Airport slot allocation: performance of the current system and options for reform

Towards a comprehensive performance framework

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***Abstract*—ACCESS (www.access-sesar.eu) is a research project within SESAR WPE which addresses demand and capacity management at congested airports, focusing on market-based mechanisms for the strategic allocation of airport capacity. Market mechanisms are expected to provide the right incentives for a more efficient use of the available capacity, but they also raise a number of concerns, from the potentially negative impact on airline operating costs to market failures. There is therefore a need for a comprehensive assessment of different market designs. In this paper we introduce some considerations about the conditions to be met by a performance framework to allow a sound comparative evaluation of different slot allocation mechanisms, we outline a preliminary proposal for a set of performance areas and indicators, and discuss the potential impact of different possible reforms of the slot allocation system.**

Keywords- airport slot allocation; market-based mechanisms, performance framework.

I. INTRODUCTION

With the continuous growth of air traffic along the last decades, many airports are facing a situation where demand exceeds capacity. There are two ways of dealing with this problem: (i) capacity enhancement programs, often not possible because of various constraints; and (ii) demand management. Airport demand management includes a wide spectrum of measures, ranging from purely administrative procedures — such as slot control according to regulations — to economic, market-based or hybrid instruments — such as congestion-based pricing, slot trading and auctions.

Even though different studies have concluded that administrative slot controls lead to inefficiencies and hinder competition [1,2], slot control and schedule coordination have been so far the dominant approach in Europe. The European Commission has recently acknowledged the need to revise the Slot Regulation to favor more efficient use of airport capacity, opening the door to the introduction of market-based approaches [3].

Our aim in this paper is to set the basis for an analytical framework allowing a comprehensive assessment of different slot allocation mechanisms. Section II describes the current system. Section III introduces the way forward proposed by the European Commission and discusses different options for reforming the system. In Section IV, we start by making some general considerations about the requirements to be met by a meaningful and comprehensive performance framework. Then we propose a set of performance areas and perform a critical analysis of the weaknesses and gaps of the indicators proposed in the literature; we discuss the performance of the current system with respect to these criteria; and we analyse how performance could be impacted by different reforms of the slot regulation. In Section 5 we draw some conclusions and present the subsequent steps of this research.

II. THE CURRENT SLOT ALLOCATION SYSTEM

Slot allocation at EU airports is governed globally by Regulation 95/93 [4] and its respective amendments [5,6,7,8], which retain and develop the principles of the IATA slot allocation process [9]. On top of the mentioned regulations, some States impose national or local laws.

A. Definitions

A *slot* is the permission "to use the full range of airport infrastructure (runway, terminal, apron, gates, etc.) necessary to operate an air service at a coordinated airport on a specific date and time for the purpose of landing or take-off." [4]

There are two levels of airport coordination:

Coordinated airports: airports where aircraft operators need a slot (allocated by a slot coordinator) to be able to operate flights;

Schedules facilitated airports: airports where there is a potential for congestion in certain time windows and a schedules facilitator is appointed to facilitate the operations of air carriers intending to use the airport in those time windows.

B. The Slot Allocation Process

The slot allocation process consists of three main phases: primary allocation; slot returns; and slot exchanges and transfers.

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1) Primary Allocation

The primary allocation of slots is an administrative process. First the airport is designated as fully coordinated, and the airport coordinator is appointed. The role of the airport coordinator is to balance the demand for slots with the supply. Each coordinated airport must specify a declared capacity (in number of aircraft movements per unit of time) taking into account all the constraints affecting availability of resources.

The airlines must send a formal request for each desired slot. The submission of requests is done about five months before the start of the season (summer starts in late March, winter in late October). Slots are allocated in series, i.e. sequences of at least five slots at the same time on the same day of the week, distributed regularly in the same scheduling season, e.g. a series of 09:15 departure slots over at least five consecutive Mondays.

