




Exploring UDPP Concepts through Computational Behavioural Economics

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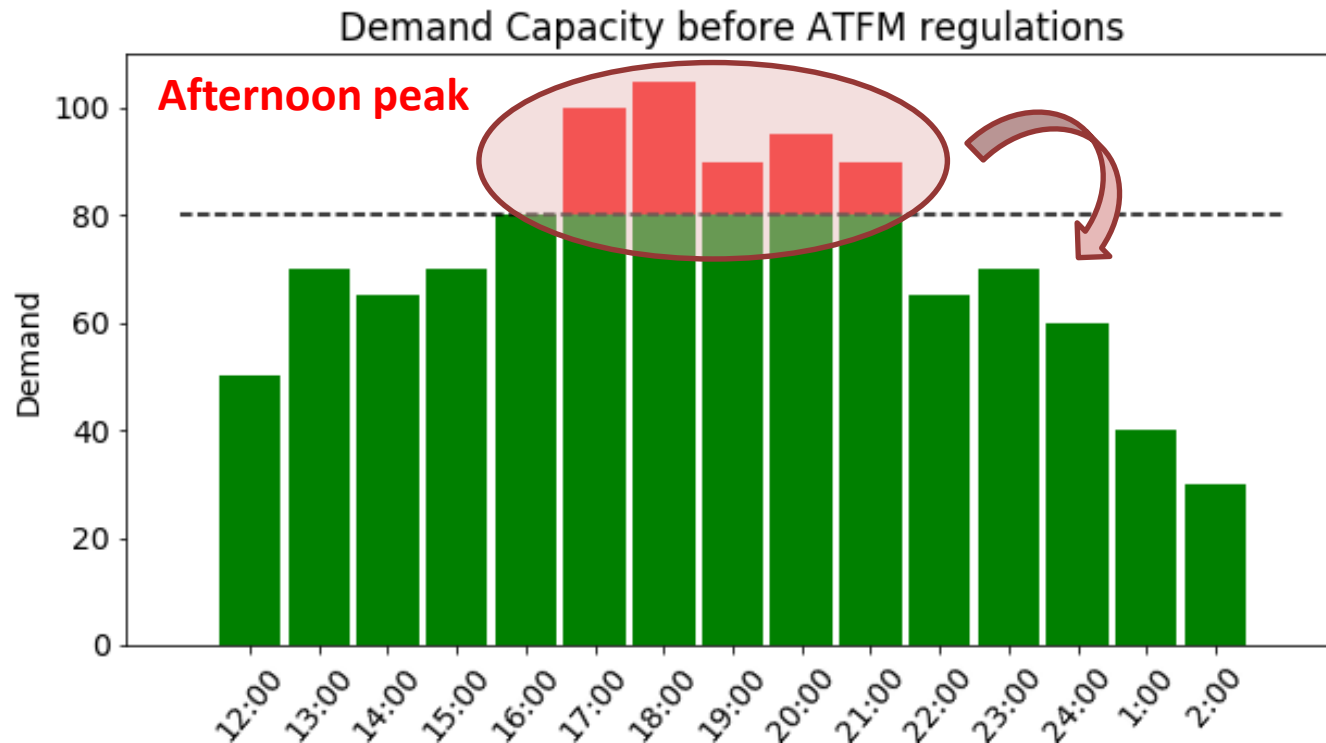
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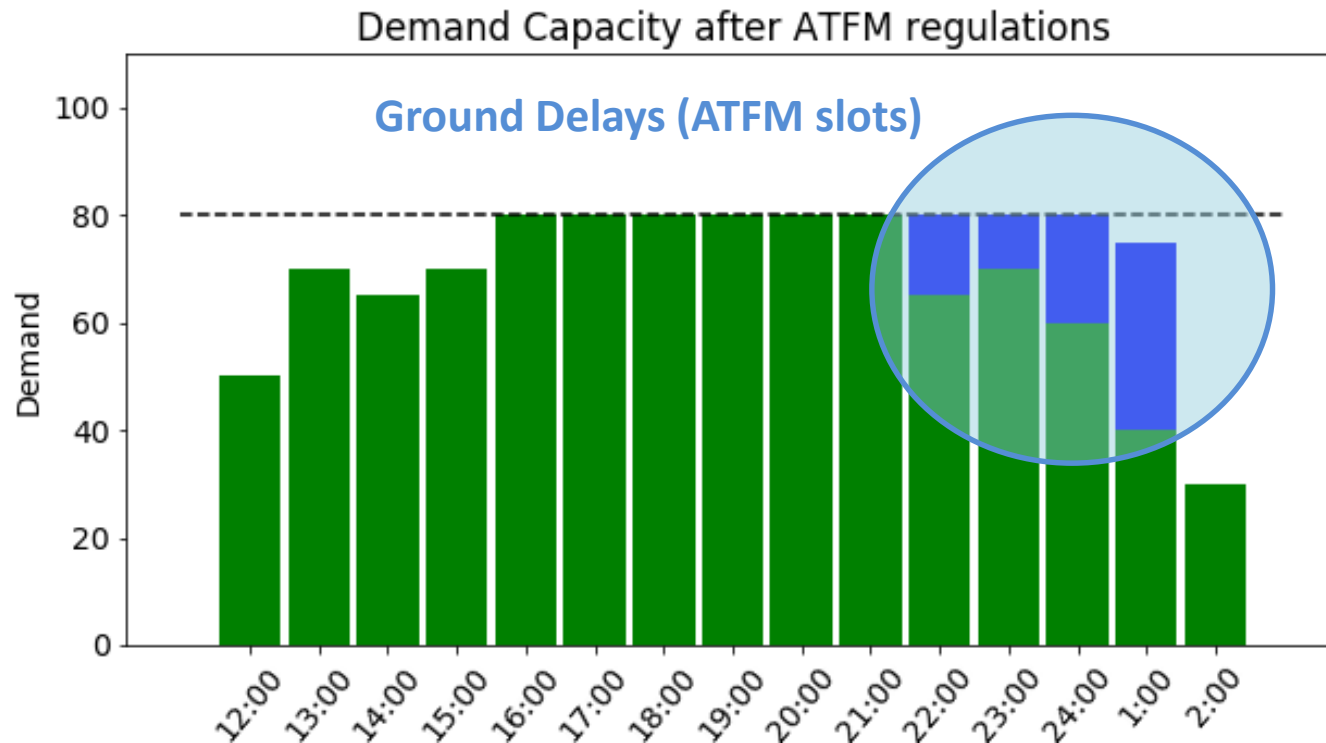
Background and Motivation

Demand - Capacity problem



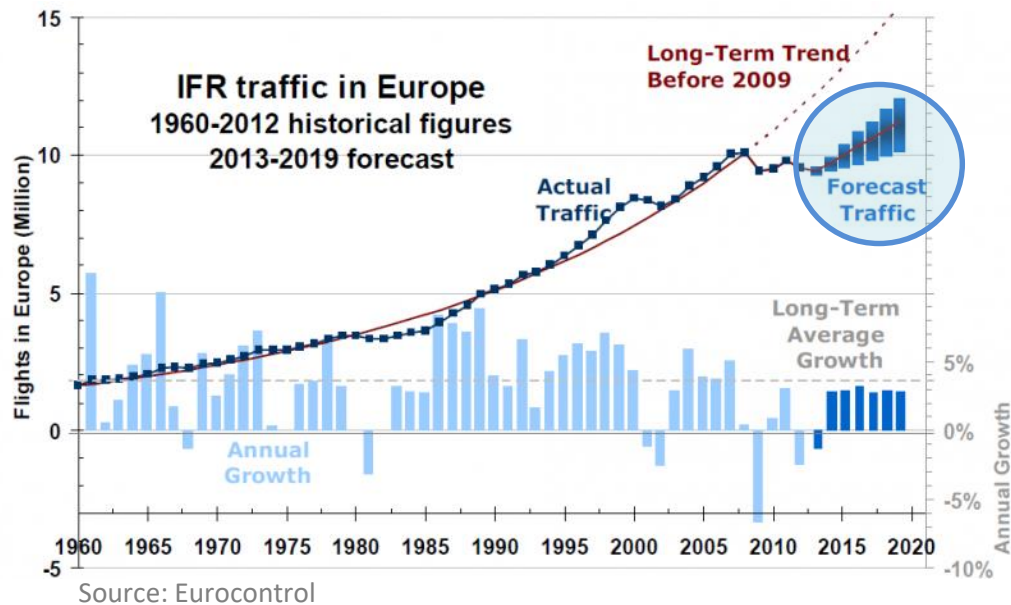
- When demand exceeds the declared capacity of an airspace sector or airport the Network Manager (EUROCONTROL) issues an **ATFM regulation**.

