

*A Work Project, presented as part of the requirements for the Award of a Master's degree in International Development and Public Policy from the Nova School of Business and Economics.*

**Slot Allocation at Airports:  
Can we propose more efficient approaches?**

**Evidence on efficient airport slot allocations through congestion  
pricing and auctioning**

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## Abstract

The existing airport slot allocation system, burdened by rising demand and limited infrastructure, promotes anti-competitive practices and economic inefficiencies. This master thesis delves into proposed alternatives, notably administrative methods like the PSAM model and market-based mechanisms, such as auctions and secondary trading. While the PSAM pilot project demonstrated potential at medium-sized coordinated airports in Portugal, experts in slot allocation claim that Germany's current decentralized process already ensures a pareto-optimal scenario. Consequently, they argue that the PSAM may not offer a significant industry benefit, challenging its purported efficiency enhancement. Contrastingly, research indicates that removing the grandfathering system and auctioning off all slots with a formal secondary market may enhance efficiency, however, it requires careful implementation to prevent the build-up of market power. Secondary slot trading offers consumer benefits, like route network expansion, yet raises competitive concerns and may prompt airlines to prioritize frequency over using larger aircraft.

## Keywords:

Airport Slot Allocation, Airport Congestion, Demand-Capacity Mismatch, PSAM, Secondary Trading, Auctions, Competition Policy, Congestion Pricing, Efficiency.

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## List of Abbreviations

2SLS	Two-Stage Least Squares
ACI	Airports Council International
ACL	Airport Coordination Limited
AI	Artificial Intelligence
ASWG	Airport Slot Working Groups
ATC	Air Traffic Control
ATM	Air Traffic Management
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
BMI	British Midland Airways
CAA	Civil Aviation Authority
CTOT	Calculated Take-Off Time
DOT	United States Department of Transportation
EASA	European Union Aviation Safety Agency
EC	European Commission
EP	European Parliament
Fluko	Flughafenkoordination Deutschland GmbH
FMP	Flow Management Position

FOB	Free on Board
GAO	United States Government Accountability Office
GDP	Gross Domestic Product
HHI	Herfindahl-Hirschman Index
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
LHR	London Heathrow Airport
LLC	Low-Cost Carrier
OLS	Ordinary Least Squares
PSAM	Priority-Based Slot Allocation Model
PSO	Public Service Obligation
RECAT-EU	European Wake Turbulence Categorization and Separation Minima on Approach and Departure
SARPs	Standards and Recommended Practices
SC	IATA Slot Conference
SES	Single European Sky
SESAR	Single European Sky ATM Research
SSIM	Standard Schedules Information Manual
WASB	Worldwide Airport Slots Board

WASG      Worldwide Airport Slot Guidelines

WWACG    Worldwide Airport Coordinators Group

# 1 Introduction

Airports are critical infrastructure for the global economy, facilitating the movement of people and goods around the world. However, airports are also limited in their capacity, and this can lead to congestion. One way to manage congestion is through the allocation of airport slots. Slots are typically allocated to airlines based on a number of factors, including historical usage, market demand, and environmental considerations. The allocation of airport slots is a complex process, and there are a number of different administrative and market-based approaches that can be used. This paper will explore the different approaches to slot allocation and will discuss the efficiency, issues, and solutions associated with each approach to provide a holistic answer to the following research question:

**“Slot Allocation at Airports: Can we propose more efficient approaches?”**

First, the paper provides a conceptual framework for understanding the market for airport slots. Chapter 3 discusses the regulatory framework that governs the allocation of airport slots and finally, chapter 4 will examine the efficiency concerns within the current slot allocation process. Afterwards two market mechanisms will be explored, that can be used to allocate airport slots: administrative mechanisms and market-based mechanisms. The accompanying advantages and disadvantages of congestion pricing and auctions will be presented in detail, in consideration of supporting literature, case studies, expert interviews and data analysis. Finally, the paper will summarize the key findings and provide policy recommendations as well as ideas for further research.

## 2 Conceptual Framework: Airports, Airlines & Airport Slots

### 2.1 Understanding the Market for Airport Slots

In recent years, air transport has increased significantly, thus leading to a surge in the demand for flights. This rapid evolution of air transport has led to severe congestion and delay problems at airports around the world as they are faced with capacity constraints (Cavusoglu & Macário, 2021; Feng et al., 2023). Moreover, an increasing number of airlines strives to capitalize on this growing market, which results in the need for efficient management of airport operations (Ribeiro et al., 2018). The main challenges are managing the growing disparity between airport capacity and demand for air traffic (Mandas & Zografos, 2010). Mechanisms on the capacity-side focus on the expansion of airport capacity, for instance by extending the number of gates or runways, and operational enhancements. In contrast, demand-side mechanisms tackle the congestion problem by managing passenger demand and scheduling of flights (Rodríguez-Sanz & Andrada, 2022). The management of demand and airport capacity generates complex decision-making processes, which have sparked intense debates among policymakers. Hereby, the central dilemma revolves around the question whether the focus should be on demand management or capacity enhancement (Ryerson & Woodburn, 2014). There is substantial controversy surrounding which aspect should be given priority. However, institutional, political, and physical limitations in expanding airport infrastructure make a purely supply-side solution virtually impossible. Given the severity of the issue, policymakers, airport users, and other stakeholders have increasingly emphasized solutions in demand management for allocating scarce airport capacity, which is often expressed in airport slots (Mandas & Zografos, 2010; Jacquillant & Odoni, 2018).

Airport slots, often also just ‘slots’, have emerged as a vital mechanism to optimize air traffic at highly congested airports (Zografos et al., 2018). Slots are defined as the “permissions to use

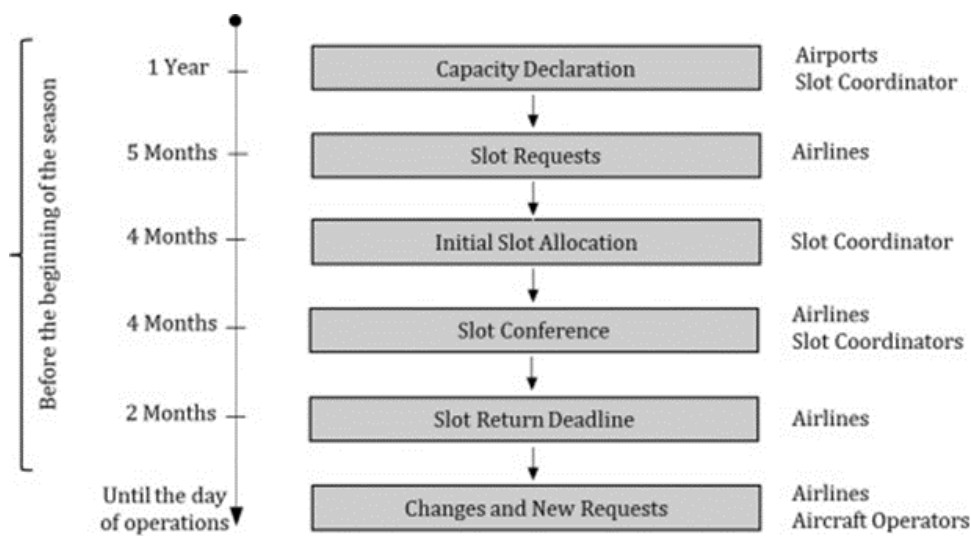
the full range of airport infrastructure necessary to arrive or depart at an airport on a specific date and time” (IATA, 2019). These permissions grant airlines the authorization to operate at an airport at a particular time, and they are used as tools to prevent delays that may result from too many flights trying to take off or land at the same time. Slots are a valuable resource as they allow airlines to operate flights at times that are convenient for passengers as well as the airline itself, thus boosting customer satisfaction and facilitating coordination of aircrafts. The combat for the best slots has resulted in a competitive market in which airlines trade slots for prices that reach millions (Pouget et al., 2023). Hence, it is understandable that the allocation of slots is a complex process, as it must balance the capacity of the airport with the needs of airlines. Even more, optimizing airport operations is crucial to ensure efficient global air transport, which for itself contributes to the global economy (Jorge et al., 2021).

This part of the paper focuses on demand management, whereby the current slot allocation process is highlighted.

### **2.1.1 Congestion and Slot Allocation Process**

Slot allocation encompasses the process of assigning time slots to airlines, thus granting them the permission to operate flights at specific times. The coordination of airports is seen as a process to maximize the efficient use of airport infrastructure by realizing its full capacity potential, optimizing congestion and delays, and ensuring that slots are allocated in a fair manner (Katsigiannis & Zografos, 2023). In general, slot allocation is only needed when airport infrastructure cannot meet the demand for flights (Ribeiro et al., 2018). Hence, in order to decide whether an airport needs slot allocation, the International Air Transit Association (IATA) differentiates between three levels of airports. Level 1 (non-coordinated) airports generally meet the demands of users at all times; thus, they do not require slot coordination. Level 2 (schedules-

facilitated) airports show potential for congestion during critical periods, however, by scheduling adjustments that have been mutually agreed between airlines and a facilitator, this issue can usually be resolved. The third category, namely Level 3 (coordinated) airports, encompasses all those airports in which congestion is at such a high level that the demand for airport facilities exceeds the availability during the relevant period (IATA, 2019; Ribeiro et al, 2018). Such schedule coordinated airports are controlled by coordinators that allocate the slots to the airlines that wish to utilize the airport’s infrastructure (Pertuiset & Santos, 2014). In the vast majority of airports where demand exceeds capacity, slot allocation is performed according to the Worldwide Airport Slot Guideline (WASG), as provided by IATA. According to these guidelines, the slot allocation process is conducted bi-annually, once for the summer and once for the winter season (IATA, 2019). Figure 1 shows the slot allocation process, divided into six major steps which reach from capacity declaration to the changes and new requests.



