PRB | Performance review body of the single european sky

The interdependency between the environment and capacity KPIs of the performance and charging scheme of the Single European Sky

June 2023

Performance Review Body of the Single European Sky | Rue de la Fusée 96, Office 50.659, 1130 Brussels
Office Telephone: +32 (0)2 234 7824 | cathy.mannion@prb.eusinglesky.eu | prb-office@prb.eusinglesky.eu | wikis.ec.europa.eu/display/eusinglesky

EXECUTIVE SUMMARY

There are few studies that investigate the relationship between environment and capacity within air traffic management, despite consensus that such an interdependency exists and influences the decision-making process of stakeholders.

This report quantifies the interdependency between the environmental and capacity key performance areas and analyses the factors influencing this interdependency. It focuses on the current KPIs defined in Commission Implementing Regulation (EU) 2019/317 and does not address factors outside its scope, such as CO_2 emissions or fuel burn.

The analysis conducted in this study demonstrates that high ATFM delays from various contributing factors have a negative impact on horizontal flight efficiency (HFE), proving the existence of an interdependency between the environment and capacity KPIs of the performance and charging scheme. However, the level of impact on HFE is found to be related to both the cause of the delay and its location.

Statistical models were developed to investigate the influence of different delay variables on HFE. This exercise revealed that an increase of one minute of average en route ATFM delay per flight causes an increase of 0.14 percentage points to HFE. Furthermore, the models showed that the theoretical average Union-wide HFE is estimated to be approximately 2.6% (within the sample of years analysed). This indicates that factors other than delay, such as inefficient route networks, airspace restrictions, and airspace user preferences, contribute significantly to HFE.

The analysis also depicted how differing delay causes have a varying impact on HFE depending on the season. The below table summarises the impact that a minute of delay per flight for each delay reason has on HFE for both the summer and winter seasons:

	Non-ATC capacity	Events	Weather	ATC disruption	ATC staffing	ATC capacity	Non-ATC disruption
Summer HFE impact	1.23 pp	0.45 pp	0.14 pp	0.12 pp	Negligible	Negligible	Negligible
Winter HFE impact	2.9 pp	0.49 pp	0.34 pp	0.18 pp	0.28 pp	0.19 pp	Negligible

Results of the modelling highlighted how delay occurrences in different Member States influence overall HFE performance with delays in Germany, Italy, and the Netherlands having the most significant impact on Union-wide HFE. At a local level, HFE was found to be influenced to varying degrees by delays in other Member States. Those most impacted by delays in other Member States include Estonia, Lithuania, and Latvia, while the least impacted include Ireland, Portugal, and Cyprus.

More generally, local HFE for Member States was found to be sensitive to en route ATFM delays in a relatively small number of other States, namely Germany, France, Cyprus, and Poland. These delays significantly affect the HFE performance of other States.

While these results are unique in their kind, they represent a first step in assessing the complex subject. The PRB recognises the need for further research to deepen understanding of the interdependency between capacity and environment in air traffic management, notably by incorporating additional datasets to provide wider perspectives on environmental performance and extending this work to include the influence of the cost of service provision.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Context

1 In recent years, public and political scrutiny of the aviation sector has increased, intensifying the debate on the environmental impact of aviation. With the European Commission's Green Deal of 2019, which sets out the new growth strategy for the European Union (EU) and the "Fitfor55 Package" proposal, all sectors in the European economy are expected to take steps towards climate neutrality by 2050.[1]

2 For the transport sector, including the aviation industry, the strategy is developed in the EU's Smart and Sustainable Mobility Strategy (SSMS), which includes improving the efficiency of the air navigation services in Europe. The European Commission expects that Air Traffic Management (ATM) improvements could reduce air transport CO_2 emissions by up to 10%, in turn helping to address the non-CO_2 impacts of the sector caused by flight inefficiencies and airspace fragmentation.[2]

3 The performance and charging scheme of the Single European Sky (SES) defines four key performance areas; each with a target that Member States are required to reach based on their performance plans.