Demand - Capacity problem



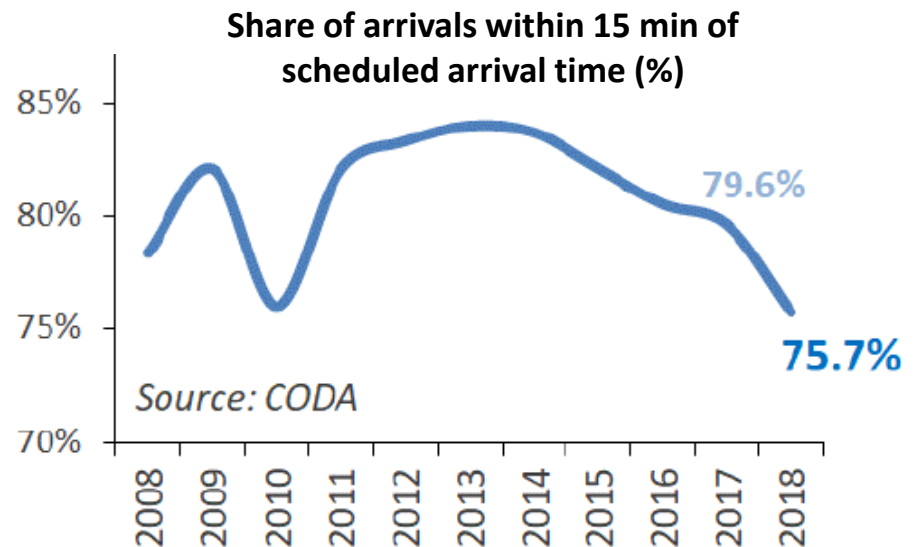
- The regulation imposes **ground delays** to Airspace Users and redistributes the flow maintaining the required safety levels

Delays in European Aviation

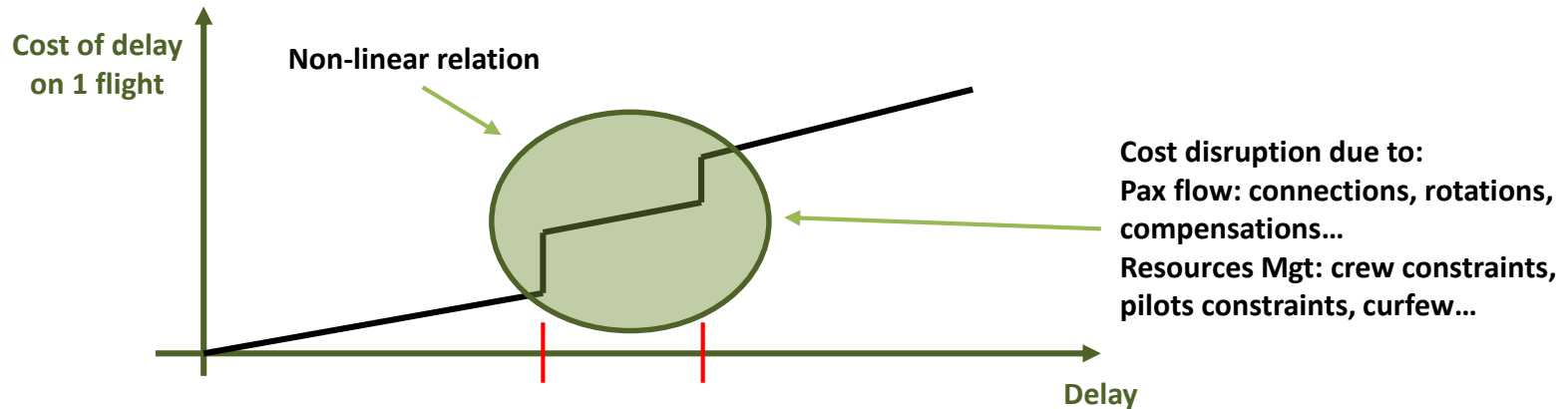


- **Demand** is expected to keep raising
- **ATC capacity** is constrained by operational limits

- 2018: fifth consecutive year that punctuality has fallen
- 2019: situation has worsened



Cost of delay for AU



AUs need more flexibility to adapt their operations in situations of demand capacity imbalances in order to decrease the cost of delay

➤ How can Airspace Users deal with delays to reduce cost?

Prioritization mechanisms have been developed to provide AUs with tools to reorganize their flights in a hotspot and reduce the cost of delay



SESAR User Driven Prioritization Process (UDPP)

Objectives and Approach

Objectives

- The goal of the project is the evaluation of advanced flight **prioritization mechanisms** in the context of **demand and capacity imbalances** through **Computational Behavioural Economics (CBE)**
- The proposed research methodology comprises four main stages:
 1. Development of an adequate performance assessment framework
 2. Identification of potential tactical slot and trajectory prioritization mechanisms.
 3. Development of an agent-based model following the CBE paradigm
 4. Simulation experiments and analysis of results

Prioritization Mechanisms

Current Concept of Operations

First Plan First Served: the Network Manager sequences the flights according to the flights' Estimated Time Over (ETO) the specific sector or airport (Ration By Schedule, RBE)

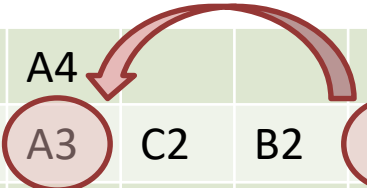
Hotspot (Baseline delay)														
Original	A1	A2	C1	B1	A3	C2	B2	A4			X1			X3
FPFS	A1		A2		C1		B1	A3	C2	B2	A4	X1		X3
Delay	0		1		2		3	3	3	3	3	1		

- **Advantages:** Preserves equity and minimizes total delay
- **Disadvantages:** Does not minimize total cost of delay (non-linearity)

Slot Swapping before SESAR UDPP

Exchange ATFM slots between flights of the same airlines affected by the same regulation.

