ITACA

Incentivising Technology Adoption for Accelerating Change in ATM

Lessons Learnt from the ITACA Project and Way Forward

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Incentivising Technology Adoption for Accelerating Change in ATM

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The ITACA project:
ITACA seeks to accelerate the development, adoption and deployment of new technologies in ATM. It has developed a new set of methodologies and tools enabling a comprehensive assessment of policies and regulations aimed at amplifying the uptake of new technologies within ATM.

Read more: www.itaca-h2020.eu

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ITACA

Lessons Learnt and Way Forward

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1. Introduction

In recent years, the need to accelerate ATM technological change has become more and more evident: growing traffic demand and new market entrants, such as commercial drone applications, are rapidly taking the ATM system to its limits, calling for disruptive solutions that boost the performance of ATM operations. Emerging technologies, especially digitalisation and automation, have the potential to facilitate this urgently needed technological upgrade. However, technology evolution is a necessary but not sufficient condition: innovation is a complex phenomenon, which depends not only on the development of new technologies, but also on the existence of regulation and institutions that facilitate and foster the implementation of such technologies.

The ITACA project aimed to shed light on the drivers and barriers for the adoption of new technologies in ATM, with the ultimate goal of supporting the identification, formulation and implementation of policies and regulations that accelerate ATM modernisation. To this end, the project has brought together the wide body of theory on technology adoption developed in the field of industrial organisation with the state-of-the-art in computational behavioural economics and participatory simulation, in an attempt to provide a rich, multifaceted analysis able to capture the complexity of the ATM R&I lifecycle.

In the following pages, the reader will get an overview of the insights gained through different analysis and modelling techniques (economic modelling, agent-based simulation, participatory experiments with industry experts) on the mechanisms that drive technology adoption in ATM, as well as a set of key takeaways, policy recommendations and a look to the future.

For more detailed information on the project outcomes, we invite the reader to download the technical deliverables available at the project website: www.itaca-h2020.eu

2. What are the main levers and barriers for the adoption of new ATM technology?

What slows down the adoption of technologies?

Technological change in ATM has historically developed at a slow pace. The reasons are multiple: the very demanding safety requirements, the coordination effort required to harmonise standards around the world, the interdependencies between ground and airborne technologies, the monopolistic nature of air navigation service provision, and the relatively small size of the global ATM market compared to other technology markets are among the factors that explain, at least in part, why ATM technological modernisation has traditionally followed a slow, evolutionary path.

Barriers for technology adoption

- The complex implementation requirements intrinsic to the aviation industry.
- The high cost of investment, often combined with budget constraints on the adopter side (e.g., ANSPs).
- The main investor is not always the main beneficiary (principal-agent problem).
- The last mover advantage, when the benefit of a technology depends on the number of users and/or costs are expected to decrease with the number of users.
- The fragmentation of the market and the need for coordinated adoption by many different stakeholders.
- A culture which is reluctant to change, related to the importance of safety and the difficulty of transition in a system that needs to remain always operable.
- Unrealistic timelines along with lack of strict enforcement create a laissez-faire attitude.

What policy measures can help us overcome these barriers?

How to tackle those problems? Technology, of course, has something to say: the operational benefits delivered by a new solution are a key precondition for the adoption of a new solution. At the same time, the level of implementation of certain technologies is highly heterogeneous across different regions, which suggests that the institutional framework, including regulation and policy measures, is equally important.

The policies investigated by ITACA aim at tackling the identified barriers by making use of one or several of the following leverage mechanisms:

- Demonstration that a technology works.
- Incorporation of outsiders with a different viewpoint.
- Introduction of flexibility in price regulation.
- Introduction of competitive forces.
- Conditional subsidies and mandates.
- Enhanced coordination across stakeholders.

Policy measures proposed by ITACA

Policy measure	Description
Cost-plus pricing	ANSPs that have implemented certain technologies are allowed to charge an increased rate to the airspace users
Best-equipped best-served	ANSPs are allowed to provide a premium service to airlines using a particular technology or to use an asymmetric charging scheme (equipped aircraft pay less)
Demonstration projects	Dissemination and demonstration of technologies to show their potential
Safety agency involvement	Closer involvement of the safety agent at an early stage of technology development to help dispel concerns about certification
Realistic timelines	Increase stakeholder involvement in the setting of target implementation timelines to avoid the postponement of deadlines
Subsidies	Financial aid for the adopters to implement a certain technology
Increase of technology maturity	Decrease the time gap between TLR4 and the deployment phase.
Mandates	Sanctions on agents not implementing the technologies (e.g., economic penalties)

3. ITACA Policy Assessment Framework

ITACA has developed a Policy Assessment Framework aimed at providing evidence-based recommendations on the most adequate policies to facilitate technology uptake in ATM. The framework, which enables the evaluation of a variety of policies on the level of adoption of ATM technologies and the resulting impact for ATM stakeholders, comprises:

1. A modeling toolset that represents the behaviour of the European ATM system by integrating industrial organisation theories with agent-based modelling and behavioural economics.
2. A methodology for model calibration and validation through gaming experiments and participatory simulations.
3. A set of guidelines for the maintenance, evolution and use of the modeling toolset.

Economic modelling: a first assessment of the proposed policies

To conduct a first quantitative analysis of the levers and barriers for ATM technology adoption and identify the most promising policy measures, ITACA has developed a model that integrates elements from industrial economics, game theory and transport economics. The model focuses on how the specific characteristics of ATM technologies could be an obstacle to their uptake.

In a numerical illustration, the model was applied to two ATM technologies, namely Controller Pilot Data Link Communication (CPDLC) and Remote Towers, leading to several conclusions:

- Adoption behaviour is strongly dependent on the characteristics of the technology.
- The adoption of technologies that require investments by several parties can be problematic, especially when the amount invested by a party is not aligned with the benefits perceived by such party.
- While the best-equipped-best-served policy gives the right incentives for airlines, it can be detrimental for the ANSPs.

Agent-based model: simulating the European aviation system

To enable a more comprehensive assessment of the proposed policies, ITACA has developed an agent-based model of the ATM research and innovation lifecycle. Agent-based modelling has proven to be particularly useful to study technology adoption and policy assessment problems, thanks to its ability to represent the heterogeneity of the stakeholders involved and capture emergent behaviour.

The model reproduces the ATM stakeholders' decisions and interactions that drive the adoption of new technologies, including the main stakeholders of the ATM ecosystem: regulatory bodies, technology providers, ANSPs, airlines and airports. Each agent in the model represents an individual entity performing its usual tasks and making decisions on implementing (or not) certain specific technologies. Figure 1 shows a high-level overview of the model.