**Figure 1: The Slot Allocation Process.**

taken from (IATA, 2019)

*Note.* Approach to slot allocation under the guidelines of the WASG

The following paper will mainly focus on the third step, i.e., the initial slot allocation. In this step of the slot allocation process, coordinators are appointed to manage the requests for slots

handed in by airlines, and the capacities of given airports (Ribeiro et al., 2018). In doing so, coordinators decide whether the slot request can be accepted or rejected. Additionally, coordinators can choose to displace a slot request, meaning that the slot time assigned to the request is different from the time requested by the airline (Jorge et al., 2021). The coordinators have the responsibility of assigning slots in an unbiased and non-discriminatory manner, as consistent with the WASG's criteria. By applying these so-called primary criteria, coordinators ensure transparency and neutrality regarding slot allocation (Sheng et al., 2019). In accordance with the primary criteria, requests for slots are categorized into four classes that are allocated in a specific order. The first class of slots are so-called "grandfathered" slots which refer to historic slots already held by airlines in the previous seasons. Grandfather rights continue until an airline ceases to utilize a slot or surrenders it back to the coordinator. A 'use-it-or-lose-it' rule is applied to determine whether a slot should be surrendered (Ribeiro et al., 2018). Currently, an airline is required to achieve at least 80% of usage of a slot in the previous season to retain grandfather right to its slot. If failing to do so, the slots will be reallocated to potential entrants and competitors (Kösters et al., 2023). After "grandfathered" slots have been allocated, the coordinators consider the remaining slots, a so-called 'slot pool', which encompasses new entrant and non-new entrant requests, as well as requests for changes to historic slots which greatly impact coordination, such as changes flight time or a new aircraft type. 50% of the pooled slots are reserved for new entrants while the rest are allocated to incumbents for free (Sheng et al., 2019).

In a third step, airlines that have the new entrant status are considered. Lastly, all other slots are taken into account. It is important to note that for each of the four classes, those requests that concern year-round flights, in contrast to seasonal flights, receive priority (IATA, 2019).

While applying these rules is relatively straightforward, coordinators are challenged by additional criteria that come into play when multiple requests from the same primary criteria class

vie for the same slots (Ribeiro et al., 2018). One key rule is that those schedules with a longer period of operation, i.e. more weeks, in the same season should be given priority over those that are shorter. At the same time, coordinators need to consider various other criteria, such as operational factors (e.g., airport curfews), an airline's time spent on the waitlist, or an airport's route network development as well as connectivity. In addition, the criterion of competition must also be taken into account in order to ensure fairness among airlines (IATA, 2019).

Today, the slot allocation process, following IATA's guidelines, governs the operations of the majority of Level 3 airports around the world, with the exception of most busy airports in the United States (Jacquillant & Odoni, 2018). In the United States, only four airports are subject to strict slot coordination, namely those in the New York Area and Ronald Reagan Washington National Airport. At the overwhelming majority of US airports, the number of flights that are allowed to land and take-off are not capped by any pre-specified limits (Feng et al., 2023).

Although this regulation is favored by many countries and regions around the world due to its simplicity, both literature and coordinators have criticized its tendency to function as a market entry barrier. This is mainly because it gives priority to incumbent airlines through "grandfather rights". As a result, the WASG have been accused of causing inefficient resource allocation for airport capacity and disregarding the principles of non-discrimination and fairness (Noto, 2020). Moreover, the 'use-it-or-lose-it' rule has received increased attention during Covid-19, when airlines induced slot hoarding behavior with which an airline operates intentionally excessive flights to keep their slots at an airport (Kösters et al., 2023).

Although these so-called slot-rescue flights reduce airline profits, they raise consumer surplus and airport profits (Sheng et al., 2019).

In an attempt to resolve this issue, alternative mechanisms have been proposed, which do not rely on administrative priority rules that may disadvantage new entrants (Gillen et al., 2016).

These market-based approaches promote the flow of slots between airlines and enhance market competition. Hence, they are expected to eliminate the major shortfalls of the slot allocation process (Feng et al., 2023). Examples of market-based allocation mechanisms include secondary slot trading, congestion pricing, and slot auction. These approaches may promote efficient utilization of airport capacity by eliminating “grandfather rights” and “use-it-or-lose-it” principles which are declared to be the main reason for airlines holding unused slots. Additional benefits include enhanced flight frequency and a more competitive aviation market (Feng et al., 2023; Zografos et al., 2018).

### **2.1.2 Industry Stakeholders**

In the aviation sector, the market for slots is influenced by several stakeholders, each playing a vital role in managing and shaping the allocation of limited airport capacity. The numerous and often conflicting interests of the stakeholders have rendered the slot allocation process a demanding task (Katsigiannis & Zografos, 2023). Firstly, airlines are central to the slot market, as they are the primary users of airport infrastructure and services. The allocation of slots directly impacts their ability to expand routes and thus, maximizing their profits and growth potential. The amount of influence that an airline has on the slot allocation process varies depending on the airport and the specific circumstances. However, in general, those airlines that are larger in fleet and more established tend to have more influence (Fairbrother et al., 2019). In addition to airlines, airports also hold considerable influence as they must strike a balance between accommodating airlines’ demands and maximizing their own operational efficiency. Although the airport operators and the slot coordinator are independent from each other, they work together by incentivizing airlines to use less congested off-peak hours or underutilized routes (Zografos et al., 2016).

### 2.1.3 Political Stakeholders

Various governmental bodies as well as local authorities also have an impact on how slots are allocated (Katsigiannis & Zografos, 2023). National governments establish overarching regulation and policies that govern slot allocation within their territories. Their main interests include the provision of fairness and efficiency in the allocation process. Governments often intervene to prioritize national interests, such as giving incentives for airlines to operate flights to remote regions in the country. In addition, the European Commission, and the European Aviation Safety Agency (EASA) both play a significant role in harmonizing slot allocation rules throughout member states of the European Union (EU). By creating a unified framework, the EU fosters competition and fair access to slots for airlines (Guiomard, 2018; Lutek, 2020). At a local level, municipal governments exert influence slot allocation to optimize the use of their airport's capacity. Local authorities often also consider environmental considerations at noise regulations, which are in the community's interests. Hence, their main objective is to ensure sustainable and responsible aviation growth in the area (Martimort et al., 2022).

### 2.1.4 Other Stakeholders

An airline's network structure is heavily affected by the demand of its customers, meaning that airline passengers play a crucial role in the process of requesting slots at different airports (Domínguez-CC et al., 2021). Adding or dropping routes to an airline's network depends on passengers' behavior which for itself is influenced by economic and political conditions of the target destination, regulatory changes, and seasonality (Dobruszkes et al., 2022; Rice et al., 2023). Additionally, environmental considerations have become paramount in choosing whether to take an airplane or not, given the high carbon emissions of air traveling (Tseng et al., 2022). Although there are considerably more factors that have an impact on the destination choice of airline passengers, those highly shape the demand for flights and thus must be taken

into account by airlines when selecting the design of their network (Domínguez-CC et al., 2021).

### **2.1.5 The Impact of COVID on the Aviation Market**

The Covid-19 crisis led to an unprecedented decline in air traffic volume, as international and national travel restrictions were imposed in March 2020, when the World Health Organization (WHO) declared the outbreak as a pandemic (Hou et al., 2021; Forsyth et al., 2020). The initial restrictions were followed by several shutdowns, lockdowns, and travel bans that lasted until 2023. The pandemic heavily affected airlines and airports, as both had to adapt their short- and long-term strategies regarding costs, flight activities, and policies (Baker et al., 2020). It is estimated that the problems caused by Covid-19 will endure in the next decade and it will take several years to achieve the pre-Covid-19 volume in air traffic (Hiney et al., 2023).

#### **Airlines**

The global aviation industry was one of the first industries to come to a standstill, as governments imposed strict travel restrictions and lockdown measures to curb the spread of the virus (Kumari et al., 2022). Airlines were compelled to ground their entire fleets, with some aircrafts sent to desert storage locations, and others parked wherever space permitted.

Despite not being actively used, the grounded aircrafts still required costly and time-consuming maintenance (Adrienne et al., 2020). One of the immediate impacts was the financial crisis as a result of the planes sitting idle and rapid decrease of passenger demand.

Many airlines faced the threat of bankruptcy, and governments worldwide had to step in to provide financial aid and bailouts to ensure the industry's survival (Abate et al., 2020; Lee, 2021). As the pandemic persisted, airlines had to navigate an ever-changing landscape of travel regulations. Each country implemented its own set of rules, which led to a confusing web of

restrictions that made planning flights even more challenging. Mandatory testing, lockdown measures, and entry bans fluctuated, thus reducing the mobility of passengers around the globe (Sobieralski, 2020).