Hotspot (Baseline delay)													
Original	A1	A2	C1	B1	A3	C2	B2	A4			X1		X3
FPFS	A1		A2		C1		B1	A3	C2	B2	A4	X1	X3
Delay	0		1		2		3	3	3	3	3	1	



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FPFS	A1		A2		C1		B1	A4	C2	B2	A3	X1		X3
Delay	0		1		2		3	0	3	3	6	1		

The swapping capability is subject to many limitations and could be extended to provide more flexibility to AUs

SESAR UDPP

- The **User Driven Prioritisation Process (UDPP)** is a SESAR initiative to provide AUs with additional flexibility to adjust their operations in a more cost-efficient manner in the presence of unforeseen demand and capacity imbalances that require the application of ATFM delays
 - **Step1:** Enhanced Slot Swapping (ESS)
 - **Step2:** Selective Flight Protection (SFP), Fleet Delay Reordering (FDR)
- UDPP is under development since 2012
 - Enhanced Slot Swapping (ESS) is already deployed
 - Fleet Delay Reordering (FDR) and Selective Flight Protection (SFP) were validated earlier in 2019

UDPP Enhanced Slot Swapping (ESS)

This concept is intended to upgrade the current slot swapping procedure by means of improving the flexibility to react to imposed delay:

1) ATFM Pre-Allocated Slot Swap

2) Multi-Swap of ATFM Slots

3) Substitution on Cancellation

4) Most Penalising Delay

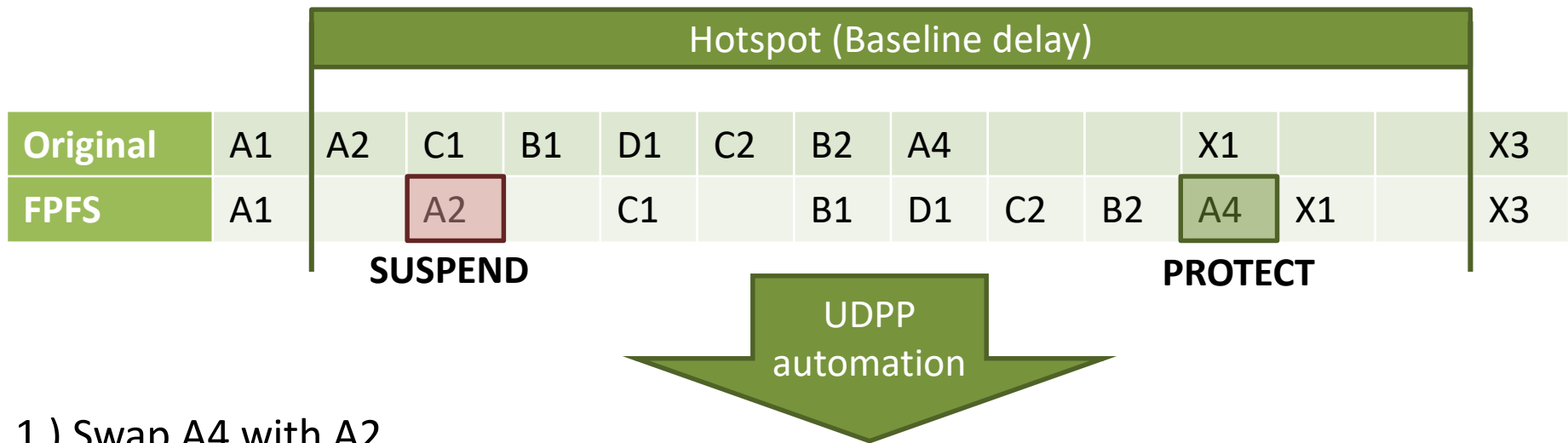
Use Case: Multi-Swap of ATFM Slots

Flight	CTO		Flight	CTO
AFR1620	10:30		AFR547	10:30
DAL219	10:35		DAL219	10:35
AAL41	10:40		AAL41	10:40
AFR547	10:45		AFR1620	10:45
EZY645	10:50		EZY645	10:50
RAE264	10:55		RAE264	10:55
SWR647	11:00		SWR647	11:00

Flight	CTO		Flight	CTO
AFR547	10:30		AFR547	10:30
DAL219	10:35		DAL219	10:35
AAL41	10:40		AAL41	10:40
AFR1620	10:45		RAE264	10:45
EZY645	10:50		EZY645	10:50
RAE264	10:55		AFR1620	10:55
SWR647	11:00		SWR647	11:00

UDPP Selective Flight Protection (SFP)

Concept based on the Ration by Effort (RBE) principle.



1) Swap A4 with A2



2) Put A4 at the first slot at schedule



Positive impact for C1, B1 and D1, A4 on time

UDPP Fleet Delay Reordering (FDR)

- Gives AUs the ability to redistribute the total delay imposed by a regulation
- AUs can reassign the imposed delay among their flights assigning numbers from 1 to 9

Hotspot (Baseline delay)													
Original	A1	A2	C1	B1	A3	C2	B2	A4			X1		X3
FPFS	A1		A2		C1		B1	A3	C2	B2	A4	X1	X3
Delay	0		1		2		3	3	3	3	3	1	
Priority			<u>B</u>					9			1		

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FPFS	A1		A2		C1		B1	A3	C2	B2	A4	X1	X3
Delay	0		1		2		3	3	3	3	3	1	
Priority			B					9			1		
UDPP automation													
FDA Seq.	A1		A2		C1		B1	A4	C2	B2	A3	X1	
FDA Delay	0		1		2		3	0	3	3	6	1	

Monetary Market Mechanisms

Due to the intrinsic nature of the flight prioritization concept it appears fairly reasonable to consider some kind of market mechanism to define it.