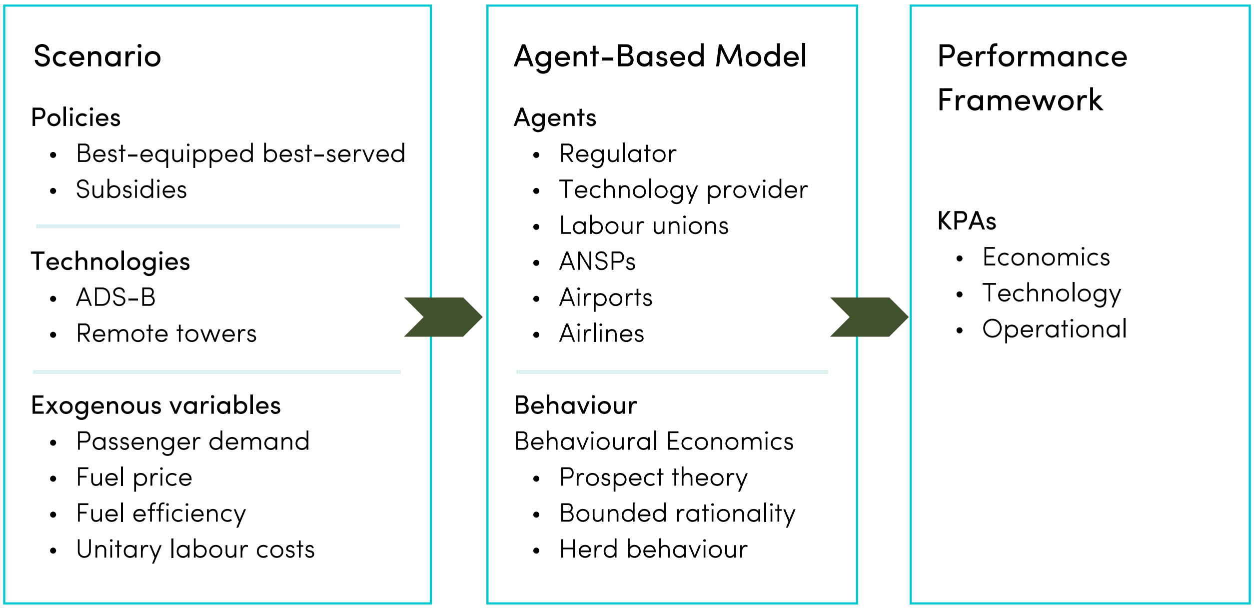

Figure 1. High-level view of the ITACA agent-based model.

The model outputs include metrics related to technology adoption, operational performance and economic outcomes.

KPA	Indicator
Technology adoption	Time for adoption decision since a technology is available
	Market share per technology
Operational performance	Average fuel burn per flight
	En-route and TMA throughput per unit time
	Average union-wide Determined Unit Cost (DUC) for en-route and terminal ANS
Economic outputs	Social welfare, including producer and consumer surplus, regulator surplus and third parties' externalities
	Enroute ANSPs' surplus
	Terminal ANSPs' surplus
	Airlines' surplus
	Airports' surplus
	Passengers' surplus
	Regulator's surplus
	Externalities, measured as the level of emissions of CO_2 and SO_2

Participatory experiments: engaging stakeholders to validate our models

ITACA has performed a set of participatory simulation experiments aimed to understand the behavioural drivers of ATM stakeholders regarding the adoption of new technologies (motivations, interests, concerns, etc.). The results of these experiments have been used to inform and validate the behavioural assumptions of the agent-based model.

Representatives of the main ATM technology adopters – airlines, airports and ANSPs – participated in the experiments, enabling the acquisition of data from an environment closely related to a real-world setting. In the experiments, the experts first played the role of an agent aligned with their expertise and then the role of the modeller, modifying different aspects of the operational scenarios (e.g., fuel price). The results confirmed that the model behaves in a realistic manner from the perspective of all three agents, even when faced with extreme values and outliers.

4. Past and future: the role of the policy environment

In order to gain insights on the conditions for a certain policy or regulatory measure to be effective, the ITACA agent-based model has been used to test different combinations of ATM technologies and policy measures. First, we investigate why some past technologies achieved high acceptance rates while others failed to live up to the expectations, and whether certain policy measures could have led to a different outcome. Then, we use the model to forecast the adoption of a set of new SESAR Solutions under different policy scenarios.

Case study 1: Technologies that did not live up to the expectation

Technologies:

- Microwave Landing System (MLS): enables an approaching aircraft to determine when it is aligned with the destination runway and on the correct glidepath for a safe landing.
- EUROCONTROL Link 2000+ programme (Datalink): used to send information between aircraft and air traffic controllers (for example, when an aircraft is too far from the ATC to make voice radio communication and radar observations possible).

Policy scenarios:

- SOL_SCN_1: Cost plus pricing
- SOL_SCN_2: Best-equipped best-served
- SOL_SCN_3: Subsidies
- SOL_SCN_4: Increase of technology maturity
- SOL_SCN_5: Mandates
- SOL_SCN_6: Cost plus pricing + Best-equipped best-served + Increase of technology maturity
- SOL_SCN_7: Cost plus pricing + Subsidies + Increase of technology maturity
- SOL_SCN_8: Cost plus pricing + Best-equipped best-served + Mandates.

Simulation time span: 1990-2021

What we try to find out

MLS was never widely adopted and it is currently decommissioned. It is an example of a technology with high costs and complex implementation requirements that faced the appearance of a cheaper alternative: Global Navigation Satellite Systems. The early Datalink programme was not adopted at the expected pace, suffering delays in their final deployment.

Could any of the proposed policies have contributed to achieving the deployment targets of these technologies?

Key results

Technology adoption

Figure 2 represents the technological uptake by the different stakeholders predicted by the ITACA models with respect to the reference scenario. For instance, SOL_SCN_7 shows a 70%, 66% and 62% increase in the market share of terminal ANSPs, enroute ANSPs and airlines, respectively, that implement the Datalink compared to the baseline scenario; the number of airports that decide to adopt this technology remains constant with respect to the reference scenario. The results show that flexible charging (i.e., cost-plus pricing) leads to the highest implementation rates for Datalink. For MLS, the best options are best-equipped best-served, cost-plus pricing and mandates. The combined scenarios involving cost-plus pricing policy also seem to enhance technology uptake (i.e., according to the model, these policies would have increased the adoption of these past technologies).

