BRA-EUR2

DECEA Performance Section, EUROCONTROL Performance Review Unit

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Preface

This report represents the 2nd edition of the Brazil-Europe Comparison of Operational Air Navigation System Performance. It characterises and compares operational performance in both regions on the basis of a set of harmonised performance measures. The report is jointly developed by the Performance Section of the Department of Airspace Control (DECEA) and EUROCONTROL's Performance Review Unit (PRU).

This report was published in October 2022. The online version is available at .

For any questions, please do not hesitate to contact one of the authoring organisations. Enjoy the read!

Performance Section, DECEA Performance Review Unit, EUROCONTROL

Forewords

Marinus de Jong
EUROCONTROL PRC Chairman

Collaboration and harmonisation are key and intrinsic principles of the aviation world. These principles were never as important as they are today, as the aviation community emerges from its worst crisis ever in the last two and half years. Since the outbreak of COVID-19, pressure on the air transportation system tested the resilience of the most integrated and interdependent mode of transport. When the pandemic was finally relieved, the Russian invasion of Ukraine raised the bar against recovery even higher, with rising fuel costs and much uncertainty once again. More than ever, the aviation system should look to its principles.

Without collaboration - both on regional and international level - and the promotion and application of standards, the aviation system we know today, would never have come to pass, and will undoubtedly fail in the future. With that in mind, this second comparison report reflects the efforts of Brazil and Europe to keep moving in the direction of cooperation and standardisation in the field of operational air navigation system performance. Furthermore, the global community is asking for all its sectors to improve efficiency and reduce environmental impact. Additionally to the challenges mentioned above, addressing the carbon footprint of air transportation and how air navigation can help in this context is mandatory. In this context transparency plays a fundamental role. This comparison report adds to providing a transparent basis for an informed discussion by providing data-driven analyses to identify performance gaps and allow stakeholders to understand better and even participate in finding solutions to the issues on the table.

Brig. Eduardo Miguel Soares
Head of SDOP/DECEA

Even though the scars of the greatest crisis of the aviation system are not fully healed yet, it is already time to assess its impact on the ATM systems, understand how the regions dealt with the challenges and learn from mistakes and successes. Therefore, the partnership with EUROCONTROL became even more valuable for DECEA during the difficult period of the pandemic and post-pandemic. The historic drop in traffic volume has significantly impacted the investment capacity of air navigation service providers making the scrutiny of resource allocation an even more complex and error-intolerant activity.

Moreover, the European institution's culture of structuring strategic planning supported by robust indicators and performance frameworks inspires us to maintain the path of clear goals and well-defined indicators for attention to strategic objectives. The SIRIUS Program's projects are examples of planning already based on performance management and further strengthened after our agencies' partnership. For instance, in the 2021 SIRIUS Program report [1], it is possible to verify that projects management, as such the TMA SP NEO, were carried out within the performance based approach and with some of their outputs expressed in metrics directly related to the well establish indicators in Europe.

This standardization of performance management also facilitates communication with the entire aviation community, contributing to the necessary transparency of today, in addition to strengthening our partnership with EUROCONTROL, our most significant source of inspiration in the area of performance.

[1](https://www.decea.mil.br/static/uploads/2022/04/Realizacoes-SIRIUS-2021.pdf)

Executive Summary

Air transportation contributes a significant percentage to the global economy and is a key sector in Brazil and Europe. Despite the impact of COVID-19, the sector is set for growth in the long term. Within this context, air navigation plays a major enabler role. On one side, air navigation facilitates economic recovery by responding to varying demand by airspace users, with re-emerging or new network connections. On the other side, there is an increased focus on reducing the impact of aviation on the climate, through a continual reduction of environmental impacts due to operational constraints as an immediate measure. Other measures, like market-based mechanism, global uptake of sustainable aviation fuel, or novel engine techniques and aircraft design will require more time.

The Brazilian Department of Airspace Control (DECEA) Performance Section and the EUROCONTROL Performance Review Unit (PRU) jointly produced this second edition of the Brazil-Europe comparison. This bi-regional operational performance report uses commonly agreed metrics and definitions to compare, understand, and improve air the performance of navigation services (ANS). This report, and previous reports, are available online at https://ansperformance.eu/global/brazil/. It is also planned to augment the reporting with a supporting dashboard.

This second edition aims to consolidate the existing comparison process and expand its scope. This report updates the overview on both (Brazilian and European) air navigation systems; broadens the temporal scope, and adds new analyses. The report focuses on a subset of the eleven Key Performance Areas identified by the ICAO Global Air Navigation Plan (ICAO 2005, Appendix D).

While the primacy of Safety is fully recognised, the scope of this report is limited to operational ANS performance due to data constraints. In particular, Predictability, Capacity, Efficiency and Environment, as shown below.

This second report also introduces an initial approach to quantify the environmental impact of operational inefficiencies.

The comparison shows similarities and differences in the air navigation service provision and observed performance in both regions. Major take-aways of this report include:

- Overall, air navigation service provision is more fragmented in Europe with a higher number of local/national air navigation service providers and their respective control units. Integrated civil/military service provision is inherent to the organisation of DECEA and the Brazilian system, while in Europe a mix of co-location and integration exists, according to local/national arrangements.
- COVID measures strongly impacted air transportation demand in both regions and affected almost all air navigation system parameters.
- The difference between Brazil's and Europe's systems reacting to the seasons became more evident during the pandemic recovery. When not hit by another COVID-19 wave,

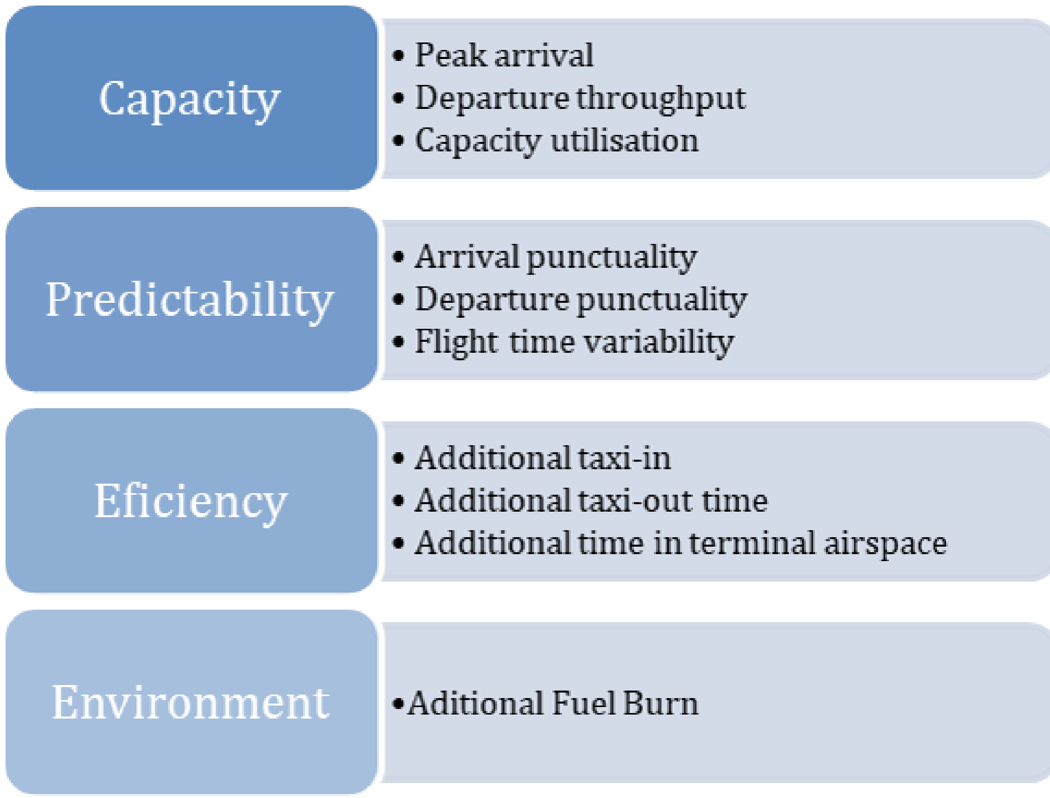

Figure 1: (ref:KPA Index)

the European region had greater variations in demand between the winter and summer seasons. The Brazilian flow recovered more gradually, showing a more continuous demand.

- Predictability in both systems degraded during and post COVID phase and is slowly recovering to pre-COVID-19 levels.
- Airport runway system capacities in both systems are designed to meet the traffic levels. Capacities at the Brazilian airports were increased in light of a change of methodology to determine these capacities and changed procedures.
- The European system showed a higher association between lower demand and increased efficiency considering additional taxi time, additional time in terminal airspace and flight time variability. Taxi performance in Brazil follows similar principles and operational procedures with no significant differences. The partial analysis of additional time in terminal airspace revealed that on average traffic in Brazil observed higher times during the arrival phase in 2021 suggesting a system-wide change. The level of variability of flight times reflected the overall trend.
- An initial approach to quantifying the emission benefit pool on the basis of the observed additional taxi-times was developed. Emissions and the improvement pool - next to operational constraints and inefficiencies - are dependent on the fleet mix operated at the different airports. This includes the role of the airport within the respective system. Larger hubs with a higher share of traffic - and in particular heavy aircraft operations - showed a higher contribution to the overall emission benefit pool.

This report will be updated throughout the coming years under the umbrella of the DECEA-EUROCONTROL memorandum of cooperation. It is also planned to establish a web-based rolling monitoring updated on a regular basis. Future editions will complement the data time series and support the development of further use-case analyses. The lessons learnt of this joint project will be coordinated with the multi-national Performance Benchmarking Working Group (PBWG) and the ICAO GANP Study sub-group concerned with the further development of the GANP Key Performance Indicators (KPIs).

1 Introduction

WHY IS THERE A PAGE BREAK IN PDF?

1.1 Background

Since its first flights, the aviation world has learned that standardisation is the key to healthy and prosperous growth. Over the years, the good lessons experienced in sharing standards in operational activities have spread to all areas, including organisational management and strategic planning. In the early 2000s, ICAO proposed an approach inspired by the renowned PDCA cycle, adding performance-based management to it. Although ICAO emphasises the importance of a performance-based approach, the lack of a common understanding of establishing and calculating the indicators would make them internationally useless. Therefore, in 2016, interested stakeholders developed a set of key performance indicators used by a variety of organisations to establish a common set of indicators. This set of indicators is proposed as part of the ICAO Global Air Navigation Plan update cycle and the related Aviation System Block Upgrades. Stakeholders are encouraged to share their common understanding and lessons learnt from measuring air navigation system performance and providing input to the decision making process in terms of operational procedure changes and deployment of novel enabling technologies.

With this willingness to partner and share, Brazil and Europe, represented by DECEA and EUROCONTROL, signed a cooperation agreement in 2015. Amongst other activities, this agreement entails the collaboration and joint developments in the field of operational performance benchmarking of Air Navigation Services (ANS).

Based on this agreement, the Brazilian Department of Airspace Control (DECEA) started a Working Group, which has become the ATM Performance Indicators Management Committee, aiming at improving performance-based management. Through lessons learnt from the best practices observed at EUROCONTROL, and in particular its Performance Review Unit (PRU), DECEA established the Performance Section.

DECEA Performance Section and the PRU have established a joint project to foster the common understanding and harmonised interpretation of the proposed ICAO GANP indicators. The technical work has been conducted throughout the recent years comprising joint face-to-face workshops/meetings and a series of web-based discussions. An essential part of the work entailed the identification and validation of comparable data sources, the development of a joint data preparatory process, and supporting analyses to produce this report.

1.2 Scope

Comparisons and operational benchmarking activities require common definitions and joint understanding. Hence the work in this report draws from commonly accepted outputs of previous work from ICAO, other bi- or multi-regional operational benchmarking activities (e.g. PBWG [1]), and regional or organisational practices. The key performance indicators (KPIs) used in this report are developed using procedures on best available data from both the DECEA Performance Section and PRU. The comparison described in this report does

[1] The Performance Benchmarking Working Group (PBWG) is a multi-regional group with participation from Singapore, Thailand, Japan, Brazil, China, United States, and Europe.

not address all eleven Key Performance Areas (KPA). From an indicator perspective, DECEA Performance Section and PRU agreed to focus on an operational benchmarking and to collaborate on the basis of the currently proposed performance indicators coordinated by ICAO in conjunction with the update of the Global Air Navigation Plan (GANP). This second edition builds on the initial report and focuses on system characteristics and the KPAs Capacity, Efficiency, Predictability and Environment. The report also presents an initial approach to quantifying potential inefficiencies in terms of fuel burn and CO_2 emissions.

1.3 Geographical Scope

The geographical scope of this report relates to Brazil and Europe.

Brazil is defined as the sovereign airspace of the national territory of Brazil. In Brazil, airspace control is performed in an integrated civil-military manner. The same institution performs both the air defence and air traffic control functions: the Brazilian Air Force. The Department of Airspace Control (DECEA) is a governmental organization subordinated to the Brazilian Air Force Command. That Department coordinates and provides human resources and technical equipment for all air traffic units within Brazilian territory, ensuring the safety of air traffic and, at the same time, contributing to military defence.

DECEA is the main body of the Brazilian Airspace Control System (SISCEAB). The department is in charge of providing the Air Navigation Services for the 22 million km^2 of airspace jurisdiction, including oceanic areas. The Brazilian airspace is composed of 5 Flight Information Regions (FIR). Air traffic within these FIRs is managed by 4 operational bases subordinated to DECEA. The areas of responsibility of these integrated Centres for Air Defence and Air Traffic Control (CINDACTA) are depicted in Figure 1.1).