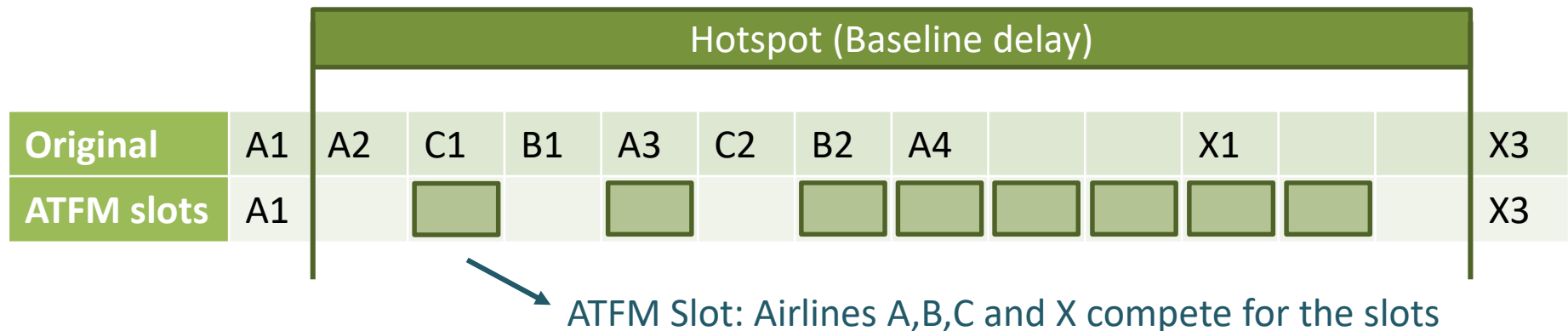
Prioritization by Auction

Congestion Pricing

Route Contracts

Prioritization by Auction

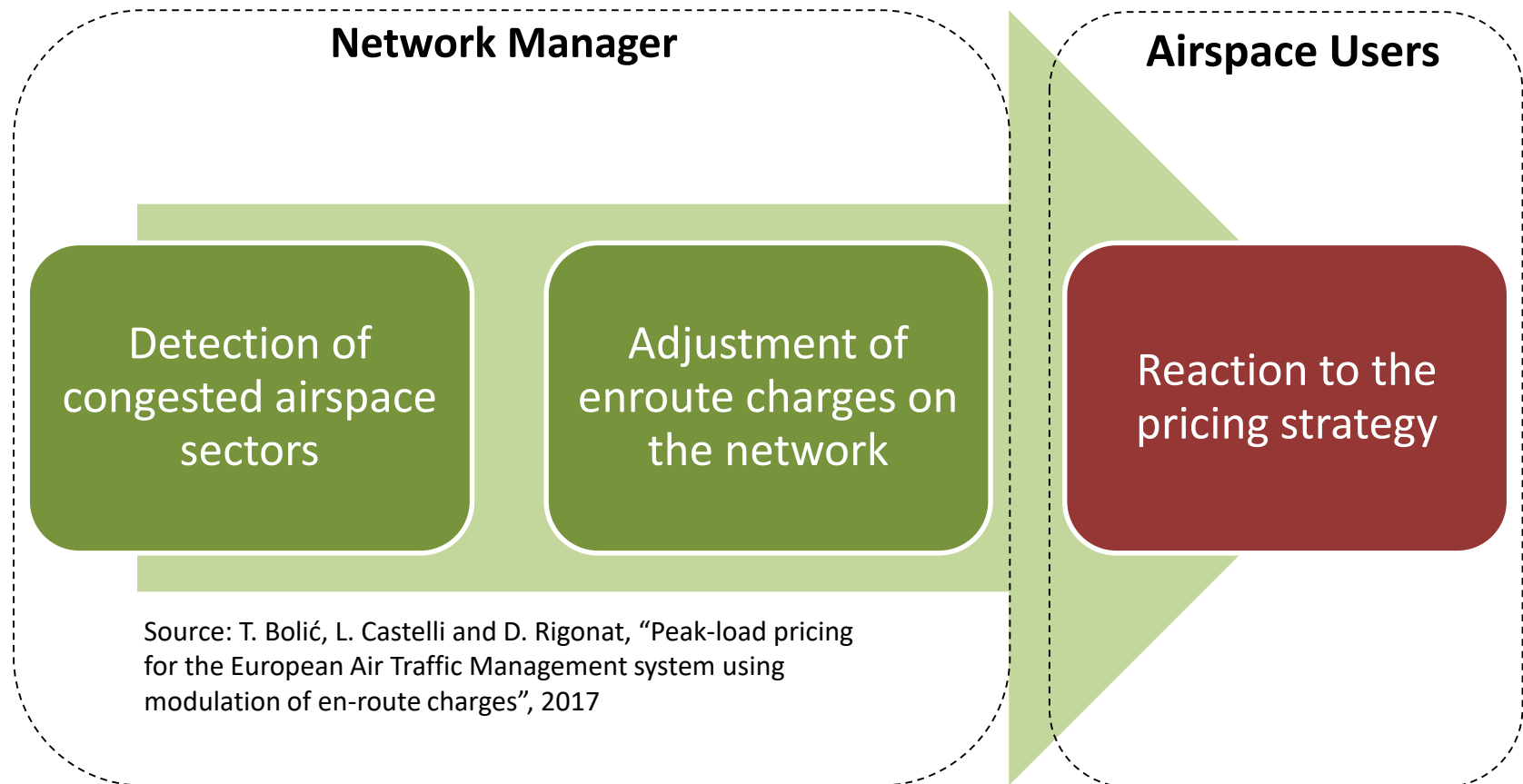
- **Primary Auction:** process by which AUs compete for ATFM slots by offering them up for bid to an honest broker (NM) which then sells each item to the highest bidder.



- Each ATFM slot is auctioned following the restrictions imposed by the **SOBT** of the flights affected by the regulation, meaning that airlines cannot bid for time slots whose new expected departure (**EOBT**) is earlier than the original SOBT of the flight willing to take that position.

Congestion Pricing

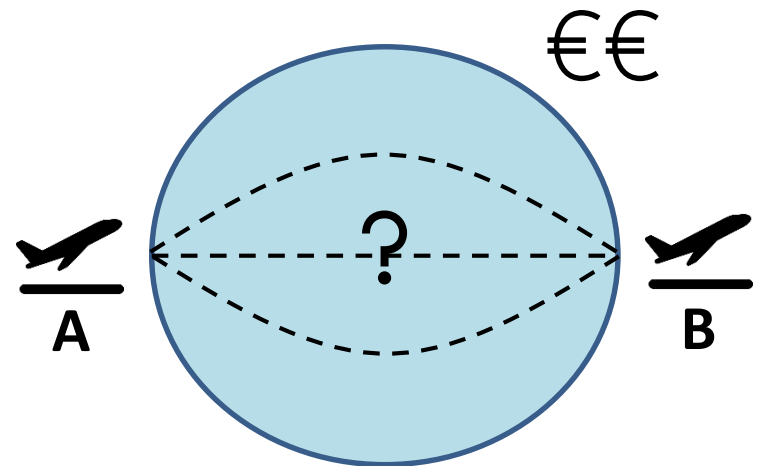
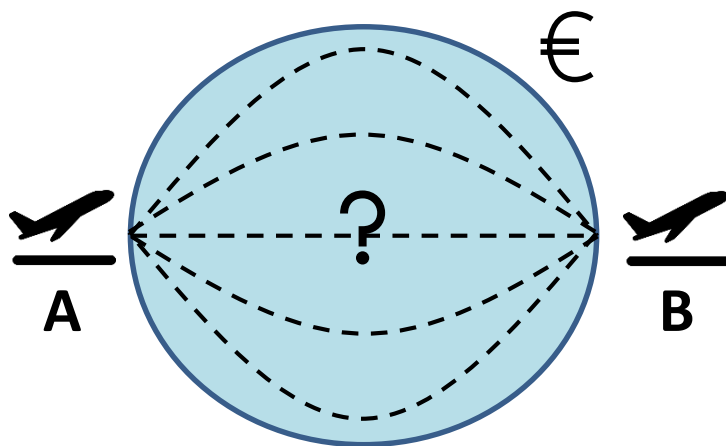
Concept based on the same ideas as the high-occupancy toll lanes used on toll roads where the variability of the price is used to control the demand



Route Contract

COCTA Project: Improves efficiency and quality of ANS provision in Europe by a better coordination of capacity and demand

- New operational paradigm for the Network Manager and AUs, which will not be charged for the air navigation services by the sectors crossed but for the city-pairs they are flying.
- AUs are set to choose between different route packages which are contractual permissions to flight within a given margin of spatial deviations from the shortest route between a city-pair.



Non-monetary Market Mechanisms

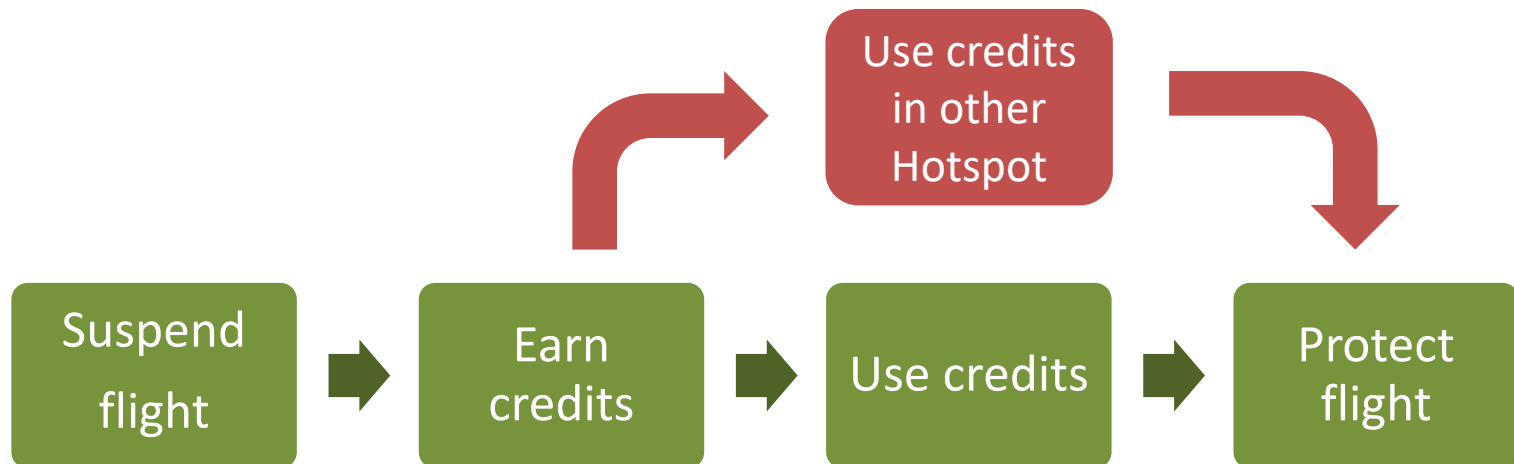
Some AUs are reluctant to accept prioritization mechanisms which involve using real money. Non-monetary market mechanisms based on the use of a virtual currency provides a good alternative to that end

