CONTRACT-BASED AIR TRANSPORTATION SYSTEM (CATS)

WP2.2.2

Benefits Assessment

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Goal

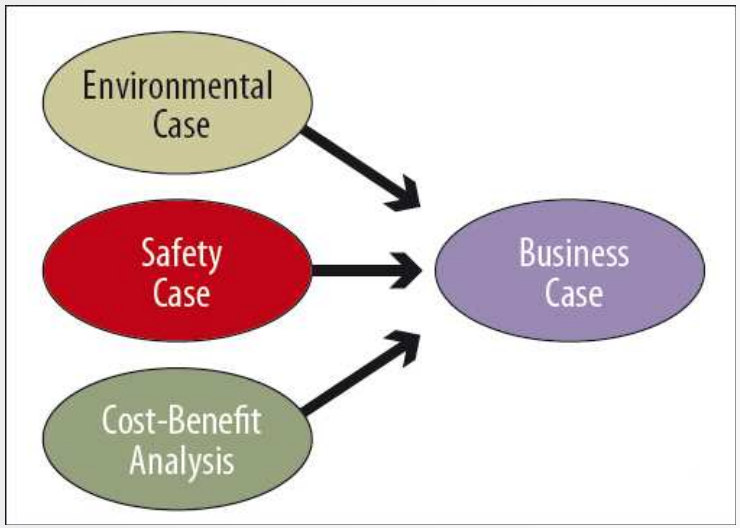
- In the context of the CATS systemic assessment, WP2.2.2 presents a Cost-Benefit Analysis (CBA) which investigates from an economic perspective the potential benefits and limitations of implementing the Contract of Objectives (CoO) for airlines, airports and air navigation service providers

Guidelines

The study follows

- E-OCVM, Version 3.0
- CAATS II project which provides guidelines to develop “cases” in compliance with E-OCVM and SESAR.
  - D19.2 Business good practices
  - D20 Guidance material for a typical business case

- E-OCVM points out that the *Business Case brings all the other cases together, and presents the underlying economic assessment to enable decision makers to make informed trade-offs. Thus a Business Case includes, but goes beyond a cost-benefit analysis*



Level of Maturity (E-OCVM)

- The CATS project ends at the V2 stage
  - V2: Feasibility. The aim of this step is the evaluation of the proposed concept. It's an iterative process to show the operational feasibility of the proposed solution
- At V2, the case-based approach is used to present the concept to the stakeholders and obtain their feedback to help the R&D activities
- The scope of this CBA is to generate an Economic Feasibility Case that serves as an instrument for presenting the economic impact of CoO to the stakeholders and obtaining their feedback regarding the acceptability of this impact

Main steps of the analysis

The CBA consists of two main steps which reflect the existing Level of Maturity of the CoO operational concept.

- Evaluation of alternatives.
  - It qualitatively weighs positive and negative impacts of the CoO with respect to the current system
- A negotiation mechanism of Target Windows
  - It presents a quantitative study which assesses the economic feasibility of a negotiation mechanism and highlights the role of Target Windows (TWs) as a possible tool to implement a User Driven Prioritisation Process

Evaluation of alternatives

- The goal of the analysis is to compare the benefits and drawbacks linked to the implementation of the Business Trajectory through the
  - “CoO/TW concept of operations" (CoO/TW) vs. the
  - “Business-as-Usual" (BaU) scenario (today's situation)
- Scenarios are developed and evaluated by representatives for the following stakeholders: airport, ANSP and airline
- The Analytic Hierarchic Process (AHP) methodology is used

Flight planning and execution phases

- Typically each flight is the result of a two step process: the planning and the execution phases
  - In the **planning** phase long-, medium- and short-term operational plans are developed and optimized
  - In the **execution** phase, such operational plans are put in place
- The analysis develops two hierarchies for each stakeholder

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Results – Airlines' Execution phase

