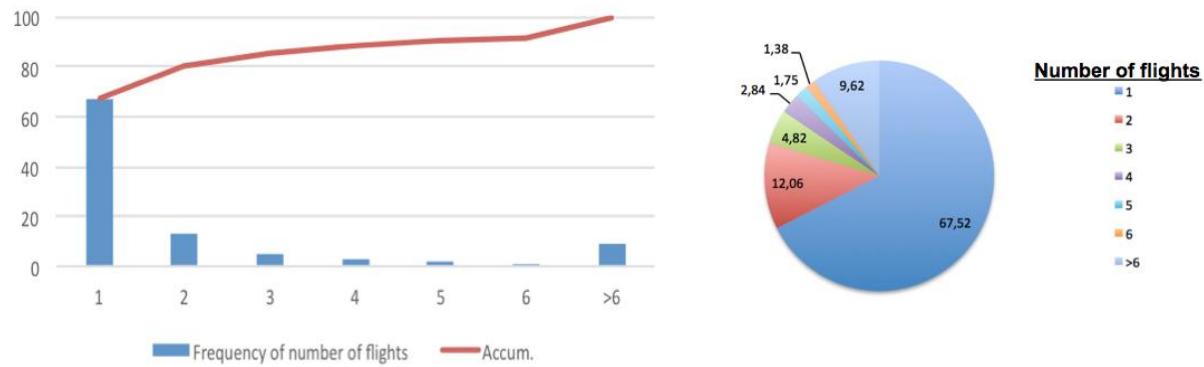
**Figure 38: Delay magnitude distributions (pie and bar charts)**

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**Figure 39: Distribution of delay among the 100 AUs with more regulations****Figure 40: Statistical characterisation (histogram) of regulation durations****Figure 41: Statistical characterisation (box diagram) of regulation durations**



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Figure 42: Frequency of AUs with a certain number of flights in a hotspot (bar and pie charts)

AU code	Max number of flights in a regulation							Total number of regulations per AU	cum_sum	cum_perc
	1	2	3	4	5	6	>6			
EZY	44.072	20.086	9.629	6.695	4.193	2.623	12.701	5795	5795	4.037
RYR	29.801	19.376	12.241	8.588	6.772	4.956	18.265	4681	10476	7.298
DLH	62.103	17.978	5.068	2.042	1.185	0.580	11.044	3966	14442	10.061
VLG	48.172	16.613	6.586	3.602	3.011	1.882	20.134	3720	18162	12.653
BAW	75.656	13.211	3.829	1.422	0.793	0.465	4.623	3656	21818	15.200
SWR	53.859	8.880	2.822	1.245	0.885	1.051	31.259	3615	25433	17.718
THY	39.691	4.460	2.076	1.487	1.234	1.543	49.509	3565	28998	20.202
KLM	87.557	9.829	1.847	0.593	0.105	0.035	0.035	2869	31867	22.200
AFR	69.415	11.769	4.141	1.453	0.872	1.017	11.333	2753	34620	24.118
BER	51.831	15.834	8.176	5.031	3.330	2.368	13.430	2703	37323	26.001
AEE	59.315	18.505	8.438	5.973	2.506	1.671	3.592	2394	39717	27.669
GWI	63.254	18.373	8.002	4.291	2.056	0.805	3.219	2237	41954	29.228
AZA	82.972	7.799	2.261	0.969	0.784	0.138	5.076	2167	44121	30.737
PGT	44.402	5.905	3.118	0.945	0.425	0.425	44.780	2117	46238	32.212
AUA	71.096	8.244	4.607	1.649	0.582	0.727	13.094	2062	48300	33.649
TAP	57.046	14.577	5.782	4.082	2.478	2.041	13.994	2058	50358	35.082
SAS	53.858	18.595	6.627	2.473	2.127	1.830	14.491	2022	52380	36.491
AEA	65.204	15.883	6.426	3.605	2.560	1.985	4.336	1914	54294	37.824
IBE	73.068	8.824	4.095	1.845	1.038	1.730	9.400	1734	56028	39.032
ZZZ	74.263	15.454	5.953	2.886	0.601	0.301	0.541	1663	57691	40.191
EWG	56.543	16.605	7.346	4.012	3.889	2.901	8.704	1620	59311	41.320

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Figure 43: Frequencies of a certain number of flights in a hotspot per AUs (partial data shown)

2462 5.4 Case studies and Simulations

2463 The purpose of the following case studies is to observe the impact of the utilization of FCL in terms of
 2464 how the delay is distributed among the different Airspace Users (AUs) and to find strategies to
 2465 provide higher flexibility to the Low Volume Users in Constraint (LVUCs).

2466 First, a description of the traffic and UDPP measure scenario will be provided.

2467 Second, a description of the cost models and related assumptions and simplifications will be
 2468 presented.

2469 After, the following case studies will be analysed (taking into account the AUs recommendations⁷ and
 2470 requirements):

- 2471 • Case study 1: All the AUs using the FCL system
- 2472 • Case study 2: LVUCs with up to 3 flights in the UDPP measure (single UDPP measure
2473 optimisation)
- 2474 • Case study 3: LVUCs with up to 3 flights in the UDPP measure (multiple UDPP measure
2475 optimisation)
- 2476 • Case study 4: LVUCs with up to 4 flights in the UDPP measure (multiple UDPP measure
2477 optimisation)
- 2478 • Case study 5: All AUs with 6 flights or less can use FCL but only for prioritising up to 3 flights
2479 (multiple UDPP measure optimisation)
- 2480 • Case study 6: All AUs with 6 flights or less can use FCL but MNIT = 6 (multiple UDPP measure
2481 optimisation)

2482 5.4.1 Description of the traffic scenario

2483 The scenario used for the case studies has been previously used in some UDPP validation exercises,
 2484 and has been slightly adapted for the purposes of this new research. It is based on historical traffic
 2485 demand of 96 flights at a coordinated airport from 12:15 to 17:00 approximately. Figure 44 shows
 2486 the available capacity per time period of 15 minutes and also the number of flights for a position in
 2487 the sequence. It is assumed that the nominal capacity (typically set to 40 flights per hour) has been
 2488 dropped to 20 flights per hour. Consequently, the size of the positions in the sequence is 3 minutes.

Period	15'	30'	45'	60'	75'	90'	105'	120'	135'	150'	165'	180'	195'	210'	225'	240'	255'	270'	285'	300'+
Capacity	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1000
Demand	3	7	6	7	11	4	13	7	5	2	2	4	3	4	6	3	4	2	3	13

2490 **Figure 44: Capacity and demand of the airport per periods**

2491 The left part of Figure 45 shows the original demand per period and the constraints of capacity. For
 2492 simplicity, the last period is considered unconstrained. An overloaded period applies between 30'

⁷ Recommendation 2, 'the use of flexible credits (ESFP) by all AUs should be explored, i.e., not limited to the role of LVUCs', and Recommendation 10, 'The compatibility of parallel and concurrent decision-making processes (i.e., different AUs using ESFP simultaneously) should be further explored, since potential incompatibilities among the concurrent prioritisation decisions could arise'.

2493 and 120'. The right of the figure shows the demand after Demand and Capacity Balancing
 2494 regulations. The orange bars depict the displacement of delays affecting the sequence of flights until
 2495 the end of the recovery period of the UDPP measure, i.e., the imbalance ends after period 285' in this
 2496 case.

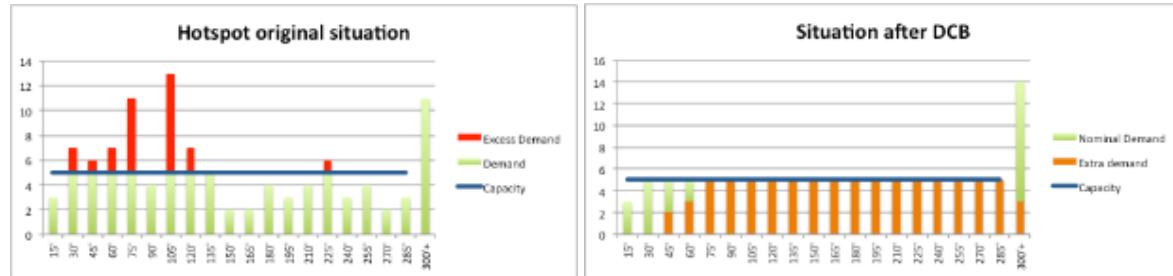


Figure 45: Capacity and demand before Demand and Capacity Balance (left) and after (right)

2499 Figure 46 shows the schedule list after the application of the FPFS policy to the original demand,
 2500 showing the Expected Time of Arrival (ETA) planned for each flight, the new Controlled Time of
 2501 Arrival (CTA) assigned by FPFS policy (CTA FPFS) and the calculated delay; also the new user-
 2502 preferred CTA after the application of FCL prioritizations (UCTA FCL) and the calculated delay. The
 2503 last column shows, for each flight, the difference in the delay allocated by FPFS and FCL mechanisms.
 2504 Note that FCL takes as a baseline the same policy applied at a given airport, in this case FPFS; thus at
 2505 the beginning there is no difference in the baseline delay.