Extended-SFP (ESFP)

Credit Points for Rerouting

Extended-SFP (ESFP)

- The concept is very similar to the SESAR Selective Flight Protection. It is considered as an extension or a complementary mechanism to other UDPP features
- The **potential advantage** of FCL is the ability to provide flexibility also to AUs with a low number of flights involved in a regulation, thus increasing the equity of the system

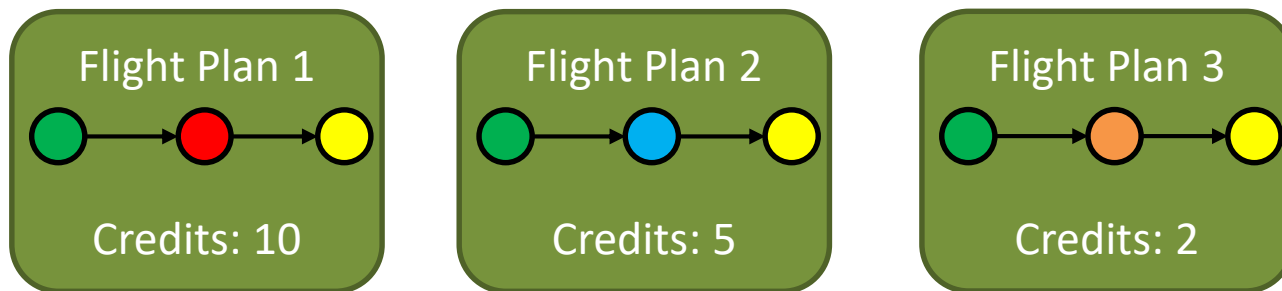


Selective Flight Protection + Flexible Credits

Credit Points for Rerouting

Relies on the ability of AUs to deliver optional routes for their flights, prioritizing each one of them with credit points.

1. AUs receive credit points based on the size of their operations
2. AUs assign different amount of credits for each route option



3. Network Manager processes flight plans
 - When a sector is congested, the flight routes are ranked by credits and the sector is filled up to capacity by the higher credit assignment.
 - Flights whose routes are ranked with the lowest amount of credits are assigned to next route preference in the list and the whole simulation is repeated.

Summary

Mechanism Name	Operational Basis	Application Phase	In use?
First Planned First Served (FPFS)	Rule-based	Tactical	Yes
UDPP - Enhanced Slot Swapping (ESS)	Rule-based	Tactical	Yes
UDPP - Fleet Delay Reordering (FDR)	Rule-based	Tactical	No
UDPP - Selective Flight Protection (SFP)	Rule-based	Tactical	No
Auction	Market monetary	Strategic / Tactical	No
Congestion Pricing (CPLP)	Market monetary	Strategic	No
Route Contracts (COCTA)	Market monetary	Strategic	No
UDPP - Extended SFP (ESFP)	Market non-monetary	Pre-Tactical / Tactical	No
Credit Points for Re-routing	Market non-monetary	Strategic / Tactical	No

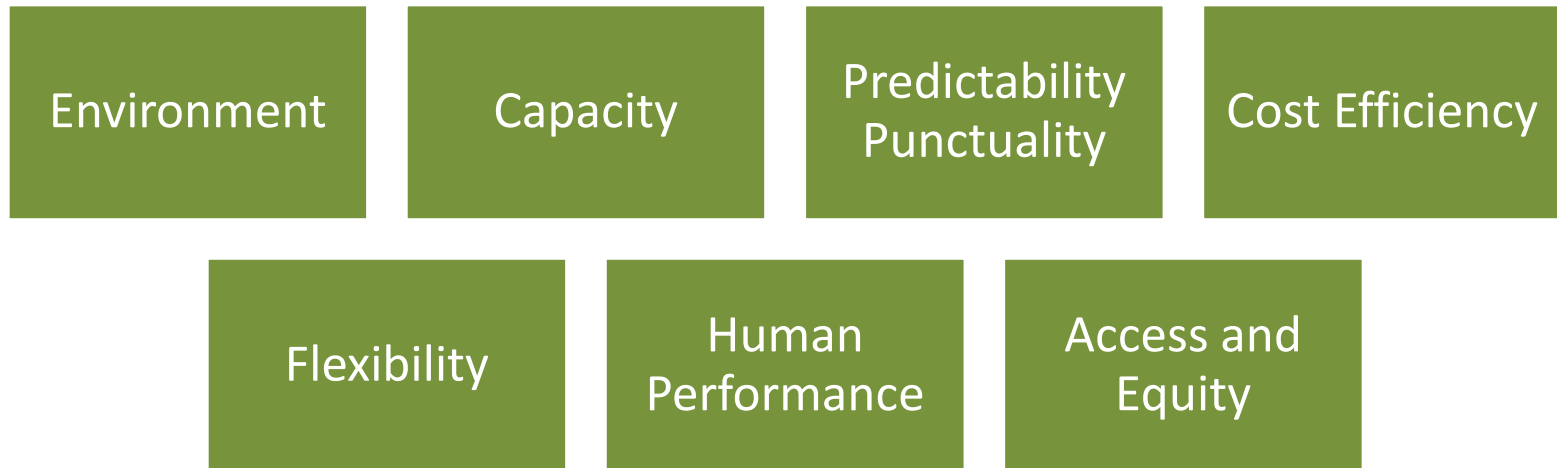
Performance Assessment

SESAR Performance Framework

The research in new methodologies and mechanisms of user driven prioritisation processes is framed within the SESAR UDPP programme.