4 During the COVID-19 pandemic, air traffic decreased significantly. In the SES area, in 2020, IFR (instrument flight rules) movements were 42% less than the STATFOR base forecast for 2020.[3] As a result, ANSPs were able to handle traffic without incurring major delays. During this year of low traffic and low delay levels, environmental performance improved. However, some Member States have struggled to meet the local environmental targets as traffic subsequently increased.

5 This pattern of poorer performance with increasing traffic suggests an interdependency between traffic levels and environmental performance, which should be taken into account when defining the targets for the key performance areas (KPAs). Whilst the interdependency between these KPAs is accepted within the air traffic management community, the precise relationship is not fully understood and has not been quantified.

1.2 Objectives

6 The objective of this report is to quantify the interdependency between the environment and capacity key performance areas (KPAs) and to better understand the key factors that define the interdependency using the current key performance indicators (KPIs) as defined in Commission Implementing Regulation (EU) 2019/317 (hereafter the Regulation).[4]

7 This report will not address interdependencies between environmental factors outside the scope of the Regulation, such as balancing CO_2 against non-CO_2 emissions, fuel burn, contrails, or noise. The study also recognises that the interdependency between environment and capacity will influence decisions taken by airspace users and ANSPs. A key factor for airspace users is cost (including route charges, connectivity, cost of delay versus cost of additional fuel burn, weather, and ANSPs' staff costs), which does not form part of the study, except where necessary to understand and explain decisions taken by stakeholders.

8 A detailed analysis into the interdependency between the capacity and environment KPIs has not previously been undertaken. This report assesses and quantifies the interdependency. The PRB recognises that it is a first step in a highly complex subject and that future work will be required to deepen the understanding of the interdependency.

9 Any future studies should incorporate additional datasets to provide wider perspectives on environmental performance and to extend this work to include the interdependencies between environment, capacity, and cost-efficiency.

---

[1] A European Green Deal, European Commission and European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions.

[2] Mobility Strategy (europa.eu).

[3] PRB Monitoring Report 2020 (October 2021).

[4] The KPIs of the Regulation are horizontal en route flight efficiency of the actual trajectory for the environment KPA, and en route ATFM delays for the capacity KPA.

1.3 Report structure

10 This report consists of the following sections:

- Section 1: Introduces the context and objectives (current section).
- Section 2: Provides a review of previous studies assessing this interdependency (literature review).
- Section 3: Presents the results of qualitative analysis to investigate the existence of an interdependency between the environment and capacity KPAs.
- Section 4: Summarises the outcome of the modelling to quantify the interdependency.
- Section5: Presents the conclusions of this report.

11 This report is accompanied by an Annex detailing:

- The literature review of previous work undertaken on such interdependencies.
- Assumptions and models used to investigate and demonstrate the interdependency between the KPAs.
- Flight trajectory case studies, which demonstrate the interdependency between the environment and capacity KPAs using specific local examples.

2 LITERATURE REVIEW

2.1 Sources consulted

12 There are few studies that investigate the relationship between environment and capacity, despite there being wide consensus that such an interdependency exists and influences the decision-making process of stakeholders. The materials identified and consulted for this study are:

- Manual on global performance of the air navigation system (ICAO);[5]
- ATM global environment efficiency goals for 2050 (CANSO);[6]
- Environmental assessment: European ATM network fuel inefficiency study (Eurocontrol);[7]
- Impact assessment of the enhanced NM/ANSPs Network Measures for Summer 2019 (Network Manager);[8]
- Interdependencies within ATM performance in the context of a dynamic environment (Workshop BLUE MED FAB, and FABEC);[9] and
- Climate change and the role of air traffic control (Workshop Baltic FAB, FABEC, GARS, Vilnius TU).[10]

13 An analysis of the literature review is included in the Annex.

2.2 Summary of findings of the literature review

14 Six studies were reviewed with differing scope and purposes. Their findings related to the interdependency can be summarised as follows:

- Some of the studies confirmed the interdependency between the capacity and environment KPAs.
- None of the studies directly quantified the impact of a lack of capacity on horizontal flight efficiency performance as measured by the performance and charging scheme to a granular level.