### **Airports**

Similar to airline companies, many airports faced financial crises, as they struggled to cover operating costs and maintaining their infrastructure (Lin et al., 2023). Around the globe, airports reported the lowest passenger number ever recorded, leading to dramatic reduction in revenues. Moreover, the pandemic prompted airports to implement strict health and safety measures, such as social distancing guidelines, and mandatory mask-wearing for all airport users. These measures aimed to create a safe environment but also added logistical complexities and additional cost for airports (Blišťanová et al., 2021).

### **Steps for the Future**

The uncertainty brought by the Covid-19 crises led to a serious wake-up call for the aviation industry. Airlines and airports had little time to adjust their organization and planning, thus resulting in only a small number of airlines to engage in developing new strategies after the initial shock (Albers & Rundshagen, 2020). Although only a minority of airlines chose to innovate in the beginning of the crisis, increasingly more airlines responded with new strategic moves. As health and safety measures became a top priority for airlines worldwide, many introduced enhanced cleaning protocols of their aircrafts, minimized contact during the flight, and increased focus on digitalization in order to provide social distancing. Even more, airlines became more flexible by offering less strict ticket change and cancellation policies to accommodate travel restrictions. Despite facing numerous challenges, airlines emerged from the crisis with a renewed commitment to resilience and flexibility (Scheiwiller & Zizka, 2021; Tirtha et

al., 2022). At the same time, airports have implemented novel measures which ensure that another standstill could be prevented. In the realm of financial sustainability, airports could implement measures such as scaling down non-operational areas, outsource services, and delay non-essential expenditure (Gao, 2022). However, the biggest challenge for airports lies in automatization and digitalization in order to create a seamless travel journey for passengers. This will involve adopting touchless security checks, improved wayfinding technologies at the airport, and providing hygiene measures (Serrano & Kazda, 2020).

### **3 Regulatory Framework: Industry Groups & National Legislators**

The regulatory framework for slot allocation at airports is essential for ensuring fair, efficient, and smooth airport operations, especially to manage capacity at heavily congested airports. The air transport sector requires a highly complex legal framework for slot allocation and its trading. Although each country has its own national aviation authority governing slot allocation, there are some general guidelines and core principles which are universally present to promote international aviation. Even if there are country-specific variations, significant components of the regulatory system were established to ensure peaceful global cooperation between states. In the following chapter, the significance of international industry groups, along with the European Union's role as a national legislator will be examined. This analysis will differentiate between industry groups that provide recommended guidelines, which airlines and other aviation stakeholders voluntarily adhere to, and national legislators who hold legal obligations within the slot allocation process and its trading parameters.

#### **3.1 The Role of Industry Groups**

This section will focus on the main actors of industry groups that shape policies and guidelines for airport coordination, with special attention on slot allocation at airports as well as on their trading processes: Chicago Convention and International Civil Aviation Organization (ICAO),

IATA and its Slot Conference (SC), Worldwide Airport Slot Guidelines (WASG), Airports Council International (ACI), Worldwide Airport Coordination Group (WWACG), Standard Schedules Information Manual (SSIM), and the European Organization for the Safety of Air Navigation (Eurocontrol). The symbiosis between airport, airline, and associations should maximize airport capacity, minimize delays, and facilitate competition while accounting for elements like historical rights, new competitors, and environmental concerns.

### **Chicago Convention and International Civil Aviation Organization (ICAO)**

Starting off with the Chicago Convention on International Civil Aviation in 1944, regulations were established to anchor air transportation within a juridical and geopolitical structure. Uniting aviation and promoting coordination were the motivation of 54 nations which created the core principles permitting international transport by air. This represents the birth of the specialized ICAO, which has overseen international aviation ever since (ICAO, n/a (a)).

ICAO provides guidelines and recommendations regarding slot allocation at airports as part of its efforts to ensure safe, orderly, and efficient international civil aviation. Promoting aviation safety, security, effectiveness, and environmental sustainability is the main goal of ICAO. As the global air transportation system becomes more complex, ICAO intends to reduce aviation safety hazards through standards and recommended practices (SARPs) (ICAO, n/a (b)). Although the ICAO does not directly govern the distribution of slots, it does provide recommendations on aspects of airport management issues, which may have an indirect impact on slot allocation procedures. The guidelines highlight the need of fair competition and efficient capacity utilization via transparent and non-discriminatory slot distribution procedures. Member states and aviation stakeholders are being encouraged to set up practices that optimize the use of the current airport capacity while taking things like safety, airspace management, and envi-

ronmental consequences into account. As ICAO's participation in slot allocation is more indirect, its recommendations rather provide a framework for creating its own slot allocation policies and procedures that align with the principles of international aviation (ICAO, 2003).

### **IATA and its Slot Conferences (SC)**

The twice-yearly IATA Slot Conference (SC), once in November to address the forthcoming summer season and again in June to address the next winter season, provides the platform for managing the planned activities at Level 2 and Level 3 airports. IATA is an international trade association of airlines with the mission to represent, lead, and serve the airline industry. The committee's primary agenda exclusively includes purposes of discussing schedule changes at Level 2 airports as well as allocating slots at Level 3 airports to better manage capacity by an independent coordinator. Conversations concerning matters beyond the committee's scope, such as flight consolidation, pricing, market entry, or competitive undertakings, are not subject of discussions. Participants attending the SC must represent their respective airline or coordinating organization with accredited status. These delegates hold the right to initiate slot transfers, exchanges, modifications, deletions, or new slot requests. The SC plays a central role in supporting an airline's operational success and in the efficient allocation of airport capacity by slot managers (ACI et al., 2022).

### **Worldwide Airport Slot Guidelines (WASG)**

The WASG offer a harmonized set of industry-developed standards and best practices for managing airport activities, especially slot allocation within the frame of airport capacity at coordinated airports (Level 3 airports) and for management of planned operations at Level 2 airports. A worldwide connected conglomerate of airports, airlines, slot coordinators, and facilitators are the principal users of the guidelines and create Airport Slot Working Groups (ASWG) to work on any specific issues of interest for the industry. The IATA, ACI, and WWACG jointly publish

the WASG to allow more flexibility within the limits of the available airport infrastructure. All this is being supervised by the Worldwide Airport Slots Board (WASB), to explore strategies to improve procedures, to conduct assessments for future trends and to recommend areas of policy development. The WASB consist of an equal number of airports, airlines, slot coordinators and facilitators which prevent that adjustments or new elements introduced into the WASG can solely be carried out by one party. As the WASG are recognized by the global air transport community, it is highly recommended that these guidelines should be adopted in cases when states or governments aim to develop own rules and procedures, since they create the basis of these regulations. The consistent, transparent, and fair method of WASG is meant to guarantee the efficient usage of airport and airline resources (ACI et al., 2022).

WASG establish key principles of slot allocation at Level 3 airports as well as general priorities for slot allocation, meaning that available airport capacity should be allocated according to a priority order. Furthermore, the WASG create primary criteria for initial slot allocation (step 3 of the slot allocation process) applying following priorities: historic slots, slot pool, new entrants, introduction of year-round operations. Additional criteria for the initial slot allocation contain effective period of operation, operational factors (curfews), time spent on waitlist, type of service and market, connectivity, competition, environment, local guidelines (ACI et al., 2022).

With new technical innovations, increasing passenger numbers and associated increasing air traffic volumes in the 1950s, the slot allocation system at airports was closely linked to the need of efficiently coordinating aircraft movements through effective transnational regulations across the board (IATA, n/a (b)).

### **Airports Council International (ACI)**

The ACI is a global trade association, representing airports. By working together with governments, industry experts, regional ACI members, and international organizations like ICAO the ACI's mission is to promote and advance the collective interests of airports and the aviation industry. 712 members, 1,925 airports within 171 countries worldwide develop policies, programs, and best practices that improve airport standards globally. In collaboration with their partners, ACI's main objectives are composed of providing members with innovative tools and expertise and focusing on enhancing aviation safety and security standards. It is important to mention that ACI advocates for the concerns of airports to policymakers at both international and national levels to shape aviation policies. Networking and fostering collaboration to share knowledge between governments, airports, international organizations, and other stakeholders, ACI is a unified voice for airports to address common challenges and opportunities in the global aviation landscape. On the one hand, this unifying force supports airports' growth, efficiency, and sustainability, while on the other hand advocates for policies that benefit the entire aviation industry (ACI World, 2023).

### **Worldwide Airport Coordination Group (WWACG)**

WWACG's goal is to contribute to optimizing airport capacity utilization. They offer services and research for efficient use of resources. By facilitating efficient coordination of airport slots on a global scale and providing airlines with the best scheduling options, the balance of demand and capacity at airports during peak hours can be ensured. WWACG promotes cooperation among slot coordinators for equitable slot distribution, aiming to maximize global airport capacity. The organization prioritizes meeting airlines' operational needs, ensuring fair and transparent slot allocation, and advancing sustainability and efficiency in the aviation industry (WWACG, n/a (a)). The WWASG comprises 81 countries with 388 coordinated airports globally. Data is sourced from 47 airports, supported by 104 slot coordinators. This forms a platform for communication and knowledge exchange on slot allocation and related topics (WWACG,

n/a (b)). The association's key aim is to advocate for members' interests globally, engaging with authorities like ICAO, IATA, and ACI. WWACG promotes transparent, unbiased, and independent airport coordination as the preferred solution for capacity limitations. Additionally, the association backs the development of professional skills in areas like slot allocation and monitoring, contributing to a more efficient and sustainable aviation industry (WWACG, n/a (a)).