2506

Flights	ETA	CTA FPFS	Baseline delay	UCTA FCL	delay UDPP	Diff. Delays	HUB 761	13:48	14:39	51	14:39	51	0
OA3 5896D	12:16	12:15	0	12:15	0	0	HUB 6242	13:51	14:42	51	14:42	51	0
HUB 8384	12:16	12:18	2	12:18	2	0	HUB 8150	13:51	14:45	54	14:45	54	0
Empty	12:21	12:21	0	12:21	0	0	LC2 2119	13:54	14:48	54	14:48	54	0
LC2 2213	12:26	12:24	0	12:24	0	0	HUB 591	13:55	14:51	56	14:51	56	0
Empty	12:27	12:27	0	12:27	0	0	HUB 5618	14:00	14:54	54	14:54	54	0
HUB 9757	12:31	12:30	0	12:30	0	0	LC2 8387	14:02	14:57	55	14:57	55	0
LC1 311	12:31	12:33	2	12:33	2	0	OA8 8611	14:04	15:00	56	15:00	56	0
HUB 6068	12:36	12:36	0	12:36	0	0	LC2 5206	14:04	15:03	59	15:03	59	0
HUB 5701	12:36	12:39	0	12:39	0	0	LC1 7103	14:06	15:06	60	15:06	60	0
HUB 6612	12:36	12:42	6	12:42	6	0	OA3 2151	14:10	15:09	59	15:09	59	0
HUB 5229	12:38	12:45	7	12:45	7	0	OA8 8667	14:11	15:12	61	15:12	61	0
LC2 6426	12:41	12:48	7	12:48	7	0	LC1 1105	14:16	15:15	59	15:15	59	0
HUB 1988	12:46	12:51	5	12:51	5	0	HUB 3749	14:24	15:18	54	15:18	54	0
OA2 320D	12:49	12:54	5	12:54	5	0	LC2 2373	14:24	15:21	57	15:21	57	0
HUB 4325	12:51	12:57	6	12:57	6	0	LC2 532	14:26	15:24	58	15:24	58	0
LC1 2612	12:51	13:00	9	13:00	9	0	OA5 108	14:26	15:27	61	15:27	61	0
HUB 3422	12:56	13:03	7	13:03	7	0	OA1 192	14:36	15:30	54	15:30	54	0
HUB 8106	12:56	13:06	10	13:06	10	0	OA1 1714	14:41	15:33	52	15:33	52	0
HUB 9359	13:02	13:09	7	13:09	7	0	OA6 7277	14:56	15:36	40	15:36	40	0
HUB 9293	13:03	13:12	9	13:12	9	0	HUB 3535	14:56	15:39	43	15:39	43	0
OA8 6731	13:05	13:15	10	13:15	10	0	HUB 8114	15:06	15:42	36	15:42	36	0
OA5 7270	13:06	13:18	12	13:18	12	0	LC2 6219	15:06	15:45	39	15:45	39	0
HUB 5126	13:06	13:21	15	13:21	15	0	OAB 356	15:08	15:48	40	15:48	40	0
LC1 4740	13:06	13:24	18	13:24	18	0	HUB 6065	15:09	15:51	42	15:51	42	0
HUB 9649	13:07	13:27	20	13:27	20	0	OA6 1107	15:16	15:54	38	15:54	38	0
OAI 5626	13:16	13:30	14	13:30	14	0	HUB 4033	15:16	15:57	41	15:57	41	0
HUB 9173	13:17	13:33	16	13:33	16	0	HUB 8308	15:19	16:00	41	16:00	41	0
HUB 9423	13:18	13:36	18	13:36	18	0	OA1 414	15:31	16:03	32	16:03	32	0
HUB 5366	13:19	13:39	20	13:39	20	0	HUB 6072	15:34	16:06	32	16:06	32	0
HUB 4009	13:19	13:42	23	13:42	23	0	HUB 5723	15:41	16:09	28	16:09	28	0
HUB 8488	13:21	13:45	24	13:45	24	0	HUB 8639	15:42	16:12	30	16:12	30	0
HUB 4025	13:22	13:48	26	13:48	26	0	HUB 5622	15:46	16:15	29	16:15	29	0
HUB 1723	13:26	13:51	25	13:51	25	0	LC1 1844	15:48	16:18	30	16:18	30	0
HUB 5084	13:27	13:54	27	13:54	27	0	OA1 824	15:52	16:21	29	16:21	29	0
HUB 4624	13:28	13:57	29	13:57	29	0	LC2 1052	15:56	16:24	28	16:24	28	0
HUB 1654	13:28	14:00	32	14:00	32	0	HUB 8374	15:56	16:27	31	16:27	31	0
OA8 4205	13:33	14:03	30	14:03	30	0	LC2 9998	15:57	16:30	33	16:30	33	0
HUB 9873	13:34	14:06	32	14:06	32	0	HUB 8498	16:03	16:33	30	16:33	30	0
HUB 3784	13:38	14:09	31	14:09	31	0	HUB 8214	16:06	16:36	30	16:36	30	0
LC2 2413	13:39	14:12	33	14:12	33	0	OA4 8655	16:06	16:39	33	16:39	33	0
HUB 5912	13:46	14:15	29	14:15	29	0	HUB 8635	16:15	16:42	27	16:42	27	0
LC1 1592	13:46	14:18	32	14:18	32	0	HUB 1729	16:15	16:45	30	16:45	30	0
HUB 1746	13:46	14:21	35	14:21	35	0	OA2 101D	16:21	16:48	27	16:48	27	0
LC2 2315	13:46	14:24	38	14:24	38	0							
LC1 6825	13:47	14:27	40	14:27	40	0							
HUB 6434	13:47	14:30	43	14:30	43	0							
OA1 318	13:47	14:33	46	14:33	46	0							
HUB 4321	13:48	14:36	48	14:36	48	0							

Figure 46: Schedule list with ETAs, CTAs and calculated delays

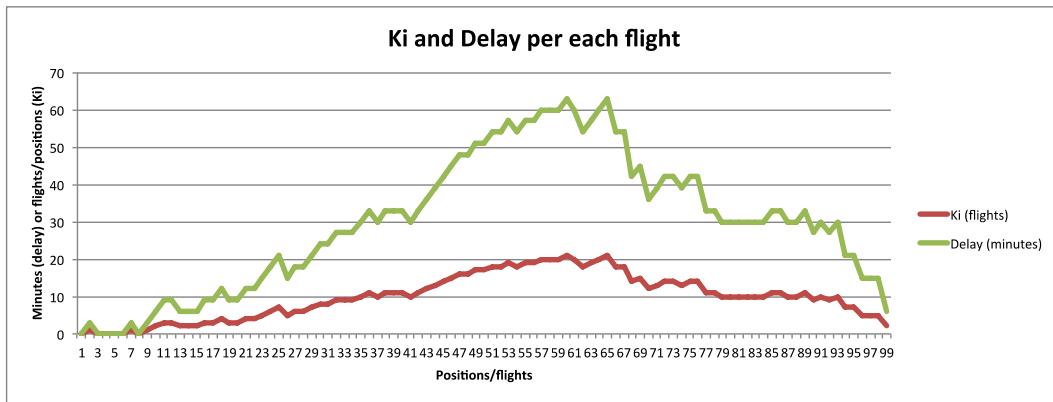
**Figure 47: Ki and delay per flight**

Figure 47 shows the evolution of the delay in the UDPP measure, which is directly correlated with the number of positions, k_i , that a flight i is far from its original position in the sequence (delay is proportional to the number of positions and the size in time of each position in the sequence).

Table 13 shows the distribution of flights and delay per Airspace User. Note that delay is distributed randomly but as a direct proportion of the share of flights. A certain degree of concentration of some flights has been identified after analysing the flight positions, especially for the user HUB and LC2. In this particular case, HUB has many of its flights in positions with low delay and LC2 has the flights concentrated in positions subject to relatively long delay.

Note that some AUs have three or less flights in the sequence; therefore they can be considered as LVUCs.

2521

AU name	Total flights	% of flights	Baseline delay (min.)	% of B.Delay	Baseline Cost (€)	% of B.Costs
HUB	52	54,17%	1316	48,74%	-29283	45,04%
LC1	8	8,33%	248	9,19%	-4735	7,28%
LC2	12	12,50%	421	15,59%	-12471	19,18%
OA1	6	6,25%	227	8,41%	-7178	11,04%
OA2	2	2,08%	27	1,00%	-425	0,65%
OA3	2	2,08%	59	2,19%	-1131	1,74%
OA4	1	1,04%	33	1,22%	-811	1,25%
OA5	3	3,13%	73	2,70%	-2632	4,05%
OA6	4	4,17%	99	3,67%	-1658	2,55%
OA7	0	0,00%	0	0,00%	0	0,00%
OA8	6	6,25%	197	7,30%	-4691	7,22%
		96	2700		-65017	

Table 13: Distribution of flights and delay per AU

2522

2523

2524

5.4.2 Description of the cost model and parameters assumed

It is fundamental to assess the potential benefits or impact of the UDPP mechanism on the AUs, not only in terms of delay but also in terms of costs. It is very difficult at this stage of research maturity to have a precise cost model that can represent to all the AUs in their daily operations. For this reason, a simplified cost model has been taken into account in the simulations. The costs of delay for flights has been modelled with a quadratic function as follows:

2531 $c(d) = \frac{\epsilon}{2} d^2$

2532 Each flight has been randomly parameterised with different sensitivities to delay (a.k.a., elasticity),
 2533 i.e., with different ϵ . The assignation of epsilons/elasticities for each flight has been done randomly
 2534 following a uniform probabilistic distribution bounded within the following range: $\epsilon \in [-2, -0.5]$. All the
 2535 flights had the same probabilities to get any value of elasticity within such range. In practice, it
 2536 means that all the flights were assigned costs as a function of their delay within the maximum and
 2537 minimum ranges illustrated in Table 14.

Minutes of delay	Low cost flight ($\epsilon = -0.5$)	High cost flight ($\epsilon = -2$)
1st minute	0.25€	1€
10 minutes	25€	100€
20 minutes	100€	400€
30 minutes	225€	900€
40 minutes	400€	1600€
50 minutes	625€	2500€
60 minutes	900€	3600€
70 minutes	1225€	4900€

2538 **Table 14: Cost thresholds examples assumed in the simulations**

2539

2540 Such approximation of AUs costs is not fully representative of the high level of complexity of the
 2541 actual cost structures (e.g., different types and sizes of knock-on delay impacts). However, the
 2542 approach is considered valid at this maturity level to observe the potential benefits and impacts of
 2543 the FCL mechanism in the presence of flights and AUs with heterogeneous cost curves. The purpose
 2544 is to early assess the potential feasibility of the FCL concept, to enable the observation of potential
 2545 emergent dynamics, and to start quantifying the potential benefits of flexibility for LVUCs and for all
 2546 AUs.

2547 Table 13 shows the baseline costs per AU. Note that since the elasticities were randomly assigned to
 2548 flights it was already expected that AUs have a similar proportion of costs than delay.

2549 **5.4.3 Case study 1: All the AUs using the FCL system**

2550 The AUs showed interest on exploring the possibility of using FCL for all the AUs, i.e., not only for
 2551 LVUCs. This case study explores such idea.

2552 Figure 48 shows the requested optimal delay changes (τ_{aus}) calculated with UDOM, as well as the
 2553 impact of the delay change on each flight. Note that it has been assumed that the UDPP measure
 2554 starts with flight LC1 2612, a flight that has 9 minutes of delay. Therefore, the AUs cannot use UDPP
 2555 to change the delay of those flights out of the UDPP measure.

2556 Table 15 shows the aggregated impact on the costs per AU. Note that in relative terms all the AUs
 2557 can optimise their costs in similar proportions, and is worthy to point out that the AU with more

2558 potential for cost reduction has only 3 flights (is an LVUC). The potential for cost reduction in this
 2559 scenario for the AUs has been found within the range of approximately 7% up to 36% (average cost
 2560 reduction of around 17%). The potential for cost reduction depends on the cost structure of the
 2561 flights in the UDPP measure, and on the amount of delay allocated by the baseline sequence to each
 2562 of the flights. Also it must be observed that some AUs cannot optimise. Note that OA2 and OA3 have
 2563 indeed just one of their flights in the UDPP measure (the others are out of the UDPP measure), thus
 2564 they cannot exchange delay between their flights. The use of credits with validity over the time could
 2565 be used for giving flexibility to those AUs.