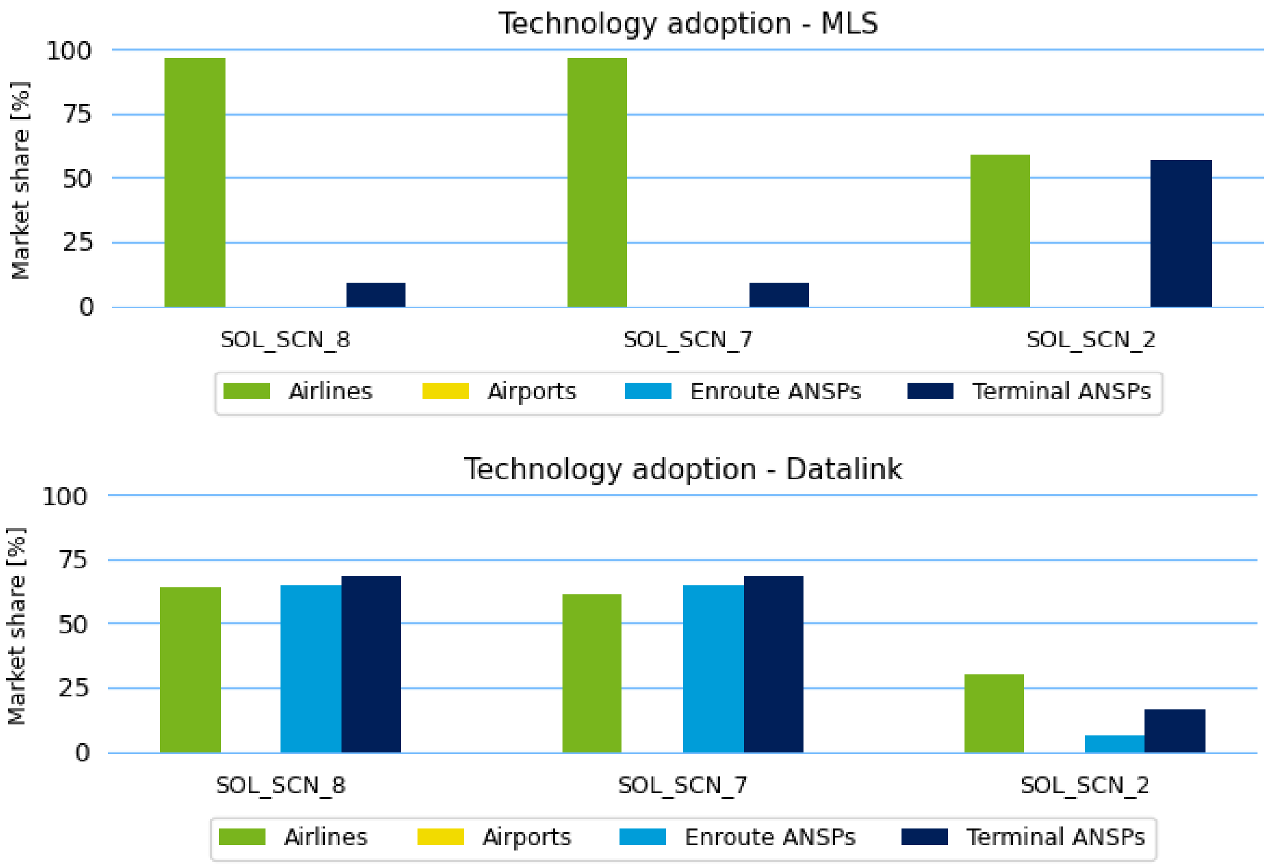

Figure 2. Technology adoption for past unsuccessful or slow adoption technologies (absolute difference with respect to reference scenario).

Operational performance

Figure 3 represents the relative values of the analysed operational metrics of each solution scenario compared to the reference scenario. The operational metrics are a result of the all the actions in the simulation, then, it aggregates the effects of all technologies considered in the case study. Subsidies (SOL_SCN_3) are the best performing measure when it comes to optimising operational performance, especially capacity and unit cost.

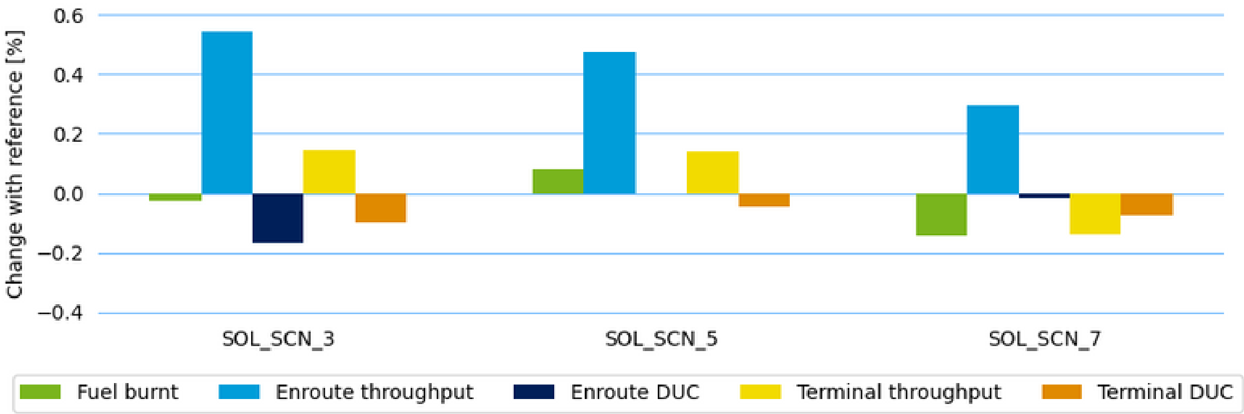

Figure 3. Operational performance for past unsuccessful or slow adoption technologies (relative values with respect to reference scenario).

Economic outcome

Figure 4 shows the absolute values of the surplus of each stakeholder under the different scenarios. The economic metrics are a result of the all the actions in the simulation, then, it aggregates the effects of all technologies considered in the case study. All the solution scenarios involving cost-plus pricing policy provide better economic results than the reference scenario.

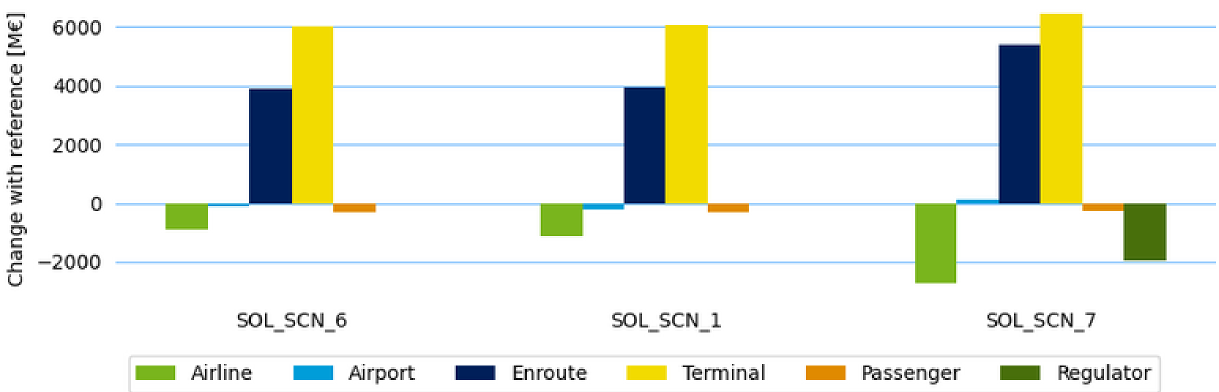

Figure 4. Economic outputs for past unsuccessful or slow adoption technologies (absolute difference with respect to reference scenario).