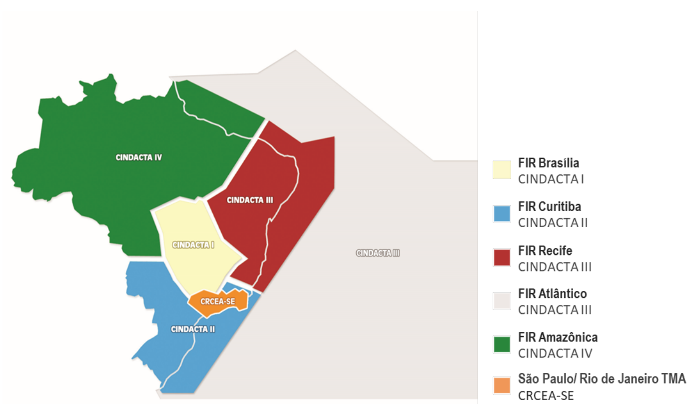

Figure 1.1: Brazilian Airspace Structure/FIRs (CINDACTAs)

The CINDACTAs combine civil air traffic control and air defence military operations. In addition to CINDACTAs, there is also the Regional Center of Southeast Airspace Control (CRCEA-SE), which is responsible for servicing air traffic for the high density air flow in the terminal areas of São Paulo and Rio de Janeiro.

In this report, Europe, i.e. the European airspace, is defined as the area where the 41 EUROCONTROL member states provide air navigation services, excluding the oceanic areas and the Canary islands (c.f. Figure 1.2). In 2016, EUROCONTROL signed a comprehensive

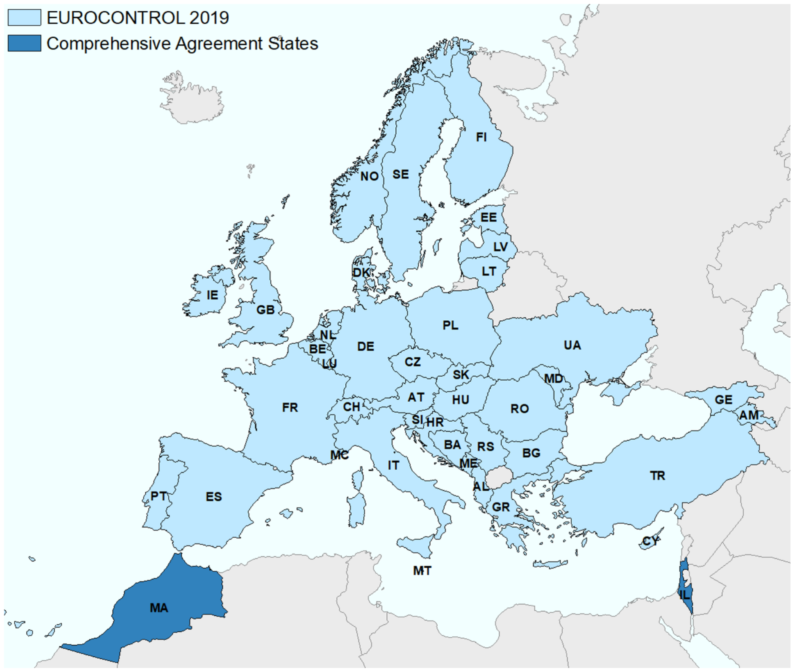

Figure 1.2: European Airspace and EUROCONTROL Member States

agreement with Israel and Morocco. Both comprehensive agreement States will be successively fully integrated into the working structures including performance monitoring. Within this report, these states are included in the reported network traffic volume.
EUROCONTROL is an inter-governmental organisation working towards a highly harmonized European air traffic management system. Air traffic services are provided by air navigation service providers entrusted by the different EUROCONTROL member states. Dependent on the local and national regimes, there is a mix of civil and military service providers, and integrated service provision. The Maastricht Upper Area Control Center is operated by EUROCONTROL on behalf of 4 States (Netherlands, Belgium, Luxemburg, and Germany). It is the only multi-national cross-border air traffic unit in Europe at the time being. Given the European context and airspace structure, the European area comprises 37 ANSPs with 62 en-route centres and 16 stand-alone Approach Control Units (i.e. totalling 78 air traffic service units).

Europe employs a collaborative approach to manage and service airspace and air traffic. This includes the integration of military objectives and requirements which need to be fully coordinated within the ATM System. A variety of coordination cells/procedures exists between civil air traffic control centres and air defence units reflecting the local practices. Many EUROCONTROL member states are members of NATO and have their air defence centres / processes for civil-military coordination aligned under the integrated NATO air defence system.

Further details on the organisation of the regional air navigation systems in Brazil and Europe will be provided in Section 2.1.

1.3.1 Study Airports

As concerns airport-related air navigation performance, this edition of the comparison report addresses the performance at a set of selected airports. These airports represent the top-10 or most relevant airports in terms of IFR movements in both regions and allow to make meaningful comparisons. In Brazil, the selected airports play a significant role in terms of the national and regional connectivity, including the major hubs for international air traffic. These study airports have consolidated systems and structured processes for data collection in support of this comparison report. For the European context, the study airports comprise the busiest airports in several states exhibiting a mix of national, regional, and international air traffic. These airports are also characterised by varying operational constraints that make them excellent candidates for an international comparison. All of these airports are subject to the performance monitoring under the EUROCONTROL Performance Review System and provide movement related data on the basis of a harmonised data specification.

Figure Figure 1.3 provides an overview of the location of the chosen study airports within the regions. The airports are also listed in **?@tbl-scopetable**.

(ref:scopetable-caption) List of study airports for the Brazil / Europe operational ANS performance comparison

Brazil	Europe
* Brasília (SBBR) * São Paulo Guarulhos (SBGR) * São Paulo Congonhas (SBSP) * Campinas (SBKP) * Rio de Janeiro S. Dumont (SBRJ) * Rio de Janeiro Galeão (SBGL) * Belo Horizonte Confins (SBCF) * Salvador (SBSV) * Porto Alegre (SBPA) * Curitiba (SBCT)	* Amsterdam Schiphol (EHAM) * Paris Charles de Gaulle (LFPG) * London Heathrow (EGLL) * Frankfurt (EDDF) * Munich (EDDM) * Madrid (LEMD) * Rome Fiumicino (LIRF) * Barcelona (LEBL) * London Gatwick (EGKK) * Zurich (LSZH)

1.3.2 Temporal Scope

This report focuses mainly on the period from January 2019 through to June 2021. Based on the initial report and data availability, a longer time series (up to June 2022) will be presented, as far as practicable. With this report the focus is on building a timeline with comparable data to be augmented in future editions.

Throughout the report, summary statistics will be given with reference to calendar years of this comparison study. It must be noted that the data for 2022 covers the first six months, January through June.

1.4 Data Sources

The nature of the performance indicator requires the collection of data from different sources. DECEA Performance Section and PRU investigated the comparability of the data available in both regions, including the data pre-processes, data cleaning and aggregation, to ensure a harmonised set of data for performance comparison purposes.

DECEA mainly uses tower data from the main airports as a data source for performance studies. This was combined with ANAC official and public data for specific indicators. Each landing and take-off operation is collected and provided automatically by the control tower system. The provided data includes such items as the times of operations, gate entry and exit, and flight origin and destination

Within the European context, PRU has established a variety of performance-related data collection processes. For this report the main sources are the European Air Traffic Flow Management System complemented with airport operator data. The sources are combined to establish a flight-by-flight record. This ensures consistent data for arrivals and departures at the chosen study airports. The data is collected on a monthly basis and typically processed for the regular performance reporting under the EUROCONTROL Performance Review System and the Single European Sky Performance and Charging Scheme (EUROCONTROL 2019).

1.5 Structure of the Report

This edition of the Brazil-Europe comparison report is organised as follows:

- **Introduction** overview, purpose and scope of the comparison report; short description of data sources used Air Navigation System Characteristics high-level description of the two regional systems, i.e. areas of responsibility, organisation of ANS, and high-level air navigation system characteristics
- **Traffic Characterisation** air traffic movements, peak day demand, and fleet composition observed at the study airports
- **Predictability** observed arrival and departure punctuality
- **Capacity and Throughput** assessment of the declared capacity at the study airports and the observed throughput, including runway system utilisation comparing achieved peak throughput to the declared capacity.
- **Efficiency** analysis of taxi-in, taxi-out, and terminal airspace operations.
- **Environment** initial analysis of the additional fuel burn and associated CO_2 emissions based on the observed operational inefficiencies.
- **Conclusions** summary of this report and associated conclusions; and next steps.

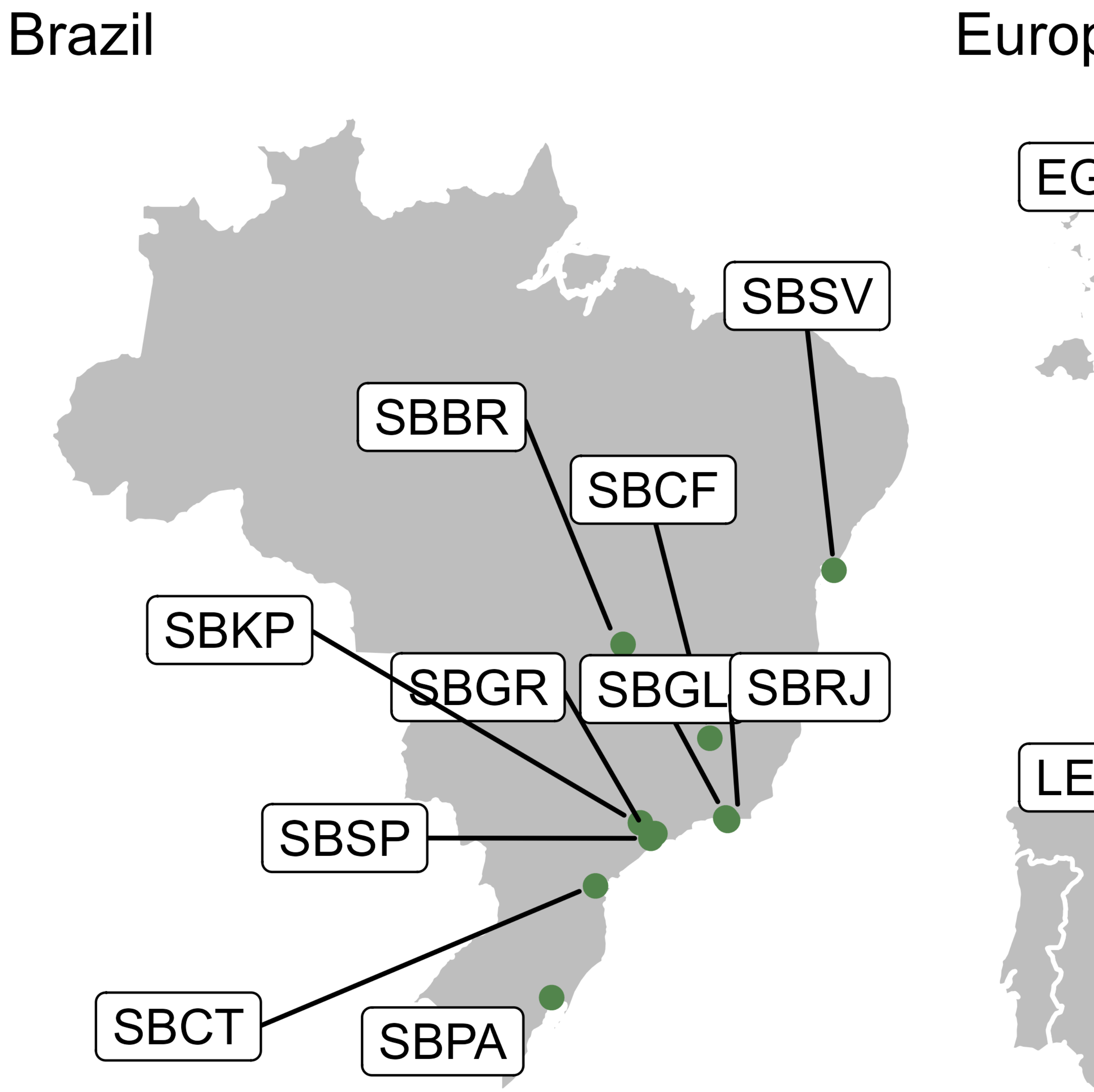

Figure 1.3: Study airports of Brazil/Europe Comparison

2 Air Navigation System Characterisation

This section provides a general overview of the Brazilian and European air navigation system. In general terms, the provision of air navigation services in Brazil and Europe are based on similar operational concepts, procedures, and supporting technology. However, there exists a series of differences between the two regional systems. These characteristics help to explain the similarities and differences in terms of key performance indicators observed throughout this report.

2.1 Organisation of Air Navigation Services

A key difference between the Brazilian and European air navigation system is the organisation of ANS in both regions. In Brazil there is one air navigation services provider, while in Europe each member state has assigned the service provision to national or local providers. To date the Maastricht Upper Area Control Centre is the only multi-national air traffic service unit in Europe [1]. Network functions, such as air traffic flow management and airspace management are centrally planned/coordinated by the European Network Manager.