The initial coordination is carried out by satisfying or retiming slot requests to meet capacity constraints. Alternative slot times (usually for the same day) may be proposed to airlines. If no adequate proposal is available, the slot request is rejected. Two fundamental criteria are applied when allocating the available capacity: (i) historical precedence (*grandfather rights*) and (ii) time adjustments of historical slots. Airlines can earn grandfather rights to a series of slots provided they operate the slots as allocated by the coordinator at least 80% of the time during a season (*use-it-or-lose-it rule*). The grandfather rights only apply to series of slots, never to single slots or other ways of grouping slots. Single slots and other types of groups of slots return to the slot pool the following season. The use-it-or-lose-it rule has some exceptions where an airline can justify a slot usage below 80%, e.g. unforeseeable and unavoidable circumstances outside the airline's control. Airlines can lose historic rights to slots due to repeated and intentional slot misuse. Time adjustments are made after historical precedence is taken into account and before the allocation of the remaining slots from the pool to the other applicant air carriers.

After this first assignment to incumbent airlines and the slot reservation for Public Service Obligations (PSO), a slot pool is created with the remaining slots. Fifty percent of the slot pool is allocated to new entrants. An airline is considered a *new entrant* at an airport on a particular day if, upon allocation, it would hold fewer than five slots in total on that day or, for an intra-EU route with less than three competitors, hold fewer than five slots for that route on that day. The remaining slots in the pool are allocated giving priority to year-round commercial air services.

2) Slot Returns

Airlines are required to return the slots they do not intend to use as soon as possible. Late slot returns are considered as unused slots and thus impact the use-it-or-lose it rule.

3) Slot Exchanges and Transfers

Under the current European Slot Regulation, slots may be exchanged or transferred between airlines in specified circumstances. Slots may be transferred by an air carrier from one route or type of service to another route or type of service operated by the same air carrier; they may be transferred (i) between parent and subsidiary companies, and between subsidiaries of the same company, (ii) as part of the acquisition of control over the capital of an air carrier, and (iii) in the case of a total or partial take-over when the slots are directly related to the air carrier taken over; or they may be exchanged one for one, between air carriers. The Regulation allows, for example, carriers in the same alliance to use each other's slots when performing joint operations or code sharing, although any actual exchange or transfer is still subject to Article 8a.

Exchanges and transfers are always subject to the express confirmation of the coordinator, who must not accept a transfer or exchange unless it conforms to the Regulation and it does not negatively affect airport operations. The coordinator must also verify that the slots exchanged or transferred are not ones which have been reserved for a PSO, and that slots from the pool allocated to new entrants are not exchanged or transferred for a period of two equivalent scheduling seasons.

The current Regulation is silent as to monetary consideration accompanying slot exchanges and transfers.

III. The Way Forward Proposed by the European Commission. Options for Reform

Whereas the current Slot Regulation has established a legal framework in which the European air transport market has grown continually over the last years, several studies commissioned by the European Commission along the last decade [2,10,11] have pointed out a number of deficiencies of the current slot allocation system, including: insufficient transparency of slot information, concerns about the independence of some airport coordinators, inconsistency with an economically efficient use of the available capacity, creation of barriers for the growth of efficient competition, or lack of consistency between slots and flight plans.

To address these problems, as part of the Airport package adopted on 1st December 2011 [12], the European Commission launched a proposal aimed at improving the use of scarce capacity at busy airports. The new proposal increases the level of transparency on slots transactions; defines stricter criteria for the independence of the coordinators; asks for enhanced cooperation between the coordinators (e.g. for the development of common slot allocation software); opens the door to the future creation of a European coordinator responsible for slot allocation at all EU airports; allows airlines to trade slots with each other at airports anywhere in the EU in a transparent way; reforms the rules designed to help new entrants access the market at congested airports; tighten the rules to demonstrate that airlines have used their slots sufficiently during the season; and advocates the integration of slot allocation with the Single European Sky initiative, by associating the European Network Manager with the slot allocation process.