15 Some studies indirectly quantified factors relating to the interdependency:

- Eurocontrol’s environmental assessment report estimated the fuel inefficiency (measured through excess fuel burn) of the ATM network between take-off and landing to be between 8.6% and 11.2%.
- CANSO estimated that interdependencies relate to half of the total inefficiencies in the system.
- The Network Manager (NM) calculated the effect of optimising traffic flows during the summer period in 2019 leading to an average delay reduction of 1.72 minutes/flight with approximately 1.1 million additional nautical miles flown.

16 The literature review also shows that regulation and policy should support the balancing and prioritisation of interdependent KPAs, supported by accurate operational forecasts to account for interdependencies.

17 The PRB has not identified any studies that have quantified the direct relationship between a lack of capacity and HFE nor any existing models which could be applied to the subject at hand.

---

[5] Manual on global performance of the air navigation system, ICAO (Doc 9883).

[6] ATM global environment efficiency goals for 2050, CANSO (2008).

[7] Environmental assessment: European ATM network fuel inefficiency study, Eurocontrol (2020).

[8] Update on the NM action plan following NMB performance task force: ENM/s2019 measures and updated impact assessment of the Eurocontrol/NM action plan, Network Manager (NMB/19/24/7).

[9] Interdependencies within ATM Performance in the Context of a Dynamic Environment, Research workshop (2020).

[10] Climate change and the role of air traffic control, Research Workshop (2021).

3 ANALYSIS OF THE INTERDEPENDENCY THROUGH INFLUENCING FACTORS

18 This section shows the existence of an interdependency between environment and capacity by analysing the historic relationship between HFE and ATFM delays by reason or influencing factor. The analysis is performed at Union-wide level, with some examples for individual Member States.[11]

19 The factors influencing performance that were assessed include those that tend to affect flight trajectories, notably delays relating to weather, ATC capacity and staffing issues and ATC industrial action.

20 The analysis is based on a sample of days between the start of 2018 and end of 2022. Each bubble on the following graphs represents a specific day, where delays occurring due to the relevant influencing factor (weather, ATC staffing and capacity, ATC strikes) represented over 50% of total en route ATFM delay on that given day.

21 All the graphs show that the year 2022 is an outlier in terms of Union-wide HFE performance relative to traffic levels. This is because of the closure of Ukrainian, Belarussian, and Russian airspace to European carriers. These events have led to a shift in traffic flows throughout the SES, resulting in inefficiencies measured by HFE.

3.1 Weather

22 Weather phenomena (including intensity and frequency) impact flight trajectories and capacity due to the potential rerouting around them.[12]

23 ATFM regulations relating to storms impact airspace capacity and flight efficiency. They lead to route restrictions and airspace users circumnavigating these areas. Due to the high density and high complexity of multiple areas, a major weather event located near a capacity-constrained sector may trigger rerouting for a significant number of flights and potentially result in knock-on performance impacts across the network. Horizontal flight efficiency can also be affected where airspace users plan routes to benefit from wind and jet streams (that are not necessarily the shortest routes) allowing faster, more fuel-efficient trajectories.

24 Figure 1 shows the relationship between weather-induced delays, HFE, and traffic levels (IFR movements), whereby higher traffic tends to be associated with poorer performance of HFE and delays in the years 2018 to 2022.[13] This is demonstrated in the figure with the larger bubbles (higher weather-related delay) in the top right of the data set (higher levels of flight inefficiency occurring with higher levels of both traffic and weather-related delay).[14] The phenomenon can be explained by re-routing being more pronounced when sectors lack capacity to accommodate the re-routed aircraft.