The Department of Airspace Control (DECEA) is responsible for the management of all the activities related to the safety and efficiency of the Brazilian airspace control. DECEA's mission is to manage and control all air traffic in the sovereign Brazilian airspace and to contribute to its defense. In that respect, DECEA operates a fully integrated civil-military system. The airspace covers an area of approximately 22 million km^2 (non-oceanic: 8.5 million NM^2) and is organised into 5 Flight Information Regions comprising 5 area control centres (ACC), 57 towers (TWR) and 42 approach units (APP) (c.f. Figure 1.1).

The European non-oceanic airspace spans over an area of 11.5 million km^2. As concerns the provision of air traffic services, the European approach results in a high number of service providers, i.e. there are 37 different en-route air navigation service providers (ANSPs) with varying geographical areas of responsibility. Next to a limited number of cross-border agreements between adjacent airspaces and air traffic service units, air traffic service provision is predominantly organised along state boundaries / FIR borders. Maastricht UAC represents the only multi-national collaboration providing air traffic services in the upper airspace of northern Germany, the Netherlands, Belgium, and Luxembourg. The level of civil-military integration varies from country to country in Europe. Within the European context, air traffic flow management (ATFM) and airspace management (ASM) are provided/coordinated centrally through the Network Manager. The design of airspace and related procedures is no longer carried out or implemented in isolation in Europe. Inefficiencies in the design and use of the air route network are considered to be a contributing factor towards flight inefficiencies in Europe. Therefore the development of an integrated European Route Network Design is

[1] On behalf of the four member states the EUROCONTROL Maastricht Upper Area Control Centre manages the upper airspace (from 24,500 to 66,000 feet) over Belgium, the Netherlands, Luxembourg and north-west Germany

one of the tasks given to the Network Manager under the European Commission's Single European Sky initiative. This is done through a collaborative decision-making (CDM) process involving all stakeholders. A further task of the Network Manager is to ensure and coordinate that traffic flows do not exceed what can be safely handled by the air traffic service units while trying to optimise the use of available and deployed capacity. For this purpose, the Network Manager Operations Centre (NMOC) monitors the air traffic situation and proposes flow measures coordinated through a CDM process with the respective local authorities. This coordination is typically affected with the local flow management position (FMP) in an area control centre. The NMOC implements then the respective flow management initiative on request of the authority/FMP.

Similar to Europe, the Brazilian CGNA (Air Navigation Management Centre), which is an organisation subordinated to DECEA, performs the same functions as the European NMOC. CGNA manages the Brazilian air traffic flows, applies ATFM measures and facilitates collaborative decision-making with airlines, airports, control and approach centres. In addition, CGNA also coordinates airspace management, the flight plan handling system, the statistical database, and all activities related to air navigation. In summary, CGNA provides the operational management of ATM processes and related infrastructure, and ensures the availability and quality of the services provided under the Brazilian Airspace Control System (SISCEAB).

2.2 High-Level System Comparison

Starting from an initial macro-comparison, it is evident that the European environment is more complex. For example, while the European non-oceanic airspace is about a quarter larger (26%) than Brazil's non-oceanic airspace, the number of 37 Air Navigation Services Providers already shows a totally different system complexity in terms of ATM operations compared to just one ANSP in Brazil. Figure 2.1 summarizes the key characteristics of the Brazilian and European air navigation system for 2021. Both regions operate with similar operational concepts, procedures and supporting technology. However, Brazil, with lower traffic density, finds a more challenging cost-benefit ratio to maintain communications coverage and surveillance for low-traffic regions, while the European region faces more considerable challenges in coordinating efforts to avoid congestion due to a higher density.

KPA	Brazil 2019	Brazil 2021	Europe 2019	Europe 2021	BRA/EUR 2019	BRA/EUR 2021
geographic area (million km^2)	8.5 non-oceanic (22.5 Total)		11.5 non-oceanic		74%	
number of en-route ANSPs	1		37		3%	
number of towers	59	57	400+		14%	
number of APP	43	42	16 (stand alone)		263%	
number of ACC	5		62		8%	
number of ATCOs in OPS	3 126	3 549	17 563[1]	17 563[1]	18%	20%
controlled IFR flights	1 594 442	1 286 224	10 995 092	6 173 101	15%	21%
flights/ATCO	510	362	626	351	81%	103,13%
traffic density non Oceanic (flights/km2)	0,187	0,151	0,956	0,536	20%	28%

[1]2018, excluding Georgia and Canary Island

Figure 2.1: High-level comparison 2021

In terms of air traffic service provision, the comparison of the number of APP and ACC facilities is less straightforward. Several relevant differences can make conclusions difficult. While in Brazil each Approach Unit (APP) is a stand alone ATC unit, the European model sees a mix of stand alone and co-located units.
Next to the partial co-location of APP and ACC units in Europe, the higher number of ACCs reflects the local/national focus of air traffic service provision. This also becomes visible when comparing the total number of ATCOs in operations. The number of ATCOs in Brazil ranges around 20% of the numbers of ATCOs in Europe. While a crude high-level measure, the ratio of IFR movements per ATCO ranged at the same order of magnitude in 2021 (+3% in Brazil). In 2019 (pre-COVID) the European ratio is about 20% higher than in Brazil. This suggests that the staffing situation in 2021 in comparison to the overall traffic situation in both regions follows similar criteria. This needs to be contrasted with the lower traffic density in Brazil (and overall lower traffic levels). On average, the shift in traffic levels per volume of airspace is significantly lower in Brazil than in Europe. This suggests that the network connectivity in Brazil is more centralised than in Europe (lower density of flights per km^2 vs similar average number of controlled flights per ATCO). The latter can also be derived from the fact that the European network also entertains a high share of intra-European traffic primarily servicing major hubs (i.e. capitals, business centres) between the European states.

2.3 Regional Approaches to Operational Performance Monitoring

2.3.1 Europe

Within Europe, the Performance Review Commission (PRC) was created by the EUROCONTROL States in 1998, following the adoption of the European Civil Aviation Conference (ECAC) Institutional Strategy the previous year. A key feature of this Strategy was that "an independent Performance Review System covering all aspects of ATM in the ECAC area will be established to put greater emphasis on performance and improved cost-effectiveness, in response to objectives set at a political level". Subsequently, the Performance Review Unit (PRU) was established to support the work programme of the PRC. The major objective of the PRC is to provide independent advice to the EUROCONTROL Permanent Commission through the Provisional Council on pan-European ATM performance.

The EUROCONTROL PRC and PRU provide objective information and independent advice based on extensive research, data analysis, and consultation with the governing bodies and interested stakeholders on all aspects of European air navigation performance. EUROCONTROL's performance review system was a world-first at the time it was established in the late 1990s.

The PRC's work has been built on in wider fora, such as ICAO's global performance-based approach, and the performance scheme of the Single European Sky (SES). The EUROCONTROL performance review system and the SES performance scheme jointly contribute towards improving the overall performance of air navigation services and network functions in Europe. PRU also supports the European region efforts of ICAO under the Doc 030 performance framework.

International cooperation and supporting further harmonisation of air navigation performance practices is one of the strategic objectives of the PRC. Within this context, the PRC is engaging with ICAO and international partners. This report is an outcome of the DECEA/EUROCONTROL MoU and the cooperation in the field of operational ANS performance. The findings of bi-lateral comparison reports are carried forward under the umbrella of multi-lateral working arrangements (e.g. PBWG). Through this harmonisation validated approaches and methods are proposed to ICAO's GANP Performance Expert Group.

Next to two major annual pan-European performance oriented publication, i.e. ACE (ATM Cost Effectiveness) and PRR (Performance Review Report), operational performance monitoring includes a series of indicator specific data products (web-pages/dashboards, self-service reports). Within the scope of this report, respective information on operational performance be found at https://ansperformance.eu. The tab "views" provides access to data products related to the ones used in this comparison study on airport, ANSP, and national level. It needs to be noted that the indicator parameterisation used in this report differs from the parameters used within the European performance monitoring (e.g. percentiles and time frame used for the determination of associated reference time). Reported trends of this comparison report are consistent with the regional monitoring, however, the actual values of the indicator may vary. PRU is constantly expanding its online reporting on performance to provide stakeholders with independent performance monitoring data for their decision-making.

2.3.2 Brazil

The performance-based approach was adopted by DECEA as a consequence of ICAO publications in the second half of the 2000s. The concept and this form of planning gained more defined contours with the publication of ICAO DOC 9883 - Manual on Global Performance of the Air Navigation System, in 2009, following DOC 9854 - Global Air Traffic Management Operational Concept, in 2005. DECEA established a project for the development of Performance Management in 2012 within the initial activities of the SIRIUS Brazil Program (https://sirius.decea.mil.br/en/). However, essential details on the definition, metrics, and, especially, the standardisation of indicators were still a regional and global challenge.

Eventually, the effort and opportunity met with the signing of the broad-purpose Cooperation Agreement between DECEA and EUROCONTROL in 2015 and the publication of "Description of the potential Performance Indicators presented in ICAO's Global Air Navigation Plan 2016", which had a fundamental contribution from EUROCONTROL. On the basis of more precise process objectives and requirements, DECEA accelerated its transformation in search of organisational self-knowledge. Since 2017, DECEA published an annual Performance Report and several comparative reports, developed a series of training courses, and continuously expanded the availability of data for performance monitoring purposes including assciated analysis tools.

In 2019, DECEA's ATM Performance Section was born to manage and coordinate activities related to performance management and represent Brazil in international agreements and forums in this field. The setup of the Performance Section was inspired by the Performance Review Unit of EUROCONTROL. With a broad and dedicated virtual environment, the Section publishes its products, data, and - in the future - recommendations for the improvement of ATM Performance (See https://performance.decea.mil.br/).

With increasing levels of expertise in operational performance monitoring and maturity in data collection and processing, DECEA published its first DECEA ATM Performance Plan 2022 - 2023 (https://publicacoes.decea.mil.br/publicaca/pca-100-3). The plan comprises the identification and definition of performance goals for twelve ICAO/Brazilian operational key performance indicators and establishes the monitoring of five complementary performance indicators. The release of this first plan is a key step in the roadmap of DECEA to implement the performance based approach in Brazil.

The performance approach is mainly about an organization's past outcomes compared to its present and future results. However, the comparisons between peers in the universe of air navigation service improve methodologies and present opportunities for advances that would not be identified otherwise.

Within the South American region, DECEA actively promotes the open culture of trust and sharing in operational performance monitoring catalysed by the relationship with EUROCONTROL. In June 2022, DECEA was invited to coordinate a Workshop with the ICAO SAM Regional Office. Participants from Argentina, Bolivia, Chile, Colombia, Ecuador, Panama, Paraguay, Peru, Uruguay and Venezuela exchanged experiences and lessons learned with speakers from DECEA. In late 2022, DECEA will promote a Performance Seminar in the technological cluster of São José dos Campos, Brazil, the host city of the Aeronautics Technological Institute, one of the event's supporters. EUROCONTROL was invited to participate as a partner in the seminar by sending speakers.

DECEA embraces the culture of collaboration and sharing perennially. DECEA made its indicators and databases easily accessible on public dashboards, available at https://performance.decea.mil.br/produtos/dashboard/). Thus, DECEA intends to carry forward the culture of reciprocity and transparency that has been presenting consistent results and benefiting the entire aviation community.

2.4 Summary

This chapter has shown high-level similarities and differences between both regions. The non-oceanic airspace in Brazil is about a quarter smaller than in Europe and is serviced by about 40% less air traffic service units (APP and ACC, Brazil: 47 vs Europe: 78). While on average traffic levels in Brazil ranged in 2019 and 2021 at 20% of the European air traffic, the number of ATCOs is commensurate with the traffic levels and difference in ATCO staffing numbers in Brazil and Europe.
The latter is also evidenced by the similar ratio of air traffic serviced vs numbers of ATCOs in operations in 2021. This suggests that traffic density and complexity during peak times at major hubs in Brazil may be comparable to Europe. More research is needed to asses the overall network composition in both regions. The general spread in numbers highlights that the European system is still dominated by a more nationally oriented approach to air traffic service provision, while Brazil benefits from a single ANSP set up.

The chapter also provides a summary of the regional approach to operational performance monitoring. The Performance Section of DECEA and EUROCONTROL's PRU are actively collaborating on the international level to foster the understanding and application of the ICAO GANP performance framework, and drive the further developments and implementation in both regions. Both groups intend to deepen its cooperation in the future by expanding the scope of this bi-regional comparison report and the joint multi-lateral work.

3 Traffic Characterisation

The overarching objective of air traffic services is the provision of safe, orderly, and efficient flow of air traffic. Accordingly, operational system performance is linked to the actual and serviced demand (i.e. air traffic). It must be noted that the serviced traffic may be different from the actual demand. Constraints, both on the airspace user and air navigation system side may lead to unsatisfied demand. However, the level of these changes is outside the scope of this comparison.
For operational comparisons, it is therefore important to have a good understanding of the level and composition of the air traffic. The previous section provided the high-level context and organisation of air navigation services in Brazil and Europe. This chapter establishes some key air traffic characteristics for both regions to frame the observed operational performance in latter parts of the report.

3.1 Annual Traffic

Figure 3.1 shows the regional traffic development in Brazil and Europe. Pre-COVID air traffic in Brazil showed only mild variation across the year [1]. This is in contrast to the strong seasonal nature of air traffic in Europe and its peaking behaviour during the summer months of 2019. In both regions, the unprecedented decline in air traffic occurred in March 2019 in the aftermath of the pandemic-declaration by the World Health Organisation (WHO).