### **Standard Schedules Information Manual (SSIM)**

With the assistance of the Slot Messaging Group (SMG) and the Minimum Connect Time Group (MCTG), the SSIM is published by the Schedules Publication Group (SPG). The SSIM is a document that outlines industry standardized procedures and guidelines for aviation industry-related information. The manual is published annually and contains recommended practices like messaging formats and data processing procedures for communicating airport coordination information such as flight schedules, coordination information, and minimum connecting time data. Industry groups suggest that these guidelines published in the SSIM are being followed by all IATA member airlines and their business partners (ACI et al., 2022; IATA, n/a (a)).

### **The European Organization for the Safety of Air Navigation (Eurocontrol)**

Eurocontrol – the European organization for the safety of air navigation – points out ways to harmonize air traffic control and to support the EU's vision of a Single European Sky (SES). They have issued an Air Traffic Flow and Capacity Management (ATFCM) manual to enhance service quality and the efficiency of the Air Traffic Management (ATM) system. The manual addresses key aspects of ATFCM including slot coordination, impact assessment on capacity, operational procedures, and system flexibility. It's a comprehensive resource for all aviation

stakeholders working on capacity and Air Traffic Flow Management (ATFM), ensuring collaborative efforts to optimize capacity, reduce delays, and enhance overall efficiency in European air traffic operations (Eurocontrol, 2018; Eurocontrol, n/a; Pernice & Debyser, 2023).

Along with ATFCM, the philosophy of a SES by the initiative of the Single European Sky ATM Research (SESAR) can support in modernizing the ATM in Europe to a pan-European one. With its focus on a more digital European sky, SESAR is exploring new technologies and reducing the fragmentation of European airspace. As SESAR enhances ATM, it indirectly impacts slot allocation, seeking improvement across all flight stages (Sesar, n/a).

The international industry groups' guidelines create the base for global aviation collaboration. However, it's crucial to note that slot allocation laws and practices are primarily established at national or regional levels. Due to global fragmentation and the importance of state sovereignty, each country independently regulates slot allocation at its airports. While the above-mentioned roles explain principles that are not legally enforceable and reliant on the goodwill of sovereign states, the following section will explain the role of the EU and national legislation in the process of slot allocation at airports.

### **3.2 The Role of Legislators**

#### **European Union Aviation Safety Agency (EASA)**

Since 2002, ensuring safety and environmental protection in civil aviation – in airspace as well as ground activities at airports – of the European Union are subject to the European Union Aviation Safety Agency's (EASA) responsibilities, based on the principles of IATA (EASA, n/a). EASA is not directly in charge of overseeing airport slot distribution or its trading processes. However, EASA can participate in slot allocation by offering its expertise in safety standards and procedures and by evaluating safety issues connected to slot allocation and flight

operations (EASA (EU) 2017/373, 2023). While EASA is in charge of the safety aspects of air traffic, the national aviation authorities of the EU member states are responsible for slot distribution and coordination issues. The decentralization leads to a more specific procedure, while topics such as fairness, competition, and capacity management are being covered by EU regulations (ACI et al., 2022).

### **EU Directive 95/93 and EC No 793/2004**

Since 1993, the EU Directive 95/93 has been responsible for the allocation of time slots at EU airports, as amended by regulation (EC) No 793/2004. When airport capacity is limited and congestion might rise, it regulates the available landing and take-off slots to utilize slots effectively and be allocated in a fair, non-discriminatory, and transparent manner. The provision of the Directive determines definitions of terms and the scope of action that are relevant for slot allocation at airports such as coordinated airports, schedules facilitated airports, functions of a coordinator and a schedules facilitator, information exchange, airport capacity, procedures for allocation of time slots (historic slots/ slot pool/ new entrants), slot monitoring, temporary relief from slot utilization rules and their enforcement. The rules for the allocation of airport slots are needed because when its capacity is scarce (demand > capacity), the compliance of EU Directive 95/93 is meant to rebalance airport demand and capacity. The implementation of the directive has effects on prices, quality, competition, environment, infrastructure, access conditions as well as horizontal and vertical integration (Debyser, 2016; EU No 95/93, 2022; EU (EC) No 793/2004, 2004). The regulation is unclear regarding secondary trading. However, the commission would only initiate infringement proceedings against states that permitted secondary trading of slots in a non-transparent manner (European Commission, 2011).

The subject of slot allocation and its trade processes embraces strategic and operational challenges as well as a high political and legal issue that does not stop at the borders of the European

Union. The collaboration and extension to neighboring countries depend primarily on the EU's policy in the field of international relations.

The following chapters will only focus on airports within the EU, apart from the case study of the UK in chapter 7, for reasons of simplicity.

#### **4 Efficiency Concerns within the Current Slot Allocation Process**

With the EU Directive 95/93 of 18 January 1993, a regulatory system for slot allocation at European airports was established that employed a grandfathering principle, where existing slot holders were given priority, and unused slots were made available to new entrants. However, this allocation system, lacking price determination based on marginal social cost, has shown increasing economic inefficiencies in recent times (De Boe, 2005). As airports face growing capacity constraints and as major airlines and alliances become more dominant, the current allocation method is reaching its breaking point. There is growing concern that the allocation system encourages anti-competitive practices and behavioral misconduct on the part of incumbent airlines. To preserve their "grandfather rights", established airlines often operate less efficient "ghost flights" using smaller aircraft and lower load factors, instead of releasing slots for redistribution. Thereby, incumbent airlines keep slot mobility low and deter market entry for potential entrants (Kösters et al., 2023). In addition to concerns about the inefficient use of airport capacity, the current regulation has faced criticism due to its legal loopholes and ambiguous interpretation of certain guidelines (Aras, 2022). Thus, especially the principle of secondary slot trading, referring to the bilateral exchange of slots between airlines, has been a focal point of discussions, as it presents opportunities for potential manipulation (ACI, 2022). The following sections will delve deeper into the economic shortcomings and constraints of the current system, highlighting the unfavorable economic behaviors it encourages.

## 4.1 The Causes of Inefficiencies

In recent decades, airline traffic growth has exceeded the available capacities at numerous global airports. As travel demand from emerging and developing nations continues to surge, projections indicate that airport capacity constraints will become an ever-growing concern in the years ahead (Picard et al., 2019). Predictions by Eurocontrol (2018) suggest that by 2040, European air traffic will approach nearly 20 million flights. Concurrently, expansions of runways at the top 20 airports will only accommodate an additional 2.4 million movements, thus creating a gap of 3.7 million flights between demand and supply. This significant capacity gap will not only intensify flight delays but also raises doubts about the current slot allocation system's efficacy in managing the elevating congestion challenges. Already now, the high number of un- or misused slots indicate a poor efficiency at the allocation process (Picard et al., 2019). Thus, even at heavily congested European airports, where the demand for slots far outpaces the available capacity, over 10% of the allocated slots remain unused. This inefficiency culminates in estimated seasonal losses of around €20 million for these airports (Zografos et al., 2017). The root causes of this inefficiency can be broadly traced back to a combination of three primary factors, which will be further explored in the following.

### 4.1.1 Regulatory Uncertainty

Beyond the primary slot allocation phase mentioned earlier, current European Slot Regulations permit a secondary phase in which airlines can exchange or transfer slots after their initial allocation (Ranieri et al., 2013). This practice, widely known as secondary slot trading, was officially recognized for the first time in 1999 during the Guernsey Case (Aras, 2022). During this case, the English High Court of the United Kingdom validated a slot transfer between Air UK and British Airways, deeming it consistent with the official allocation guidelines (Haylen &

Butcher, 2017)<sup>1</sup>. Yet, the legality of this practice remained uncertain due to its vague definition in the official regulation (ACI, 2022). In 2008, however, the European Commission (EC) clarified its stance, indicating that it „*does not intend to pursue infringement proceedings against Member States where such exchanges take place in a transparent manner*” (EC COM(2008) 227, p. 6). This clarification led to the establishment of a valuable secondary market in the UK, with a significant focus on London Heathrow Airport (Erdogan, 2018). This market has expanded to such an extent that the majority of allocated slots currently do not come from the slot pool but are traded in the secondary market (Haylen & Butcher, 2017). Although there are indications to suggest that secondary trading occurs at other European airports as well, there is no accessible data to confirm this. This is because details of these transactions between airlines are seldom disclosed, as they are typically conducted in a confidential manner between the involved airlines (Aras, 2022). Adding to the ambiguity is the uncertainty about the role of monetary incentives in slot trades, since the current regulation does not provide clear guidance on whether monetary exchanges for slot transfers are permissible (Ranieri et al., 2013). To improve regulation of the secondary market, the European Commission proposed the “Better Airports” package in 2011. However, negotiations on this proposal were suspended in 2013 after being blocked in the Council (Truxal, 2014; European Parliament, 2023). Since then, the issue remains unresolved, awaiting further developments. Meanwhile, slot mobility is being regulated at the national level, with countries like Spain completely prohibiting secondary trading practices (SDG, 2011)<sup>2</sup>.