Flights	Baseline delay	Epsilon	Baseline cost	Optimal tau	Delay request	Optimal cost	Diff
OA3 5896D	0	-1,34	0	0	0	0,00	
HUB 8384	2	-1,5	-3	0	2	-3	0,00
Empty	0	-1,85	0	0	0	0,00	
LC2 2213	0	-1,35	0	0	0	0,00	
Empty	0	-1,86	0	0	0	0,00	
HUB 9757	0	-0,51	0	0	0	0,00	
LC1 311	2	-1,55	-3	0	2	-3	0,00
HUB 6068	0	-1,63	0	0	0	0,00	
HUB 5701	0	-0,97	0	0	0	0,00	
HUB 6612	6	-1,69	-30	0	6	-30	0,00
HUB 5229	7	-1,95	-48	0	7	-48	0,00
LC2 6426	7	-0,7	-17	0	7	-17	0,00
HUB 1988	5	-1,39	-17	0	5	-17	0,00
OA2 320D	5	-1,38	-17	0	5	-17	0,00
HUB 4325	6	-1,54	-28	0	6	-28	0,00
LC1 2612	9	-1,44	-58	12	21	-325	-267,06
HUB 3422	7	-1,93	-47	11	18	-298	-250,60
HUB 8106	10	-1,23	-61	18	28	-467	-405,91
HUB 9359	7	-1,31	-32	19	26	-439	-406,77
HUB 9293	9	-1,7	-69	11	20	-338	-269,33
OA8 6731	10	-1,59	-79	16	26	-546	-466,13
OA5 727D	12	-1,19	-86	23	35	-739	-653,18
HUB 5126	15	-1,62	-182	6	21	-355	-172,63
LC1 4740	18	-0,81	-131	20	38	-578	-447,24
HUB 9649	20	-0,88	-176	19	39	-653	-477,31
OA1 5626	14	-1,01	-99	38	52	-1361	-1261,91
HUB 9173	16	-1,02	-131	17	33	-564	-433,08
HUB 9423	18	-1,13	-183	12	30	-509	-325,71
HUB 5366	20	-1,82	-364	-1	19	-316	-48,11
HUB 4009	23	-1,42	-376	1	24	-405	-29,28
HUB 8488	24	-0,71	-204	24	48	-810	-605,25
HUB 4025	26	-1,04	-352	7	33	-553	-201,28
HUB 1723	25	-2	-625	-8	17	-287	337,54
HUB 5084	27	-1,39	-507	-3	24	-414	93,05
HUB 4624	29	-0,58	-244	29	58	-991	-747,34
HUB 1654	32	-1,33	-681	7	25	-432	-248,70
OA8 4205	30	-1,65	-742	-5	25	-526	-216,71
HUB 9873	32	-1,57	-804	-10	22	-366	-437,65
HUB 3784	31	-1,71	-822	-11	20	-336	-485,45
LC2 2413	33	-1,43	-779	2	35	-874	-95,65
HUB 5912	29	-0,87	-366	10	39	-661	-294,98
LC1 1592	32	-0,55	-282	24	56	-852	-570,31
HUB 1746	35	-1,5	-919	-12	23	-383	-535,48
LC2 2315	38	-0,79	-570	25	63	-1583	-1012,18
LC1 6825	40	-1,15	-920	-13	27	-407	512,56
HUB 6434	43	-1,6	-1479	-22	21	-359	-119,88
OA1 318	46	-1,92	-2031	-19	27	-716	-1315,47
HUB 4321	48	-1,12	-1290	-18	30	-513	-776,93
HUB 761	51	-0,51	-663	15	66	-1127	-464,02
HUB 6242	51	-1,05	-1366	-19	32	-548	817,99
HUB 8150	54	-2	-2916	-37	17	-287	2628,54
LC2 2119	54	-0,84	-1225	6	60	-1488	-263,64
HUB 5911	56	-0,61	-956	0	56	-942	14,00
HUB 5618	54	-0,66	-962	-3	51	-871	91,20
LC2 8387	55	-1,12	-1694	-10	45	-1116	577,73
OA8 8611	56	-0,94	-1474	-12	44	-923	550,99
LC2 5206	59	-1,03	-1793	-10	49	-1214	578,91
LC1 7103	60	-0,56	-1008	-5	55	-837	171,30
OA3 2151	59	-0,65	-1131	0	59	-1131	0,00
OA8 8667	61	-0,96	-1786	-18	43	-904	882,38
LC1 1105	59	-0,87	-1514	-24	35	-539	975,67
HUB 3749	54	-1,94	-2829	-37	17	-296	2532,17
LC2 2373	57	-1,14	-1852	-13	44	-1097	755,24
LC2 532	58	-1,2	-2018	-16	42	-1042	976,55
OA5 108	61	-1,28	-2381	-28	33	-687	1694,53
OA1 192	54	-1,33	-1939	-15	39	-1033	905,68
OA1 1714	52	-1,12	-1514	-5	47	-1227	287,01
OA6 7277	40	-1,01	-808	-12	28	-408	400,04
HUB 3535	43	-0,98	-906	-8	35	-587	319,37
HUB 8114	36	-1,94	-1257	-19	17	-296	960,77
LC2 6219	39	-2	-1521	-14	25	-625	895,89
OA8 356	40	-0,72	-576	18	58	-1205	628,93
HUB 6065	42	-0,71	-626	6	48	-810	-183,51
OA6 1107	38	-0,72	-520	2	40	-572	-52,44
HUB 4033	41	-1,07	-899	-9	32	-537	362,03
HUB 8308	41	-0,99	-832	-7	34	-581	251,38
OA1 414	32	-1,75	-896	-2	30	-785	110,57
HUB 6072	33	-1,29	-660	6	26	-446	214,81
HUB 5723	28	-1,19	-466	0	28	-483	-16,64
HUB 8639	30	-0,88	-396	9	39	-653	-257,31
HUB 5622	29	-0,87	-366	10	39	-661	-294,98
LC1 1844	30	-1,82	-819	-13	17	-257	561,55
OA1 824	29	-1,66	-698	3	32	-828	-129,98
LC2 1052	28	-1,82	-713	-1	27	-687	26,50
HUB 8374	31	-1,42	-682	-7	24	-405	277,44
LC2 9998	33	-0,53	-289	32	65	-1120	-831,04
HUB 8489	30	-0,76	-342	15	45	-756	-414,46
HUB 8214	30	-1,4	-630	-6	24	-411	219,35
OA4 8655	33	-1,49	-811	0	33	-811	0,00
HUB 8635	27	-1,29	-470	-1	26	-446	24,54
HUB 1729	30	-0,72	-324	17	47	-795	-471,24
OA2 101D	27	-1,12	-408	0	27	-408	0,00
HUB 5815	30	-1,39	-625	-6	24	-414	211,89
OA6 955	21	-1	-220	8	29	-412	-191,54
OA5 680D	21	-0,75	-165	5	26	-254	-88,13
OA6 2033	14	-1,12	-110	2	16	-143	-33,60
HUB 771	13	-0,8	-68	1	14	-78	-10,80
OA8 8223	11	-0,55	-33	0	11	-33	0,00

2566 2567 Figure 48: Schedule list with delay, costs and optimal delay requested per flight (case study 1)

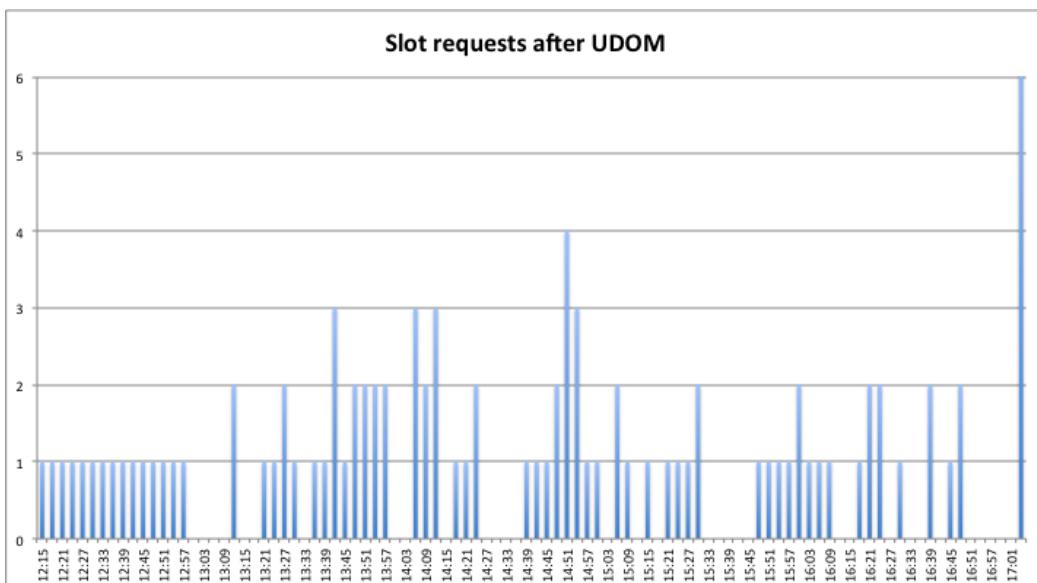
AU name	Total flights	Baseline delay	Baseline cost	Optimal cost	Diff.	% Reduc.
HUB	52	1316	-29283	-23007	6276	21,43%
LC1	8	248	-4735	-3799	936	19,78%
LC2	12	421	-12471	-10863	1608	12,90%
OA1	6	227	-7178	-5951	1227	17,09%
OA2	2	27	-425	-425	0	0,00%
OA3	2	59	-1131	-1131	0	0,00%
OA4	1	33	-811	-811	0	0,00%
OA5	3	73	-2632	-1679	953	36,21%
OA6	4	99	-1658	-1536	122	7,39%
OA7	0	0	0	0	0	0,00%
OA8	6	197	-4691	-4136	555	11,83%
96 2700 -65017 -53339 11678 65017						

2568 2569 Table 15: Potential cost reductions per AU using UDOM (case study 1)

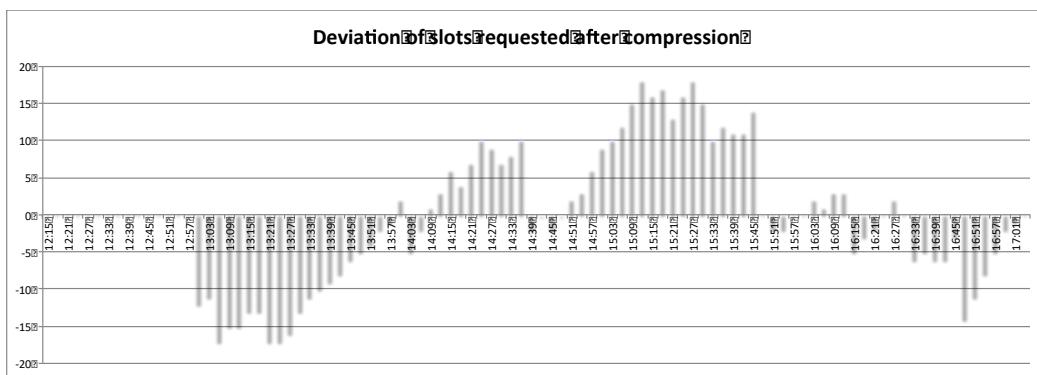
The difficult part of implementing the optimal solutions calculated by UDOM is the interference between the different solutions, which generate emergent complex dynamics that are still not well understood. See in Figure 49 which are the slots demanded by the AUs to optimise their own costs. It can be observed in the figure that the demand is more or less evenly distributed, at least apparently. However, due to the need to allocate one flight to each available sequence position, the flights have been sorted by requested CTA and then they have been compressed to avoid empty slots and optimise capacity.