The allocation of airport capacity has been in the agenda of transport economics research for a long time, and different

mechanisms have been proposed with the aim to provide the right economic incentives to favor a more efficient use of the available capacity, including primary allocation of slots through auctioning, secondary trading of slots, and congestion pricing. The benefits that could be obtained from the abovementioned mechanisms (alone or combined in different manners) are far from generating consensus, and the transport economics literature, as well as air transport stakeholders, also point out a number of risks and concerns. There is therefore a need for a sound performance framework allowing a comparative assessment of different market designs.

IV. Towards a Comprehensive Performance Framework for the Assessment of Slot Allocation Mechanisms

A. Concepts and Definitions

A *performance framework* can be defined as the set of performance areas and indicators that will guide the evaluation of a particular slot allocation mechanism.

A *performance area* can be defined as a broad focus area encompassing one or several goals or objectives.

Indicators can be defined as a means of summarizing the current position and the direction and rate of change of progress towards a particular goal or objective. The use of indicators for the control and monitoring of processes helps evaluate and monitor developments; focuses the discussion with stakeholders; promotes the idea of integrated action; demonstrates progress towards goals and objectives; and ultimately supports decision-making. Indicators can be classified according to many different criteria. We will classify indicators according to the following categories:

1) Outcome Indicators vs Intermediate Indicators

Outcome indicators measure progress towards policy objectives (i.e. the variables one wants to optimize in the system).

Intermediate (or process) indicators, which provide useful information about the system (e.g. they may serve as a proxy for outcome indicators or have an influence on their evolution), but are not policy objectives per se. Expressing policy objectives in terms of intermediate indicators often leads to well-intentioned but ill-targeted policies.

2) Quantitative Indicators vs Qualitative Indicators

Quantitative indicators use numbers and express amounts or quantities.

Qualitative indicators use words, symbols or colors to express attitudes and views.

3) Local Indicators vs Global Indicators

Local indicators are measured at airport level.

Global indicators are measured at network level.

4) System-wide Indicators vs Stakeholder Indicators

System-wide (or social) indicators are measured at societal level.

Stakeholder-specific indicators are linked to a specific stakeholder or group of stakeholders.

B. Required Properties

There is abundant literature on the requirements to be met by a performance framework to properly meet its intended functions. In the particular case of airport slot allocation, a performance framework should have the following properties:

- the framework should be comprehensive, i.e. encompass the full range of economic, social and environmental impacts of the slot allocation system;
- it should be target relevant, i.e. outcome indicators should be relevant to the target they intend to measure;
- it should be understandable to all stakeholders;
- outcome indicators should be independent of each other;
- indicators should be measurable based on available and reliable data.

C. Preliminary Proposal for a Performance Framework

A comprehensive evaluation of capacity allocation mechanisms requires an analysis of impact along several performance areas. In our proposal, we have tried to be as consistent as possible with the concepts and terminology used by the SES II Performance Scheme and the SESAR Performance Framework; we also include other dimensions which fall outside the scope of SES II and SESAR performance schemes, but are considered necessary for a comprehensive impact assessment. We propose the categorization of the impacts of capacity allocation mechanisms according to six performance areas: Economic Efficiency; Equity and Distributional Issues; Access and Competition; Flexibility and Resilience; Interoperability; and Capacity and Delay.

1) Economic Efficiency

Economic efficiency measures the ratio between the total social welfare created and the maximum welfare that could be created. Social welfare is the sum of consumer and producer surplus (i.e. the sum of the effects on airlines, airports and passengers) and net benefits to third parties (externalities). The property of maximizing economic efficiency is often referred to as *social optimality* [13]. According to economic theory, maximum efficiency is achieved only if a good is produced by the lowest cost producers and the products are consumed by the consumers with the highest willingness-to-pay.

Economic efficiency indicators. When regarding capacity as a limited resource, economic efficiency is arguably the most adequate measure to evaluate its efficient use. Slots would be efficiently allocated when used by those airlines able to

generate the greatest social value. It seems therefore appropriate to use the ratio between the total social welfare created and the maximum welfare that could be created as outcome indicator.