To understand the magnitude of the impact of COVID on air traffic, Figure 3.2 depicts the regional traffic in a normalised form. The reference level for the normalisation is set at the 90th percentile of the traffic observed in 2019. The initial drop in traffic due to COVID-related travel constraints started a few days earlier in Europe. This was related to the reaction of several air transport operators to limit their flights to Asia. Furthermore, some European states already responded to the initial surge of infections in anticipation of the declaration by the WHO.

Both regions responded initially similar to the world wide restrictions for air travel in combination with immediate regional health measures following the declaration by the WHO. The traffic declined in both regions in the order of magnitude of about 80-90%. While traffic in March through May 2020 showed a similar pattern, Europe experienced a higher share of air traffic in June, July and August of 2020. Traffic levels in Brazil grew gradually and consistently in 2020 and broke even with Europe in the early autumn. At that point in time Europe was facing a second wave of infections following an initial relaxation of health constraints to facilitate the summer vacation season. In consequence, governments had to impose again restrictions on the regional traffic to curb the further spread. While air traffic in Europe declined, traffic in Brazil continued its initial recovery until the end of 2020. In both regions the spikes (twin peaks) of the seasonal Christmas and New Year's traffic are visible. A significant

[1] For Brazil, the depicted volume of air traffic is the sum of all movements at the study airports. This captures a significant share of the total traffic and shows the overall development.

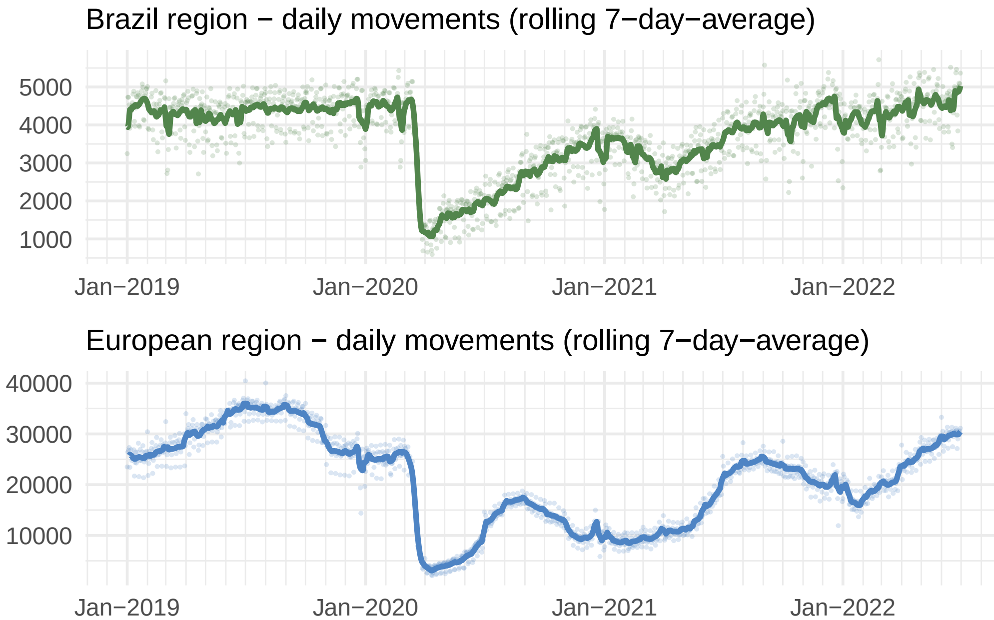

Figure 3.1: Timeline of regional air traffic

change in the pattern developed with the beginning of 2021. Following the seasonal pattern, Europe observed a continual increase in air traffic as of end January/beginning February 2021 and a strong recovery to about the 65-70% pre-COVID level ensued. The pattern of air traffic was different in Brazil. After having reached a level of about 65% at the end of 2020, Brazil also faced a second wave of COVID infections in early 2021. This resulted in a distinct reduction over the first 6 weeks in 2021 followed by a similar recovery rate throughout March and April 2021. Both regions reached 65-70% of their pre-COVID traffic levels in April and May 2021. While traffic continuously increased in Brazil, Europe saw another wave post-summer 2021. Traffic levels reached the pre-COVID 90% (and higher level) in Brazil in early 2022. With the continual relaxation of travel constraints for inner-European traffic in early 2022, Europe also reached the 85% pre-COVID level with July 2022.

In general, the gradual recovery over 2020 and 2021 also suffered severe setbacks by the subsequent reappearances of the virus characterised by the subsequent waves (i.e. ripples) in Figure 3.2. Comparing both regions, the recovery patterns of the two regions show a coherent central tendency, with relevant differences according to the season or increased regional health measures (i.e. travel restrictions). It is pertinent to note that European air traffic was more sensitive to the effects of winter and summer, reflecting the holiday seasons and climatic variations. It is interesting to note, that the Brazilian system shows little sensitivity to calendrical and seasonal effects.

By the time of the publication of this report (October 2022), the world economy and global air transportation is still recovering. There is growing confidence that COVID transitioned from its pandemic stage to an endemic stage. By the end of 2021, traffic volume was 26% and 25.5% higher for Brazil and Europe compared to 2020. The Brazilian Gross Domestic Product grew by 4.6% in 2021 and the World Bank's estimate for 2022 is a growth of 1.4%. The European market has shown a 5.4% GDP [2] increase for EU in 2021. The traffic volume

[2] Source: https://ec.europa.eu/eurostat

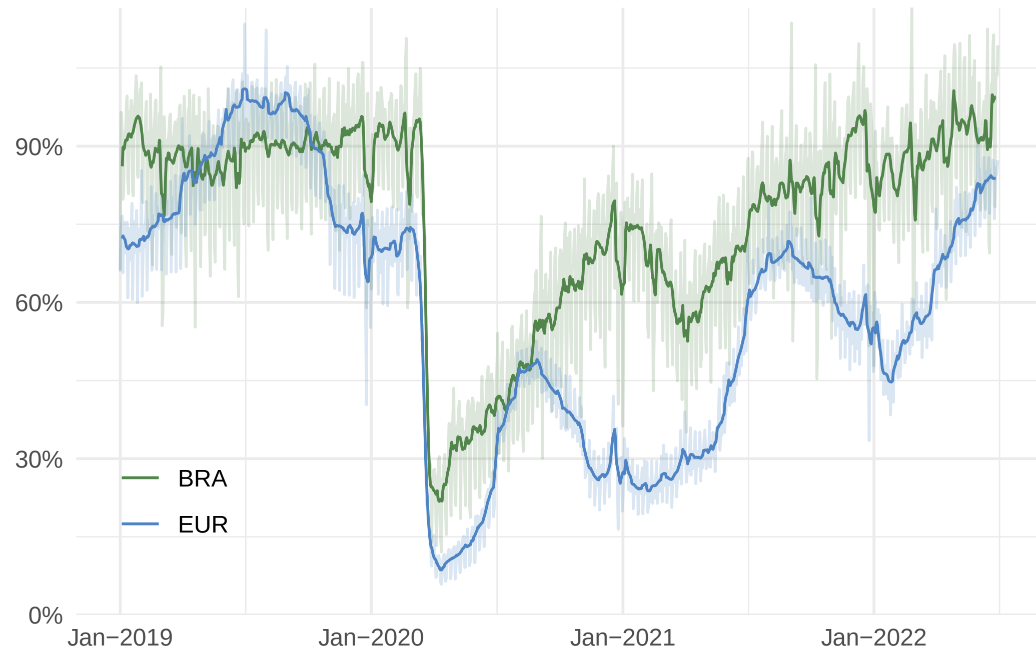

Figure 3.2: Normalised daily traffic in Brazil and Europe

of 2019 is expected to be reached towards end 2023 or beginning of 2024 for both regions, if the economic activity keeps on track.

3.2 Study Airport Level Traffic

The previous section showed the traffic development on the network level and Airports, in turn, represent nodes in this overall network. Thus, changes in the overall traffic situation will ripple down to the airport level. However, connectivity and type of traffic may differ from airport to airport. It is therefore useful to understand how traffic developed locally on the level of the selected study airports.

Figure 3.3 shows the variation of air traffic across the study airports. On average, the annual traffic at the Brazilian airports in 2020 and 2021 ranged about 45% respectively 47% lower than in 2019. The European study airports observed a higher decrease. The airports serviced -60% in 2020 and -55% in 2021. The airports of this study had been selected based on their role in the regional networks. While the numbers vary slightly, a similar pattern is observed in Brazil and Europe. This suggests that the traffic related pressure on air traffic services behaved in a similar fashion. This observation will be relevant for the following chapters. Considering all 10 airports per region may however mask varying behaviour at different airports. It is important to note that the pandemic affected both sets of 10 airports more severely than their national levels, recalling that Brazil closed 2021 with -20% and EUR with -43% compared to 2019 overall aircraft movement.

Figure 3.4 shows the annual traffic observed at the study airports in 2021 and the associated annual variation of traffic comparing 2020 and 2021. On average, traffic levels at all airports in both regions increased following the initial drop in 2019. But there are notable exemptions. São Paulo/Guarulhos (SBGR) in Brazil and London Heathrow (EGLL) in Europe show a

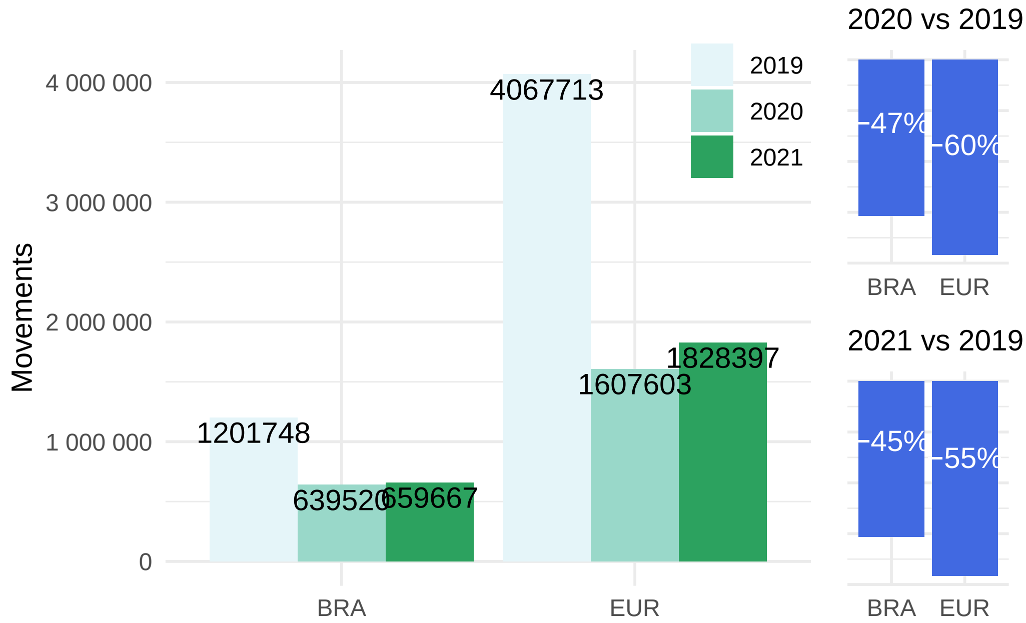

Figure 3.3: Movements at study airports in both regions

similar lagging recovery. This reflects the high share of international air traffic serviced at both airports. Both airports observed an about -5% lower traffic on an annual basis in 2021 than in 2020. Almost -10% lower traffic was observed in 2021 in comparison to 2020 at Curitiba (SBCT).This drop may be related to the strong connection between Curitiba and the Argentine capital, Buenos Aires, which faced more severe travel restrictions due to COVID. London Gatwick (EGKK) serviced about -30% less traffic in 2021 than in 2020, probably reflecting the UK's more severe anti-COVID restrictions at that time. Traffic levels in 2021 at SBGR and São Paulo/Congonhas (SBSP) range in the order of magnitude of the less busy airports in the top-10 of Europe.

3.3 Peak Day Traffic

While the annual traffic provides insights in the total air traffic volume and associated demand, it does not provide insights on the upper bound of achievable daily movement numbers. The latter depends on demand, operational procedures and constraints, and the use of the runway system infrastructure. The peak day traffic is determined as the 99th percentile of the total number of daily movements (arrivals and departures). The measure represents thus an upper bound for comparison purposes.

Figure 3.5 shows the peak day traffic in 2019 with reference to the number of runways.

Figure 3.5 shows the peak day traffic in 2021. Peak traffic at the 2-runway airports Guarulhos (SBGR) and São Paulo Congonhas (SBSP) in Brazil and London Heathrow (EGLL) and Munich (EDDM) in Europe achieve similar or higher peak numbers than airport with more runways. It's valid to note that Campinas (SBKP) and Salvador (SBSV) were stable due to an already low traffic concentration regarding per day granularity.