2577 Figure 50 is an evidence of those emergent complex dynamics, and shows at each sequence position,
 2578 the difference between the allocated position and the one requested. In general, less delay than the
 2579 one requested (negative values in the chart) will have less impact on AUs. In the middle of the
 2580 sequence there are some flights that they wanted less delay and now they are going to be placed
 2581 back again with more delay than requested. Therefore, due to the incompatibilities of the many AUs
 2582 requests, some flights are getting less delay (and less cost) and some more delay (more cost). Table
 2583 16 shows the total effect in the total cost supported by the AUs, while Table 17 shows the new
 2584 distribution of delay per AU. It can be noted that some AUs are worst-off after trying to optimise
 2585 their costs through the FCL mechanism.

2586 **Conclusion:** On the light of these results, it seems quite unlikely that all the AUs can use FCL in its
 2587 current form. With the current system rules, and due to the complex interactions and emergent
 2588 dynamics between the different AUs prioritisations, it cannot be guaranteed that the resulting FCL
 2589 sequence will have a positive or neutral impact on the AUs costs. Further research could be done,
 2590 however, to investigate new strategies that may find good solutions with positive cost reduction for
 2591 all the AUs.



2592
 2593 **Figure 49: Slots requested by AUs after using UDOM (case study 1)**



2594
 2595 **Figure 50: Deviation of slots requested after compression (case study 1)**
 2596

AU name	Baseline cost	Optimal cost	Diff. (optim.-base)	% Reduc.	Actual cost	Diff. (actual - base)	% Reduc.
HUB	-29283	-23007	6276	21,43%	-21624	7659	26,15%
LC1	-4735	-3799	936	19,78%	-4361	374	7,90%
LC2	-12471	-10863	1608	12,90%	-14785	-2314	-18,56%
OA1	-7178	-5951	1227	17,09%	-7999	-821	-11,44%
OA2	-425	-425	0	0,00%	-340	86	20,14%
OA3	-1131	-1131	0	0,00%	-1927	-796	-70,32%
OA4	-811	-811	0	0,00%	-543	268	33,06%
OA5	-2632	-1679	953	36,21%	-1783	849	32,25%
OA6	-1658	-1536	122	7,39%	-1706	-48	-2,91%
OA7						0	#DIV/0!
OA8	-4691	-4136	555	11,83%	-4678	13	0,27%

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2598

Table 16: Effect of sequence compression on the AUs actual costs (case study 1)

AU name	Total flights	Baseline delay	Assigned delay	Difference	Av.Del.
HUB	52	1385	1283	102	26,63
LC1	8	250	259	-9	31,25
LC2	12	461	524	-63	38,42
OA1	6	227	260	-33	37,83
OA2	2	32	29	3	16,00
OA3	2	59	77	-18	29,50
OA4	1	33	27	6	33,00
OA5	3	94	79	15	31,33
OA6	4	113	110	3	28,25
OA7	0	0	0	0	0,00
OA8	6	208	214	-6	34,67
	98	2862	2862	0	

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2602 **5.4.4 Case study 2: LVUCs with up to 3 flights in the UDPP measure (single** 2603 **UDPP measure optimisation)**

2604 In this case study the purpose is to assess the benefits of enabling FLC mechanism only for LVUCs
 2605 that have up to three flights. The impact to others is also assessed. As shown in Figure 51, only OA2,
 2606 OA3, O4 and OA5 are LVUCs in this UDPP measure scenario. Note that OA3 and OA4 have 1 flight
 2607 each in the UDPP measure (OA3 has another flight, but is placed before the UDPP measure), OA2 has
 2608 2 flights and OA5 has 3 flights. In the figure they can be found highlighted with different colours. The
 2609 optimal delay requests found with UDOM for those AUs can be also found in the figure, together
 2610 with the cost variation for those flights.

2611 In this case study only optimisation within the UDPP measure is allowed, i.e., AUs cannot optimise
 2612 their delay throughout multiple UDPP measures. Note that LVUCs with one single flight can do
 2613 nothing in this case to minimise the impact of baseline delay.

2614

Flights	Baseline delay	Epsilon	Baseline cost	Optimal tau	Delay request	Optimal cost	Diff	HUB 761	51	-0.51	-663	0	51	-663	0
OA3 5896D	0	-1.34	0	0	0	0	0	HUB 6242	51	-1.05	-1366	0	51	-1366	0
HUB 8384	2	-1.5	-3	0	2	-3	0	HUB 8150	54	-2	-2916	0	54	-2916	0
Empty	0	-1.85	0	0	0	0	0	LC2 2119	54	-0.84	-1225	0	54	-1225	0
LC2 2213	0	-1.35	0	0	0	0	0	HUB 591	56	-0.61	-956	0	56	-956	0
Empty	0	-1.86	0	0	0	0	0	HUB 5618	54	-0.66	-962	0	54	-962	0
HUB 9757	0	-0.51	0	0	0	0	0	LC2 8387	55	-1.12	-1694	0	55	-1694	0
LC1 311	2	-1.55	-3	0	2	-3	0	OA8 8611	56	-0.94	-1474	0	56	-1474	0
HUB 6068	0	-1.63	0	0	0	0	0	LC2 5206	59	-1.03	-1793	0	59	-1793	0
HUB 5701	0	-0.97	0	0	0	0	0	LC1 7103	60	-0.56	-1008	0	60	-1008	0
HUB 6612	6	-1.69	-30	0	6	-30	0	OA3 2151	59	-0.65	-1131	0	59	-1131	0
HUB 5229	7	-1.95	-48	0	7	-48	0	OA8 8667	61	-0.96	-1786	0	61	-1786	0
LC2 4246	7	-0.7	-17	0	7	-17	0	HUB 1105	59	-0.87	-1514	0	59	-1514	0
HUB 1988	5	-1.39	-17	0	5	-17	0	HUB 3749	54	-1.94	-2892	0	54	-2892	0
OA2 3200	5	-1.38	-17	9	14	-142	-125	LC2 532	57	-1.14	-1852	0	57	-1852	0
HUB 4325	6	-1.54	-28	0	6	-28	0	OA5 108	61	-1.28	-2381	-28	33	-687	1695
LC1 2612	9	-1.44	-58	0	9	-58	0	OA1 192	54	-1.33	-1939	0	54	-1939	0
HUB 3422	7	-1.93	-47	0	7	-47	0	OA1 1714	52	-1.12	-1514	0	52	-1514	0
HUB 8106	10	-1.23	-61	0	10	-61	0	OA6 7277	40	-1.01	-808	0	40	-808	0
HUB 9359	7	-1.31	-32	0	7	-32	0	HUB 3535	43	-0.98	-906	0	43	-906	0
HUB 5293	9	-1.7	-69	0	9	-69	0	HUB 8114	36	-1.94	-1257	0	36	-1257	0
OA8 6731	10	-1.59	-79	0	10	-79	0	LC2 6219	39	-2	-1521	0	39	-1521	0
OA5 2720	12	-1.19	-86	23	35	-739	-653	OA8 356	40	-0.72	-576	0	40	-576	0
HUB 5126	15	-1.62	-182	0	15	-182	0	HUB 6065	42	-0.71	-626	0	42	-626	0
LC1 4740	18	-0.81	-131	0	18	-131	0	OA6 1107	38	-0.72	-520	0	38	-520	0
OA1 5626	14	-1.01	-99	0	14	-99	0	HUB 4033	41	-1.07	-899	0	41	-899	0
HUB 9173	16	-1.02	-131	0	16	-131	0	HUB 8308	41	-0.99	-832	0	41	-832	0
HUB 9423	18	-1.13	-183	0	18	-183	0	OA1 414	32	-1.75	-896	0	32	-896	0
HUB 5366	20	-1.82	-364	0	20	-364	0	HUB 6072	32	-1.29	-660	0	32	-660	0
HUB 4009	23	-1.42	-376	0	23	-376	0	HUB 5723	28	-1.19	-466	0	28	-466	0
HUB 8488	24	-0.71	-204	0	24	-204	0	HUB 8635	30	-0.88	-396	0	30	-396	0
HUB 4025	26	-1.04	-352	0	26	-352	0	LC2 1844	30	-0.87	-366	0	30	-366	0
HUB 1723	25	-2	-625	0	25	-625	0	OA1 824	29	-1.66	-698	0	29	-698	0
HUB 5084	27	-1.39	-507	0	27	-507	0	LC2 1052	28	-1.82	-713	0	28	-713	0
HUB 4624	29	-0.58	-244	0	29	-244	0	HUB 8374	31	-1.42	-682	0	31	-682	0
HUB 1654	32	-1.33	-681	0	32	-681	0	LC2 9998	33	-0.53	-289	0	33	-289	0
OA8 4205	30	-1.65	-742	0	30	-742	0	HUB 8498	30	-0.76	-342	0	30	-342	0
HUB 9873	32	-1.57	-804	0	32	-804	0	HUB 8214	30	-1.4	-630	0	30	-630	0
HUB 3784	31	-1.71	-822	0	31	-822	0	OA4 8655	33	-1.49	-811	0	33	-811	0
LC2 2413	33	-1.43	-779	0	33	-779	0	HUB 8635	27	-1.29	-470	0	27	-470	0
HUB 5912	29	-0.87	-366	0	29	-366	0	HUB 1729	30	-0.72	-324	0	30	-324	0
LC1 1592	32	-0.55	-282	0	32	-282	0	LC2 2373	27	-1.12	-408	-9	18	-175	234
LC2 2315	38	-0.79	-570	0	38	-570	0	OA6 955	21	-1	-220	0	21	-220	0
LC1 6825	40	-1.15	-920	0	40	-920	0	OA5 6800	21	-0.75	-165	5	26	-254	-88
HUB 6434	43	-1.6	-1479	0	43	-1479	0	OA6 2033	14	-1.12	-110	0	14	-110	0
OA1 318	46	-1.92	-2031	0	46	-2031	0	HUB 771	13	-0.8	-68	0	13	-68	0
HUB 4321	48	-1.12	-1290	0	48	-1290	0	OA8 8223	11	-0.55	-33	0	11	-33	0

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Figure 51: Schedule list with delay, costs and optimal delay requested per flight (case study 2)

AU name	Total flights	Baseline delay	Assigned delay	Difference	Variation
HUB	52	1385	1375	10	0,72%
LC1	8	250	250	0	0,00%
LC2	12	461	470	-9	-1,95%
OA1	6	227	224	3	1,32%
OA2	2	32	32	0	0
OA3	2	59	62	-3	-5,08%
OA4	1	33	33	0	0
OA5	3	94	92	2	2,13%
OA6	4	113	110	3	2,65%
OA7	0	0	0	0	0,00%
OA8	6	208	214	-6	-2,88%
	96	2862	2862	0	

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Table 18: Effect of sequence compression on the distribution of delay (case study 2)

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AU name	Baseline cost	Optimal cost	Diff. (optim. - base)	% Reduc. (optim. - base)	Actual cost	Diff. (actual - base)	% Reduc. (actual - base)
HUB	-29283	-29283	0	0,00%	-29438	-155	-0,53%
LC1	-4735	-4735	0	0,00%	-4924	-189	-3,99%
LC2	-12471	-12471	0	0,00%	-13072	-601	-4,82%
OA1	-7178	-7178	0	0,00%	-7140	38	0,53%
OA2	-425	-317	109	25,61%	-330	95	22,34%
OA3	-1131	-1131	0	0,00%	-1249	-118	-10,43%
OA4	-811	-811	0	0,00%	-811	0	0,00%
OA5	-2632	-1679	953	36,21%	-1622	1010	38,38%
OA6	-1658	-1658	0	0,00%	-1616	42	2,53%
OA7							
OA8	-4691	-4691	0	0,00%	-5033	-342	-7,29%

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Table 19: Effect of sequence compression on the AUs actual costs (case study 2)

Figure 52 shows the changes in the sequence after the implementation of the LVUCs requests. It can be observed that the maximum impact on individual flights of other AUs has been of 3 minutes (the size of one sequence position).