The determination of the social value of a slot and thus the evaluation of economic efficiency is not an easy task. Economic efficiency includes all allocative and productive efficiencies, and finding the optimal trade-off poses a number of theoretical and practical challenges. One of the main criticisms of the current slot allocation system is that it does not allocate capacity in an efficient manner: since it makes no explicit consideration of the value that airlines attach to a slot, services may not be allocated to those with the greatest willingness to pay and therefore slots may be operated inefficiently by airlines who do not make the most efficient use of the available capacity. It is generally accepted that market mechanisms, such as auctioning of slots or secondary trading, would improve allocative efficiency by bringing appropriate incentives so that the available scarce capacity is used by those airlines able to make best economic use of it [2,10,14,15]. Congestion pricing could in principle lead to an equally efficient allocation, though the need to estimate demand elasticity and marginal congestion costs in order to dynamically determine the optimal structure and level of airport charges could lead to efficiency losses in practice. A detailed discussion of this issue can be found in [16]. On the other hand, these mechanisms could have an impact on productive efficiency that should not be underestimated. In what follows we make some considerations about several key dimensions that should be taken into account for a sound evaluation of economic efficiency, as well as possible intermediate indicators associated to these dimensions.

Revenues. To assess the extent of welfare creation, one should first assess consumer and producer surplus. By buying airline tickets, passengers would indicate their willingness to pay for the utility derived from a particular service [17]. Most literature on air transport economics argues that, given the sophisticated price discrimination strategies used by most airlines today, it is reasonable to take the value that an airline places on a slot as a proxy for consumer and producer surplus. However, due to the network nature of the air transport system, the calculation of revenues collected from passengers can become very complex, e.g. a small aircraft feeder flight could use slots more efficiently than a charter flight with more passengers, but less total revenue once network effects are taken into account [2].

Cost efficiency. Cost efficiency is used in SESAR to evaluate the ANS cost for flight. The ICAO equivalent KPA, Cost effectiveness, is defined as the full cost of providing the ANS, including appropriate amounts for cost of capital and depreciation of assets, as well as the cost of maintenance, operation, management and administration. In the case of capacity allocation, different capacity allocation mechanisms may affect cost efficiency in different manners:

- *Cost of operating the system*. One of the arguments in favor of the current system is that it is relatively simple and inexpensive [18]. This is also one of the arguments against the use of auctions for primary slot allocation: even if economic theory indicates that auctions should be a more effective way of achieving allocative efficiency than other alternatives, there is considerable concern about the cost of designing and operating an auction system, due to the complexity created by the interdependencies between the value of different slots. For an auction system to allocate access rights efficiently, the simultaneous auctioning of slots at all slot-constrained airports would be required, and airlines should be able to submit package bids, which leads to an extremely complex auction and therefore to the need for sophisticated software and bidding facilities, which would impose high costs on both the auctioneer and the bidders. Even if auctions were used to allocate slots, a secondary slot market would still be necessary to ensure that slot allocation remains efficient by dynamically reallocating slots to their highest valued uses. Secondary trading should be significantly easier and cheaper to operate than auctions, so many authors argue that the most effective measure for the efficient allocation of scarce capacity would be the extended use of secondary slot markets [10]. These authors argue that, as long as slots could be traded in a secondary market and in the absence of market imperfections, the initial allocation of slots should make no difference in terms of efficiency [14]. The initial allocation will nevertheless affect wealth distribution; equity and distributional issues are discussed later on in this paper, as a separate performance area.
- *Dynamic efficiency*. Dynamic efficiency is concerned with the productive efficiency of a firm over a period of time. There may be a trade-off between static and dynamic efficiencies over different periods of time, and it is thus reasonable to argue that sacrificing efficiency in the short run is justified, for example, to reduce the cost of managing uncertainty in the long run. The argument of schedule continuity could be seen as a particular instance of this type of trade-off: incumbent carriers argue that grandfather rights maintain stability and continuity in scheduling, thus facilitating long term planning, operational stability and economic viability to airlines and airports; on the other hand, new entrants claim that grandfather rights deny them opportunities to enter the market, often leading to an inefficient use of capacity.
- *Cost of delay*. Another issue identified in the literature on airport slots is that different slot allocation mechanisms may change not only the use of capacity at congested airports, but also lead to different route structures. Both factors may in turn affect delay distribution. We address delays more in detail within

the section dedicated to Capacity and Delays, but we will point out here that a lot of modelling work remains to be done for a proper quantification of the cost of delay for airlines and passengers [13,19].