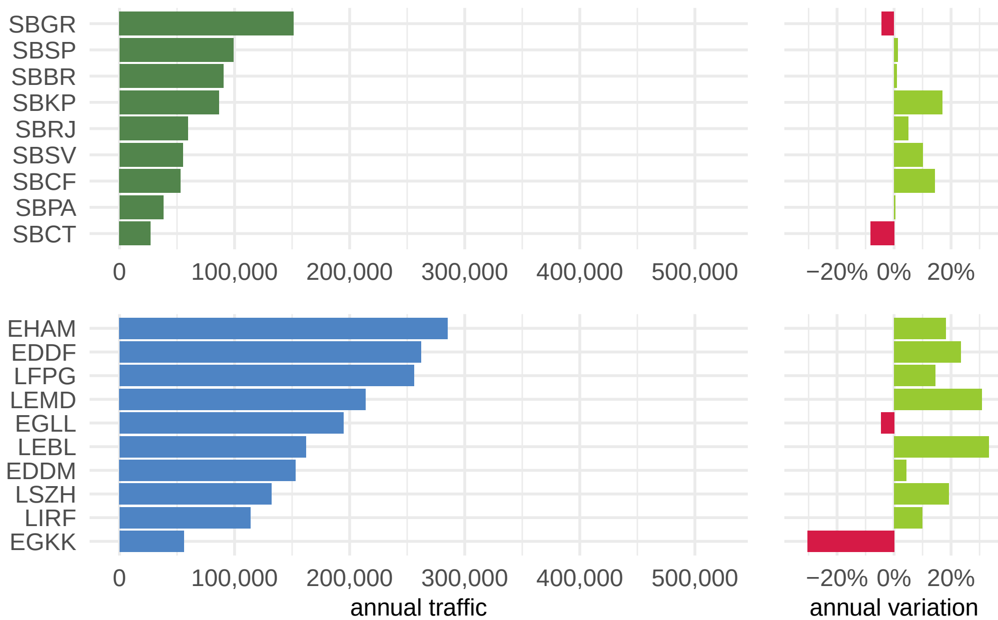

Figure 3.4: Annual traffic at study airport in 2021 and variation 2020/2021

For European with more than 2 runways it needs to be noted that the runway system does not support independent operations of all available runways. Thus, the serviced peak traffic is also impacted by the runway system configuration. Peak operations as SBGR range in the same order of magnitude than Munich (EDDM) and exceed the peak movement observed in Zurich (LSZH, 3 runway system) or Rome Fiumincino (LIRF, 4 runway system).

Figure 3.1 and Figure 3.2 depict the decline in air traffic with the start of the COVID pendemic in March 2020 at the same moment in both regions. However in terms of peak movements the seasonal difference between Brazil and Europe become more visible in Figure Figure 3.6. While in Europe a sharp drop in peak day traffic is already observed for the year 2020, the respective peak day movements in the first 3 month in 2020 in Brazil range in the same number than the years before. The recovery seen in 2021 movements did not reflect at Peak Days. The distribution was more equalized, resulting in lower peaks.

3.4 Fleet Mix

The fleet mix - and in particular the separation requirements between the different aircraft types - is an important influencing factor for the capacity and observed (and realisable) throughput. In particular, aircraft with longer runway occupancy times or larger proportions of heavy aircraft may result in lower throughout due to the larger wake turbulence separations. The locally defined capacity values may therefore differ based on the predominant fleet mix and operational characteristics, and ultimately result in different observed Peak Day movement numbers.

Figure 3.7 depicts the observed share of different wake turbulence categories (WTC) across the study airports in 2021. In both regions, “medium” aircraft types are the predominant aircraft type.

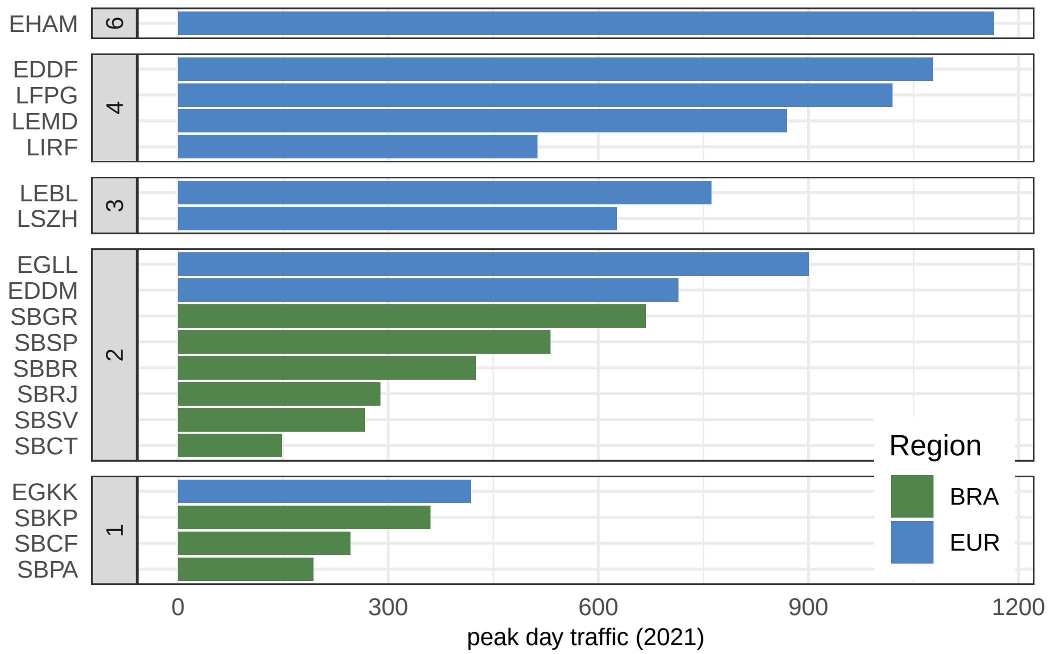

Figure 3.5: Peak day traffic (99th percentile of annual movements)

On average, airports in Europe observed a higher share of "heavy" aircraft in 2021. In Brazil, Guarulhos (SBGR) and Campinas (SBKP) serviced a noticeable share of "heavy" aircraft of around 12% which is comparable to the share at Zurich (LSZH). In Brazil, "light" types play a larger role at the study airports than on the European side. The fleet mix at SBGR and SBKP showed a similar pattern (high share of medium, discernible share of heavy, and shallow share of light types) as observable at European airports. The heavy category represents wide-body passenger aircraft and full cargo flights. Within the European region - and its multitude of national hubs - a significant number of international long-haul flights is operated at the chosen study airports. In Brazil, the highlighted airports, Guarulhos (SBGR) and Campinas (SBKP), play a major role in terms of international connectivity. It follows that medium and light types are used for inter-reginal connections. Based on the selected study airports, the underlying decentralised structure of the European network becomes more visible. While international air traffic is centralised in Brazil with 2 pre-dominant hubs, capital or main national hubs are more frequent in Europe. London Heathrow (EGLL) is a noteworthy exemption. The level of international connectivity can be derived from a 50% share of heavy types.

Figure 3.8 and Figure 3.9 depict the evolution of the annual fleet mix for the years 2019 through 2021 for nine of the study airports in both regions [3]. Two principal patterns emerge: (i) airports with COVID-related contraction of traffic, i.e. the reduction in overall traffic in 2020 and 2019 did not influence the relative share of aircraft types serviced at the airport, and (ii) airport with a reduction of the share of "heavy" aircraft and increase of the relative share of "medium" or "light" types.
With the exception of Zurich (LSZH) in Europe, "light" types did not feature widely. There appears to be a reciprocal relationship between the relative share of "heavy" and "medium" types utilised in Europe. At major hubs (e.g. EDDF, EGLL, EHAM, LFPG) the ratio of "heavy" aircraft increased across the years.

[3]To increase readability of the visualisation an airport with low variability has been removed from the figure for both regions.

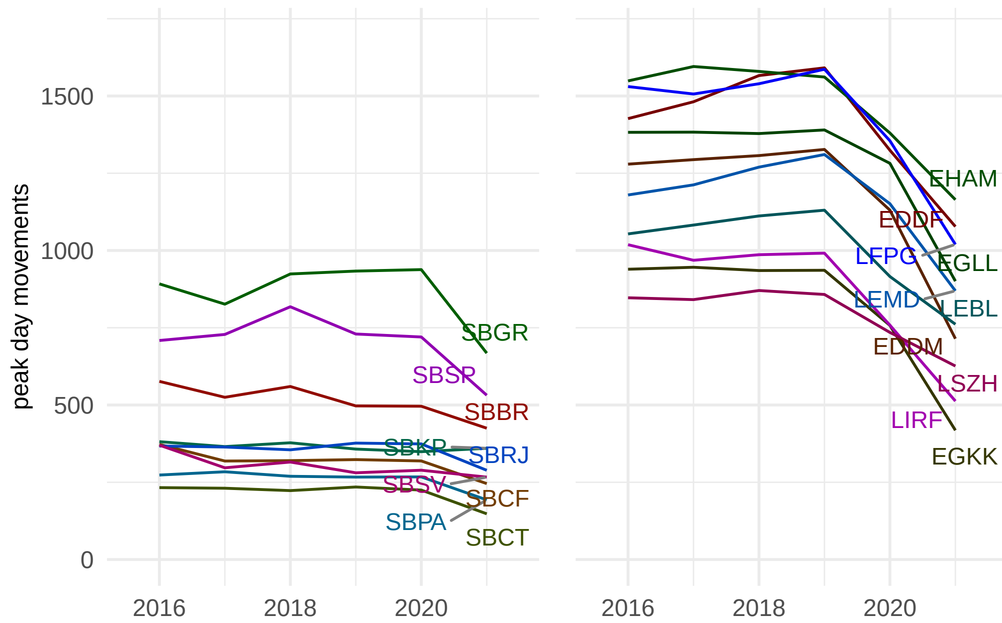

Figure 3.6: Variation of Peak day traffic over time

The fleet mix in Brazil showed a different pattern. While the share of "heavy" types remained on average constant across the period 2019 through 2021, lower shares of "medium" types resulted in higher utilisation rate of "light" types.

For future reports it will be interesting to investigate also the connectivity in terms of operated aerodrome pairs and aircraft types.

Figure 3.10 and Figure 3.11 focus on the temporal evolution of the fleet mix on a rolling weekly basis (7-days) for heavy and medium type aircraft. This shows a more varied behaviour across all airports.

The synchronicity of the relative reduction and increase can be observed at all European airports. The overall traffic pattern at these airports followed the overall traffic development in Europe for the observed period. The increased share of heavy aircrafts may reflect the resilience of cargo flights over the pandemic. Zurich (LSZH) - based on a structurally overall lower share of heavy aircraft and on the presence of a good share of light types - showed a pattern that reflected the overall trends. With a lower share of heavy aircraft for most Brazilian airports, the evolution of the medium type share follows the overall traffic development in Brazil. The decline in March 2020 is characteristic. For example, in Sao Paulo (SBSP) - with a negligible share of heavy aircraft - the share of medium aircraft mirrors the overall trend in Brazil. This shows that SBSP predominantly serviced domestic or short-range traffic. That is somehow expected for São Paulo (SBSP) and Rio de Janeiro (SBRJ) since their runaway length and airport infrastructure are not suitable for heavies, but it is interesting to note that other Brazilian airports such as Brasília, Confins and Curitiba, which can accommodate heavies, do not serve a significant number of these aircraft. That is a good opportunity for future studies and explorations.

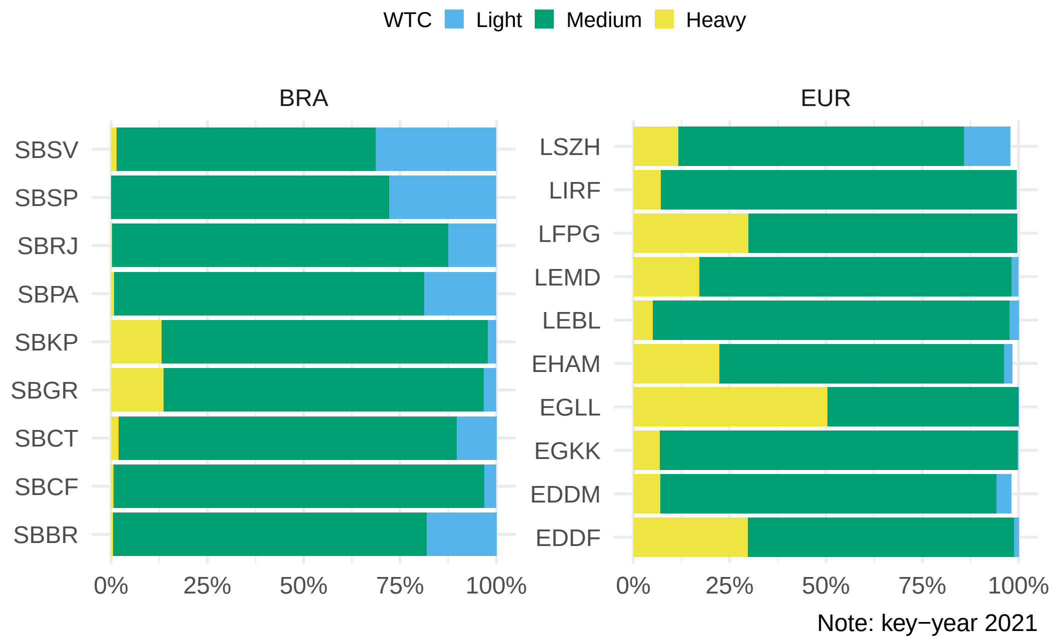

Figure 3.7: Fleet mix observed at study airports in 2021

3.5 Summary

This chapter described the overall evolution of air traffic in Brazil and Europe and offered a closer look at the selected subset of study airports. Both regions observed a unprecedented decline in air traffic in March 2020 in response to COVID. However, the response pattern differed. Both regions observed COVID waves resulting in measures to limit air travel and curb the spread of COVID. Despite these waves, the Brazilian system recovered more consistently in structural terms. This shows the effect of the additional coordination and harmonisation effort of policies in Europe. As national governments varied in their assessment and introduction of health measures, including travel restrictions.