Table 18 shows the aggregated impact on the delay of the different AUs, which on the light of the figures it can be considered as negligible impact. Note as well that OA2 and OA5 have in practice the same delay as the baseline.

In terms of costs Table 19 shows that OA2 and OA5 could optimise their costs close to what they expected during the optimisation process (UDOM), i.e., a 22.34% of cost reduction for OA2 (who optimised for a 25.61% cost reduction) and a 38.38% cost reduction for OA6 (who aimed at reducing the cost in 36.21%).

Regarding the impact on the rest of the AUs, some relatively small variations can be observed. It must be pointed out that variation of 1-2% of cost could be considered as very huge impacts in reality, however to interpret the results of this simulation exercises it must be reminded that flights typically operate with some tolerances that makes the flight costs to be typically not so sensitive to an extra minute of delay (the quadratic cost structure is probably not representing well the impact to others). In addition, it is assumed that the AUs that are not LVUCs may participate in FDR/SFP features of UDPP, thus optimising their costs and most likely compensating the relatively small impacts from LVUCs.

Conclusion: The FCL feature seems to be a good mechanism to give access for LVUCs with more than 1 flight in a UDPP measure. For those LVUCs with 1 flight the access to UDPP through multiple UDPP measures might be necessary to guarantee access and equity of UDPPs. For a reduced number of LVUCs using the FCL the expected impact to other AUs is considered negligible (to be confirmed with AUs).

2648 5.4.5 Case study 3: LVUCs with up to 3 flights in the UDPP measure (multiple 2649 UDPP measure optimisation)

2650 To illustrate the impact of LVUCs optimising over the time (multiple UDPP measures) let us consider
2651 that the OA3 and OA4 can reduce the delay of their flights because they did efforts in other UDPP
2652 measures (i.e., they increase their delay, thus reducing the delay to flights of other AUs). In the paper
2653 of Appendix A the reader can find how the UDOM can be adapted to optimise the costs of operations
2654 by managing delay over the time across multiple UDPP measure.

2655 For the purpose of this case study, let us assume that in the same situation as shown in previous case
2656 study 2, the LVUCs OA3 and OA4 want to reduce the delay of their flights in 18 minutes each (6
2657 sequence positions in this UDPP measure scenario). It is assumed that proportional efforts were
2658 done by such AUs in the past to have the right for reducing their delay in this occasion.

2659 Figure 53 shows the new sequence situation after the implementation of all the LVUCs requests. It
2660 can be noted that in this case a maximum delay impact of 6 minutes has been found in some flights
2661 (the flight of OA3 and the flight OA5 108 overcome the same three flights, thus generating an impact
2662 of two sequence positions, i.e., 6 minutes in this UDPP measure).

2663 Table 20 show similar figures as in case study 2 for delay and cost impacts. The impact on delay
2664 caused by LVUCs using FCL could be considered negligible, whereas the impact to other in terms of
2665 costs is not conclusive due to the simplifications done in the cost curves of flights. OA2 and OA5
2666 could still optimise their costs in the same order as calculated by UDOM. OA3 and OA4 are assumed
2667 to reduce their total –over the time– costs in the same order as OA2 and OA5 (information of costs in
2668 past UDPP measures is needed to conclude on the overall cost reduction for OA3 and OA4).

2669 Conclusion: **The impact of LVUCs (up to 3 flights in a UDPP measure) using FCL with optimisation
2670 over multiple UDPP measures has been found negligible in contrast to the benefits it can
2671 potentially bring. According to the results of the statistical analysis (Table 12) most of the AUs are
2672 LVUCs quite often, therefore the AUs impacted in this given UDPP measure scenario can potentially
2673 be benefited from the FCLs feature in other UDPP measures (besides the fact that in the given UDPP
2674 measure scenario they could use the FDR/SFP features, that shall compensate the small impact
2675 generated by LVUCs. The statistical characterisation of UDPP measures also showed that this UDPP
2676 measure scenario used in the simulations is not very far from the typical UDPP measure in terms of
2677 duration, severity and number of AUs and LVUCs affected; therefore, it is supposed a certain degree
2678 of extrapolation of the results to other UDPP measure situations.**

2679

Flights	ETA	CTA FPFS	Baseline delay	UCTA FCL	Delay UDPP	Diff. Delays	HUB 761	13:48	14:39	51	14:39	51	0
DA3 5896D	12:16	12:15	0	12:15	0	0	HUB 6242	13:51	14:42	51	14:42	51	0
HUB 8384	12:16	12:18	2	12:18	2	0	HUB 8150	13:51	14:45	54	14:45	54	0
Empty	12:21	12:21	0	12:21	0	0	LC2 2119	13:54	14:48	54	14:48	54	0
LC2 2213	12:26	12:24	0	12:24	0	0	HUB 591	13:55	14:51	56	14:51	56	0
Empty	12:27	12:27	0	12:27	0	0	DA3 2151	14:10	15:09	59	14:54	44	15
HUB 9757	12:31	12:30	0	12:30	0	0	HUB 5618	14:00	14:54	54	14:57	57	-3
LC1 311	12:31	12:33	2	12:33	2	0	LC2 8387	14:02	14:57	55	15:00	58	-3
HUB 6068	12:36	12:36	0	12:36	0	0	OAS 108	14:26	15:27	61	15:03	37	24
HUB 5701	12:36	12:39	0	12:39	0	0	OAS 8611	14:04	15:00	56	15:06	62	-6
HUB 6612	12:36	12:42	6	12:42	6	0	LC2 5206	14:04	15:03	59	15:09	65	-6
HUB 5229	12:38	12:45	7	12:45	7	0	LC1 7103	14:06	15:06	60	15:12	66	-6
LC2 6426	12:41	12:48	7	12:48	7	0	OAS 8667	14:11	15:12	61	15:15	64	-3
HUB 1988	12:46	12:51	5	12:51	5	0	LC1 1105	14:16	15:15	59	15:18	62	-3
HUB 4325	12:51	12:57	6	12:54	3	3	HUB 3749	14:24	15:18	54	15:21	57	-3
LC1 2612	12:51	13:00	9	12:57	6	3	LC2 2373	14:24	15:21	57	15:24	60	-3
DA2 3200	12:49	12:54	5	13:00	11	-6	LC2 532	14:26	15:24	58	15:27	61	-3
HUB 3422	12:56	13:03	7	13:03	7	0	OAI 192	14:36	15:30	54	15:30	54	0
HUB 8106	12:56	13:06	10	13:06	10	0	OAI 1714	14:41	15:33	52	15:33	52	0
HUB 9359	13:02	13:09	7	13:09	7	0	OAE 7277	14:56	15:36	40	15:36	40	0
HUB 9293	13:03	13:12	9	13:12	9	0	HUB 3535	14:56	15:39	43	15:39	43	0
OAS 6731	13:05	13:15	10	13:15	10	0	HUB 8114	15:06	15:42	36	15:42	36	0
HUB 5126	13:06	13:21	15	13:18	12	3	LC2 6219	15:06	15:45	39	15:45	39	0
LC1 4740	13:06	13:24	18	13:21	15	3	OAS 356	15:08	15:48	40	15:48	40	0
HUB 9649	13:07	13:27	20	13:24	17	3	HUB 6065	15:09	15:51	42	15:51	42	0
OA1 5626	13:16	13:30	14	13:27	11	3	OAE 1107	15:16	15:54	38	15:54	38	0
HUB 9173	13:17	13:33	16	13:30	13	3	HUB 4033	15:16	15:57	41	15:57	41	0
HUB 9423	13:18	13:36	18	13:33	15	3	HUB 8308	15:19	16:00	41	16:00	41	0
HUB 5366	13:19	13:39	20	13:36	17	3	OAI 414	15:31	16:03	32	16:03	32	0
OA5 7270	13:06	13:18	12	13:39	33	-21	HUB 6072	15:34	16:06	32	16:06	32	0
HUB 4009	13:19	13:42	23	13:42	23	0	HUB 5723	15:41	16:09	28	16:09	28	0
HUB 8488	13:21	13:45	24	13:45	24	0	HUB 8639	15:42	16:12	30	16:12	30	0
HUB 4025	13:22	13:48	26	13:48	26	0	HUB 5622	15:46	16:15	29	16:15	29	0
HUB 1723	13:26	13:51	25	13:51	25	0	LC1 1844	15:48	16:18	30	16:18	30	0
HUB 5084	13:27	13:54	27	13:54	27	0	OA4 8655	16:06	16:39	33	16:21	15	18
HUB 4624	13:28	13:57	29	13:57	29	0	OAI 824	15:52	16:21	29	16:24	32	-3
HUB 1654	13:28	14:00	32	14:00	32	0	LC2 1052	15:56	16:24	28	16:27	31	-3
OAS 4205	13:33	14:03	30	14:03	30	0	HUB 8374	15:56	16:27	31	16:30	34	-3
HUB 9873	13:34	14:06	32	14:06	32	0	LC2 9998	15:57	16:30	33	16:33	36	-3
HUB 3784	13:38	14:09	31	14:09	31	0	HUB 8498	16:03	16:33	30	16:36	33	-3
LC2 2413	13:39	14:12	33	14:12	33	0	HUB 8214	16:06	16:36	30	16:39	33	-3
HUB 5912	13:46	14:15	29	14:15	29	0	OA2 101D	16:21	16:48	27	16:42	21	6
LC1 1592	13:46	14:18	32	14:18	32	0	HUB 8635	16:15	16:42	27	16:45	30	-3
HUB 1746	13:46	14:21	35	14:21	35	0	HUB 1729	16:15	16:45	30	16:48	33	-3
LC2 2315	13:46	14:24	38	14:24	38	0	HUB 5815	16:21	16:51	30	16:51	30	0
LC1 6825	13:47	14:27	40	14:27	40	0	OAS 955	16:33	16:54	21	16:54	21	0
HUB 6434	13:47	14:30	43	14:30	43	0	OAE 2033	16:46	17:00	14	16:57	11	3
OAI 318	13:47	14:33	46	14:33	46	0	HUB 771	16:48	17:01	13	17:00	12	1
HUB 4321	13:48	14:36	48	14:36	48	0	OA5 6800	16:36	16:57	21	17:01	25	-4