Externalities. As previously mentioned, in the presence of externalities, the value of a slot for an airline will not be the same as the social value of a slot. Examples of externalities are the impact on environment or on the accessibility of European regions, which have been discussed e.g. in [2]. We leave for future research whether some of these externalities deserve to be analyzed within separate performance areas.

2) Equity and Distributional Issues

The performance framework should not only address the total social welfare, but also the distributional impacts of different mechanisms, as they will alter how different stakeholders gain or lose. For example, due to commercial and operational reasons, an airline will have an ideal pair of departure and arrival slots (ideal slots) for each of its flights. When this ideal pair is not available, the airline has to advance or delay its flight, which induces an undesired cost (shift cost) [20]. From the airline's point of view, the main objective is the minimization of its shift costs. A system-wide efficiency indicator instead may look for optimizing the social welfare that, in this case, could be approximated by the minimization of the sum of the shift costs imposed to all flights. However, this minimum overall cost could be achieved at the expenses of some individual airlines or flights that can be enormously more penalized than others.

Equity indicators. A proper outcome indicator for equity and distributional issues would be an indicator stating whether each stakeholder gets a non-negative utility. The property of a mechanism such that each stakeholder is expected to get a non-negative utility is referred to in the literature as *individual rationality* [13,20]. To compute such indicator, it is in turn necessary to measure *revenues and costs per stakeholder*.

While secondary trading should in theory improve equity, as both the seller and the buyer will only carry out a transaction if it increases their utility, this is not the case for other potential reforms, such as auctions or congestion pricing. The opposition from certain stakeholders to these mechanisms can be understood from this perspective. Incumbent airlines, for example, oppose slot auctions because they would reduce the slot rents they are currently obtaining thanks to grandfather rights. Airlines also oppose congestion pricing, as it would lower their profits. Generally speaking, mechanisms that could in principle have the potential of increasing social welfare may raise distributional issues if they don't include appropriate compensation mechanisms or certain constraints. An example is the question of who receives the revenues in the case of slot auctioning; it has been suggested, for example, that they could be earmarked for airport expansion. Reference [21] introduces some monetary compensation mechanisms in the slot allocation process for redistributing among airlines the surplus deriving from the elimination of grandfather rights.

3) Access and Competition

According to ICAO, a global Air Navigation System should guarantee that all airspace users have access to the resources needed to meet their operational requirements, while ensuring that the shared use of the airspace can be achieved safely. Generally, the global Air Navigation System should ensure an equitable treatment for all airspace users that have access to a given airspace or service, except where special considerations (e.g. significant overall safety or efficiency considerations, national defense, etc.) advise to establish priority on a different basis.

The issue of competition and access of new entrants is, together with that of economic efficiency (to which it is intimately and intricately linked), the other major criticism of the current system. In order to effectively compete with the dominant carrier at a given airport, a new entrant needs to build up a sustainable slot portfolio. Under the current rules, airlines quickly fall outside the definition of new entrant, which obstructs the growth of efficient competition [11]. At the same time, there is little incentive for incumbents to release slots even if they cannot use them efficiently (slot hoarding or babysitting). Moreover, the slot pool is usually made of slots at less commercially attractive times than those assigned due to grandfathering. This aspect is also sometimes referred as competitive efficiency, i.e. the capability of promoting competition through the elimination of entry barriers to newcomers and discriminatory practices in favor of established carriers. It must also be pointed out that, even if the new entrant rule has not been overall extremely successful at promoting sustainable competition, it has made it possible for low cost airlines such as Ryanair and especially EasyJet to achieve significant growth at some congested airports. Schemes to provide equal opportunities to new entrants have been addressed in two recent studies. Reference [21] compares airlines' costs when grandfather rights are either enforced or not. Reference [22] introduces five types of slot allocation strategies consisting of different combinations of grandfather rights, central coordination and free market and characterized by an increasing level of differentiation with respect to the current system.