Consistently, the construction of the assessment framework will take the **SESAR Performance Framework** as a starting point

Relevant Key Performance Areas (KPAs)



UDPP Performance Framework

The **robustness** of each mechanism is measured comparing a baseline perfectly rational situation with other simulations where the behaviour of the AUs is modified to simulate "irrational" practices (Behavioural Economics)

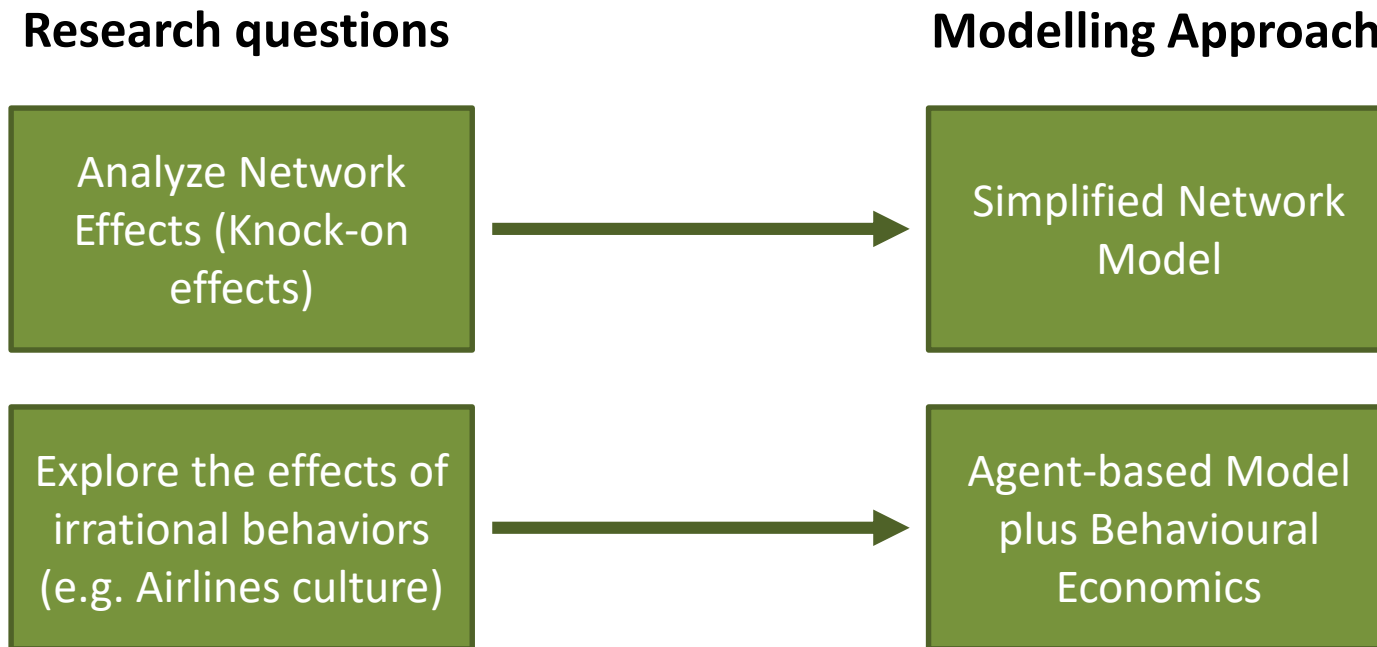
Relevant Key Performance Areas (KPAs)

Environment	Capacity	Predictability Punctuality	Cost Efficiency
Flexibility	Human Performance	Access and Equity	Robustness

Modelling Approach

Research questions & Modelling Approach

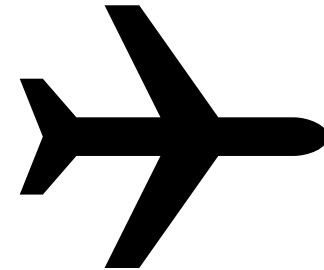
Simulation objective: Performance evaluation of different flight prioritization mechanisms



Agent-based Model – Agents

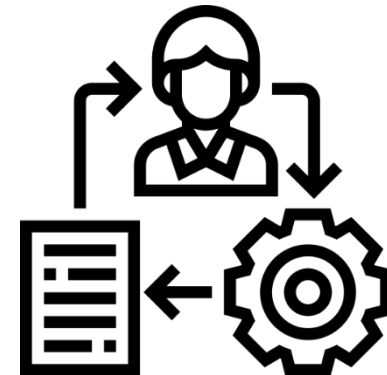
Airlines

- Main agent of the simulation
- Functions:
 - Compute cost of delay
 - Make flight prioritization decisions



Network Manager

- Agent in charge of the ATFM processes
- Functions:
 - Detect demand-capacity imbalances
 - Apply flight prioritization rules



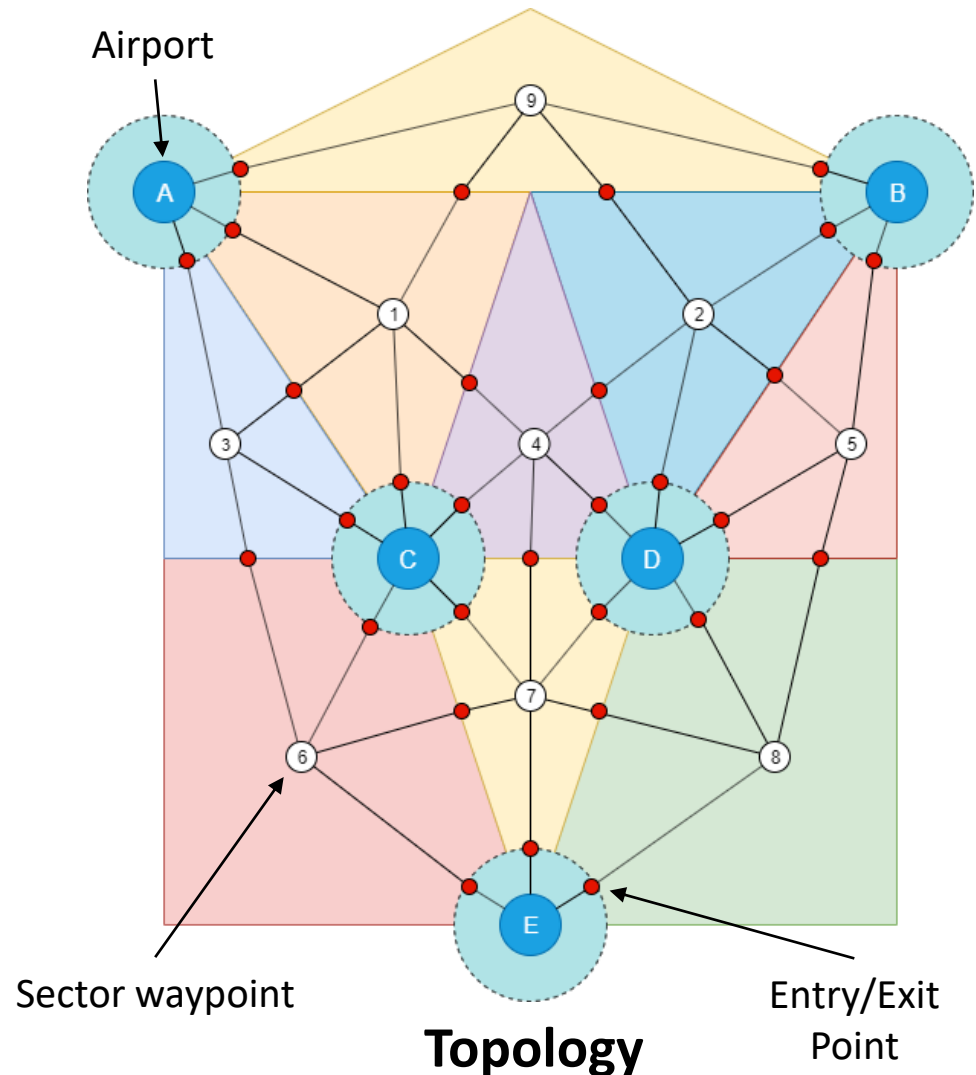
Agent-based Model – Environment

Network Structure

- Airports: 5 airports, mix of hubs and secondary airports
- Airspace Sectorization: 9 enroute sectors plus TMA around each airport
- Aircraft: 2 different types of aircraft considering size and performance