<u>Summary</u>

In order to provide the reader with a complete picture of the trade-offs in the different KPAs under study, the following figures show, for each stakeholder and each KPA, the difference between the most promising policy scenarios and the reference case. Each vertical axis represents a different metric, and next to each axis the maximum and minimum values obtained in such metric are highlighted. The first axis (technology adoption) represents an averaged metric of the technology adoption metric for all the technologies considered in the case study. For example, for the airlines graph, the difference in technology adoption, the change in fuel burnt and the difference in airline surplus over the baseline scenario are included for solution scenarios 1, 3, 6 and 7, which are represented by each line on the graph. The green shaded area represents the area of negative values for each axis. For some metrics (e.g., technology adoption), an increase with respect to the baseline is a positive change, while for other metrics (e.g., fuel burnt, Determined Unit Cost) the desired change is a reduction from the baseline. The desired trend is shown with arrows next to each indicator.

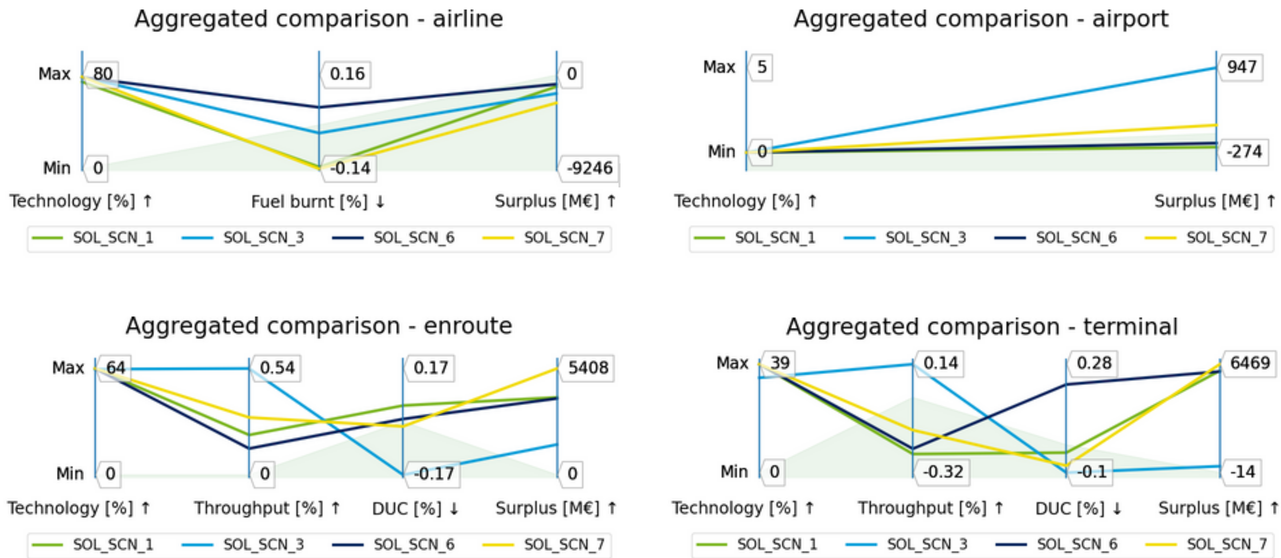

Figure 5. Overall results for past unsuccessful or slow adoption technologies: improvement with respect to the reference scenario.

Policy recommendations

- There is a trade-off between economic and operational indicators.
- The scenarios involving cost-plus pricing policy achieve best economic outcome, at the cost of reducing operational performance.
- The scenarios involving subsidies have the largest benefits in terms of operational indicators, but they are economically inefficient for all stakeholders except for the airports.
- Airlines surplus is always negative, due to the increase in navigational charges (when cost-plus pricing is applied) or airport charges (when subsidies are in place), so some type of compensation mechanism could be needed to get airlines' buy-in.

Case study 2: Past technologies that achieved high adoption rates

Technologies:

- Airport Collaborative Decision Making (A-CDM): allows the exchange of more accurate departure information to improve the efficiency and resilience of airport operations by optimising the use of resources and improving the predictability of air traffic.
- Continuous Climb and Descent Operations (CCOs and CDOs): allows aircraft to follow a flexible, optimal flight path that delivers major environmental and economic benefits.
- Remote towers: allows aerodrome Air Traffic Control (ATC) or Flight Information Service (FIS) to be provided from a location other than the aerodrome whilst maintaining safety levels.
- Automatic Dependent Surveillance–Broadcast (ADS-B): is a Surveillance technique that relies on aircraft or airport vehicles broadcasting their identity, position and other information derived from on board systems (e.g., GNSS).

Policy scenarios:

- SOL_SCN_1: Cost plus pricing
- SOL_SCN_2: Best-equipped best-served
- SOL_SCN_3: Demonstration projects
- SOL_SCN_4: Realistic timelines
- SOL_SCN_5: Demonstration projects + Realistic timelines
- SOL_SCN_6: Cost plus pricing + Best-equipped best-served

Simulation time span: 2003-2021

What we try to find out

The technologies considered in this case study succeeded in their adoption expectations due to their interest for the stakeholders involved and the institutional support they received (e.g., EUROCONTROL guidelines on A-CDM). The ITACA Assessment Framework provides similar outcomes in the baseline scenario, which suggests that the model is indeed able to capture stakeholder behaviour in a realistic manner.

Would the proposed policies have contributed to accelerate the deployment of these technologies? Would any of these policies have been detrimental for their adoption?

Key results

Technology adoption

The combination of cost-plus pricing and best-equipped best-served policies worked the best to accelerate and increase the adoption rate with respect to the reference scenario. Only with cost-plus pricing (SOL_SCN_1), the achieved benefit is already noteworthy in terms of adoption by ANSPs. However, if adoption by other stakeholders is sought, the combined policies in SOL_SCN_6 emerge as the best option.