An intersting observation is that despite the overall variation of traffic on regional and local level, the share of operated aircraft types varied to a lesser extent on an annual level. However, distinct patterns become visible on the airport level. A central factor is the difference in terms of network connectivity and the role of the selected study airports. Based on the historic context, there exists a higher number of national hubs across Europe. In Brazil, international and cargo air traffic are more centralised and primarily operated to/from SBGR and SBKP. This can be obsered based on the differences of shares of heavy types (predominantly wide-body aircraft = long-haul international and cargo traffic).

These differences may impact - amongst others - separation and throughput. This chapter also highlighted potential areas for further research to better qualify the level of network and pan-regional connectivity.

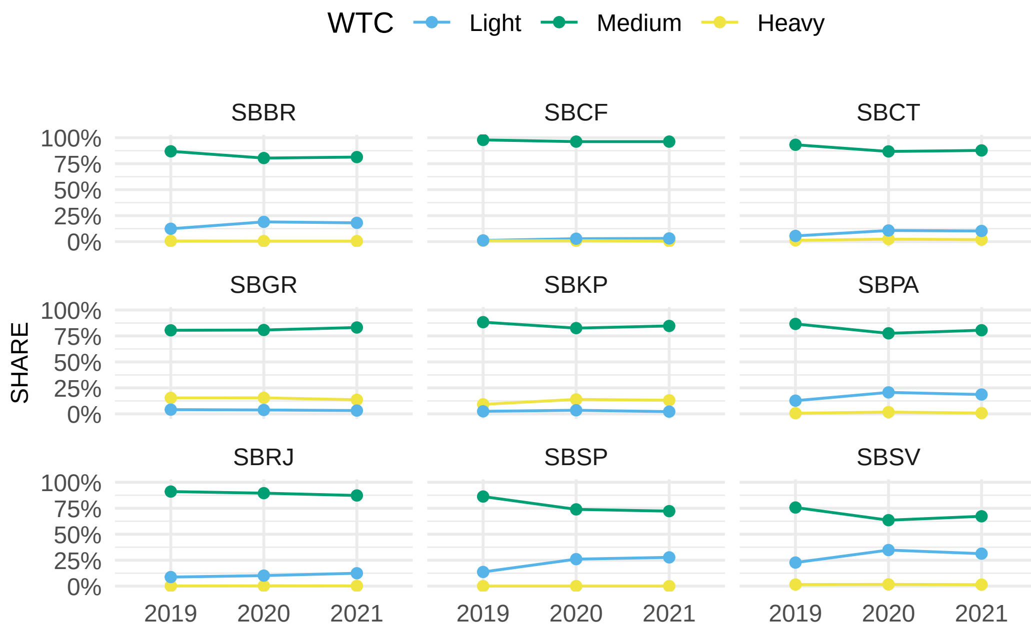

Figure 3.8: Fleet mix change over time observed at study airports in Brazil in 2021

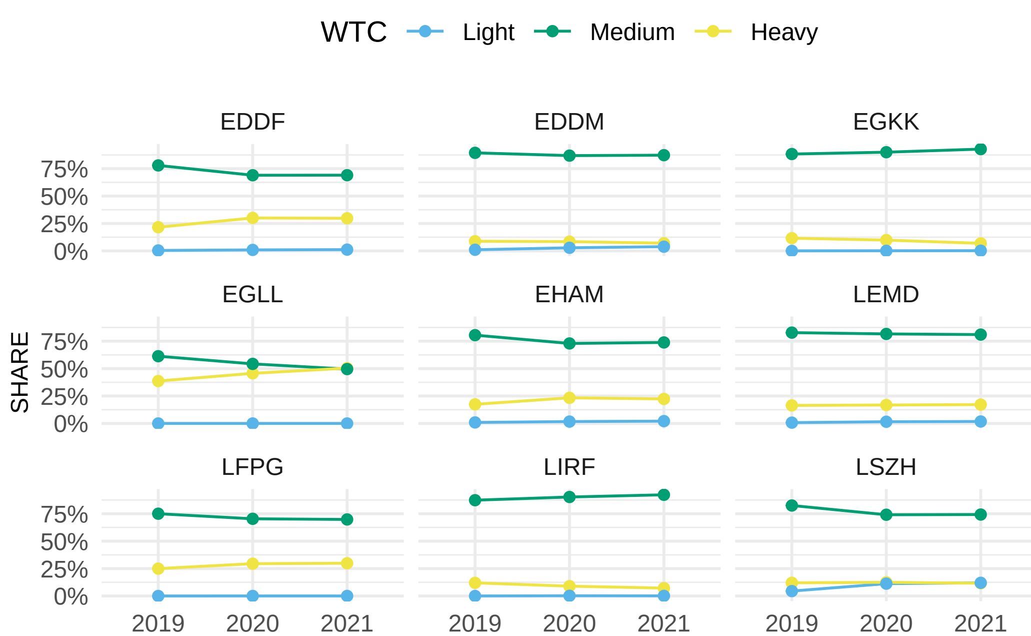

Figure 3.9: Fleet mix change over time observed at study airports in Europe in 2021

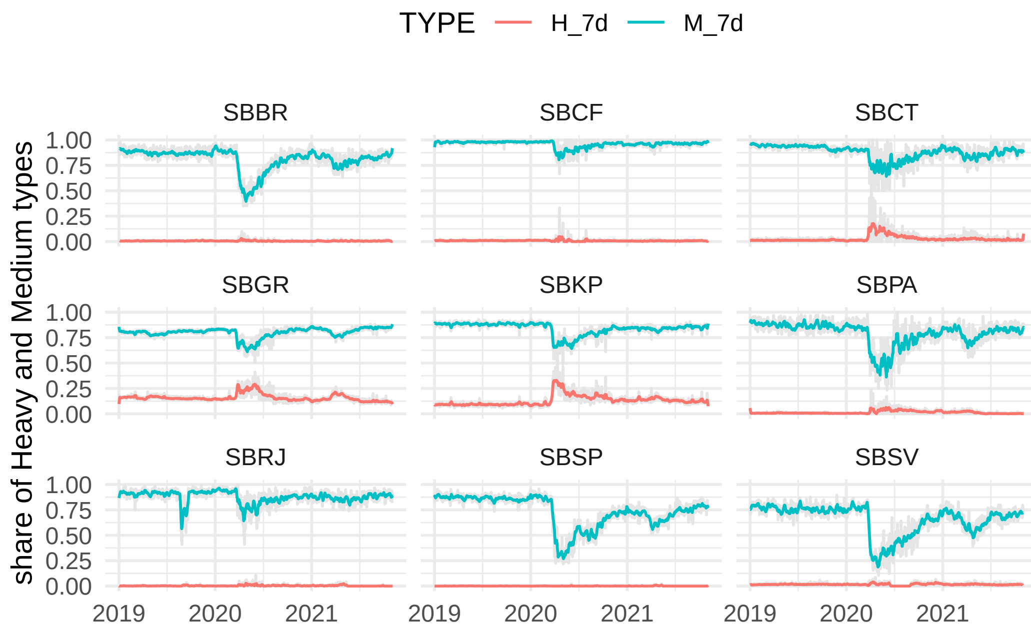

Figure 3.10: Evolution of fleet mix at selected Brazilian airports

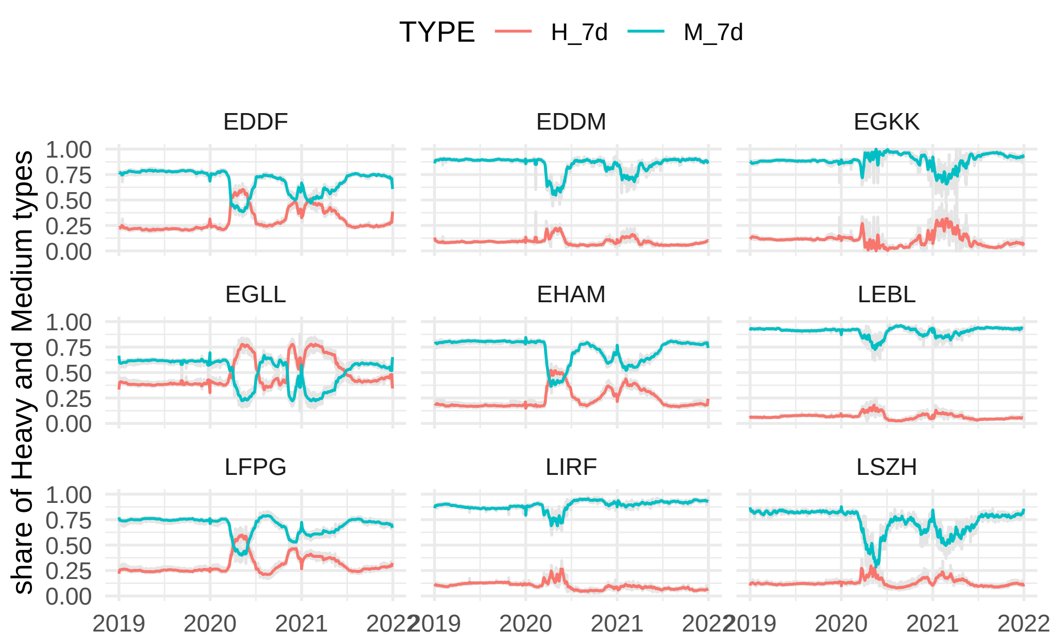

Figure 3.11: Evolution of fleet mix at selected European airports

4 Environment

4.1 Overview and Motivation

At ICAO Assembly 40 in 2019 two global aspirational goals for curbing the impact of the international aviation sector were agreed. This includes an annual fuel efficiency improvement of 2% through 2050 and carbon neutral growth from 2020 onwards (c.f. ICAO (2019b)). Across the globe, states have defined ambitious political goals to address the impact of climate change. For example, the European Union launched its Green Deal (European Commission (2019)) and Fit-for-55 initiative. The latter strives strives towards cutting the net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels (European Commission (2021)).

In general terms, air navigation shall contribute to the protection of the environment by considering noise, gaseous emissions and other environmental issues in the implementation and operation (KPA Environment, c.f. Appendix D ICAO (2005). Accordingly, there is a higher interest in monitoring/estimating the impact of operational (in)efficiency. Operational inefficiencies typically increase the aircraft flying time (i.e. airborne and surface movement times) and , thus, engine running time. Engine time is directly linked to fuel burn and associated emissions and pollutants. In that respect, inefficiencies contribute to the ditremental effect of excessive emissions to climate change.

The Global Air Navigation Plan (GANP) proposes indicators for regional benchmarking (ICAO 2019a). However, there is no detailed guidance on how to measure *additional fuel burn*. Fuel burn per se is known to the aircraft operator. While the actual fuel burn and fuel flow during the flight is recorded (e.g. flight data recorder), these data are not commonly shared. It is noteworthy that aircraft operators have to report their fuel burn per flight in Brazil (c.f. ANAC reporting files). This level of data is not available in Europe (or generally across the globe).

For this report, both groups tapped into openly available data sources and developed an initial approach to quantifying operational inefficiencies with respect to fuel burn. It is planned to refine this approach in consultation with the international operational performance benchmarking community.

4.2 Fuel Burn Estimation

The appendix presents an initial approach to estimating fuel burn during taxi operations as part of a comparison report. Figure 4.1 depicts the monthly estimated fuel burn at a European hub for the taxi-in and taxi-out phase. It must be noted that the metric uses parameters of the ICAO landing and take-off cycle (LTO). The LTO estimates represent upper bounds for the fuel estimation and overestimates the actual fuel burn.

Figure 4.1 highlights that there is a higher fuel burn during the departure phase. This phase entails the take-off roll with a thrust setting at or close to 100%. This adds a substantial component to the fuel burn during take-off in comparison to the taxi-in phase. As mentioned above, the quantities shown reflect upper bounds based on the LTO assumptions and do not account for operational reduction measures such as single-engine taxi or reduced thrust take-offs. It is planned to refine the approach with the international benchmarking community and account for such operational measures.

4.3 Environmental Benefit Pool - Taxi

Earlier work has introduced the concept of an environmental benefit pool, c.f. EUROCONTROL Performance Review Unit and FAA Air Traffic Organization (2019).

Figure 4.2 shows the fuel benefit pool for the taxi-in phase per arrival. The benefit pool is influenced by the fleet mix and the overall taxi-in performance. Thus, it varies significantly across the airports.

With the exception of Rome Fiumicino (LIRF), there is an increase in the benefit pool when comparing 2020 and 2021 within the European region.

Comparing Figure 4.3 with Figure 4.2 shows the overall impact of higher observed taxi-out times and the high-thrust take-off run. For the major hubs in Europe the traffic decline during the COVID phase culminated in sharp decline of the average additional fuel burn per departure when comparing 2019 levels to 2020 or 2021. The impact of congestions on the taxi-operations and the associated refernce times was highlighted already in the efficiency chapter. In light of this, the results for London Heathrow (EGLL) and London Gatwick (EGKK) need to be interpreted comparing the absolute different between the different years. The decline in traffic allowed to operate without constraints which resulted in a - numerical - gain.
However, this showcases that the determined reference times internalised inefficiencies. The values for these airports range higher than presented. Future research will address how such variations in terms of traffic load can be better captured as part of the benefit pool approach.