- There is no significant impact of the implementation of CATS with respect to Business-as-Usual in terms of use of resources
- Benefits are going to be strongly improved

	Use of resources	Common responsibility	Better use of ground resources	Reduction of in-block time variability	Reduction of taxi time variability	Reduction of flight duration variability
Global priority	0.75	0.063	0.016	0.030	0.034	0.108
BaU	0.5	0.167	0.25	0.25	0.25	0.25
CATS	0.5	0.833	0.75	0.75	0.75	0.75

AHP – Final Results

	Planning Phase	Execution Phase
Airline	0.57	0.57
ANSP	0.73	0.78
Airport	0.43	0.44

Priority assigned to “implement the CoO/TW concept of operations” from the AHP models

Evaluation of Alternatives - Conclusions

- Main benefits of CoO/TW
  - Common (or shared) responsibility
  - Increase of predictability
- CoO/TW to be preferred from the Airline and the ANSP
  - This result is quite robust
- BaU to be preferred from the Airport
  - This result is NOT robust and strongly depends on the current economic situation

A TW Negotiation Mechanism - Motivation

- SESAR states that airspace users will be fully involved in the process of demand and capacity balancing
- Implementation of ad-hoc Collaborative Decision Making (CDM) processes
  - **Strategically** Agreements on how traffic demand or individual trajectories will be adjusted if ANSP and Airports cannot provide sufficient capacity
  - **Tactically** In the User Driven Prioritization Process (UDPP) designed to prioritize traffic queues caused by unexpected capacity shortfalls.
  - *The airspace users among themselves can recommend to the Network Management a priority order for flights affected by delays caused by an unexpected reduction of capacity. The airspace users will respond in a collaborative manner to the Network Management with a demand that best matches the available capacity*. [SESAR D3]

CATS and CDM

- CoO concept proposed by CATS relies on the CDM principle.
- The CoO is the solution proposed by CATS to achieve an agreed and stable balancing between demand and capacity. It results from a collaborative layered planning, based on CDM, coordinated by a network management function. [CATS D1.2.2 – Concept of Operation]
- This innovation with respect to the current mode of operations will introduce potential benefits for users.
- We provide through model-based simulations (mixed-integer linear programming) an estimation of the benefits achievable.

CATS Target Windows (TWs)

- TWs are the results of a negotiation process among stakeholders [CATS D1.2.2 – Concept of Operation]
  - It starts in the long term Planning phase giving as the main result airport TWs.
  - It continues in the medium-term Planning phase according to ANSP/FAB available resources and users demands
  - It concludes in the Short-term planning phase, just before flight's departure, when CoOs and TWs are signed.

SESAR requirement → Improve Equity KPA:

"*For priority management ensure that more options will be available than just the First-Come-First-Served*"

Our proposal

The UDPP is based on an *iterative combinatorial exchange* .

- Each flight is assigned a set of TWs according to the FCFS principle
- TW values are determined according to the current excess of demand
- TWs are exchanged: airlines decide for each flight if it is preferable to acquire resources at the current market price or accept the delay;
  - The flight receives a payment for each TW released (assigned under FCFS)
  - The flight pays for each optimal TW its correspondent value to the releasing flight
- The TW negotiation mechanism fulfils the following properties
  - *Individual Rationality*: NO flight will increase its cost with respect to the baseline solution
  - *Budget Balance:* the mechanism can run without subsidization from the outside
  - *Allocative Efficiency*: the mechanism can produce an allocation which minimizes the sum of costs reported by airspace users

The Central Model

- The Aircraft Operators communicate for each flight affected the cost of delay suffered
- The network manager calculates the minimum cost assignment of TWs to flights and the value of each TW, according to these costs of delay
  - Single resource: Assignment Problem
  - Multiple resources: Weighted Set Packing Problem (NP-hard)
- Each flight exchanges its FCFS assigned TWs with the optimal ones at their respective values