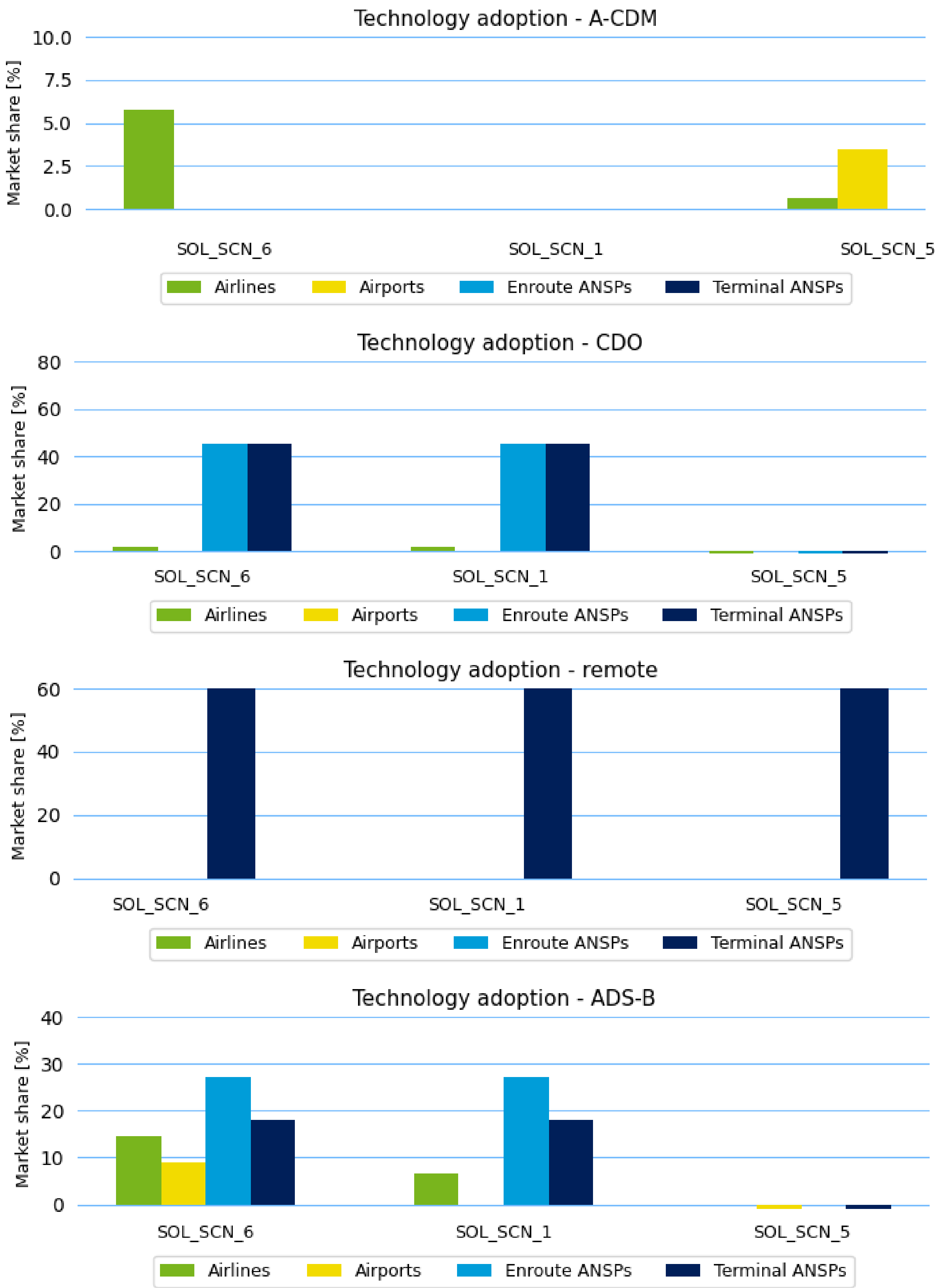

Figure 6. Technology adoption for past successful technologies (absolute difference with respect to reference scenario).

Operational performance

The best-equipped best-served policy (SOL_SCN_2) stands out among the rest, being the one that provides the highest improvement of all the considered metrics except for fuel consumption. The lowest fuel burn values are achieved for the scenarios involving demonstration projects and realistic timelines (SOL_SCN_3, 4 and 5). These results suggest that a combination of these policies with the best-equipped best-served policy could be worth exploring.

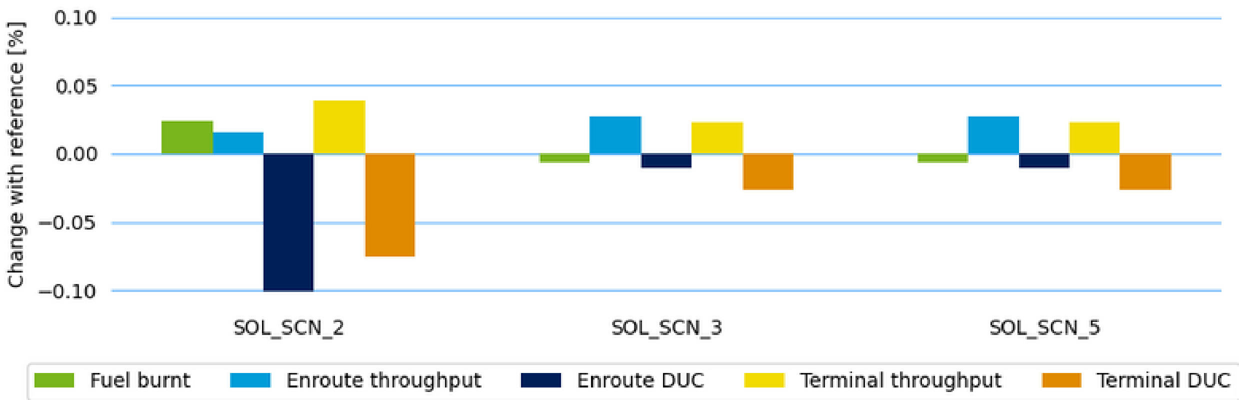

Figure 7. Operational performance for past successful technologies (absolute difference with respect to reference scenario).

Economic outcome

The combination of demonstration projects and realistic timelines (SOL_SCN_5) is the only policy scenario that provides a benefit with respect to the reference case when considering all surplus factors, by lowering the uncertainty about the feasibility and benefits of the technologies. However, even for the best case, the benefits are relatively small with respect to the reference case.

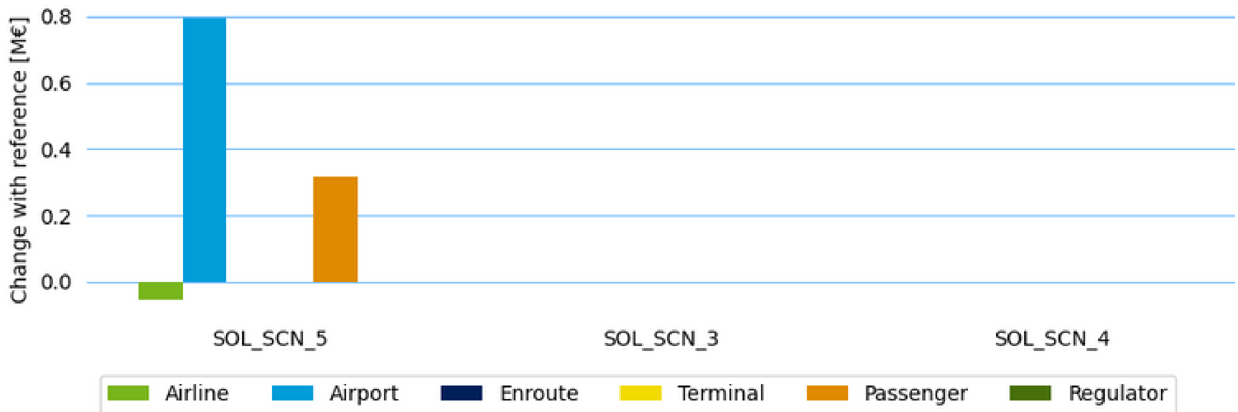

Figure 8. Economic outputs for past successful technologies (absolute difference with respect to the reference scenario).