4.4 Mapping of Benefit Pools

The following Figures depicts the observed shares of additional fuel burn for taxi-out and taxi-in. It must be noted that the totals are based on the assumptions of the ICAO LTO cycle. As such the estimates present an ***upper bound*** and do not take into consideration single-engine taxi-operations, reduced taxi-thrust, etc.

4.5 Summary

This chapter is a first attempt to estimate the environmental impact of operational inefficiencies at airports. The determined benefit pools for taxi-in and taxi-out vary significantly between airports. While operational inefficiencies, e.g. higher sequencing and holding times, impact on the overall taxi-phase duration - and ultimately - the total fuel burnt during these phases, the metric is also dependent on the different fleet mix observed at these airports. The impact of wide-bodies (and primarily international traffic) can be readily observed for the major hubs during 2019. The COVID related decline of operations of these types and connections, resulted in a sharp drop of the measured benefit pool in 2020 and 2021.

Based on the underlying databank of aircraft types and associated fuel burn indices, more detailed analyses will be feasible in future reports.

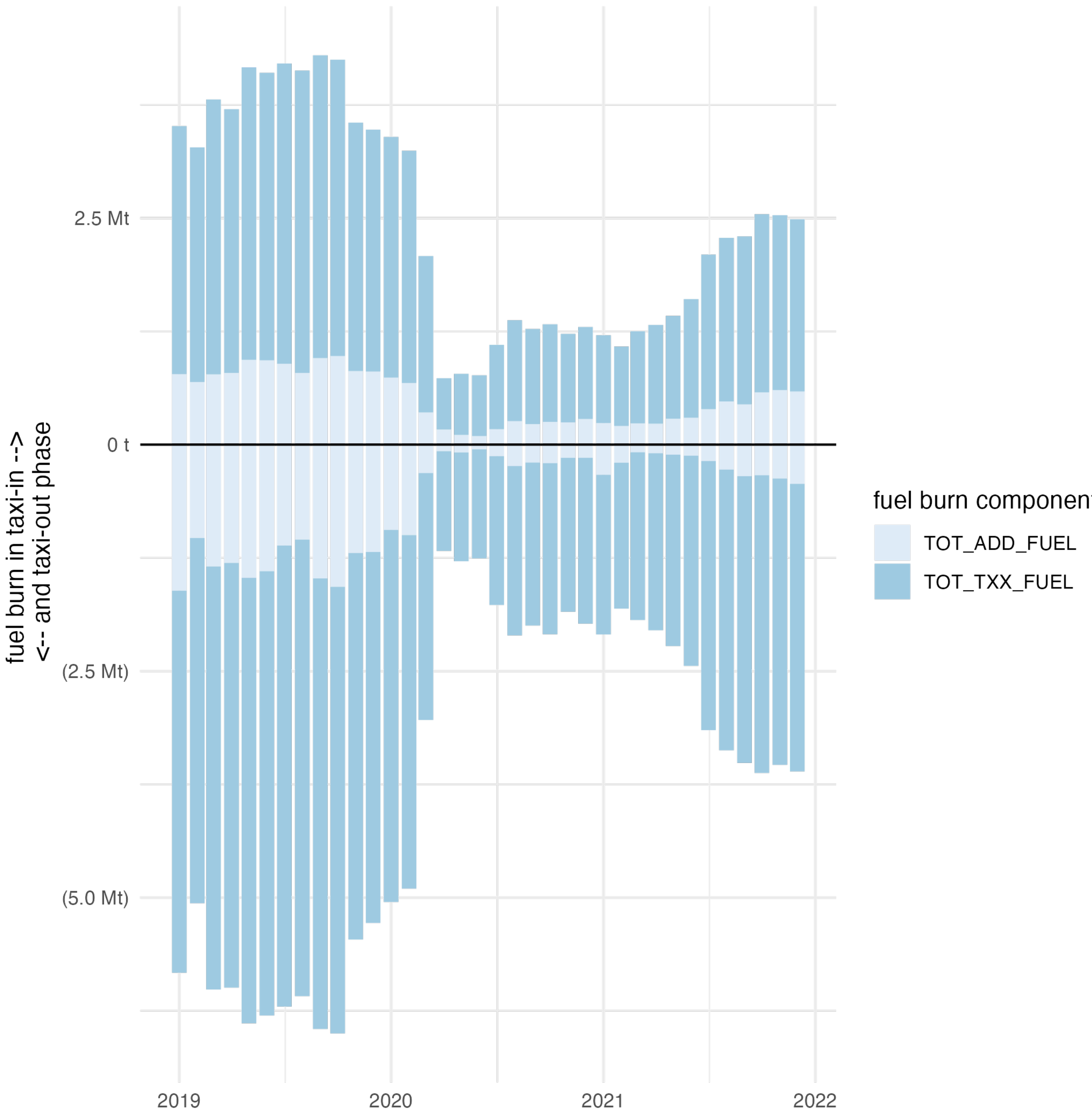

Figure 4.1: Example fuel burn estimation at a European hub airport

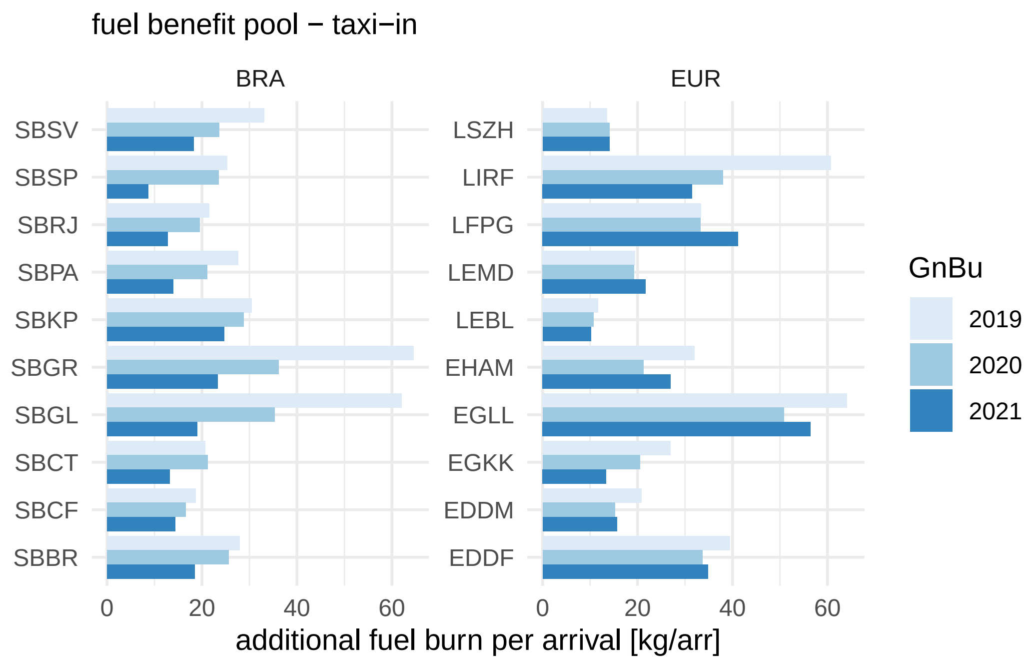

Figure 4.2: Benefit pool in terms of additional fuel burn during taxi-in phase

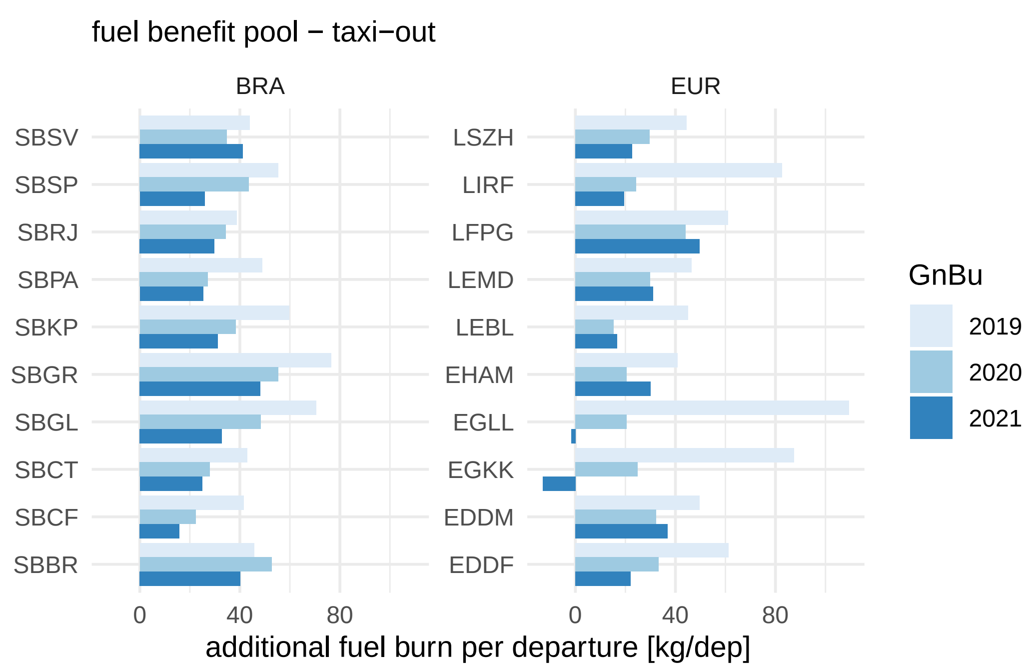

Figure 4.3: Benefit pool in terms of additional fuel burn during taxi-out

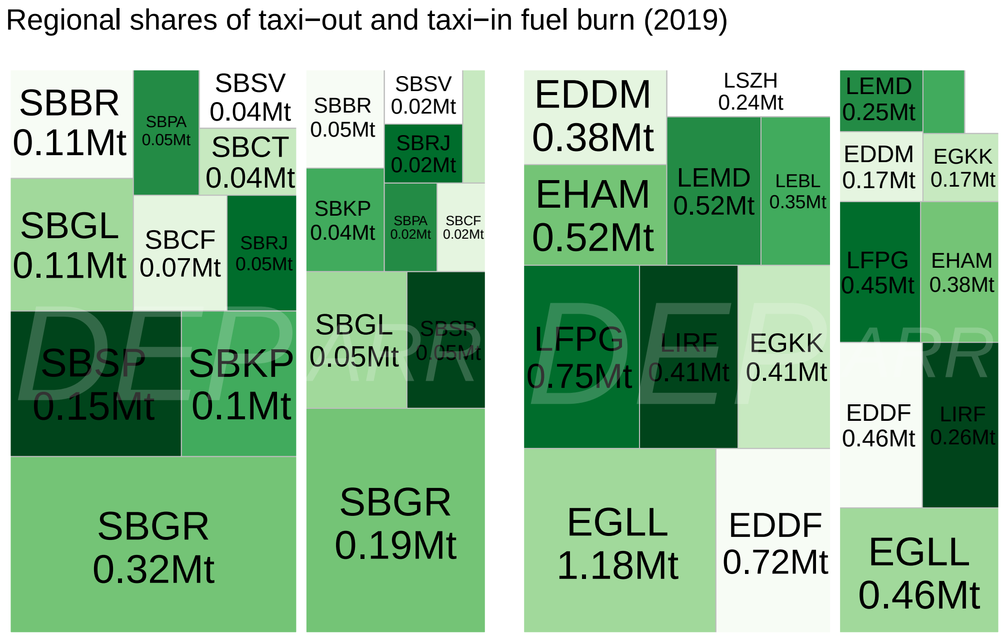

Figure 4.4: Regional shares of additional fuel burn during ground movement phase

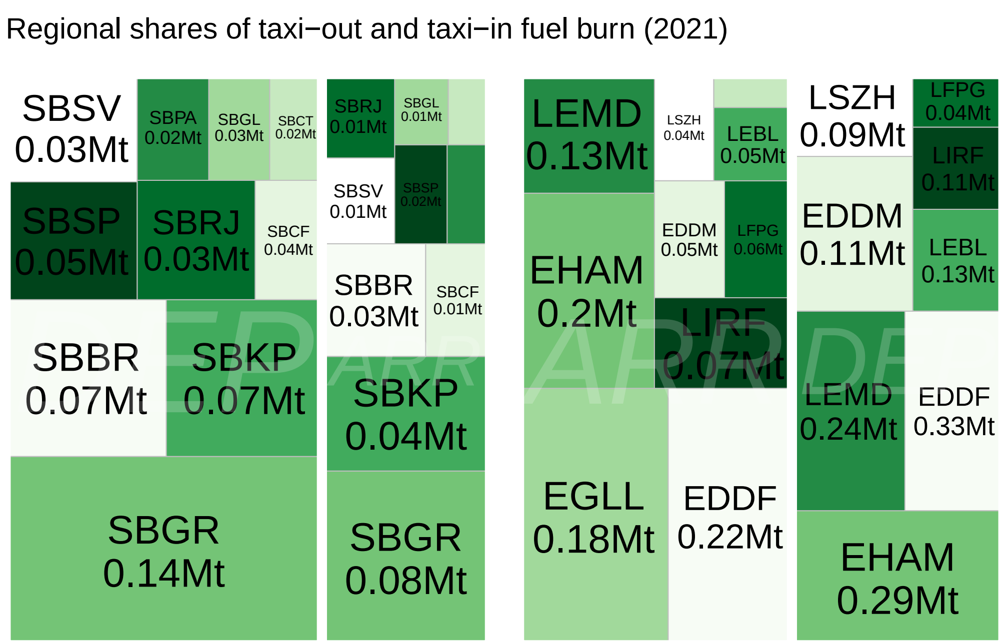

Figure 4.5: Regional shares of additional fuel burn during ground movement phase

5 Conclusions

This second iteration of the Brazil-Europe operational ANS performance comparison report builds on the joint project between the DECEA Performance Section and the Performance Review Unit of EUROCONTROL.