Figure 53: Impact of LVUC decision-making on the sequence and on the delay of flights (case study 3)

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AU name	Total flights	Baseline delay	Assigned delay	Difference	Variation
HUB	52	1385	1387	-2	-0,14%
LC1	8	250	253	-3	-1,20%
LC2	12	461	482	-21	-4,56%
OA1	6	227	227	0	0,00%
OA2	2	32	32	0	0
OA3	2	59	44	15	25,42%
OA4	1	33	15	18	54,55%
OA5	3	94	95	-1	-1,06%
OA6	4	113	110	3	2,65%
OA7	0	0	0	0	0,00%
OA8	6	208	217	-9	-4,33%
	96	2862	2862	0	

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Table 20: Effect of sequence compression on the distribution of delay (case study 3)

AU name	Baseline cost	Optimal cost	Diff. (optim. - base)	% Reduc. (optim. - base)	Actual cost	Diff. (actual - base)	% Reduc. (actual - base)
HUB	-29283	-29283	0	0,00%	-29890	-607	-2,07%
LC1	-4735	-4735	0	0,00%	-5033	-297	-6,27%
LC2	-12471	-12471	0	0,00%	-13674	-1203	-9,65%
OA1	-7178	-7178	0	0,00%	-7292	-114	-1,59%
OA2	-425	-317	109	25,61%	-330	95	22,34%
OA3	-1131	-1131	0	0,00%	-629	502	44,38%
OA4	-811	-811	0	0,00%	-168	644	79,34%
OA5	-2632	-1679	953	36,21%	-1758	874	33,20%
OA6	-1658	-1658	0	0,00%	-1616	42	2,53%
OA7	-4691	-4691	0	0,00%	-5204	-513	-10,93%

2686

2687

Table 21: Effect of sequence compression on the AUs actual costs (case study 3)

2688 5.4.6 Case study 4: LVUCs with up to 4 flights in the UDPP measure (multiple 2689 UDPP measure optimisation)

2690 In this case study the definition of LVUC is changed, allowing AUs with up to 4 flights to be
2691 considered as LVUC and therefore be able to participate in FCL. In this case the slots requests of OA6
2692 has been added to the previous results shown in case study 3 (incremental approach). The following
2693 figures show the impact on the other AUs in terms of delay and cost. In this case the impact has only
2694 roughly varied for OA1, which in terms of delay has only received 6 minutes more of extra delay.
2695 Again no single flight was impacted with more than 6 minutes of extra delay. However, it must be
2696 pointed out that the optimal delay exchange calculated by UDOM for OA6 only involved the
2697 exchange of delay between two of the OA6's flights, which means that in practice the OA6 behaved
2698 as an LVUC with two flights.

2699 **Conclusion:** Is not conclusive if the definition of LVUC can be extended to AUs having up to four
2700 flights in a UDPP measure. Further research is needed.

AU name	Total flights	Baseline delay	Assigned delay	Difference	Variation
HUB	52	1385	1387	-2	-0,14%
LC1	8	250	253	-3	-1,20%
LC2	12	461	482	-21	-4,56%
OA1	6	227	227	0	0,00%
OA2	2	32	32	0	0
OA3	2	59	44	15	25,42%
OA4	1	33	15	18	54,55%
OA5	3	94	95	-1	-1,06%
OA6	4	113	110	3	2,65%
OA7	0	0	0	0	0,00%
OA8	6	208	217	-9	-4,33%
	96	2862	2862	0	

2701
2702 **Table 22: Effect of sequence compression on the distribution of delay (case study 4)**
2703

AU name	Baseline cost	Optimal cost	Diff. (optim.-base)	% Reduc.	Actual cost	Diff. (actual - base)	% Reduc.
HUB	-29283	-29283	0	0,00%	-29847	-564	-1,93%
LC1	-4735	-4735	0	0,00%	-5033	-297	-6,27%
LC2	-12471	-12471	0	0,00%	-13674	-1203	-9,65%
OA1	-7178	-7178	0	0,00%	-7693	-515	-7,18%
OA2	-425	-317	109	25,61%	-330	95	22,34%
OA3	-1131	-1131	0	0,00%	-629	502	44,38%
OA4	-811	-811	0	0,00%	-168	644	79,34%
OA5	-2632	-1679	953	36,21%	-1689	943	35,82%
OA6	-1658	-1536	122	7,39%	-1605	53	3,18%
OA7							
OA8	-4691	-4691	0	0,00%	-5204	-513	-10,93%

2704
2705 **Table 23: Effect of sequence compression on the AUs actual costs (case study 4)**

2706 5.4.7 Case study 5: All AUs with 6 flights or less can use FCL but only for 2707 prioritising up to 3 flights (multiple UDPP measure optimisation)

2708 In this case study the number of LVUCs available in the scenario is augmented with a double purpose:
2709 a) to check a potential new FCL rule that could allow AUs with up to 6 flights to use FCL to protect up
2710 to 3 flights; and b) to observe what is the effect in equity of augmenting the number of LVUCs in a
2711 UDPP measure.

2712 Following figures show an impact on delay and costs that in some cases are notably larger than in the
 2713 case study 3 (4 LVUCs instead of 6). In addition, a maximum impact of time of up to 9 minutes was
 2714 observed in the sequence.

2715 **Conclusion:** The total number of flights that can use FCL in a UDPP measure must be controlled
 2716 carefully, because if the number of LVUCs in a UDPP measure is large, then the number of flights
 2717 using FCL may be large as well, even if each LVUC has only three flights or less in the UDPP measure.
 2718 Further research is needed to determine which is the maximum number of flights prioritised with FCL
 2719 in a UDPP measure (possibly related also to how close those flights are in the sequence).

AU name	Total flights	Baseline delay	Assigned delay	Difference	Variation
HUB	52	1385	1354	31	2,24%
LC1	8	250	259	-9	-3,60%
LC2	12	461	503	-42	-9,11%
OA1	6	227	239	-12	-5,29%
OA2	2	32	32	0	0
OA3	2	59	47	12	20,34%
OA4	1	33	15	18	54,55%
OA5	3	94	94	0	0,00%
OA6	4	113	114	-1	-0,88%
OA7	0	0	0	0	0,00%
OA8	6	208	205	3	1,44%
	96	2862	2862	0	

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 2722

Table 24: Effect of sequence compression on the distribution of delay (case study 5)

AU name	Baseline cost	Optimal cost	Diff. (optim. - base)	% Reduc. (optim. - base)	Actual cost	Diff. (actual - base)	% Reduc. (actual - base)
HUB	-29283	-29283	0	0,00%	-29701	-418	-1,43%
LC1	-4735	-4735	0	0,00%	-5477	-742	-15,67%
LC2	-12471	-12471	0	0,00%	-14608	-2138	-17,14%
OA1	-7178	-5980	1198	16,69%	-6628	550	7,66%
OA2	-425	-317	109	25,61%	-330	95	22,34%
OA3	-1131	-1131	0	0,00%	-718	413	36,54%
OA4	-811	-811	0	0,00%	-168	644	79,34%
OA5	-2632	-1679	953	36,21%	-1884	748	28,42%
OA6	-1658	-1536	122	7,39%	-1713	-55	-3,31%
OA7							
OA8	-4691	-4301	390	8,32%	-4222	469	9,99%

2723
 2724

Table 25: Effect of sequence compression on the AUs actual costs (case study 5)

2725 5.4.8 Case study 6: All AUs with 6 flights or less can use FCL but MNIT = 6 2726 (multiple UDPP measure optimisation)

2727 Solutions that are found inequitable could possibly be balanced in favour of higher levels of equity
 2728 while the cost efficiency gains are still possible. In this case study all the AUs with 6 flights or less (i.e.,
 2729 from OA1 to OA8) could use FCL for prioritising all of their flights. The maximum negative impact of
 2730 time (MNIT) allowed was set to 6 minutes (MNIT=6). If any flight is impacted more, the closest flight
 2731 that took earlier positions in the sequence will be placed in the nearest position after the flights
 2732 impacted. In this scenario a correction was needed for flight OA5 108, which was placed 3 positions
 2733 later than requested, thus avoiding big impacts on individual flights.

2734 **Conclusion:** The number of interactions has clearly grown, whereas it is less clear whether the impact
 2735 could be acceptable from the point of view of equity. New advanced strategies and rules could
 2736 perhaps be researched to mitigate the impact on LC1 and LC2 while preserving the efficiency.
 2737 Compared to the case study 5, this case study presents less impact to non-LVUCs, even when there
 2738 are more flights interacting and generating impact to others. With additional constraints the LVUCs
 2739 does not have so big cost reductions as in e.g., case study 3, however, they may still have some

2740 benefits. Further research is needed to fully understand the complex dynamics of such a complex
 2741 system and to conclude whether FCL or similar mechanisms could be used by more AUs.

AU name	Total flights	Baseline delay	Assigned delay	Difference	Variation	Av.Delay
HUB	52	1385	1354	31	0,29%	27
LC1	8	250	256	-6	-1,20%	31
LC2	12	461	494	-33	-4,56%	38
OA1	6	227	239	-12	-2,64%	38
OA2	2	32	32	0	0,00%	16
OA3	2	59	47	12	25,42%	29
OA4	1	33	15	18	54,55%	33
OA5	3	94	100	-6	3,19%	31
OA6	4	113	114	-1	-0,88%	28
OA7	0	0	0	0	0,00%	0
OA8	6	208	211	-3	-4,33%	35
	96	2862	2862	0		

2742

2743

Table 26: Effect of sequence compression on the distribution of delay (case study 6)

AU name	Baseline cost	Optimal cost	Diff. (optim.-base)	% Reduc.	Actual cost	Diff. (actual - base)	% Reduc.
HUB	-29283	-29283	0	0,00%	-29623	-340	-1,16%
LC1	-4735	-4735	0	0,00%	-5198	-463	-9,77%
LC2	-12471	-12471	0	0,00%	-14403	-1932	-15,49%
OA1	-7178	-5951	1227	17,09%	-6642	536	7,47%
OA2	-425	-317	109	25,61%	-330	95	22,34%
OA3	-1131	-1131	0	0,00%	-718	413	36,54%
OA4	-811	-811	0	0,00%	-168	644	79,34%
OA5	-2632	-1679	953	36,21%	-2238	395	15,00%
OA6	-1658	-1536	122	7,39%	-1634	24	1,45%
OA7							
OA8	-4691	-4136	555	11,83%	-4375	317	6,75%

2744

2745

2746

Table 27: Effect of sequence compression on the AUs actual costs (case study 6)