Drawbacks of the Central Model

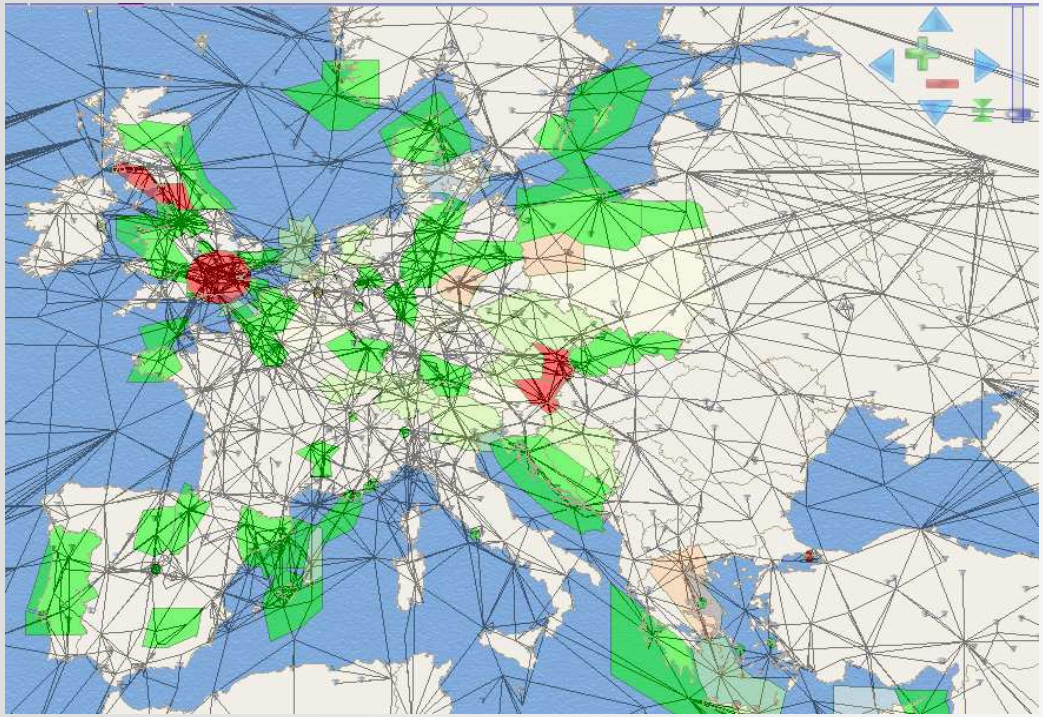
- The high computational effort for the Central Authority
- The high communication cost of sending the complete set of costs over a network
- The disclosure for Airlines of confidential information

The Iterative and Distributed Model

1. Each flight is assigned a set of TWs according to FCFS principle, one on each capacity constrained resource.
2. The network manager calculates and publishes individual TW values on the base of the excess of demand
3. Aircraft Operators respond with the TWs they want to acquire and sell at current values
   - Lagrangean relaxation of the central approach
   - No disclosure of private information about their cost of delay
4. Points 2-3 are repeated until:
   - An equilibrium is reached, represented by a feasible solution
   - A maximum number of iterations is reached; in this case the network manager can propose a “good” exchange on the base of the willingness to pay observed during iterations