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<sup>1</sup> R v. Airport Co-Ordination LTD Ex P. The States of Guernsey Transport Board, High Court of Justice, Queen’s Bench Division (Divisional Court), 25 March 1999

<sup>2</sup> Ministerio de Transportes, Movilidad y Agenda Urbana, Ley 21/2003 de 7 de Julio, de Seguridad Aérea

#### 4.1.2 Increasing Market Power

Over the past few decades, the European Union has played a leading role in the liberalization of international air transport markets (Abate & Christidis, 2020). However, this was not always the case. Before the late 1980s, Europe's air transport was comprised of distinct national markets with each country having its own unique regulations and bilateral agreements for international flights (Burghouwt et al., 2015). This lack of a unified regulatory framework allowed for strict control over route entry and capacity, often enabling airlines to engage in revenue pooling practices (Butcher, 2010). Moreover, many international routes were designated for a single airline from each country, resulting in significant disparities in the level of competition permitted or encouraged (Butcher, 2010; ICAO, 2003). It was clear that this scheme was not aligned with the principles of the European Union, which advocate for an "*open market with free competition*" (TFEU 2012, Article 119). As a result, a comprehensive process spanning over a decade following the enactment of the Single European Act in 1986 has progressively transformed formerly protected national aviation markets into a unified and competitive single market for air transport through three reform packages (Burghouwt et al., 2015). These packages deregulated fares, capacities, and route permissions, culminating in 1992's third package that established a comprehensive European single aviation market (European Parliament, 2023).

The liberalization of the aviation market in Europe brought about transformative changes, such as the emergence of new (low-cost) airlines and the expansion of the passenger market, resulting in increased travel to a wider range of destinations at considerably reduced ticket prices (Harvey et al., 2021). Moreover, it was about that time that the first global alliances and partnerships between airlines emerged. In 1997, Air Canada, Lufthansa, SAS, Thai Airways, and United Airlines formed the pioneering alliance called Star Alliance. Subsequently, Oneworld was established in 1999, and SkyTeam followed suit in 2000, becoming the other two major

alliances (Douglas & Tan, 2017). Starting with only a few members, these alliances rapidly expanded their partnerships. Especially, the EU-US Open Skies agreement, implemented in 2008, played a crucial role in enhancing airline cooperation opportunities (European Commission, 2010). By removing all barriers for airlines from both sides to fly between and beyond Europe and the United States, the agreement allowed for new commercial freedoms, such as code-sharing, frequent-flier programs, and revenue-sharing joint ventures. This resulted in a significant expansion of alliance networks. As of today, the member airlines of the three global alliances collectively account for more than half of all worldwide passenger traffic (Bilotkach, 2019).

Additionally, the increasing dominance of global alliances in the airline industry can be attributed, in part, to the rise in granted antitrust immunities between airlines (Gillespie & Richard, 2012). Partner airlines operating with antitrust immunity gain the explicit right to jointly set fares for interline itineraries (Bilotkach, 2019). Thus, antitrust immunity enables the carriers to operate as if they are one carrier by allowing them to coordinate fares and schedules (Fukui, 2014). In the United States, the Department of Transportation (DOT) has sole authority over granting antitrust immunity to airline alliances, while in Europe, the European Commission has this responsibility (ICAO, 2013). Airline executives claim that their customers benefit from antitrust immunized alliances through access to more destinations, better service, and lower prices. On the other hand, customer advocates are concerned that granting such immunity may result in significant competition loss (Gillespie & Richard, 2012).

#### **4.1.3 Strategic Behaviors of Airlines**

New entrants, such as low-cost airlines with innovative business models, have substantially contributed to a dramatic increase in passenger volumes – rising from 1.3 billion in 1995 to 4.2 billion in 2018. In response to these industry shifts, incumbent airlines did not only become

more efficient, partly through forming alliances, executing mergers, or entering into other cooperative agreements but also by changing their corporate strategies (Finger et al., 2019). The prevailing slot allocation regime, enacted over 30 years ago, however, has struggled to adapt to this changing landscape of the aviation industry. There is evidence that the current allocation mechanism may potentially foster anti-competitive and inefficient behavior among incumbent airlines (Kösters et al., 2023). Thus, it contributes to slot immobility across successive schedule seasons, as airlines have a strong incentive to retain their slots. Although individual airlines may efficiently reallocate slots within their own route networks, there is limited mobility of slots between different airlines. Such a behavior, where slots are transferred to non-competing airlines, often within alliance partners, is commonly referred to as “babysitting” (European Parliament, 2016). Furthermore, the “grandfather rights” require airlines to use at least 80% of their slots to maintain their entitlement to them in the subsequent scheduling period (ACI, 2022). Such a system gives rise to “slot hoarding” behavior, where incumbent airlines prefer to hold on to underutilized slots and intentionally operate excessive or even unprofitable flights rather than returning them to the slot pool, in order to prevent potential competitors from entering the market (Sheng et al., 2019). This practice became particularly noticeable at airports worldwide during the COVID-19 pandemic (Sun et al., 2022). A report by the Guardian (2022), drawing upon data from the civil aviation authority (CAA), revealed that 40,000 flights with less than 10% occupancy have operated in the UK between 2019 and 2022. Although it is challenging to precisely quantify the overall extent of these anti-competitive behaviors due to the difficulty in assessing the current value of a slot for an airline, statistics show that the turnover rates of slots at European airports are indeed typically very low (DotEcon, 2001). Thus, data from the European air transport market in summer 2008 revealed that major airports in the EU had a relatively low proportion of slot returns to the pool. Specifically, Heathrow had a withdrawal rate of only

0.4%, while Paris-Orly and Paris-Charles de Gaulle had rates of 2.0% and 2.4% respectively. Frankfurt and Munich had similarly low rates of 2.3% and 2.6% respectively (SDG, 2011).

The increasing capacity constraints at European airports do not only give rise to competitive concerns but are also reflected in increasing air fares. With airports able to handle only a limited number of passengers and aircraft at any given time, airlines are responding to heightened demand by inflating prices. Consequently, aircraft seats become scarce goods that are allocated to those passengers who can afford the increased fares (ACI, 2017). According to recent estimations, a 10% increase in airport capacity constraints leads to a 1.4% - 2.2% rise in average air fares. By 2035, this leads to an extra €6.3 billion in annual air fare costs for European passengers, solely due to limitations in airport capacity (SEO Amsterdam Economics, 2017). To sustain these elevated fares, airlines employ sophisticated revenue management strategies, targeting passengers with the greatest willingness and ability to pay at an airport. Airlines thus charge higher prices for last-minute bookings and offer more premium first-class and business-class seats at congested airports. Additionally, high congestion restricts entry for low-cost carriers (LCCs), particularly during peak hours. The expensive cost of acquiring runway slots might make offering low fares unfeasible, resulting in a reduced presence of LCCs at highly congested airports (ACI, 2017). However, most severely congested airports are part of city-pair markets, which have several alternative airports within reach. Consequently, to gauge the effect of congestion on air fares accurately, it is important to examine its impact on the entire city-pair market, rather than confining the analysis to individual airports (CAA, 2019).

## **4.2 Indicators of Inefficient Use of Slots**

A system can achieve efficiency through two distinct ways: productive efficiency and allocative efficiency. Productive efficiency entails maximizing the utilization of available slots within the system. In the context of slot allocation, this means ensuring each slot is used to transport the

highest number of passengers or generate the maximum revenue passenger kilometers. The goal is to reach an allocation where further improvements in load factors are not feasible (Mott MacDonald, 2006). On the other hand, allocative efficiency aims to allocate slots in a manner that maximizes their social value. This entails considering the destinations that society values the most for air travel and ensuring slots are allocated accordingly. Ideally, an optimal slot system should incorporate both productive and allocative efficiency, ensuring efficient utilization of slots while maximizing societal benefits (European Parliament, 2016). However, the current European slot allocation mechanism does not incentivize such an outcome. Beyond its influence on the competitive landscape, as discussed in the previous section, it's widely accepted that the strategies driven by the "grandfather rights" policy can also impact the type and manner of aircraft operations. Thus, both slot hoarding and babysitting practices can lead to operations characterized by higher frequencies, smaller aircraft, and/or lower load factors (European Parliament, 2016). Assessing this hypothesis poses a challenge as all major European airports operate under slot coordination, making direct comparisons with non-slot-coordinated airports difficult (Kösters et al., 2023). However, the United States of America provide a unique context where both systems exist, allowing for such a comparison. In this regard, Fukui (2012) conducted a study revealing a negative impact of slot allocation on aircraft size. The findings indicated that airlines with a greater number of slots tended to operate smaller aircraft, suggesting a stronger motivation to retain slots and limit competition. Additionally, a study by the United States Government Accountability Office (GAO, 2012) observed higher frequencies, smaller aircraft, and lower load factors at slot-coordinated airports, potentially indicating the presence of slot hoarding behavior. In fact, GAO's statistical analysis demonstrated that scheduled passenger flights at slot-controlled airports had a 75% higher likelihood of being operated by airlines using aircraft with fewer than 100 seats compared to flights at other similarly sized non-slot-controlled airports. Furthermore, slot-controlled airports tended to have certain routes

flown at higher daily rates and lower aircraft occupancy levels. While these insights from the US context provide valuable implications regarding the potential effects of the slot allocation system on aircraft operations and competition, it still remains exceedingly challenging to ascertain the hypothetical aircraft size at major EU airports in the absence of a slot system and the “grandfather rights” rule (European Parliament, 2016).