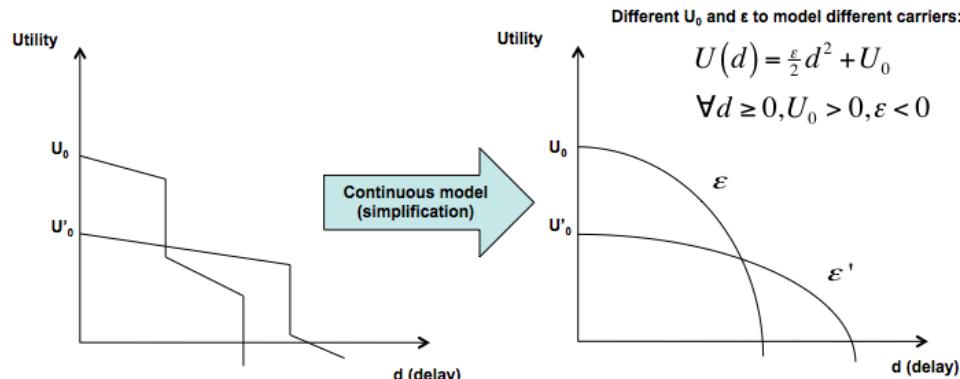
2747 6 Limitations of the Research and 2748 Identification of Future Work

2749 The body of evidence presented is considered valid for the current level of maturity of the FCL
2750 concept. However, for further developments of the concept in higher maturity levels, the following
2751 aspects should be sooner or later further developed:

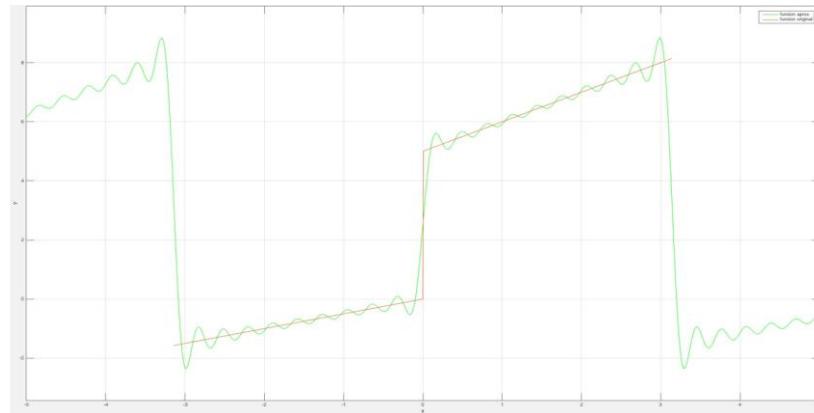
- 2752 • Mathematical representation of the utility or delay cost functions for flights
- 2753 • User delay-cost optimisation model (UDOM)
- 2754 • FCL exchange rate between credits and minutes of delay
- 2755 • FCL merging rules
- 2756 • Proof of equity based on fast-time simulations
- 2757 • Uncertainty and dynamicity of the UDPP measure severity
- 2758 • Other potential concept improvements and case studies

2759 6.1 Mathematical representation of the utility or delay cost 2760 functions for flights

2761 Regarding the mathematical representation of the utility or cost functions, in this research it has
2762 been modelled as a continuous quadratic function, as it can be observed in Figure 54. For future
2763 research, it could be useful to explore alternative continuous models, e.g., any shape of cost function
2764 can be de-composed by Fourier-Legendre transformation and represented as a sum of continuous
2765 sinusoidal components. See for instance the Figure 55 in which a discrete function is shown
2766 (representing typical cost models in real operations) and its continuous approximation is superposed.
2767 The continuous approximation has been found by Fourier-Legendre transformation computing the
2768 fundamental frequency with the Fourier-Legendre method ($f_0 = 1/30$ Hz in this case), taking the 20
2769 first harmonics (Figure 56), building the sinusoidal signals with their corresponding amplitudes and
2770 harmonic frequencies (Figure 57), and adding up such signals to reconstruct the continuous
2771 approximation (Figure 55). Note that with more harmonics the approximation will be even closer to
2772 the discrete cost curve.

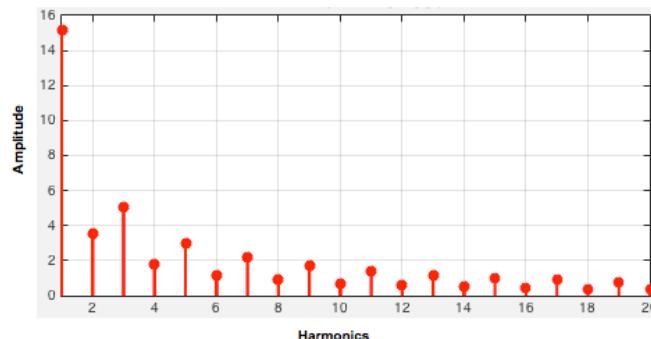


2773 2774 **Figure 54: Approximation of the utility function as a continuous quadratic function**
2775



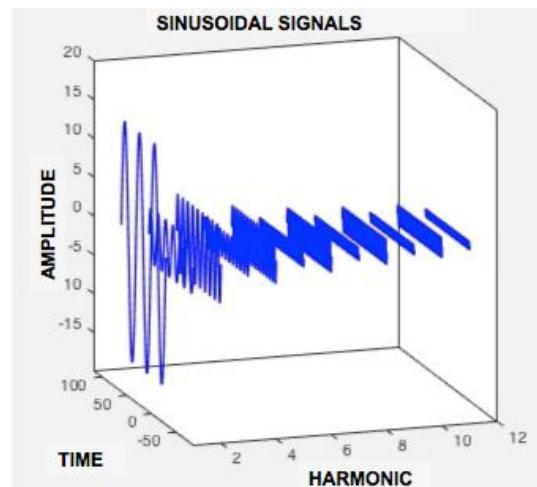
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Figure 55: Representation of a –realistic– discrete cost function (red line) and its continuous approximation with 20 harmonics (green line)



2780
2781

Figure 56: Amplitude of the 20 first harmonics calculated to transform the discrete cost curve



2782
2783
2784

Figure 57: Sinusoidal signals with their corresponding amplitudes and frequencies whose sum can reconstruct the continuous approximation of the cost model

2785 6.2 User delay-cost optimisation model (UDOM)

2786 The UDOM model used in this research is based on the use of the parabolic approximation. In this
2787 research this simplified model has been useful to explore some of the fundamental aspects of the
2788 FCL, for instance to understand the dominant strategies of the AUs, to observe non-linear

relationships between the delay and cost of delay, as well as to be able to perform early fast-time simulations emulating the LVUCs optimised decision-making. However, if the cost model is updated towards a more realistic representation, then the simplified UDOM presented in this research needs to be updated as well, accordingly to the new type of cost models. Among the foreseen options for further research, there is the possibility to model the cost curves as non-smooth functions (with shifts), and therefore a new discrete optimisation model should be developed (typically less efficient and potentially non-feasible for relatively large problems), or well to build an advanced smooth approximation function as shown above and use advanced non-linear optimisation methods. Some powerful mathematical approaches might be found in the field *spectral methods*.

6.3 FCL exchange rate between credits and minutes of delay

Another potential improvement identified, also related with the FCL rules, is the possibility to apply a different exchange rate between credits and minutes of delay. In this research, 1 DC = 1 minute of delay, however, the optimisation models could be updated with a exchange rate that could depend on the position in the sequence of a flight under optimisation. For instance, in positions with higher delay it is expected that more AUs would like to reduce their delay, therefore reducing one minute of delay should possibly be more expensive than in positions in which the delay is lower. Correspondingly, increasing a minute of delay in positions with low delay should be rewarded with less credits that in positions in which the delay is relatively larger. Note that the simplified UDOM could be adapted to that dynamic exchange rate if new constraints are added to the model. This would avoid unfair exchange of delay between flights that have small delay in favour of the ones with large delay.

6.4 FCL merging rules

Another aspect of this research that has been found as affecting largely to the results is the FCL merging rules, i.e., the methodology and principles applied during the combination of the AU's UDPP requests. It is believed that if this merging problem is further studied new interesting and relevant knowledge could be found regarding the possibility to extend the use of FCL to non-LVUCs AUs (i.e., to extend the possibility to exchange sequence positions among all the AUs and over the time), which could provide much more flexibility and consequently a better ATM quality of service for all the AUs.

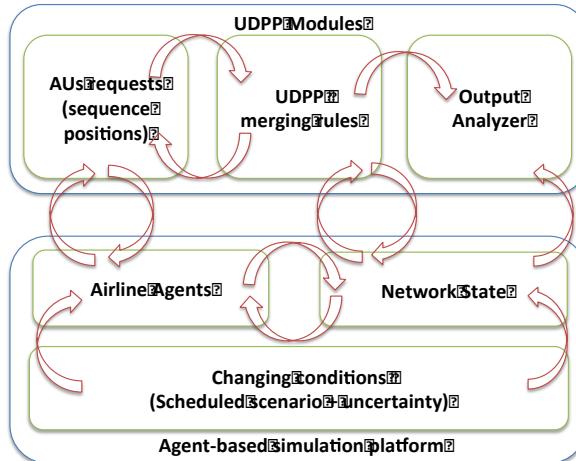
6.5 Proof of equity based on fast-time simulations

Also, an agent based simulation platform (see Figure 58) should be developed (or configured) as soon as the concept reaches higher maturity levels to facilitate the analysis of several UDPP features being used in parallel by different AUs, and possibly at different airports, to proof the equity over time, the potential network effects, and the compatibility/feasibility of the de-centralised cooperative decision-making approach.

Finally, to proof equity over the time in a robust and confident way, a large set of realistic scenarios over a large period (e.g., two years), should be explored to develop the required evidence. However, generating a set of realistic scenarios that can represent the situation of all the AUs during congested situations, including the complex dynamics and relationships between fleet management and costs, is a task vastly difficult that requires a lot of efforts. The data obtained from DDR2 could be a starting

2829 point, but the preparation of such data as input scenarios for the UDPP simulator is neither trivial nor
 2830 direct. This will be proposed therefore as key point of a Validation Strategy.

2831



2832
 2833 **Figure 58: Simulation platform architecture**
 2834
 2835

2836 **6.6 Uncertainty and dynamicity of the UDPP measure severity**

2837 For the sake of simplicity the uncertainty and dynamicity of the UDPP measure severities have not
 2838 been considered. However, this aspect is of vital importance for any UDPP feature (e.g., what happen
 2839 with the prioritisations made by AUs if the capacity constrained situation gets more constraining?)
 2840 and therefore should be addressed at some point in the future.

2841

2842

2843 **6.7 Other potential concept improvements and case studies**

2844 The following features and rules could be explored in future research:

- 2845 • Explore how the '**slot overload**' concept accepted today in operations could be used
 2846 occasionally to enable flight prioritisations that otherwise could not be possible (e.g., due to
 2847 MNIT reached for flights in front one LVUC trying to reduce his delay).
- 2848 • Explore the idea of allocating '**NM slots**' (**empty positions**) **at the beginning of the UDPP**
 2849 **measure and/or every certain 'x' number of positions**. Such positions would belong to the
 2850 DCB and the baseline FPFS sequence would be applied to all the flights while respecting the
 2851 slots that DCB reserved. The purpose of these slots would be to use them in case that some
 2852 AUs need to protect and no feasible positions are available (e.g., flights in front have reached
 2853 their MNIT). In case that the empty slots are not used, the DCB could apply compression in
 2854 the sequence, thus reducing the delay for every flight after such empty positions.