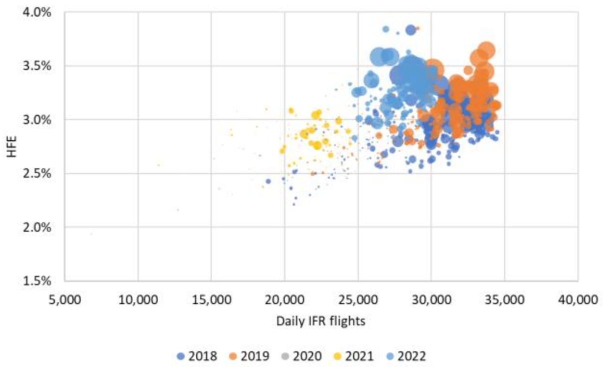

Figure 1 – Relationship between weather delays, traffic levels, and HFE at Union-wide level (Source: PRB elaboration). Bubble size indicates extent of weather-related delay in minutes, whereby the largest bubble represents 174,533 minutes).

3.2 ATC capacity and staffing

25 Both ATC capacity and ATC staffing are factors that ANSPs can influence. ATC capacity delays occur during periods of high traffic demand, when one or more ATC sectors in a Member State are projected to exceed capacity limits (unable to

---

[11] As the environment KPI (KEA) is defined as an annual average, with exclusion of the ten highest daily values and the ten lowest daily values from the calculation, daily and monthly values are referred to as Horizontal Flight Efficiency (HFE).

[12] The most important weather phenomena for aviation operations: Wind, turbulence, and precipitation (rain, snow). In general, turboprops are more sensitive to weather impacts than jets. If weather phenomena occur within 40NM from the origin/destination, their impact is not fully visible on KEA due to KEA calculation algorithm.

[13] Note: As horizontal lights efficiency is measured in (unnecessary) route extension, a higher HFE indicates poorer performance.

[14] The PRB Annual Monitoring Report 2022 will provide a more detailed description.

meet demand) leading the ANSP concerned to declare ATFM regulations to limit future traffic flow in the regulated sectors. ATC staffing delays are caused when (despite pre-tactical planning) there are fewer ATCOs on duty than required to open the planned number of ATC sectors. In both cases, airspace users wishing to operate in the impacted sectors must either wait on the ground for their designated slot or route around the constraint. Re-routing can impact HFE through an additional distance flown (Figure 2 and Figure 3).

26 These figures also show how the yearly number of flights in the SES influences performance. The years 2018 and 2019 (orange and blue in the figures) were more sensitive (in terms of delay and HFE variation) than 2021, as more flights were operating in those years within the SES airspace. With increasing number of flights, the number of optimised trajectories available to airspace users decreases as a result of maximum sector throughput being reached.

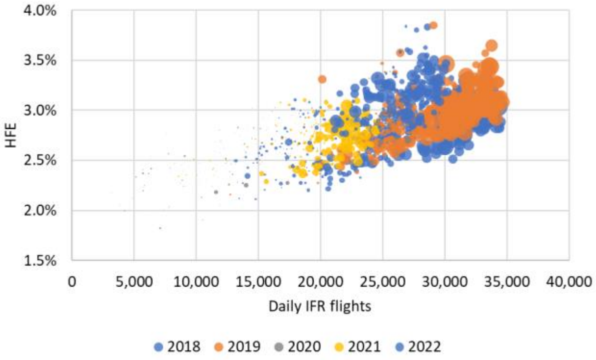

Figure 2 – Relationship between ATC staffing delays traffic levels and HFE at Union-wide level (Source: PRB elaboration). Bubble size indicates extent of ATC staffing-related delay in minutes, whereby the largest bubble represents 72,966 minutes.