The collaboration project aims at the development of a joint and common understanding of agreed metrics and definitions to compare, understand, and improve operational air navigation system performance. This report uses a subset of the key performance indicators established by ICAO's GANP. The work is also used as a show-case for applying the GANP indicators within a bi-regional project, to augment the associated guidance material, and inform further multi-regional comparison efforts. The comparison shows similarities and differences in the observed performance in both regions. Throughout the report several observations and ideas for future research have been identified. This will allow to further develop and complement the performance framework.

The first part of this report examined commonalities and differences in terms of air traffic management organisation and performance influencing factors, such as air traffic demand and fleet composition. These factors can have a large influence on the observed performance. Overall, air navigation service provision is more fragmented in Europe with local/national ANSPs and their respective control units. The integrated civil/military service provision is inherent to the organisation of DECEA and the Brazilian system. Irrespective of the airspace volume, the large difference in numbers of control units in Europe and Brazil demonstrates this. Both systems operate a central flow management center to ensure network wide flow management processes and functions.

Both regions encountered an unprecedented decline of air traffic in response to COVID-19. Regional and global traffic restrictions resulted however in different patterns regarding the initial and continued recovery. European traffic levels showed several waves in light of the variety of national and pan-European measures. The Brazilian evolution of traffic showed a delayed wave pattern in comparison with Europe, however, showed a more steady recovery overall.
Additional diversity in terms of air traffic was observed across the Brazilian airports as there was a significant share of light types serviced. Within the European context, the share of light types was mostly negligible. A higher share of wide-body (heavy) aircraft operated from the European airports including a higher level of international connectivity. This is more nuanced in Brazil where the level of international connections is more centralised.

In terms of predictability and puncutality, the results were strongly influenced by the prevailing COVID-19 traffic evolution. Both systems suffered from the disruption of schedules and cancellations of flight connections. Europe showed a higher number of aircraft arriving more than 15 minutes ahead of schedule (early arrivals) and flights departing later than 15 minutes after their scheduled time). In Brazil, this behaviour was only observed for arriving traffic. Returning traffic levels drove a gradual move towards punctuality levels comparable to 2019 levels. However, there is a higher level of uncertainty in terms of movements in both regions.

Runway system capacities in Brazil were adapted over the past years to accommodate the projected growth. Respective capacities at European airports were constant over the horizon of this report as part of the local/national declaration process and operated traffic levels. Despite the COVID-related change in traffic, accomplished peak throughput levels ranged at the level of earlier years. This suggests that airport runway system capacities are commensurate with the observed (and expected) traffic levels and represent not a primary driver for operational inefficiencies during the arrival phase.

Operational efficiency in this report is measured for the taxi-in and taxi-out phase, and additional time in terminal airspace. Similar patterns were observed at the different airports in both regions. On average, arriving traffic was observing little additional taxi-in times in both regions. However, the variation across airports suggests that local specifics (traffic levels, used combinations of runway system / parking positions) contributed the varying taxi-in performance. It will be interesting to study the associated drivers in the future. The levels of additional taxi-out times is generally higher for departing flights in comparison to arrivals. The additional taxi-out times for the study airports showed a clear association with the traffic levels during and post COVID-19 in Brazil. This behaviour is less prominent for the European airports and may be linked to the partail use of runway system, terminals, and parking positions. In general surface movement operations see a higher variation in Brazil than in Europe. Although trends might be masked and impacted by the available data for this comparison for Brazil, the sequencing of arrival flights appeared to be independent of the traffic volume. The increase in additional times in 2021 appeared to be linked to a change in terms of en-route / terminal airspace interface. For the European context, the overall reduction in air traffic resulted in lower pressure on the sequencing of arrivals. On average, arriving traffic at all airports observed a lower additional times. Flight time variability was obviously affected by the varying traffic levels. However, the Brazilian system is less impacted by seasonal variation than the European system.

Political priorities require to address the impact of air transportation on climate change. There is a growing interest in both regions to better quantify the potential benefit pool actionable by air navigation. This report develped a first approach to better quantify inefficiencies observed in the taxi-in and taxi-out phase. Higher operational performance will ultimately lead to higher levels of fuel efficiency and lower fuel burn. Absolute numbers in terms of fuel burn / CO_2 emissions are linked to the volume of air traffic and aircraft types in service. The latter impacts a direct comparison and require more research for future editions. This comparison shows the potential benefit pool at the different airports. This pool provides a higher margin of improvement at airports with higher levels of air traffic and large (heavy) aircraft. As such, the role of the airport within the system - heavy aircraft & international connectivity - is a fundamental aspect in terms of addressing the contribution of air navigation.

This second edition of the operational comparison between Brazil and Europe allowed to further harmonise the application of GANP performance measures and identified areas for further research and joint developments. Both groups, Performance Section of DECEA and Performance Review Unit of EUROCONTROL, plan to continue the close collaboration and expand on the analyses of this report. This report will be updated throughout the coming years under the umbrella of the DECEA-EUROCONTROL memorandum of cooperation. Building on this collaboration, the idea is to establish a web-based rolling monitoring complementing this and future editions. A web-based monitoring will enable updates on a regular basis. Future editions will also enable to complement data time series and support the development of further use-case analyses. The lessons learnt of this joint project will also be coordinated with the multi-national PBWG and ICAO GANP Study sub-group concerned with the further development of the GANP KPIs.

A Fuel Burn Methodology

A.1 Fuel Flow Estimation - Look-Up Table Approach

At the time of writing no consolidated fuel burn methodology for operational performance benchmarking existed. The guidance material for the application of the GANP KPI16 suggests to apply **average fuel burn estimates**. To advance the state-of-the-art, PS and PRU established a look-up table on the basis of openly available mappings of aircraft type and (representative) engine.

With the ICAO Aircraft Engine Emissions Databank certification data for registered engines allowed for the identification of associated fuel flow indices for specific thrust levels per engine during the landing and take-off cycle (LTO). Further engine specific consumption data - primarily piston engines - were obtained from the database of the Federal Office for Civil Aviation of Switzerland. This dataset will be made available and further augmented with the help of the international benchmarking community. While the approach supported a good coverage of current aircraft types (about 90%), there was a need to make fuel burn assumptions for the remaining fleet.

Earlier work, c.f. EUROCONTROL Performance Review Unit and FAA Air Traffic Organization (2019), defined a benefit pool on the basis of a generic **"average flight"** (i.e. A320, 450NM leg). These values were taken as defaults for aircraft types not yet accounted for in the established data set.

For the estimation of the fuel burn in the en-route portion (climb-cruise-descent := CCD) it is proposed to apply an heuristic approach in future reports. This however requires for research and validation. The principles are laid out as follows:

- ICAO's Carbon Emission Calculator Methodology supports the identification of **average fuel burn** on a per aerodrome pair.
- The calculator methodology estimates the fuel burn on the basis of pre-dominantly flown aircraft types, i.e. it can be assumed to be a fleet mix representative sample estimate.
- This estimate can be scaled for each arrival and compared to the additional time in terminal airspace.

An improvement to these estimates, i.e. estimating the fuel burn during surface operations and during the arrival phase, will be subject to further research.

A.2 Assumptions for Estimation of Taxi-in and Taxi-Out Fuel Burn

For this report, the operational LTO Cycle is defined as follows:

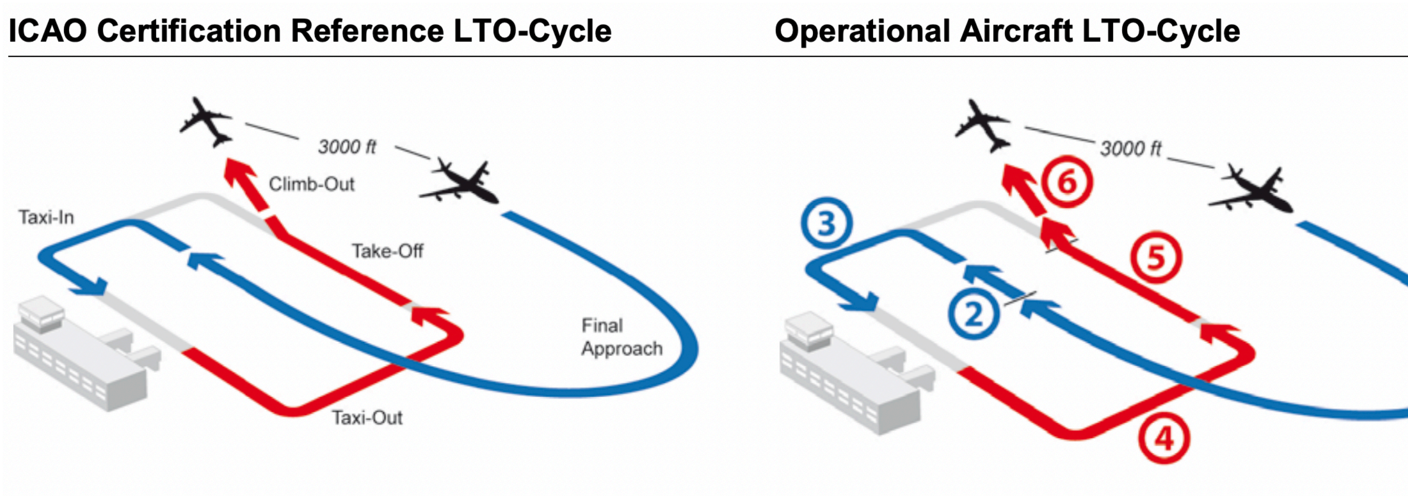

Figure A.1: Operational LTO cycle based on Fleuti, Maraini, and Janicke (2012).

#	Phase	Comment
1	approach	3000ft GND to actual landing
2	landing roll	touchdown to end rollout
3	taxi-in	taxi from end rollout/runway to stand
4	taxi-out	taxi from stand to runway/line-up position
5	take-off roll & initial climb	take-off roll to lift-off, including initial climb to 'throttle back'
6	climb-out	climb-out to 3000ft GND'

Taxi-in is defined as the difference between the actual landing time (ALDT) and the actual in-block time (AIBT), i.e. $TXIT = AIBT - ALDT$.

Conversely, taxi-out is defined as $TXOT = ATOT - AOBT$.

Based on the LTO assumptions, TXIT comprises phases 2 and 3. For TXOT, phases 4 and 5 apply until the actual take-off/lift-off - strictly speaking without the initial climb to 'throttle back'.

By convention, the standard ICAO LTO cycle assumes a specific *"time-in-mode" (TIM)* for each phase. Research has shown that the TIMs are not representative for many airports and operations. This report, thus, replaces the TIMs with the observed ground movement times, i.e. ALDT, AIBT, AOBT, ATOT.

The standard LTO cycle uses 0.7 min (42 sec) for the take-off roll and lift-off. From an operational perspective, this value is realistic for large (and heavy) aircraft or reduced thrust take-off (resulting in lower acceleration and longer take-off roll).
No provisions are made for decelaration during the landing roll (e.g. reverse thrust).

Per definition, the taxi-in and taxi-out indicator includes the landing roll or take-off roll. This report applies the following assumptions:

- taxi-in:

  - inefficiencies during the taxi-in phase are primarily encountered following the landing roll;
  - the landing roll is a systemic duration and can be broadly assumed to be constant per aircraft type, variations in terms of landing roll (shorter & longer durations) are equally distributed; and
  - measured additional taxi-in times are therefore encountered after vacating the runway and during taxi to the stand/gate.

- taxi-out:
  - inefficiencies during the taxiout phase are primarily encountered during taxi from the stand/gate to the holding point at the runway;
  - line-up and take-off roll are a systemic duration and do not vary significantly per aircraft type, thus, can be considered equally distributed; and
  - measured additional taxi-in times represent therefore the inefficiency during taxi-out.

While the additional time approach and assumptions eliminate the need to consider the landing-roll or take-off roll for the calculation of the additional fuel burn during these modes, the absolute fuel burn needs to considers the associated time-in-mode.

- For the landing, ICAO LTO assumes a 7% idle thrust and taxi setting.
  Thus, the overall measured taxi-in time, i.e. $TXIT = AIBT - ALDT$ is performed under the continuous 7% thrust setting.
- For take-off operations, the take-off roll / lift-off is performed under 100% thrust setting.
  Accordingly, the take-off roll duration needs to be deducted from the total observed taxi-out time.
  Total taxi-out fuel is then calculated based on the reduced taxi-out phase at 7% thrust setting and the take-off roll at 100% thrust setting.

To account for missing data regarding aircraft types and/or respective reference engines, an estimate for the fuel burn for “similar” flights is calculated on the basis of complete data records. This similarity is based on aircraft wake turbulence category and engine type (e.g. light jet, medium jet, heavy/medium/light turboprop). This ensures that nuances of the fleet mix are captured and reduces the further overestimation by using general averages, etc.

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