2855 In addition to FCL, LVUCs could still have access to FDR/SFP features by grouping together in a
 2856 voluntarily basis and operating as a single operator through a virtual flight operation centre (V-
 2857 FOC). Such approach would respect equity out of the V-FOC (i.e., LVUCs could exchange their own
 2858 slots without generating impact to others), but two major questions should be addressed in future
 2859 research to guarantee that the access to LVUCs through V-FOCs is effective in practice: a) is such
 2860 mechanism flexible enough when the different LVUCs in a V-FOC all want to reduce their delay?; and
 2861 b) how the equity can be preserved within the VFOC over the time? Such last question is an internal
 2862 private aspect of the AUs grouping in a V-FOC, but if a pragmatic way of coordination for AUs in a V-
 2863 FOC is not foreseen, the concept of V-FOC could not work in practice and thus the actual access
 2864 supposedly given to LVUCs would be not effective.

2865

2866 7 Conclusions and Recommendations

2867 7.1 Conclusions

2868 In this research the following conclusions⁸ about Flexible Credits for LVUCs (FCL) have been reached:

- 2869 1. The FCL concept can be considered **partial V1**, although the concept might still be at V0
2870 maturity in some parts.
- 2871 2. FCL mechanism has shown good properties to **give effective access for LVUCs to UDPP**. In
2872 particular it has been found that:
 - 2873 a. An LVUC can find for each of his flights the **optimal amount of delay** minutes that
2874 should be increased or decreased in order to minimise his total costs.
 - 2875 b. An LVUC can obtain **delay credits** by accepting extra delay (amount of extra delay
2876 controlled/decided by the LVUC) and use the credits in the same UDPP measure (if
2877 the LVUC has more than one flight) or save the credits and use them in future UDPP
2878 measures (i.e., LVUCs are able to optimise their operations over the time).
 - 2879 c. The **FCL rules are simple** and the level of coordination required is very efficient, so
2880 the LVUCs and the rest of the AUs can concentrate on optimising their own
2881 operations.
 - 2882 d. Early evidence showed that with the FCL baseline rules and principles, **equity could
2883 be preserved over the time**. The number of flights being prioritised with FCL in a
2884 UDPP measure and the maximum negative impact allowed per flight are key
2885 parameters to be defined to control de equity.
- 2886 3. FCL has been thought to **coexist with other UDPP features such as FDR or SFP**, among
2887 others, in a way that every AU can get the same levels of Quality of Service (QoS) from the
2888 ATM, i.e., efficiency, predictability, and flexibility. FCL can fulfil the need for giving access to
2889 all the AUs (Access & Equity KPA). Nevertheless, additional research is required to study
2890 equity, fairness and efficiency in the cases where the target positions requested by LVUCs
2891 that use FCL could enter in competition with the requests of other AUs that may use other
2892 UDPP features.
- 2893 4. A **robust proof of equity over the time is estimated to be a costly and complex task** (e.g.,
2894 the generation of representative UDPP measure scenarios), which might be necessary to
2895 further develop the access for LVUC at higher the maturity stages of the concept cycle.
2896 Further research is therefore required to fine-tune the FCL mechanism and rules, as well as
2897 to prove equity over the time in a robust way.
- 2898 5. **Realistic cost function should be agreed with AUs** to approximate the cost of delay of flights
2899 of the baseline delay, or the marginal cost –higher or lower– generated as a consequence of
2900 the AUs own decisions, or other AUs' decisions.

⁸ See also in Appendix C the conclusions of previous research together with some updating comments from the perspective and knowledge acquired in this new research.

- 2901 6. **Significant cost reductions and more stable schedules are expected** for AUs using FCL (using
 2902 simplified quadratic cost curve approximations typical values of 20%-30% cost reductions
 2903 were observed; even larger cost reductions are expected if realistic non-smooth cost curves
 2904 were used, due to the significantly different elasticities of cost curves before and after the
 2905 operational margins of a same flight).
- 2906 7. **All AUs are often LVUCs** in the 85% of the UDPP measures where some of their flights are
 2907 affected. All AUs could be potentially benefited directly from participating in FCL in UDPP
 2908 measures in which they could be considered as LVUCs. Different rules could be applied for
 2909 AUs that are always LVUCs (e.g., a Business Aviation company with only one or two aircraft).

2910

2911 7.2 Recommendations

2912 Proving the equity is something complex for advanced concepts such as FCL, where some AUs can
 2913 take the sequence positions of other AUs and compensate them, directly or indirectly, in the same or
 2914 in other UDPP measures over the time. Even if a certain degree of inequity is allowed (i.e., MNIT per
 2915 flight) and the number of flights using FCL in a UDPP measure is limited, a robust proof of equity over
 2916 the time is not trivial to generate. See in the paper in [38] about the discussion about flexibility vs
 2917 equity. Further research must be therefore conducted in such direction. The recommended steps
 2918 are:

- 2919 1. **FDR/SFP should be used in a UDPP measure instead of FCL for AUs that are non-LVUCs,**
 2920 since FDR/SFP features can guarantee full equity over the time ('equity' understood as no
 2921 negative impact to others).
- 2922 2. **FCL could be recommended as a mechanism to give access for LVUCs to UDPP.** FCL can
 2923 provide high flexibility to LVUCs and according to the evidence shown in this document, the
 2924 equity could be controlled by fine-tuning the set of rules that limit the number of flights in a
 2925 UDPP measure and the maximum negative time impact allowed per flight (MNIT).
- 2926 3. All the AUs –even the largest airlines– are often LVUCs in many regulations that occur every
 2927 day. **The possibility to include all the AUs –irrespective to the number of flights operated**
 2928 per day– **when they are LVUCs in a UDPP measure is recommended**, since it may contribute
 2929 to reduce the cost for all the AUs, and possibly increase the predictability and robustness of
 2930 fleet schedules (e.g., for a hub carrier a single flight delayed in a remote/non-hub airport
 2931 could have a knock-on impact on the hub connections and cause disruption on the full-day
 2932 operations). **Special rules may apply for AUs that are always LVUCs**, e.g., Business Aviation.
- 2933 4. The number of flights that determines whether an AU can be considered an LVUC (and thus
 2934 have access to FCL) is still not clearly determined. However, according to the evidence
 2935 generated in this research, **3 flights could be recommended as a starting point to determine**
 2936 **whether an AU is an LVUC in a UDPP measure.** Such value could potentially be increased in
 2937 the future if advanced FCL rules are further developed to control the equity aspects.
- 2938 5. **Further research is needed to determine the MNIT parameter and the number of flights**
 2939 **that can use FCL in a UDPP measure.** An early recommendation for these values is: **MNIT=6**
 2940 and a **10% of flights to be allowed for using FCL in a UDPP measure.** According to the
 2941 statistical evidence, such parameterisation could introduce enough flexibility for LVUCs in
 2942 typical UDPP measures, while the impact to others is expected to be negligible (and most

2943 likely compensated by the situations in which the impacted AUs are LVUCs in other UDPP
 2944 measures).

- 2945 6. In addition to FCL, **LVUCs could still have access to FDR/SFP features by grouping together**
 2946 **in a voluntarily basis and operating as a single operator through a virtual flight operation**
 2947 **centre (V-FOC)**. Such approach would respect equity out of the V-FOC (i.e., LVUCs could
 2948 exchange their own slots without generating impact to others), but two major questions
 2949 should be addressed in future research to guarantee that the access to LVUCs through V-
 2950 FOCs is effective in practice: a) is such mechanism flexible enough when the different LVUCs
 2951 in a V-FOC all want to reduce their delay?; and b) how the equity can be preserved within the
 2952 VFOC over the time? Such last question is an internal private aspect of the AUs grouping in a
 2953 V-FOC, but if a pragmatic way of coordination for AUs in a V-FOC is not foreseen, the concept
 2954 of V-FOC could not work in practice and thus the actual access supposedly given to LVUCs
 2955 would be not effective.
- 2956 7. Further research should **study in detail the integration/complementarity of FCL and**
 2957 **FDR/SFP**, in particular **to identify potential incompatibilities** (e.g., should MNIT be allowed
 2958 when a certain flight has been protected by a non-LVUC?) and how to rule such cases to
 2959 reach a good trade-off between flexibility, equity and fairness.
- 2960 8. To enhance equity and fairness in FCL a **different 'value' should be assigned to the minutes**
 2961 **of delay given or taken to others** by the LVUCs: the level of delay at the original and
 2962 requested sequence positions of their flights should be taken into consideration, since the
 2963 marginal cost of allocating one minute of extra delay to flight with large delay may be higher
 2964 than for flights with low level of delay. In practice, it means that **reducing delay in sequence**
 2965 **positions where the delay is high would require more efforts from flights that are**
 2966 **increasing their delay in positions in the sequence where the delay is low**. The same idea
 2967 can be applied to exchange credits **across different UDPP measures**.
- 2968 9. To generate further evidence for the FCL and UDPP business cases **the cost model and**
 2969 **optimisation model used in this research should be updated** towards more realistic flight
 2970 cost structures.
- 2971 10. To generate a robust proof of equity over the time, **more effort must be dedicated to**
 2972 **develop validation scenarios** (more difficult to demonstrate equity in the long-term). To
 2973 build the scenarios, keep building them with the help of **DDR2**, or try **commercial databases**
 2974 (**obtained via ADS-B tracks**) **such as FlightAware or FlightRadar24**. **Rotation information** is
 2975 not today in the DDR2, and it is important to provide in the future strong evidence about the
 2976 reactionary delays, the impact of delay on AUs operations, and to build more advanced
 2977 models.
- 2978 11. The following features and rules could be explored in future research:
 - 2979 a. Explore how the '**slot overload**' concept accepted today in operations could be used
 2980 occasionally to enable flight prioritisations that otherwise could not be possible (e.g.,
 2981 due to MNIT reached for flights in front one LVUC trying to reduce his delay).
 - 2982 b. Explore the idea of allocating '**NM slots**' (**empty positions**) **at the beginning of the**
 2983 **UDPP measure and/or every certain 'x' number of positions**. Such positions would
 2984 belong to the DCB and the baseline FPFS sequence would be applied to all the flights
 2985 while respecting the slots that DCB reserved. The purpose of these slots would be to
 2986 use them in case that some AUs need to protect and no feasible positions are
 2987 available (e.g., flights in front have reached their MNIT). In case that the empty slots

2988 are not used, the DCB could apply compression in the sequence, thus reducing the
2989 delay for every flight after such empty positions.

2990 **12. New performance indicators are needed to measure flexibility and equity.** DCB/NM should
2991 possibly use visible information revealed by the AUs with the request and preferences
2992 indications. If the UDPP solutions found are close to the AUs request, then they may be
2993 considered **efficient**. DCB may be also interested in measuring **reactionary delay**, in case it
2994 could lead to further inefficiencies, traffic unpredictability and capacity problems.

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