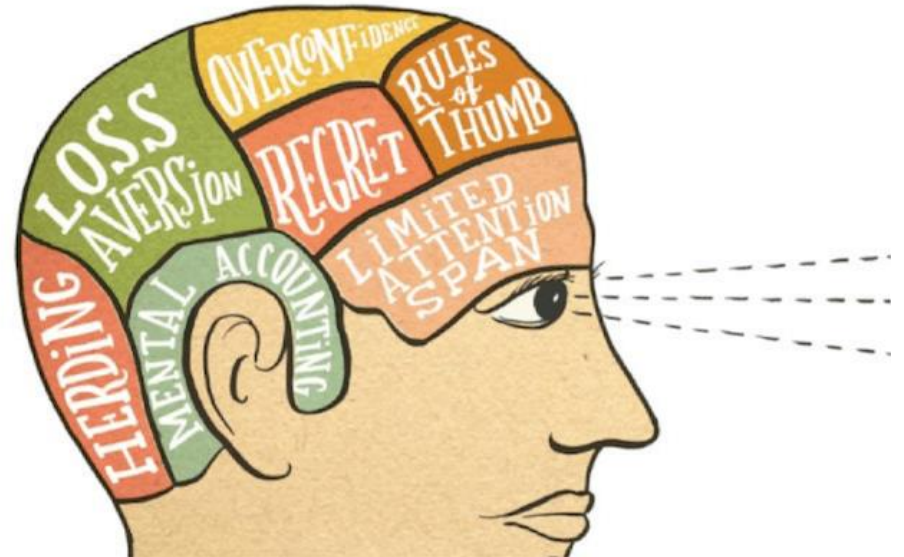
Exogenous Variables

- Passenger connectivity
- Fuel prices
- Flight Schedules

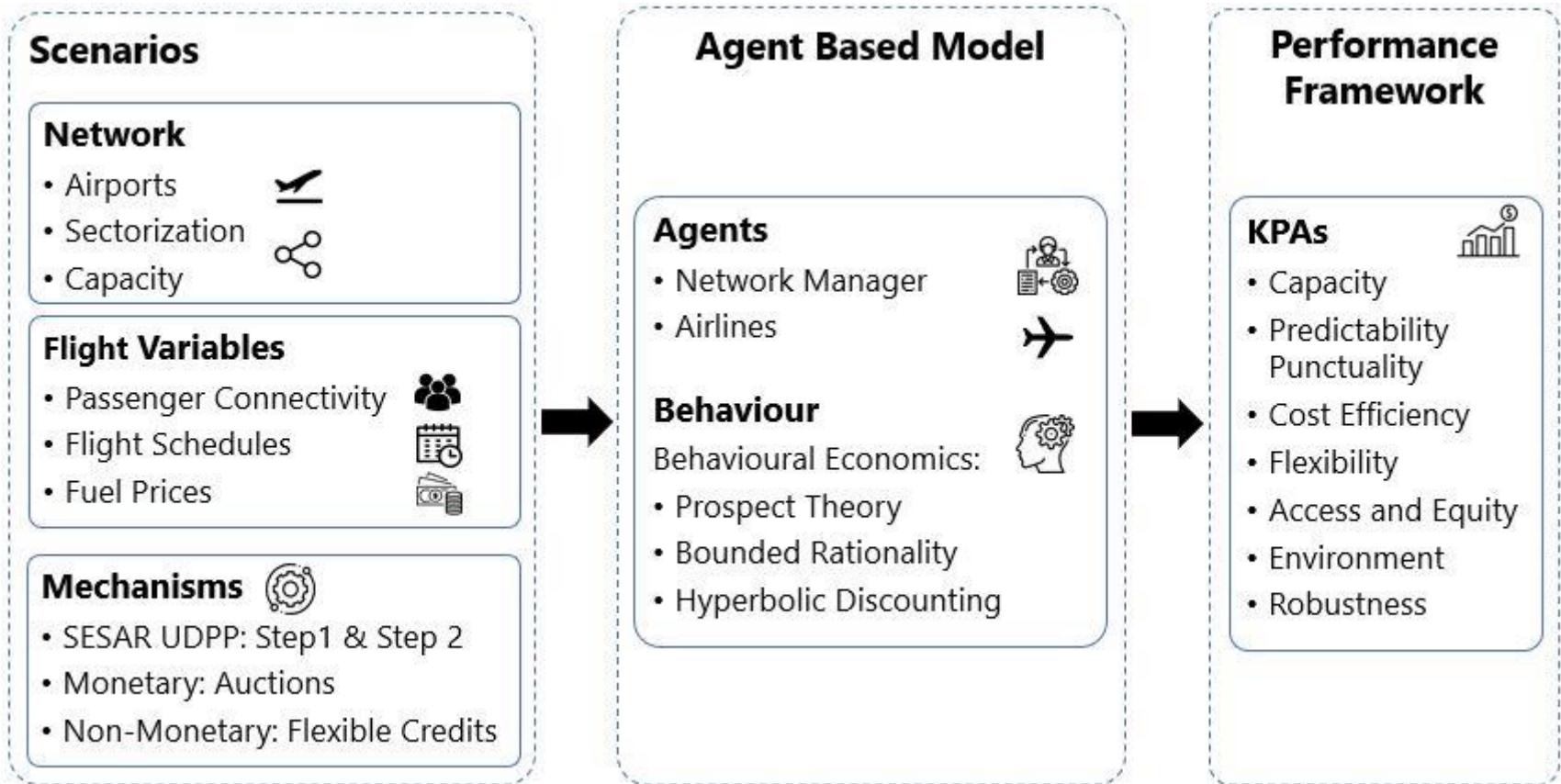


Behavioural Economics

- The convergence of agent-based modelling and behavioural economics provides a natural framework to incorporate behavioural economics insights about human behaviour into operational simulation models.
 - Prospect Theory
 - Risk Aversion
 - Endowment Effect
 - Bounded Rationality
 - Limited Information
 - Mental Accounting
 - Hyperbolic Discounting
 - Intertemporal Choice



Simulation Model



Stakeholder Engagement

Stakeholders Engagements

The stakeholders' participation and involvement are very important aspects in the development and success of the project. In particular, the three most relevant aspects are.

1. Benefits and potential risks of proposed flight prioritization mechanisms
2. Adequate KPAs and metrics to measure impact and performance of each mechanism
3. Possible stakeholders irrational behaviours and unexpected outcomes resulting from them