Summary

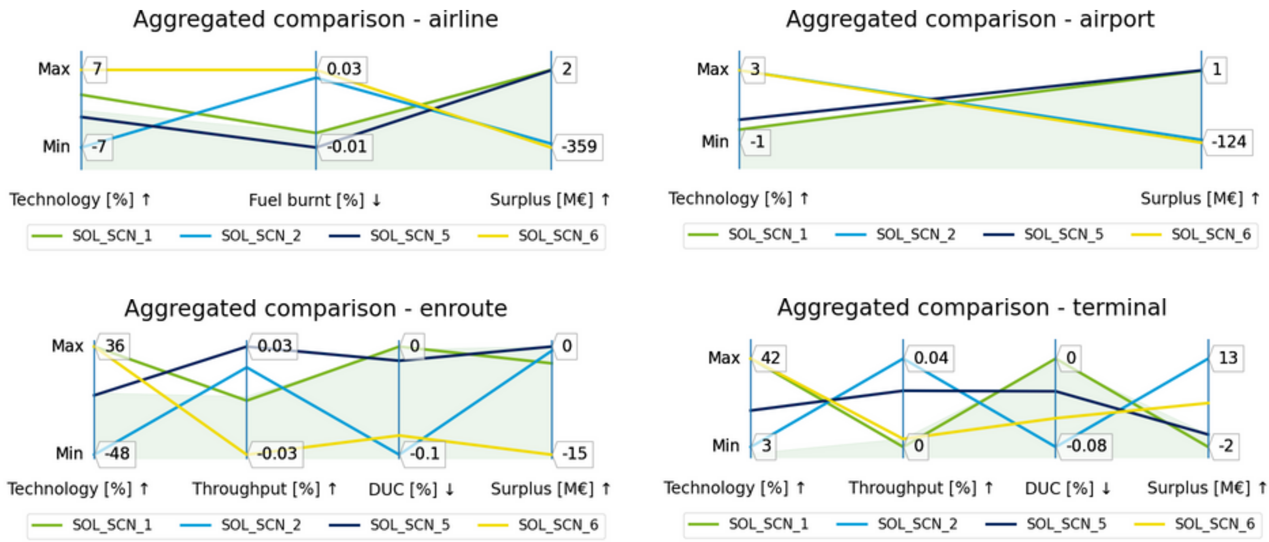

Figure 9. Overall results for past successful technologies: improvement with respect to the reference scenario.

Policy recommendations

- As in the previous case study, there are trade-offs between the different performance areas considered in the study.
- The cost-plus pricing and best-equipped best-served policies are the ones that lead to faster adoption and larger operational benefits; however, during the simulation time span these benefits do not completely compensate for the investment costs, leading to a slight decrease (-0.3%) in overall social welfare. From a social welfare point of view, the best options are the Demonstration projects & Realistic timelines policy combination (SCN_5), at the cost of slightly slowing down technology adoption.
- The increased implementation costs for airlines when adoption is increased translates into an increase of ticket prices, reducing the passengers carried and therefore the throughput (see SOL_SCN_6 for airlines in Figure 9), which explains the lower-than-expected correlation between the adoption rate and the operational metrics.

Case study 3: Future technologies

Technologies:

- System-wide information management (SWIM): enables seamless information access and exchange between all providers and users of ATM information and services.
- Dynamic Airspace Configuration (DAC): is a new operational paradigm that proposes to migrate from the current structured, static airspace to a dynamic airspace capable of adapting to user demand while meeting changing constraints of weather, traffic congestion and complexity.
- SAFEDRONE: is a SESAR JU project that investigated the required services and procedures necessary to operate drones in a safe, efficient, and secure way within U-space.
- Initial Trajectory Information Sharing (i4D): allows the connection between aircraft and ground systems to optimise the aircraft trajectory in the three spatial dimensions plus time.

Policy scenarios:

- SOL_SCN_1: Cost plus pricing
- SOL_SCN_2: Best-equipped best-served
- SOL_SCN_3: Demonstration projects
- SOL_SCN_4: Involvement of the safety agency
- SOL_SCN_5: Realistic timelines
- SOL_SCN_6: Subsidies
- SOL_SCN_7: Increase of technology maturity
- SOL_SCN_8: Mandates
- SOL_SCN_9: Best-equipped best-served + Demonstration projects + Involvement of the safety agency
- SOL_SCN_10: Cost plus pricing + Demonstration projects + Subsidies
- SOL_SCN_11: Demonstration projects + Realistic timelines + Increase of technology maturity
- SOL_SCN_12: Subsidies + Mandates

Simulation time span: 2022-2040

What we try to find out

The use cases considered have very different scopes and were considered attending to their operational interest. While we acknowledge the difficulties to accurately predict the future adoption of these technologies, we aim to provide a comparative assessment of the effects of the different policies under consideration.

Are the proposed policies likely to contribute to accelerate or ease the deployment of these technologies?

Key results

Technology adoption

The combination of subsidies and mandates works best to accelerate and increase the adoption rate with respect to the reference scenario. These results imply that there are two main mechanisms for accelerating the adoption of these future technologies: first, increasing incentives; second, imposing the obligation to adopt the technologies through mandates.