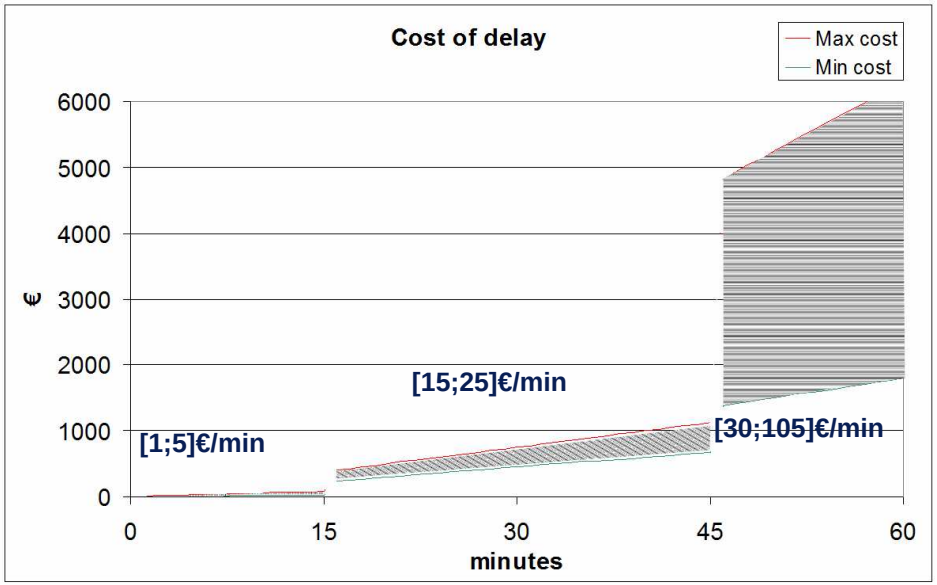
Simulations

- Dataset extracted from real data (15/08/2008, 9:00 - 11:00)
- 485 regulated flights
- 60 capacity-constrained resources (sectors + airports)



Simulations

- Cost of delay per flight (in line with [Cook et al., 2004])



- Global cost of delay under different TW assignment

FCFS	Central EXCH	Iterative EXCH
740 187 €	620 692 € (-16%)	634 438 € (-14%)

Negotiation - Conclusions (I)

- We propose a negotiation mechanism to allocate TWs to flights, which enables airlines to pay for delay reduction or receive compensations for delay increases;
- Whenever a solution is found, it is economically preferable to the current FCFS one;
- To avoid the complete disclosure of private information, we suggest a distributed approach directly involving airlines in the decision making process.

Negotiation - Conclusions (II)

The TW negotiation mechanism is consistent with:

- SESAR: it extends the current FCFS priority principle, ensuring transparency, equity and efficiency of the prioritization process
- European Commission practices: *"exchanges of Airport slots for money already occurring at some European Airports are permitted since they bring advantages"* [COM (2008) 227, 31-4-2008]
- Literature: recent publications in ATFM suggest exchanges with side payments

Conclusions (I)

- WP2.2.2 presents a Cost-Benefit Analysis (CBA) which
  - qualitatively weighs benefits and costs of the CoO with respect to the current system;
  - quantitatively assesses the economic feasibility of a TW negotiation mechanism, which is at the very core of the CoO concept.
- For three main stakeholders, we present two distinct AHP models to evaluate the effect of the introduction of the CoO in the planning and execution phases of a flight.
- Our findings indicate that there are net benefits for airlines and ANSPs. The opposite holds for airports due to the current unfavourable economic conditions which deter any new investment.