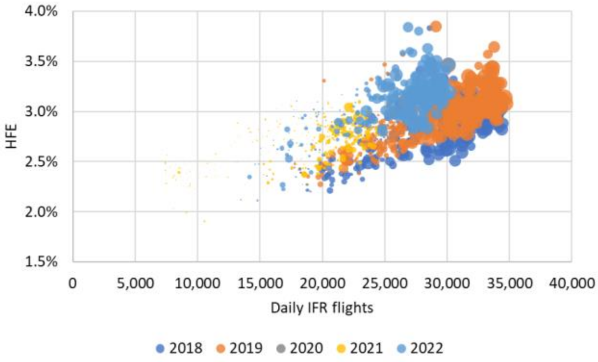

Figure 3 – Relationship between ATC capacity delays, traffic levels and HFE at Union-wide level (Source: PRB elaboration). Bubble size indicates extent of ATC capacity-related delay in minutes, whereby the largest bubble represents 87,202 minutes.

3.3 ATC strikes

27 ATC strikes can cause major disruptions across Europe, namely cancellations, delays, and deviations from the ideal trajectory, because:

- The airspace is closed, leading airspace users to avoid the airspace; or
- The airspace is open at reduced capacity leading to both increased delays and rerouting around the affected area; or
- The Network Manager reroutes the flows to mitigate the delays.

28 Airspace users tend to avoid airspace (either voluntarily or under Network Manager rerouting) where strikes take place, resulting in deviations from ideal entry and exit points to individual airspace, and higher (inefficient) HFE. Although the limited number of ATC strikes per year, they have the potential to cause a major deterioration of HFE and capacity on the days of strikes. At Union-wide level, ATC strikes can cause delays up to eight minutes per flight and HFE up to 4% measured across all flights on the given strike day (Figure 4, next page).

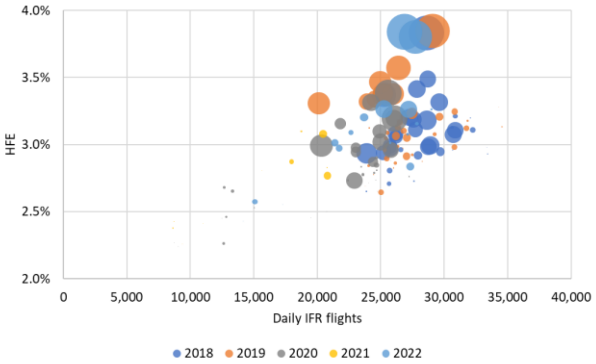

Figure 4 – Relationship between ATC strikes, traffic levels and HFE at Union-wide level (Source: PRB elaboration). Bubble size indicates extent of ATC strike-related delay in minutes, whereby the largest bubble represents 210,309 minutes.

3.4 Key findings

29 The above analysis demonstrates that high levels of ATFM delays from various contributing factors have a negative impact on HFE.

30 For some of these contributing factors (weather, ATC capacity, ATC staffing delay causes), higher traffic at Union-wide level leads to further delays and inefficiency. This shows that an interdependency exists between the environment and capacity KPIs of the performance and charging scheme. The following section seeks to quantify this interdependency.

4 QUANTIFICATION OF THE INTERDEPENDENCY THROUGH STATISTICAL ANALYSIS

31 The interdependency between ATFM delay and HFE has been analysed using statistical models to understand the influence of different variables on HFE. All the models examined the relationship between HFE and average en route ATFM delays per flight. The models analysed daily data between 2017 and 2021.[15]

32 The focus of the analyses is on Union-wide daily HFE: The different models examine how these varied, and if/how en route ATFM delays (and their different components) explained these variations.

33 Based on the outcome of Section 3, three research objectives were formulated and tested:

- To quantify the interdependency between Union-wide HFE and en route ATFM delays;
- To quantify if/how en route ATFM delays due to different causes have different impacts on HFE and how seasonal changes affect the interdependency; and
- To estimate if/how en route ATFM delays occurring at different locations of the European ATM network have different impacts on Union-wide HFE.