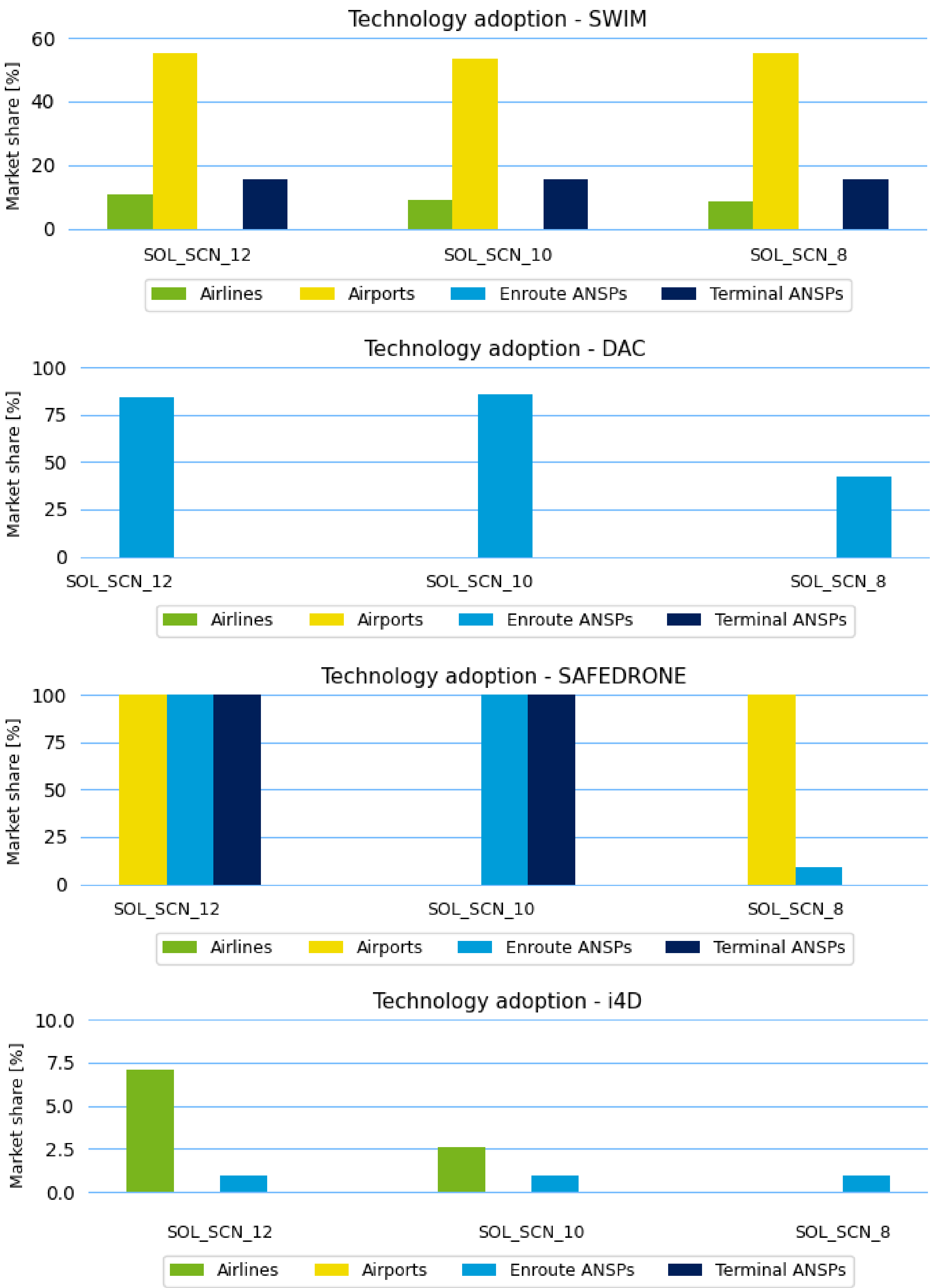

Figure 10. Technology adoption for future technologies (relative values with respect to reference scenario).

Operational performance

The combination of subsidies and mandates (SOL_SCN_12) also works the best, providing positive results in all metrics except for Terminal DUC; no policy scenario improves the results of this metric compared to the reference scenario. The fact that the combination of these two policy measures leads to the best operational performance is a direct consequence of the higher adoption rates. The subsidies help improve the capacity and DUC for terminal ANSPs, while mandates show the best isolated results in the remaining three metrics.

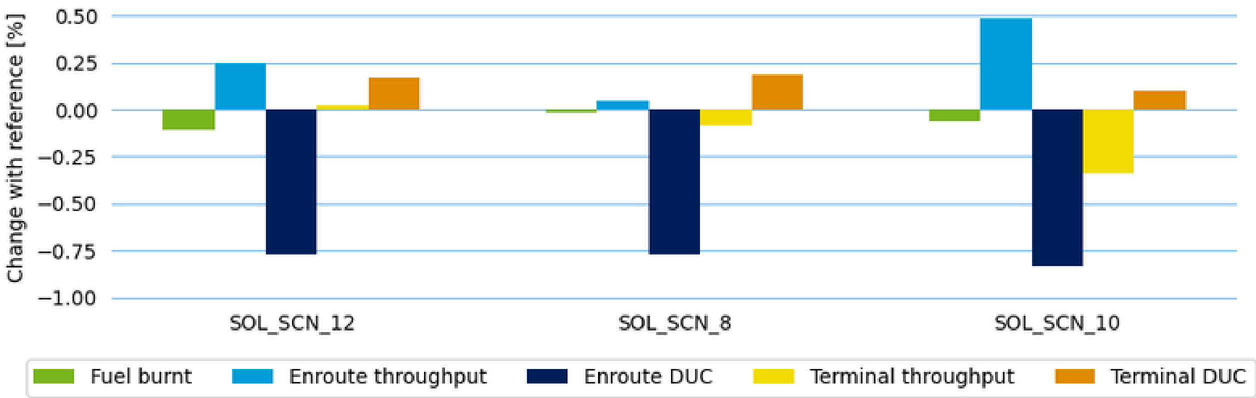

Figure 11. Operational performance for future technologies (relative values to reference scenario).

Economic outcome

All solution scenarios improve the results offered by the reference scenario. However, the cost-plus pricing policy (SOL_SCN_1) and its combination with demonstration projects and subsidies (SOL_SCN_10) offer significantly superior overall values, with around 5% growth in social welfare. In addition, the implementation of the cost-plus pricing policy (under the price regime applied) leads to a surplus increase for all the agents involved, with airlines and airports being the agents with the highest increase.

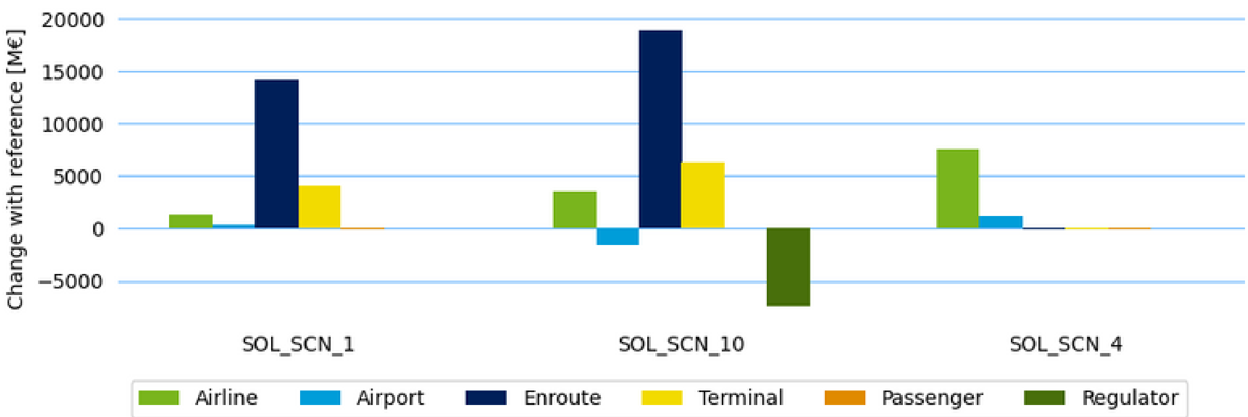

Figure 12 Economic outputs for future technologies (absolute values).