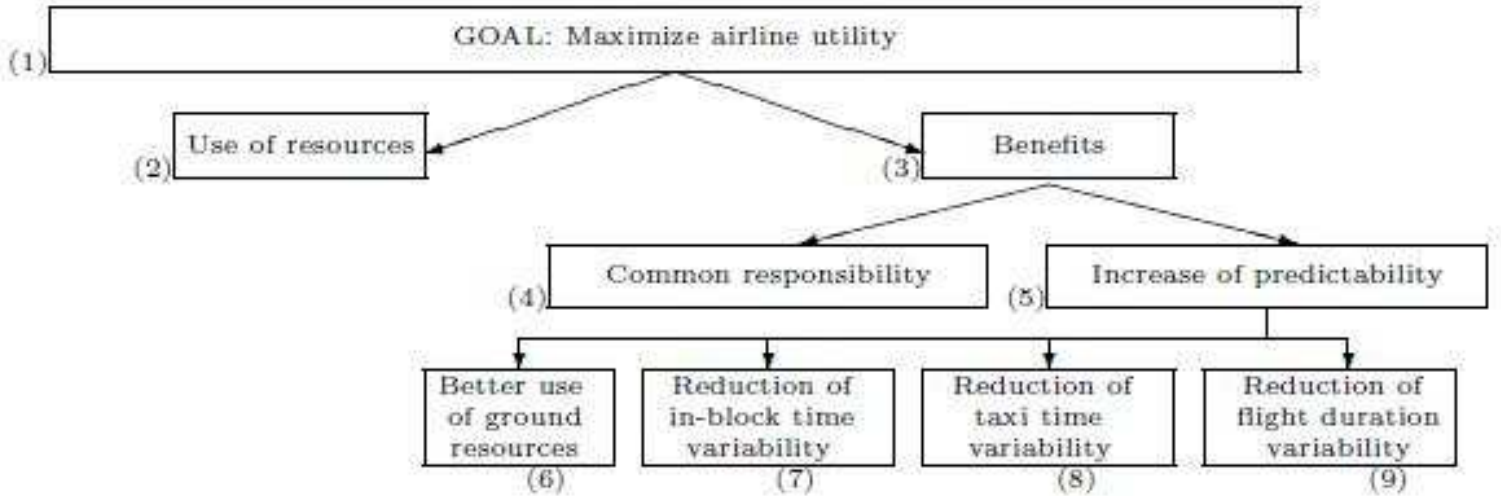
Conclusions (II)

- We introduce a possible mechanism for TW negotiation, and an evaluation of its economic impact on the airspace users
- Remarkable cost savings are possible for aircraft operators if they were offered the possibility to actively participate in the sequencing of flights imposed by capacity restrictions
- The introduction of the TW concept constitutes a fundamental tool to achieve CDM capabilities
- The proposed TW negotiation mechanism prevents the disclosure of users' private information by being decentralized and letting users make independent decisions based on their internal business objectives and according to the value attached by other users to individual TWs on capacity constrained resources.

Credits

- L. Castelli, P. Pellegrini *An AHP Analysis of Air Traffic Management with Target Windows*, forthcoming on Journal of Air Transport Management
- L. Castelli, A. Ranieri, R. Pesenti (2010) *Short-term allocation of Time Windows to flights through a distributed market-based CDM mechanism*, **Best Paper Award** of the 1st International Air Transport and Operations Symposium (ATOS 2010), Delft, The Netherlands, 14 - 15 April 2010.