Access and competition indicators. Among the competition indicators proposed in the literature, one can find the ratio between the number of slots allocated to new entrants and the total number of allocated slots, or the level of slot concentration. The use of this type of indicators has sometimes led regulators to take measures to limit such concentration. However, measuring slot concentration as an indicator of competition could be misleading. It may happen that the maximization of social welfare occurs for a high level of concentration of slots at certain airports. Indeed there is some evidence that concentration of slots may increase when slot trading is allowed [23], which could be due to the value of slots in a hub and spoke network, so that large carriers have a higher willingness-to-pay. Reference [24] argues that higher fares at slot constrained airports do not necessarily constitute a case for abuse of market power; other reasons may exist, such as the

cost of providing for passenger connections and operating at a bigger airport. The definition of suitable outcome indicators to measure competition is not a trivial task: there is a need for more sophisticated indicators able to grasp whether the output is being deliberately restrained below capacity, i.e. whether the slot allocation system prevents the entry of new competitors with a higher willingness-to-pay than those airlines operating the available slots. Other aspects related to access and competition are discussed below.

Access costs. One could think that if a primary slot allocation based on auctions were established, it would be more difficult for small carriers with lower purchasing power to get slots at the busiest airports. That slot allocation in the current system is free of charge is sometimes seen as a positive feature from the point of view of competition, though it would not necessarily imply more economic efficiency.

Public Service Obligations. A PSOs is an arrangement to operate a specified service of public transport for a specified period of time for a given subsidy. Article 9 of Regulation EC 95/93 as amended in 2004 provides that slots may be reserved for PSO routes. This guarantees that services to regional communities are operated regularly even in those cases in which they are not profitable for airlines.

Independence of the coordinator. According to the Regulation the coordinator must be a qualified natural or legal person, acting in an independent, neutral, non-discriminatory and transparent manner. Nevertheless, the limits of this independence are sometimes vague. As an example, in Spain the coordination is undertaken and fully funded by AENA, the national airport operator and air navigation services provider.

Transparency of slot information. The quantity and the quality of the information provided by coordinators could be improved. Many airlines believe that they should receive more information on coordination parameters, local rules and sanctions systems [11], and most stakeholders consider that standardization of online formats across coordinators would be beneficial. Some airlines complain about the fact that, when slots become available, not all coordinators make this publicly known, which may reduce the competition for these slots. The level of transparency may be characterized by means of a qualitative indicator. What information is shared (and when) is a key design parameter for market mechanisms that will have an impact on how the market develops.

4) Flexibility and Resilience

Flexibility, as defined by ICAO, addresses the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times to exploit operational opportunities as they occur. While the ICAO concept is restricted to operations at the tactical or flight execution stages, herein we will use flexibility in a wider sense, covering the ability to modify the trajectory at its different instantiations, from the strategic phase across the collaborative layered planning process, to the tactical phase. Flexibility will be thus understood as the ability provided by the system to modify the allocation and use of slots in order to cater for a changing environment. Flexibility can be analysed at different temporal and spatial scales.