Summary

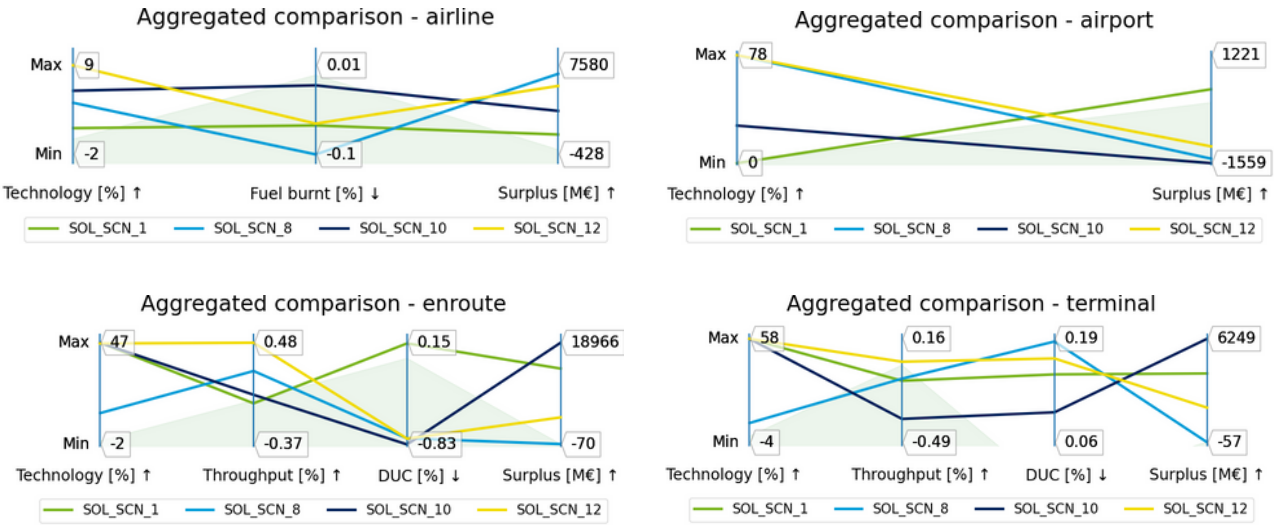

Figure 13 Overall results for future technologies: improvement with respect to the reference scenario.

Policy recommendations

- The combination of mandates and subsidies provide the best results from the technology adoption and operational point of views, showing also an improvement in social welfare, especially regarding passenger surplus.
- The cost-plus pricing policy measure shows a positive economic impact in all the scenarios analysed and for all stakeholders, also accelerating technology adoption.
- These results suggest that a proper combination of economic support (subsidies and cost-plus pricing) and mandates could be the optimal policy mix for these technologies, paying attention to potential negative economic outcomes for airports.

5. ITACA key takeaways

The need for a smart combination of policies

There is no policy that performs better than the others for the scenarios under study and across the three evaluation criteria (technology adoption, economic performance and operational efficiency). However, a combination of economic incentives (e.g., cost-plus pricing, subsidies) and enforcement through mandates provides the best results on the economic and operational sides. The ITACA framework can help optimise the design of such policies.

The heterogeneous impact of a policy across stakeholders may lead to worse results than a do-nothing policy

A clear example is the best-equipped best-served policy: while it provides the right incentives for airlines, it can be detrimental for ANSPs if not accompanied by other compensation policies, lowering the resulting levels of technology adoption and the social welfare with respect to the do-nothing scenario.

The importance of regulating ANSPs charges

Regulation of navigation fees is necessary, as without regulation the natural monopoly of ATM could lead to prohibitively large charges on airlines. On the other hand, an excessively strict limitation of air navigation charges may hamper the investment in new technology if it prevents ANSPs from recovering the cost of the investment in a reasonable payback period. Regulation should be flexible enough to allow ANSPs to make a fair profit that justifies the investment.

The need to deal with the asymmetric benefits of certain technologies

The market uptake of new technologies in a one-to-one setting is easier. The adoption of technologies that require several parties to make investments is often problematic. If one of the agents does not see any benefits, extra incentives to adoption may be necessary.

Enforcement works

The experiments performed by ITACA show that a technological mandate for a proven technology can be a welfare improving solution, by reducing the uncertainty that would be caused by a market-led uptake of the technology in a fractured and competitive market.

Flexible charging regulation deserves consideration

The cost-plus pricing policy can provide significant benefits, especially combined with other policies such as best-equipped best-served, subsidies and mandates.

There is no one-size-fits-all solution: pay attention to the specificities of each technology

The characteristics of the technology that wants to be incentivised play a key role in the optimal combination of policies to be applied. If the technology is already delivering clear benefits, proper economic incentives will suffice to obtain the desired uptake. On the other hand, if return on investment and the recovery period is long, the social optimum may only be achieved through the application of mandates.

The importance of rigorous, comprehensive and credible cost-benefit analysis

The outcome of a certain combination of policies is highly sensitive to the benefits and costs of the technology under study. The CBA of new technologies is thus an essential input to design an optimal policy mix. For many SESAR Solutions, cost-benefit analysis documentation is either not available or incomplete. Policy assessment frameworks like the one developed by ITACA would be much more robust if SESAR technologies were systematically the subject of a comprehensive CBA and this CBA were publicly available. The same problem affects stakeholders' decisions, slowing down the adoption of new ATM solutions.

The 'master key' stakeholder: the principal agent problem

When the main investor is not the main beneficiary, policies should focus on accelerating the adoption by this key stakeholder, since the other stakeholders, with lower implementation effort, will follow its lead (e.g., airports in A-CDM: airlines will benefit with little or no effort).

6. A look to the future

ITACA's vision is that of a European ATM system that incorporates the most advanced technologies in a dynamic and agile way to drive continuous innovation, deliver enhanced performance and adapt to changing market needs.

ITACA aims to contribute to realising this vision by helping design policies and regulations that accelerate the adoption and implementation of new technologies in ATM. The ITACA Policy Assessment Framework can be applied to all ATM solutions; the only prerequisite is the existence of a rigorous, comprehensive CBA.

The ITACA simulation engine, coupled with an interactive visualisation module, will help explore the impact of different policy options on a wide range of parameters and indicators. Such a tool would enable effective and efficient coordination between policy makers, such as the European Commission, and promoters of new technologies, such as the SESAR 3 JU, with the ultimate goal of achieving the objectives of the ATM Master Plan while providing the best outcome for the stakeholders of the aviation industry and for society as a whole.

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Lessons Learnt
and Way Forward

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