### **4.3 Conclusion of the Literature Review**

The existing airport slot allocation system is undoubtedly in need of a comprehensive overhaul. The current regulations not only foster anti-competitive practices among airlines and drive-up air fares, but they also promote inefficient load factors for aircraft and excessively high flight frequencies. To tackle this persistent issue, the literature offers two alternative research approaches for allocating capacity among competitive users and attaching value to scarce airport capacity: administrative approaches and market-based approaches (Zografos et al., 2017). A substantial body of research advocates for the adoption of market-based mechanisms such as secondary trading or auctioning of airport slots. These mechanisms are favored as they better reflect the value of slots and airline preferences, leading to a more efficient allocation of slots to airlines that can utilize them optimally. Furthermore, market-based methods encourage the transfer of slots between airlines, potentially boosting market competition and mitigating the major shortcomings of administrative allocation (Wang et al., 2023). On the other hand, a considerable number of researchers endorse slot scheduling approaches. These focus on tackling the allocation issue as a scheduling challenge, underlining aspects such as operational efficiency, resource utilization, and equitable distribution, with the aim of enhancing effectiveness (Zografos et al., 2017). In the forthcoming chapter, a deeper exploration of these distinct approaches will be undertaken, evaluating their impacts on various aspects of efficiency.

## 5 Exploring Efficiency, Issues & Solutions – Market-Based Mechanism 1

International air transportation demand is growing rapidly, with revenue passenger kilometers (RPK) expected to double between 2014 and 2029. This growth is being driven by developing countries, such as China, but even developed regions with historically high demand are seeing growth, especially in long-haul, international traffic. However, airport runway capacity is a limiting factor for growth in flight operations. To limit congestion, entities with oversight of airport access or performance often employ mechanisms to restrict airport access. The most common mechanism used is the IATA Slot Allocation System. This system defines a set of airport “slots” and allocates those slots to flight operators through a system of administrative controls (Feng et al., 2023). A slot is a time window during which an airline can land or take off at an airport. Slot control systems divide the day into a series of time windows, typically between 15 minutes and 1 hour wide. This helps to manage air traffic and prevent delays and congestion. (Ball et al., 2018). Airport time slots are a scarce resource, and the current methods of allocating them are often inefficient. In the European Union, slots are typically allocated based on historic use, which can lead to incumbent airlines locking up slots that they do not use efficiently. This can suffocate competition and limit the choice of routes available to consumers (Bichler et al., 2023). In addition to administrative slot allocation, market-based approaches have also been proposed to limit airport access and control congestion. These approaches can be broadly classified into two categories: congestion pricing and slot auctions (Ball et al., 2018).

### 5.1 Congestion Pricing as a Market Solution

The use of price mechanisms to manage congestion has been gaining traction, as it is seen as a way to reduce congestion without the need for major infrastructure investments (Silva & Verhoef, 2013). A majority of economists believe that congestion pricing is an effective way

to reduce airport congestion. Congestion pricing is a good way to manage airport congestion as it makes flying more expensive during peak hours, thus encouraging airlines and passengers to shift their flights to off-peak hours. This helps to reduce congestion and improve the overall efficiency of the airport. However, the unique characteristics of the aviation market may make it difficult to simply set congestion prices equal to the value of marginal travel delays (Pels & Verhoef, 2004). In fact, the airport literature differs from other literature on congestion pricing in that it considers the case of market power. This introduces an additional distortion into the analysis, namely non-competitive pricing (Silva & Verhoef, 2013). A number of studies have investigated optimal airport pricing. For example, Brueckner (2002) showed that in an oligopolistic market, airlines competing in a Cournot fashion internalize the congestion they impose on themselves. Cournot competition is a type of imperfect competition in which firms simultaneously choose the quantity of output to produce. In a Cournot market, each firm takes the output of its rivals as given when making its own output decision. This means that firms do not directly compete on price, but rather on quantity (Allaz & Vila, 1993). It follows that the optimal charge should only account for the fraction of congestion that is imposed on competitors. However, it implies that larger leading airlines pay a much lower toll than smaller airlines making the proposal politically unpopular (Silva & Verhoef, 2013). Nevertheless, the traditional Cournot view has been recently questioned with the market becoming more competitive and shifting towards a Bertrand behavior (Bhattacharjee & Prasun, 2016). Bertrand competition is a model of competition in which firms compete by setting prices. In a Bertrand competition, firms assume that their competitors will not change their prices in response to their own price changes. This means that each firm has an incentive to undercut its competitors' prices in order to gain market share (Muto, 1993). In a duopoly market with imperfectly substitutable goods, airlines that behave in a Bertrand fashion will internalize less than the full congestion costs they impose on themselves. The reason for this is that they will take into account the fact that an

additional flight will also impose congestion on their competitors' passengers, which will increase their own demand and profits. This leads to an optimal congestion toll that is between the Cournot toll (which only accounts for the congestion imposed on competitors) and the atomistic toll (which accounts for the full congestion costs) (Silva & Verhoef, 2013).

## **5.2 Limitations and Possible Solutions to Congestion Pricing**

As highlighted, the main limitation of using congestion pricing is finding the optimal cost to internalize congestion issues. Estimating airline conduct parameters can be difficult because the optimality of congestion charges depends on how airlines behave. In some cases, the degree of substitutability between airlines' products also has a major influence on the size of optimal tolls. This means that it is important to accurately estimate airline conduct parameters in order to design effective congestion pricing schemes. Another interesting finding is that a straightforward application of Pigouvian tolls is suboptimal under asymmetric information. This is because the regulator will not be able to accurately anticipate how the informed agent will react to the toll, as the agent has private information that the regulator does not know. As a result, the optimal toll will be different from the simple expected Pigouvian tax (Aravena et al., 2019).

A study on the Chinese Guangzhou Baiyun International Airport by Wang (2022) highlighted the mechanisms behind congestion pricing and how airlines tend to reduce their congestion fees. The first method suggests the adjustment of flight schedules, which would encourage airlines to change their flight plans at congested airports. The second method is to merge flights, which would reduce queue length by combining two flights into one using a larger aircraft. The results of the empirical analysis suggest that both methods could be effective in reducing congestion and congestion fees, additionally having positive economic, operational, and environmental benefits. Table 1 depicts where flight merging is done using two types of aircraft,

namely Boeing 747-400 (with 524 seats) and Airbus 330-300 (with 335 seats). Although this second method can reduce the number of flights at an airport it is not always feasible. The aircraft type and the queue length of the original flights must be considered, and the airline may have other reasons for operating two flights instead of one. For instance, they may want to offer more frequencies to capture a greater market share, or they may need to use two aircraft to reach different destinations. If the wrong aircraft type is chosen for flight merging, the fees will be higher, making the method impractical (Wang, 2022).

	Schedule adjustment	Flight merging		
		By B744	By A333	By B744&A333
Basic idea behind the method	“Peak shaving and valley filling” of a flight schedule	Reducing the total quantity of flights but without reducing total seat capacity by operating bigger aircraft		
Scenario of the best practices	The flight schedule is an interweaving of peaks and valleys	The flight schedule is balanced and has some flight routes with high frequency		
Performance of reducing total congestion fees	Fair	Very good	Good	Excellent
Performance of operational benefits	Good	Very good	Fair	Excellent
Performance of environmental benefits	Good	Very good	Fair	Excellent
Performance of reducing fees per adjusted flight	Excellent	Very good	Fair	Good

**Table 1: Summarized Result Comparison of the Two Methods.**

(Wang, 2022)

### 5.3 Issues with Current Slot Allocations

As mentioned above, airport slots are allocated based on the previous year's usage. This means that airlines that have been using a slot for a long time tend to obtain it again the next year. This system can stifle competition, as it makes it difficult for new airlines to enter the market. It can also lead to inefficient use of slots, as airlines may continue to operate routes that are not profitable in order to keep their slots. In extreme cases, airlines may even fly "ghost flights" with no passengers on board, just to meet the use-it-or-lose-it requirements. The use-it-or-lose-it rule is especially problematic during times of low air traffic, such as during the Covid-19 pandemic.

This is why the European Commission is considering relaxing the rule to allow airlines to temporarily surrender their slots. If slots are not reallocated periodically, airlines have no incentive to provide the services that consumers want or to use airport capacity efficiently. This is because they can keep their slots even if they are not using them effectively. However, if slots are reallocated periodically, airlines will have to compete for them, thus encouraging them to provide better services and use airport capacity more efficiently. Additionally, it will also allow new airlines to enter the market, which will increase competition and benefit consumers. Hence this explains why the European Commission proposed to assign 48 Lufthansa slots via auction (Bichler et al., 2021).

#### **5.4 Lufthansa's Case: Auctioning Slots in Europe**

Lufthansa, Europe's largest airline by revenue, had to sell time slots for the first time. The auction was a condition of €9 billion in grants and loans that Lufthansa received from Germany's Economic Stabilization Fund after the coronavirus pandemic put the airline into financial trouble. As part of the auction, Lufthansa agreed to give up 24 slots per day at each of the Frankfurt and Munich hub airports. These slots are valuable assets, as they allow airlines to operate flights at these busy airports. The auction of Lufthansa's time slots could be a sign of the changing landscape in the airline industry. As the industry consolidates, airlines are under pressure to reduce costs and improve efficiency. Selling time slots is one way to do this. The auction also opens up the possibility for new entrants to the market. Airlines that were previously unable to secure slots at Frankfurt and Munich airports may now be able to do so, which could lead to increased competition (Press corner, 2020).