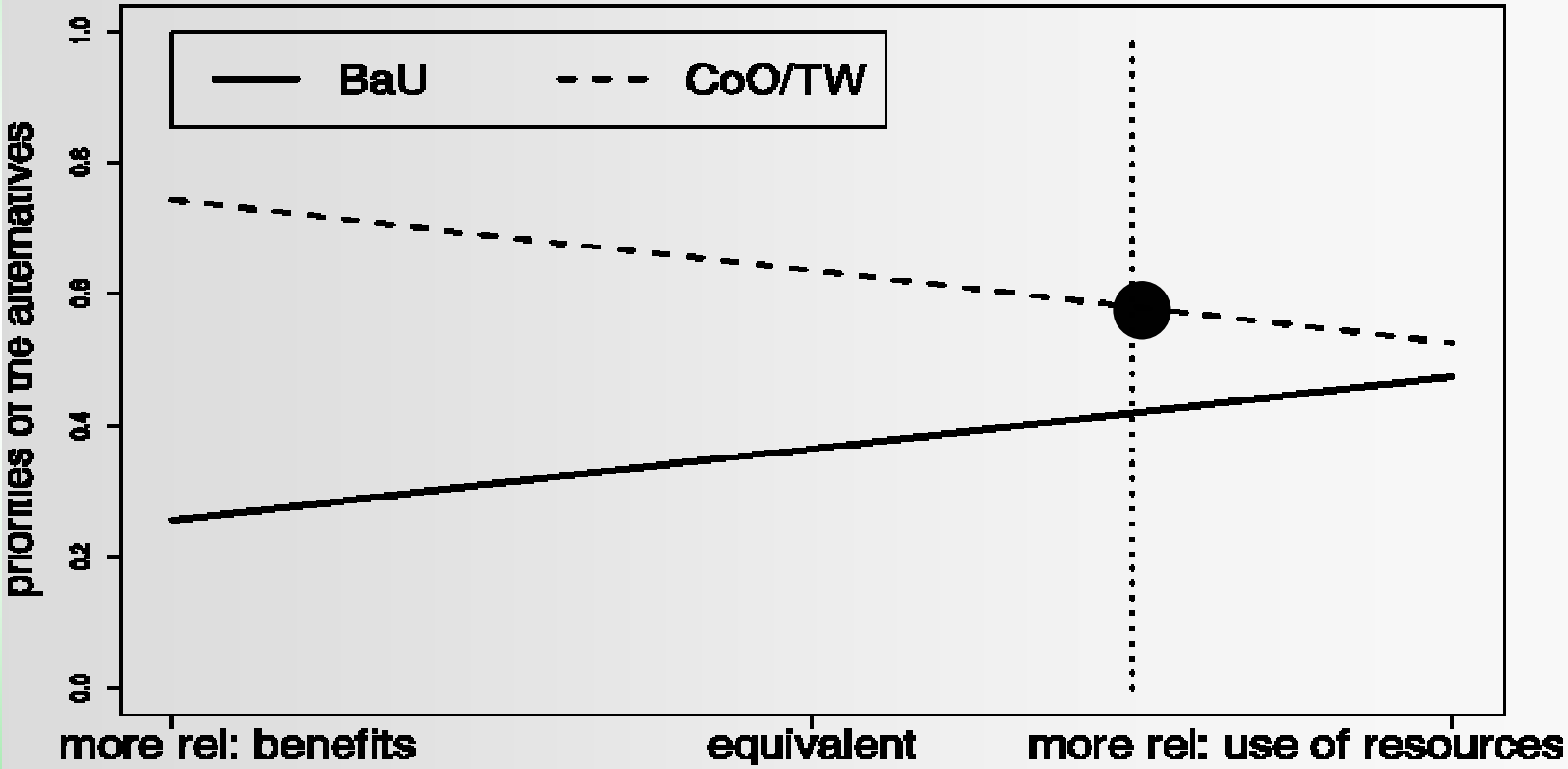
Flight Execution Phase - Airlines



Results of the AHP analysis - airlines

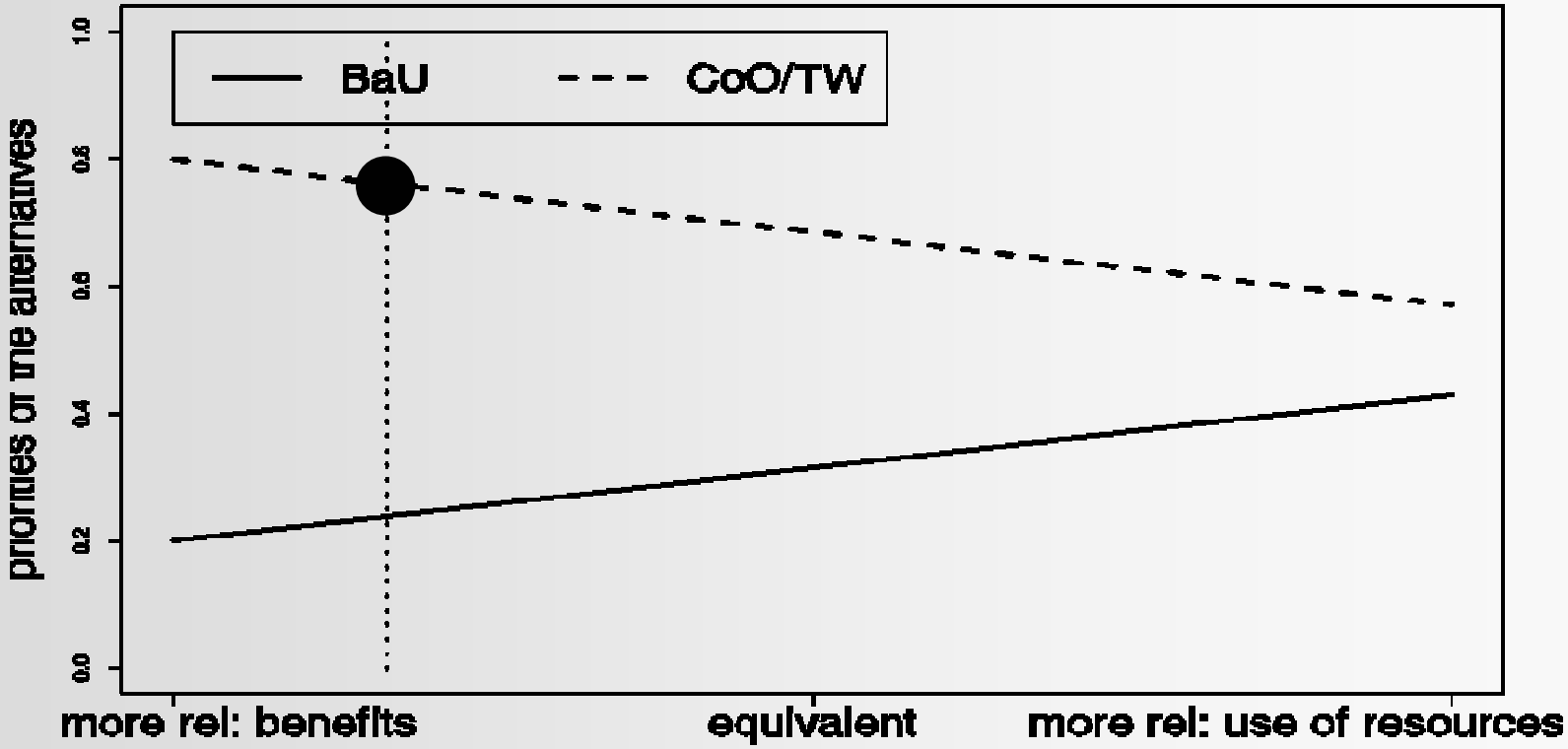
CATS is the preferable alternative:

Priority of 0.57 for both planning and execution phases



Results of the AHP analysis - ANSPs

CATS is the preferable alternative:
Priority of 0.73 (planning) and 0.78 (execution)