34 The results of the statistical analyses are summarised in the following sub-sections.[16] The detailed technical description of the models is included in the Annex. The Annex also illustrates the output of the following analyses through case studies of selected flight trajectories.

4.1 Interdependency between HFE and ATFM delays

35 The results show that the interdependency between Union-wide HFE and en route ATFM delays exists and can be quantified. As delays increase, HFE deteriorates: An increase of one minute of average en route ATFM delay per flight causes an increase of 0.14 percentage points to HFE. Moreover, the results show that, theoretically, on days when there are no en route ATFM delays, Union-wide HFE is estimated to be on average 2.59%. In comparison, the average yearly HFE over the period calculated from the actual data was 2.71%.

4.2 The relationship between HFE and specific delay causes

36 En route ATFM delays are generated by ATFM regulations, which limit how many aircraft can fly through a given block of airspace in a defined period of time. The reasons behind the ATFM regulation may determine how long the delays occur, what volume of the airspace is affected and to what extent airspace capacity is reduced. It is assumed that these reasons for ATFM regulations affect the relationship between delays and flight efficiency to differing extents. In order to explore these differences, the analysis considered en route ATFM delays per delay cause group (namely ATC capacity, ATC staffing, ATC disruptions, weather, special events, non-ATC capacity, and non-ATC disruptions).

37 Furthermore, air traffic in the SES area has seasonal trends: Traffic levels, major flows, and traffic complexity are all significantly different during the peak summer period and during winter.

38 To understand and quantify the relationship between HFE and en route ATFM delays per cause, the analyses aim to explain variations in the daily Union-wide HFE with daily average en route ATFM delays per flight for each delay reason group.[17]

39 Using delay reason groups instead of individual delay codes simplifies the analysis, but still identifies delays largely within the control of ANSPs (ATC capacity, ATC staffing, and ATC disruptions). Delay groups represent delays similar in their operational characteristics.

40 The delay reason groups are from the datasets published by the Aviation Intelligence Unit of Eurocontrol and are shown in Table 1 (next page).[18]

---

[15] The data used in the analysis was sourced from the datasets provided by the Aviation Intelligence Unit of Eurocontrol, and the calculation of the different metrics was also performed applying the methodology of Eurocontrol.

[16] The domain of applicability of the results is limited to the geographical scope and time period of the analysis. While the findings are statistically significant and robust, careful consideration is required before generalising the results.

[17] While there is no specific delay code for delays related to military operations, these delays are captured in the figures under delay codes “M”, “O”, and “P”, depending on the nature, scale, and duration of the military operation in question.

[18] https://ansperformance.eu/definition/atfm-delay-codes/.

Disruption	Code	Description
ATC Capacity	C	Indicates that the capacity provided by the ANSP is generally lower than the demand.
ATC Staffing	S	Indicates that the ANSP cannot provide sufficient capacity due to staffing issues (e.g. controllers being on sick leave, shortage of working hours, etc.).
ATC Disruptions	I & T	Indicates that the ANSP cannot provide sufficient capacity due to industrial action or failure of technical equipment.
Weather	W & D	Indicates that the capacity of the ANSP is reduced due to adverse weather in general or due to de-icing.
Events	P	Indicates that delays are occurring due to large-scale special events (e.g.: major sports events, system transitions, large-scale military exercises, etc.).
Non-ATC Capacity	G, M, R & V	Indicates that delays are occurring due to reduced/insufficient aerodrome capacity, airspace management reasons, routing, or environmental issues.
Non-ATC Disruption	A, E, N, O & NA	Indicates that delays are occurring due to accidents/incidents, non-ATC equipment failure, non-ATC industrial action, other delay reasons or delays without specific reasons.[19]

Table 1 – Delay reason groups (Source: Aviation Intelligence Unit, Eurocontrol).