## 5.5 The Four Main Types of Auctions

The economics literature has extensively studied four key auction mechanisms that are widely used in practice and have high theoretical value: the English auction (also known as oral or ascending auction), the Dutch auction (also known as downward or descending auction), the first-price sealed bid auction, and the second-price sealed-bid auction (also known as Vickrey auction or second-price auction). An English auction is a type of auction in which the price of an item starts low and is gradually increased until there is only one bidder left. The bidder who remains wins the item at the price they last bid. English auctions are often used to sell goods such as art and antiques, and they are characterized by the fact that all bidders are aware of the current price and the previous bids of their opponents. This allows bidders to make informed decisions about how much to bid, and it can lead to higher prices for the seller. In a Dutch auction, the auctioneer starts by announcing a very high price. The price is then gradually lowered until one of the participants agrees to buy the item at the current price. Unlike an English auction, where participants can see all of the bids that have been made, in a Dutch auction, participants only know the winning bid. In a first-price sealed-bid auction, participants submit their bids in secret envelopes, without knowing the bids of other participants. The item is sold to the highest bidder, who pays the price they bid. This auction is the most common mechanism used by governments for public procurement. A second-price sealed-bid auction is similar, but the winner pays the second-highest bid instead of their own bid. This auction is sometimes called a "Vickrey auction" after its inventor, William Vickrey. It is a theoretically sound auction mechanism, but it is rarely used in practice due to three main disadvantages. It is vulnerable to collusion between participants, even among losers, it incentivizes shill bidding, where participants bid strategically to drive up the price for other participants and it can produce a final price of zero, if the winner's bid is the only one to have a non-zero value (Agostini, 2015).

## 5.6 Auctioning Slots as a Possible Efficient Solution

A slot auction approach is similar to the IATA Slot Allocation System, but instead of allocating slots by administrative rule, they are allocated via auction (Ball et al., 2018). The idea of auctioning airport slots has been around for a long time. It was first proposed in a study sponsored by the US government in 1979, and there have been many academic articles discussing how such an auction could be organized (Rassenti et al., 1982). Auction markets have been used successfully around the world to allocate a variety of scarce resources, including spectrum licenses, treasury bonds, electricity, wind farm capacity, and various commodities. These markets have been shown to be effective in generating competition and ensuring that resources are allocated to the highest-value uses (Milgrom, 2017).

## 5.7 Recent Developments in Auctioning Computations

The allocation of slots at a fully coordinated airport poses a complex task. It involves thousands of slots and large packages of flights that need to be allocated for a half-year season, following the IATA Worldwide Scheduling Guidelines. These guidelines impose nested capacity constraints, which make the problem computationally hard (Ritter, 2008). Twenty years ago, such problems were considered intractable for realistic problem sizes. However, recent advances in algorithms and computers have led to stunning computational speedups. As a result, problems of up to 20% of the capacity of major airports can now be allocated optimally in minutes (Bixby, 2012). These computational advances have allowed for the implementation of a variety of successful auction designs that can be tailored to the setting. These auctions allow airlines to bid for slots, and the slots are allocated to the highest bidders. This process ensures that slots are allocated to the airlines that value them most, and it also helps to maximize the efficiency of the airport (Bichler, 2021).

The challenge of allocating air slots is not as substantial as it may initially appear. Only the busiest airports are congested, and even at these airports, only a fraction of the slots need to be auctioned each year to create significant value for buyers, sellers, and society. Suitable market designs and efficient tools are available. By auctioning a fraction of the slots at congested airports each year, one can create significant value for all stakeholders. The European Commission's ruling on Lufthansa air slots is a step in the right direction, and it should spur further discussion about how to best allocate air slots in a fair and efficient manner (Bichler, 2021).

### **5.8 Case Study: The European Telecom Auctioning Market**

To understand how a possible auctioning market would work in air slot allocations, the telecom market could serve as a suitable model keeping in mind the main limitations that will be later discussed. Spectrum is a scarce resource that is essential for the provision of mobile services, just like air slots are for airlines. The demand for mobile services has been growing steadily since the introduction of smartphones in the late 2000s. In order to allocate spectrum efficiently, national regulatory authorities (NRAs) began using auctions in the mid-1990s (Salant & Ershov, 2022). Mobile service providers must compete with each other both in auctions for spectrum licenses and in the mobile product market. Excluding the impact on market concentration that favors stronger players, spectrum auctions should be welfare-improving. This is because auctions ensure that spectrum is allocated to the highest value user, which is more efficient than administrative procedures, such as the grandfather rule in air slot allocation (Genakos et al., 2018). In the early 2000s, when the third-generation cellular network (3G) was developed, major European countries held auctions to sell new frequencies. The results of these auctions varied widely, despite the fact that the portions of spectrum sold were similar throughout Europe. This was due to the different auction designs that were used. Most countries used a simultaneous multiple-round ascending auction model but with different variations. The United

Kingdom, which was the first country to hold a public auction, achieved excellent results thanks to its rules that encouraged new entrants. On the other hand, other EU members, such as Italy, and the Netherlands, had much more disappointing results because they were unable to make the auction participation as attractive (Klemperer, 2002).

## 5.9 Simultaneous Multiple-Round Auctions

A simultaneous ascending auction is a type of auction in which multiple items are auctioned off at the same time. Bidders make sealed bids for the items they are interested in, and the auction proceeds in rounds. At the end of each round, the results are posted, including the identities of the new bidders and bids, as well as the standing high bid and the corresponding bidder. The standing high bid is the highest bid for an item, and the corresponding bidder is the person who made that bid. As the auction progresses, the standing high bid for an item will increase until no bidder is willing to make a higher bid. The auction ends when there are no new bids in any round. Bidders can change their minds about which lots they want to bid on until the end of the auction. This means that the auction is not a series of separate auctions, one for each lot. Instead, it is a single auction for all of the lots. This allows bidders to bid strategically on multiple lots, and it can lead to more efficient outcomes (Milgrom, 2000). In a simultaneous ascending auction, bidders have an incentive to wait as late as possible to make their bids. This is because they do not want to give away any information about their intentions to other bidders. If they bid early, other bidders will know how much they are willing to pay, and they can then make higher bids. To prevent bidders from waiting too long to make their bids, there are so-called activity rules. These rules require bidders to make a bid in each round of the auction, even if they don't want to bid on any of the items. This keeps bidders' options open for later in the auction, and it prevents them from gaining an unfair advantage by waiting until the last minute to make their bids (Bichler, 2017). Since simultaneous ascending auctions are open

auctions, bidders can see the bids of other bidders. This allows bidders to compare their own estimates of the value of the lots to the bids of others, in essence constructing a market in which the prices of lots emerge. This can help bidders to reduce the uncertainty about the value of the lots, and it can help them to make more informed bids (Bedard et al., 2023).

### **5.10 Adapting Simultaneous Multiple-Round Auctions for Air Slots**

Air traffic control requires access to three types of capacity in order to facilitate air movement: runways, stands, and terminals. However, it is not possible to simply bundle a right to use a stand and a fixed amount of terminal capacity with a landing or take-off slot, because different aircraft sizes and types of service will have different stand and passenger handling requirements (Sentance, 2003). There are two main approaches to solving the problem of bundling a right to use a stand and a fixed amount of terminal capacity along with a landing or take-off slot:

- Separate markets for terminal and stand capacity. In this approach, a slot would only grant an airline the right to use a runway. The airline would then have to purchase additional terminal capacity or the right to use a stand in separate ancillary services markets. These ancillary services could be sold either alongside the main auction of slots, or else subsequent to the main auction.
- A single market for flexible bundles. In this approach, an auction format would be used where an airline would make a bid that specified not only what it would be prepared to pay to use a particular runway slot at a particular time, but also provided information that could be used to determine its stand and terminal capacity requirements. In essence, any bid for a runway slot would have multiple dimensions that would need to be considered by the auctioneer when determining which bids for a particular runway slot were the winning bids.

The main benefit of using separate ancillary services markets is that it is simpler for the auctioneer to run the auction. The auctioneer only needs to consider the highest bids for each slot, without having to worry about the stand and terminal capacity requirements of each bid. However, using separate ancillary services markets is more complex and risky for bidders. Bidders would need to bid for both slots and ancillary services, and there would be a risk of acquiring either a slot or ancillary services but not both. This could lead to bidders not being able to use as large an aircraft as they might wish, or else holding a scarce right to use stand or terminal capacity without any matching right to land or take-off. This is inefficient, as it could lead to slots being used inefficiently and to significant social losses. A better approach is to combine bids for runway, terminal, and stand capacity. This would allow the auctioneer to ensure that all capacity constraints are respected, and it would simplify the bidding process for bidders. This approach would lead to more efficient outcomes, as it would ensure that slots are used in the most efficient way possible (Sheng, 2015). Furthermore, in an auction system, there is a greater chance that the traffic mix in any given hour will change significantly from the previous season, especially if a significant proportion of all slots are auctioned at once. As a result, the current method of estimating runway capacity on an hourly basis based on historical traffic mix is unlikely to be successful. Instead, it is necessary to determine available runway capacity endogenously within the auction system. This means that the auctioneer must take into account the actual traffic mix that is expected to use the runway in each hour, rather than simply relying on historical data. In order to implement such a system, carriers would need to provide enough information in their bids so that the auctioneer can determine the demands they would make on terminal and stand capacity. With this information, the auctioneer can process all bids and identify the current highest bidders for each lot. For any given lot, there could be multiple current highest bidders, as multiple traffic movements are possible within a given time window. The

exact number of current highest bidders cannot be predetermined, as the runway capacity depends on the traffic mix (Sentence, 2003). After declaring the current highest bidders for each lot, the auctioneer would need to set a minimum bid for the subsequent round. This would be set as a small increment over the lowest of the multiple current highest bids on any particular lot. Having set these minimum bids, the next round would be started. Bidding would proceed through multiple rounds until there was no further bid activity. Finally, when an airline wins a slot, it will be granted the right to make an air movement within a particular time window for a number of consecutive seasons, as long as the airline does not exceed the usage limits that it specified in its bid (Fu et al., 2015). Table 2 proposes a timetable for the summer and winter seasons using a sealed-bid multiple-round auction format. The main assumption is that this type of auction must begin earlier to allow its completion to be within the IATA Conference deadlines.