ENGAGE Workshop TC4

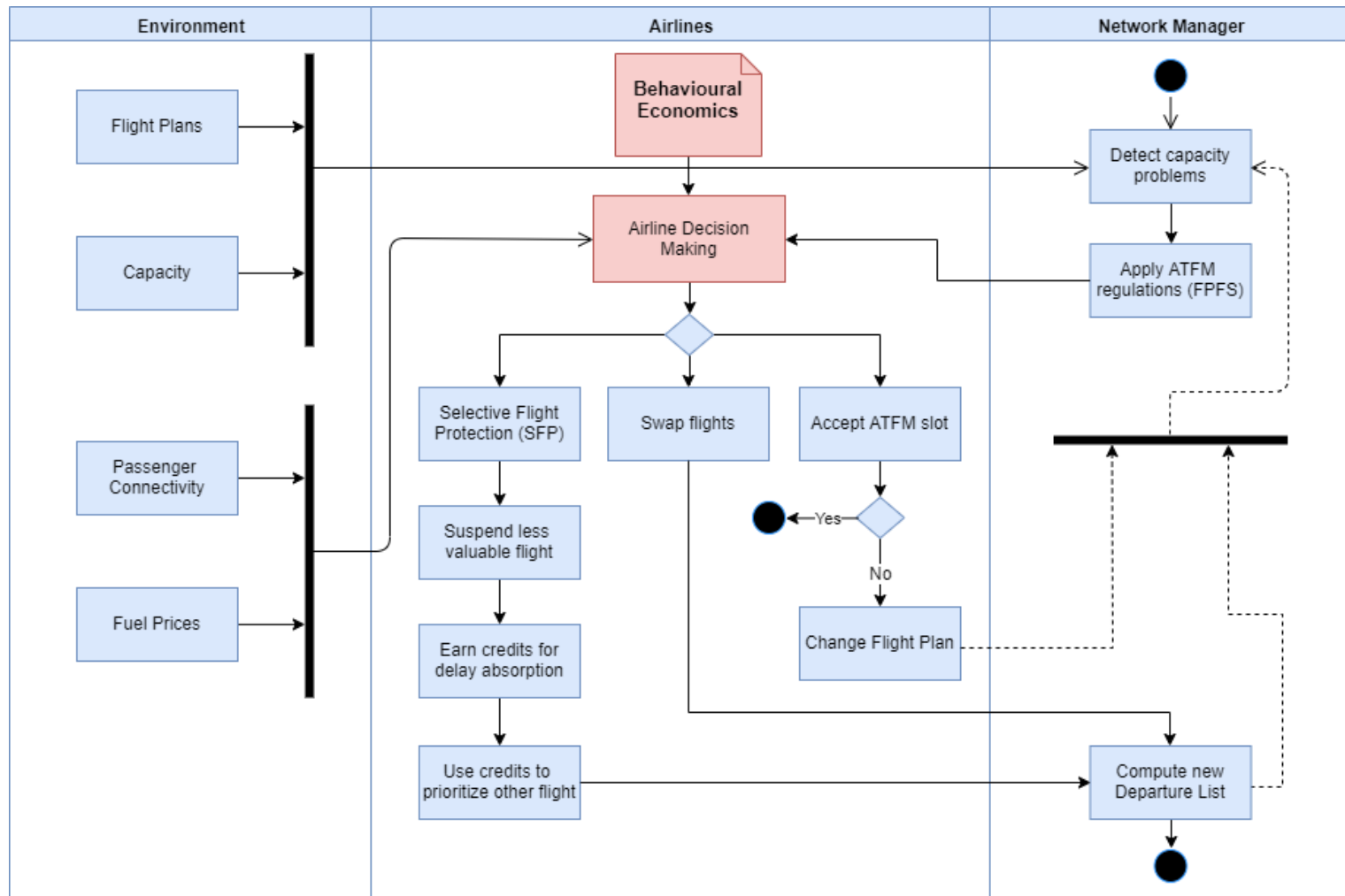
Questions?



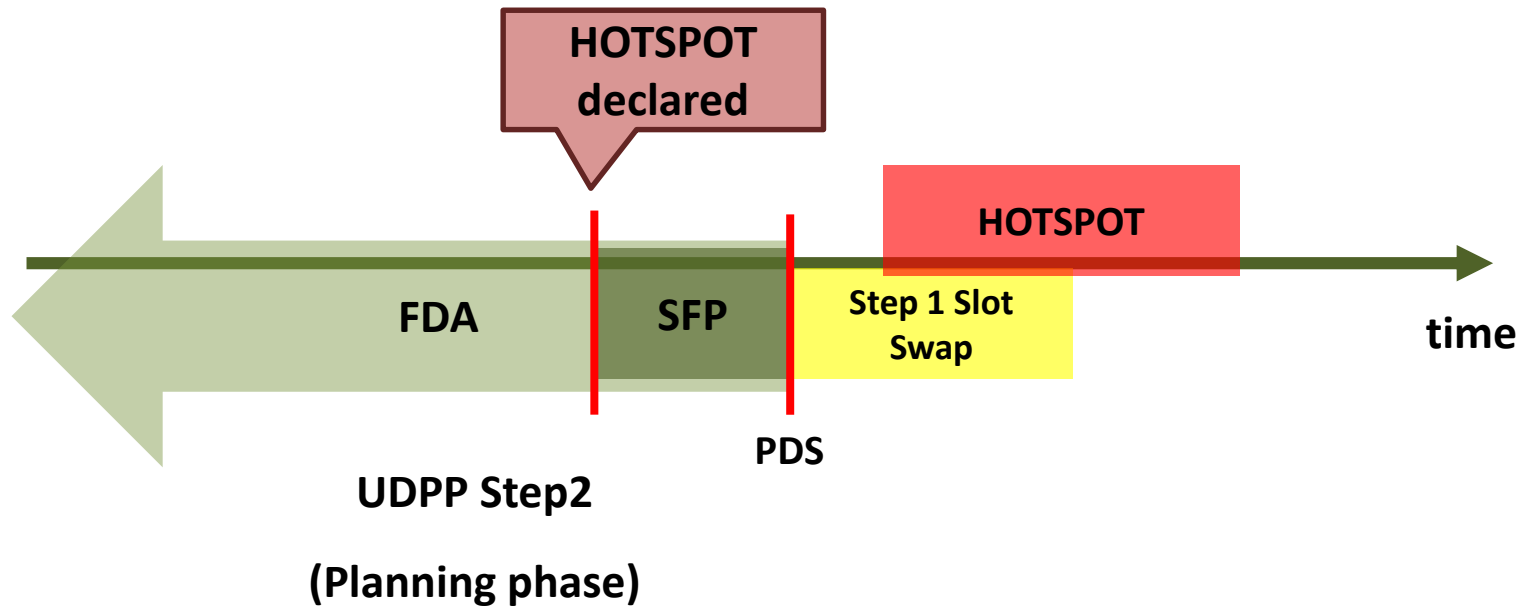
Annex

Simulation Example

SESAR UDPP Selective Flight Protection (SFP) workflow



UDPP Concept Availability



KPA	Operational Focus Area	Metrics
Environment	<ul style="list-style-type: none"> Fuel Efficiency Noise impacts Local Air Quality (LAQ) 	<ul style="list-style-type: none"> Average fuel burnt per flight (kg/flight)
Capacity	<ul style="list-style-type: none"> Airspace Capacity Airport Capacity Network Capacity Resilience 	<ul style="list-style-type: none"> Minutes of delay (min) Number of cancellations (flights)
Predictability Punctuality	<ul style="list-style-type: none"> On-time operation (Departure Punctuality, Arrival Punctuality) Knock-on effect Predictability 	<ul style="list-style-type: none"> Flight departure/arrival delay (min) Pax departure/arrival delay (min) Variance of difference in actual and FP (min)
Cost Efficiency	<ul style="list-style-type: none"> Direct gate-to-gate ANS cost Direct Airspace Users cost Indirect costs 	<ul style="list-style-type: none"> Sequence optimisation benefit (EUR) Direct operating cost (EUR) Per-flight pax hard/soft cost (EUR/flight) Reactionary delay ratio (ratio)
Flexibility	<ul style="list-style-type: none"> Non-scheduled traffic Trajectory modifications Military airspace requirements Impacted trajectories 	<ul style="list-style-type: none"> Average delay for scheduled flights with change request (min) Average delay for non-scheduled flights delayed (min)
Human Performance	<ul style="list-style-type: none"> Human role consistency versus capabilities Technical systems, and team structure support performance HP transition factors 	<ul style="list-style-type: none"> Consistency of human role with respect to human capabilities (Qualitative) Suitability of technical system in supporting the tasks of human actors (Qualitative)
Access and Equity	<ul style="list-style-type: none"> Fairness Access Transparency 	<ul style="list-style-type: none"> Change in AU delay/cost compared with other AUs (%) Advantage of AU over the others weighted by impacted flights (%) Final delay per AU relative to baseline delay per AU (%) Number of flights advantaged and/or disadvantaged (%)