Flexibility of allocation: ability of the system to modify the slot allocation matching airlines request. The current system provides some flexibility of allocation to both airlines and coordinators. Initially, each slot may be allocated as desired, rejected, or allocated but rescheduled. In the last two cases, negotiations can be carried out at the IATA conferences to find a proper solution and, if this is not possible, airlines can hand-back the unusable slots and possibly benefit from the slots returned by other airlines. On the other hand, no mechanism is implemented to link dependent (origin-destination) requests. Airlines can use overbidding as a hedging strategy to mitigate the risk of not being allocated certain slots, e.g. the risk of not getting the relevant complementary slot(s) [17]. Although it provides some flexibility during the slot allocation phase, the current system tends to be reactionary rather than proactive. Different instruments have been suggested to improve this aspect, from optimisation techniques to minimize the difference between requested and allocated slot time [22] and mechanisms for linking slot requests at dependent airports [20,21], to the use of combinatory auctions in conjunction with secondary trading. Defining suitable *flexibility of allocation indicators* is again a non-trivial task. A suitable outcome indicator should measure how close the resulting slot allocation is from that which would minimize shift costs, possibly under certain equity constraints. Intermediate indicators such as the percentage of slot requests rejected by the coordinator for a given level of capacity usage can provide useful hints, but they don't allow the extraction of straightforward conclusions about the performance of the system in this respect.

Flexibility of use (in normal conditions). The current system gives some flexibility for air carriers to adapt their offer to the actual demand. The 80-20 rule gives some margin to change the schedule once slots are allocated, allowing airlines to make certain decisions based on the commercial viability of individual flights, such as cancelling some flights on “cold” days (e.g. Christmas Day). On the other hand, most of the major European airports have become so congested that some airlines are willing to pay other airlines to give up their slots for cash or in exchange for other slots. According to [11], over 10% of the slots allocated in Europe in the 2008-2010 period were not used; unused slots are taken into account for the application of the 80-20 rule, but do not involve a fine or penalty to the carrier. Uncertain factors which may lead to late return include changes in travel demand, traffic rights, availability of the right aircraft type for each particular route, or last minute problems [11]. Here again, secondary slot trading in a transparent market would arguably increase the flexibility of slot use. Regarding *flexibility of use indicators*, similar considerations to those previously made for flexibility of allocation can be made: a suitable outcome indicator should measure how close the resulting slot use is from that which would minimize shift costs. The level of slot mobility, measured as the number of exchanges/transfers accepted

against the total number of exchange/transfers requests, can also be useful to evaluate the performance of the system in this dimension.

Flexibility of adaptation to disturbances: ability of the system to adapt the final slot allocation to temporal, force majeure circumstances. The concept is closely linked to that of resilience, which and can be loosely defined as the ability of a system to absorb disturbances and then to re-organize so as to retain its basic structure and functions. The allocation rules under the current system are not adaptable to special circumstances. When these have occurred, the regulator has made temporal amendments to the law, such as the suspension of the 80-20 rule due to a decrease in air traffic demand in 2002, after the 11/9 terrorist attacks [5], in 2003 due to the Iraq war [6], or in 2009 as a consequence of the global economic crisis [8]. It is expected that under a more liberalized framework (e.g. auctions, secondary trading), the market would be able to self-adapt to these circumstances. *Resilience indicators* could be a particular instance of *flexibility of use indicators* in case of disruptive events.

Flexibility of adaptation to local geographical conditions. The current system leaves some room for local rules, especially regarding the definition of coordination parameters, the acceptance of a secondary market and the imposition of PSOs. The reforms under consideration, in particular the introduction of market-based mechanisms, would in principle be compatible with providing flexibility at local level.

5) Interoperability

The Air Navigation System should be based on global standards and uniform principles to ensure technical and operational interoperability and facilitate homogeneous and non-discriminatory global and regional traffic flows. As far as slot allocation is concerned, two dimensions are considered particularly relevant: interoperability of slot allocation systems, and interoperability of

Interoperability of slot allocation systems. The European slot allocation system is based on IATA Guidelines, which have an international scope and are used almost all around the world. Each country or airport may add local rules, but the principle is the same. This homogenization eases planning for carriers that operate flights between Europe and other territories where IATA Guidelines apply. This is one of the arguments used by legacy carriers against the modification of the slot allocation system.