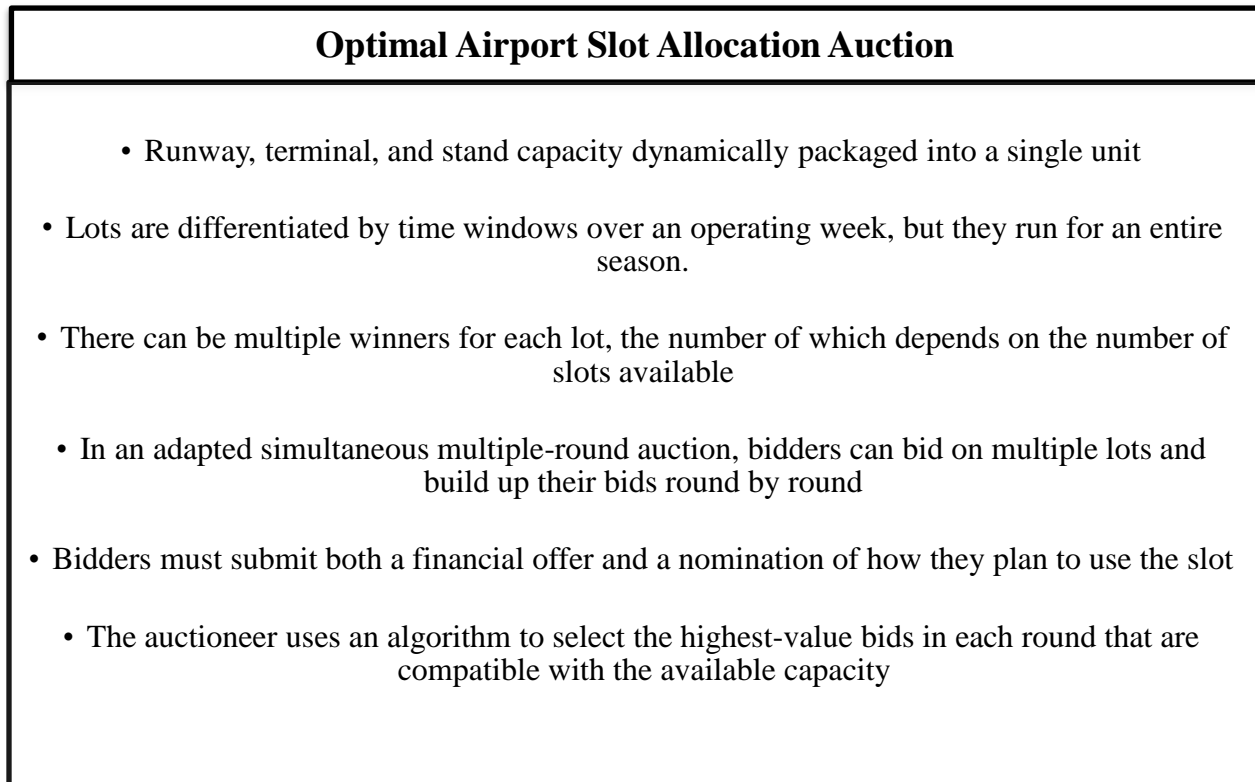
	Summer April - October	Winter November - March
<b>Approval Process for Bidders</b>	September	April
<b>Finalized List of Bidders</b>	Last Week of September	Last Week of April
<b>Auction Begins</b>	Early September	Early April
<b>Auction Finishes</b>	Late October	Late May
<b>IATA Conference</b>	Mid-November	Mid-June

**Table 2: Timetable for Slot Allocation Using a Sealed Bid Multiple Round Auction.**

Built using data from <https://www.iata.org/contentassets/4ede2aabfcc14a55919e468054d714fe/calendar-coordination-activities.pdf>

### 5.11 Policy Implications and Feasibility of the Method

As demonstrated, it is feasible to develop an auction that can handle the complexity of slot allocation within a reasonable period of time. The preferred auction design for allocating airport slots has been summarized in Figure 5.



**Figure 2: Key Points for the Optimal Auction Design.**

The best case scenario to implement auctions would be that the grandfathering system would be removed, and slots would be auctioned off with a formal secondary market. This case has the greatest potential for improving efficiency and promoting competition. However, it is essential to have adequate measures in place to prevent the build-up of market power. The use of an auction as the primary means of allocation would complement the establishment of a formal secondary market, as the latter would allow for the simplification of the former (Wit & Burghouwt, 2008). Slots could be reclaimed gradually, with a fixed proportion of slots being auctioned off each season until all grandfathered rights are eliminated. In this case, the size of

the seasonal pool would be gradually expanded until it covers all slots. This gradual reclamation would provide a simple way to transition to a system of rolling auctions, in which a proportion of slots come up for auction each season as tenures expire. A rolling system would result in less complex auctions and may be more compatible with existing international coordination procedures. However, there are equity concerns about reclamation. It is crucial to make sure that no airline is unfairly advantaged or disadvantaged during the transition from grandfathered rights to a system of auctioning slots (Naumann, 2012).

Moving to a market-based allocation system for slots can bring benefits even if it is not coordinated across the European Union. The current system has many inefficiencies, so any mismanagement that could result from moving to a market-based system would be minor. However, there would be additional efficiency benefits for the economies and consumers of any EU member state if other congested EU airports also used market mechanisms to allocate slots. One area where EU coordination could be important is in setting uniform rules against the concentration of slots and the build-up of market power. This is because airlines compete not only at airports but also between congested hubs. If rules against concentration were applied to just one member state, they could significantly distort competition between hubs. However, EU-wide coordination on this issue would remove this concern (Castelli et al., 2012).

## 6 Conclusion

### 6.1 Summary

The allocation of airport slots is a multifaceted challenge that sits at the nexus of commercial interests, regulatory oversight, and passenger convenience. Although the current system is functional, it struggles to meet the escalating demands and capacity limitations of the aviation sector. Chapter 2 provided an overview of the current slot allocation mechanism, underscoring the importance of aligning airport capacity with the evolving needs and challenges of airlines, all while ensuring a high level of practicability. Chapter 3 underscored the complexities arising from the involvement of various industry groups and national legislators, each bringing their own set of legal rules and recommendations. This diversity has led to economic inefficiencies and suboptimal behaviors among airlines, as discussed in chapter 4. To address these challenges, this study explored three innovative allocation mechanisms. Chapter 5 delved into the administrative PSAM model, drawing insights from interviews with industry experts. While the PSAM pilot project indicated potential benefits for medium-sized coordinated airports in Portugal, experts believe that Germany's current decentralized system already achieves an optimal scenario. As a result, they question the tangible advantages of PSAM, casting doubt on its claimed efficiency improvements as a unified alternative for also large-scale airports worldwide. Chapters 6 and 7 examined market-based strategies. Chapter 6 identified congestion pricing as an effective tool to discourage peak-hour flight operations. Moreover, the auctioning of slots, exemplified by Lufthansa's recent actions, signals a shift in the industry. As airlines seek efficiency, selling slots emerges as a viable strategy, potentially fostering greater competition by allowing new entrants access to previously inaccessible slots. The econometric analysis of secondary slot trading at London Heathrow Airport laid down in chapter 7 presented a nuanced picture. While slot trading enhances allocative efficiency, its impact on economic efficiency

and consumer welfare remains ambiguous. The data suggests benefits in terms of route network expansion but also indicates potential challenges, such as increased route concentration and a preference for flight frequency over larger aircraft deployment.

## **6.2 Policy Recommendations and Further Research**

The findings from this study have led to specific policy recommendations, as outlined in chapters 5.6, 6.11, and 7.6. In general, feedback from aviation industry experts suggests that current slot allocation guidelines are antiquated and require an overhaul. The revised framework should clarify ambiguities in slot allocation and be open to incorporating market-based strategies, including congestion pricing, auctions, or secondary trading. These strategies promise a more dynamic and responsive allocation system. However, they also come with potential drawbacks, such as adverse effects on competition, and therefore should not completely replace administrative approaches but instead complement them. Given the fast-changing nature of the aviation sector, ongoing research is essential. Future studies should delve into the feasibility and challenges of these mixed strategies and their enduring impacts. Moreover, considering the distinct dynamics across regions, the universal relevance of these recommendations needs assessment. In sum, while there are avenues to enhance the current slot allocation system, no single solution emerges as a panacea. A balanced mix of administrative and market-based strategies, tailored to specific airport contexts and underpinned by continuous research, will be pivotal in steering the future of airport slot allocation.

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## **Affidavit**

We, the undersigned, do hereby state that we have not plagiarized the paper enclosed and that we are the only authors of all sentences within this master thesis entitled

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