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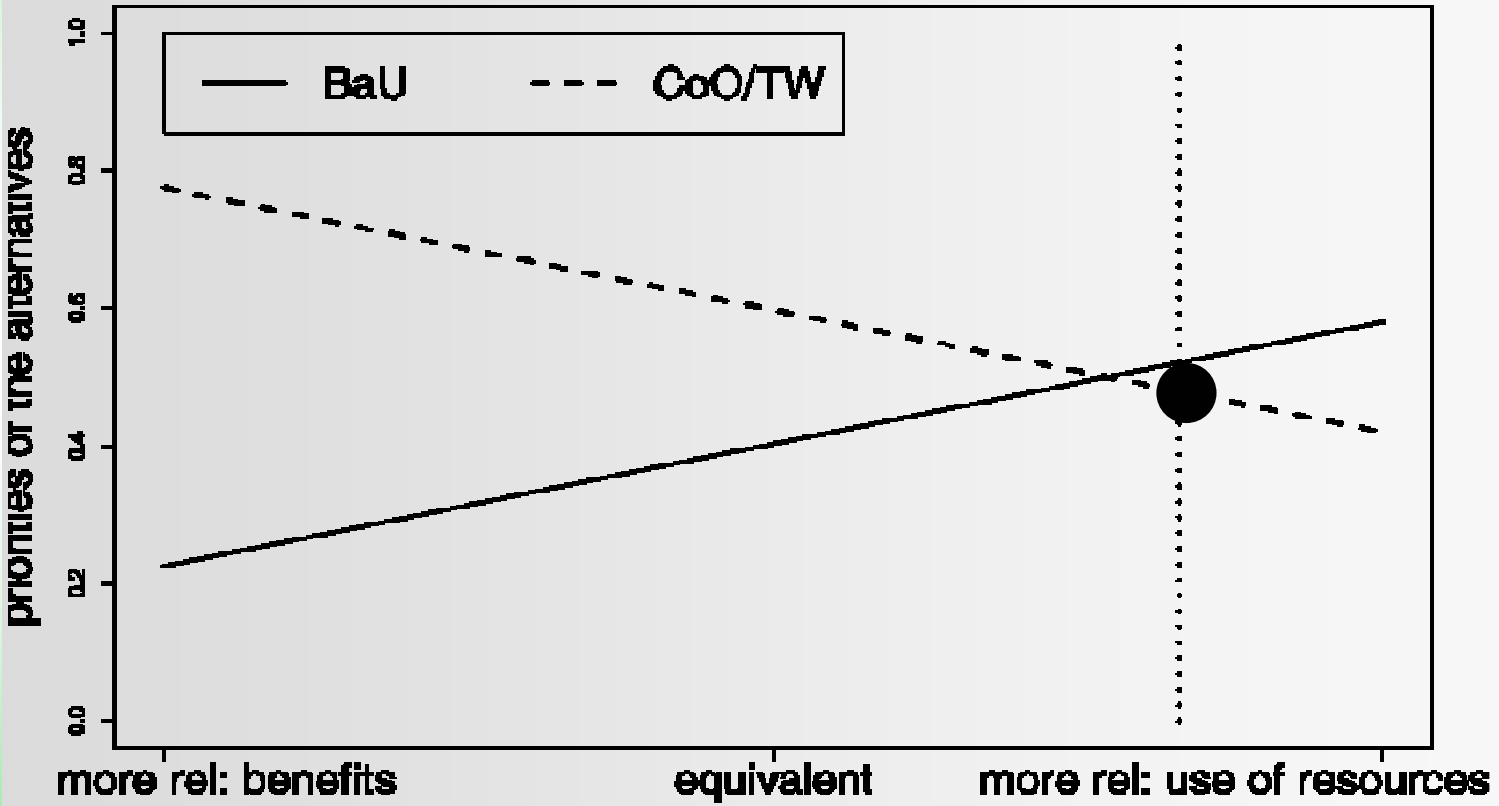
Results of the AHP analysis - Airports

CATS is NOT the preferable alternative:
Priority of 0.43 (planning) and 0.44 (execution)



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Assumptions

- We assume that a first sequencing is performed through the FPFS *(Fairness + Smooth transition)*
- Resulting TWs on all capacity constrained resources are assigned to flights *(Transparency + Awareness)*
- Successively an exchange of TWs among flights is sought that minimizes the overall cost.
- This is done in order to conciliate two apparently conflicting goals *(Global & Local Efficiencies)*

Maximizing social welfare = Maximizing individual utility

SESAR WP-E

- ‘Economics and Performance’ Research theme
- Trading of scarce resources and incentive schemes:
  - *Trading models, innovative pricing models, incentive setting all offer new opportunities to allocate limited resources to market actors, including market based approaches. The objective is to identify ‘ATM resources’ with high and increasing value, whose allocation and use may provide opportunities for incentive mechanisms aiming to drive technology uptake and market/business realignment.*

Future prospects

- Perform a quantitative economic analysis to compute financial metrics (as the CoO Level of Maturity progresses)
- Extend the TW negotiation mechanism to ANSPs and airports
- Link TW negotiation (prior to flight departure) with TW renegotiation (during flight execution)