Interoperability of flight information. Currently flight plans are validated by the CFMU, whereas airport slots are assigned by the airport coordinator. Historically there has been very little information sharing between these organisations, and airlines have often operated their flights according to a flight plan with departure and/or arrival time differing notably from the slots schedule. According to the Single European Sky principle of adopting a gate-to-gate perspective, airports shall be integrated into network planning. The consistency between slot times and flight plans is explicitly addressed in [12], and there is also an Operational Improvement Step in the SESAR Master Plan to address this problem (OI DCB-0301) [25].

Interoperability indicators. The interoperability of slot allocation systems could be qualitatively assessed as the level of commonality and compatibility with the IATA guidelines. A suitable indicator to measure the level of interoperability of flight information could be the difference between slot times and take-off and arrival times in flight plans.

6) Capacity and Delay

The global Air Navigation System should exploit capacity to meet airspace user demand at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, along with improvements in other performance areas, capacity must increase. This paper deals with the allocation of airport capacity, which is taken as a fixed, given input. Notwithstanding, the design of the slot allocation system may influence capacity and delays in several respects, which we briefly discuss hereafter.

Capacity specification. While the question of whether slot allocation mechanisms are economically efficient has been the subject of different research efforts, less attention has been paid to the previous step, i.e. the optimal choice of the number of slots at a given airport. The question is to determine what level of scheduled flight demand, in the presence of different sources of uncertainty (e.g. weather), provides the right trade-off between the costs of additional delays (and possibly, environmental costs) and the benefits from additional throughput. Some studies on the topic, mainly related to the US, are illustrated in [26]. The current practice at European airports has been criticized based on a number of arguments, such as the ample room for local interpretation or the empirical ad-hoc processes often applied.

Incentives for capacity expansion. Another aspect that shall be taken into account in relation to capacity is the ability of a certain slot allocation system to create the right incentives for investment. Increases in airport capacity devaluate slots. Some authors argue that auctions or congestion pricing could create perverse incentives for airports to underinvest in new capacity if they make profits from pricing or auctioning of scarce capacity [16]. On the other hand, it is also reasonable to argue that, with the current system, incumbent airlines which have very valuable slots at busy airports have an incentive to moderate their requests for capacity expansion [15].

Delay. With respect to a congestion-based, first-come first-served system like the one adopted in almost all US airports, a slot system not only reduces congestion through reduced throughput, but it also reduces congestion at any level of throughput by means of a more ordered, less random traffic. Additionally, the reform of the slot allocation system, e.g. through the introduction of market mechanisms, may lead to changes in airlines' route structures [2], which may in turn modify the level and distribution of delay.

V. Conclusions and Next Steps

The strategic allocation of airport slots is a complex problem. The diversity of perspectives, goals and strategies implies that, at the time of designing and evaluating the characteristics of several alternative systems, the impact of different mechanisms needs to be assessed along multiple dimensions. In this paper we identify several types of indicators according to their nature and scope, and categorize the implications of the slot allocation system into six performance areas: economic efficiency, equity, access and competition, flexibility, interoperability, and capacity. Each area is defined and delimited so as to ensure clarity and avoid overlapping. We propose a set of indicators aimed at covering each performance area in an objective and measurable way, and we discuss the potential impact of different possible reforms. Far from being exhaustive and definitive, the paper represents a first approach aimed at conveying some general reflections with a view to establishing a comprehensive framework for the comparative assessment of slot allocation mechanisms. The next steps of this research will involve completing and refining the proposed framework through a set of consultations with stakeholders, the formalization of different possible designs for market approaches to airport slot allocation, and the development of a simulated test environment. The modeling work will rely on agent-based computational economics to evaluate the proposed market designs along the specified performance areas.

Acknowledgment

This work is co-financed by EUROCONTROL acting on behalf of the SESAR Joint Undertaking (the SJU) and the European Union as part of Work Package E in the SESAR Programme. Opinions expressed in this work reflect the authors' views only and EUROCONTROL and/or the SJU shall not be considered liable for them or for any use that may be made of the information contained herein.

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