41 Performance monitoring of previous years indicates that seasonality influences en route ATFM delays. Based on this finding, the analysis examines if the relationship between flight efficiency and delays is also subject to seasonality.[20] Summer and winter seasons are defined on the basis of general traffic patterns of the past years. The summer period lasts from May to September, and the winter period from October to April.

42 The results of the analysis show that delays due to ATC capacity have a negligible impact on Union-wide HFE in the winter.[21] In the summer, a minute of delay per flight in this group adds 0.2 percentage points to HFE. This seasonality can be explained by the higher traffic levels which occur during the summer, meaning capacity is under more strain and such delays are more persistent, hence making rerouting a preferable option (rather than waiting on the ground) for airspace users.

43 ATC staffing delays do not have a significant impact on Union-wide HFE in the summer period. In the winter, a minute of ATC staffing delay per flight adds 0.28 percentage points to HFE. This may be explained by the seasonal trends in sick leave (being more common, for example for influenza, in the winter months).[22]

44 The impact of ATC disruption related delays had a similar level of impact on HFE in both summer and winter (each minute of average delay per flight adding 0.12 percentage points to HFE in the summer and 0.18 percentage points in the winter). This is because there is no clear seasonal tendency for the occurrence of such delays, which tend to be relatively localised (equipment failures) and/or planned (industrial action).

45 Weather-related delays have a stronger impact on Union-wide HFE during the winter, with each minute of average delay per flight adding 0.34 percentage points to HFE. However, there is also an (lesser) impact in the summer, when with each minute of average delay per flight added 0.14 percentage points to HFE. This can be explained by the differing types of weather events occurring in summer and winter. In summer, these tend to be related to convective conditions and storms which require airspace users to route around the affected area.

46 Event-induced delays have the second most important impact on HFE, with almost equal effects

---

[19] A detailed definition of the codes used to denote ATFM regulations can be found in the Network Manager ATFCM Operations Manual.

[20] https://wikis.ec.europa.eu/display/eusinglesky/Public+Library.

[21] Summer and winter in the following paragraphs refer to the periods defined in paragraph 41.

[22] https://flunewseurope.org/.

noted in both seasons (each minute of average delay per flight adding 0.45 percentage points to HFE in summer and 0.49 in winter). This lack of seasonality occurs because events are usually planned in advance, meaning routes and schedules can be adapted accordingly.

47 Delays due to non-ATC capacity issues have the highest impact on HFE, which may also be because this category is a collection of different reasons. This is most significant in the winter when each minute of average delay per flight adds 2.9 percentage points to HFE. The impact remains strong in the summer, although less so, with each minute of average delay per flight adding 1.23 percentage points to HFE.

48 On the other hand, ATC capacity has a higher impact in the summer, which can be explained by the increased traffic and congestion occurring during these months, straining network capacity and slot flexibility. As a result, airspace users will often prefer to take a longer (potentially less efficient) route.

49 Finally, delays relating to disruptions not related to ATC (non-ATC disruption) did not have a significant impact on Union-wide HFE in the summer or in the winter.

50 The reasons for the varying scales of delay impact on HFE can mostly be explained by the operational reactions of airspace users to different delays. When delays occur due to a larger-scale disruption such as issues with non-ATC capacity, events and weather phenomena, either a part of the affected airspace is blocked from traffic (or at least generally avoided by airspace users) or the airspace throughput is greatly reduced for longer periods of time. Thus, airspace users are more likely to reroute and fly less horizontally efficient trajectories. On the other hand, when delays are due to ATC capacity, airspace users typically do not reroute as long as the duration of the delay is not disrupting the schedule of their operations.

4.3 The impact of local capacity issues on Union-wide HFE

51 In addition to quantifying the relationship between HFE and different types of en route ATFM delays the analysis also assesses how delays occurring at different places in the network affect Union-wide HFE.

52 Traffic flows, capacities, and airspace structures are not uniform across the SES ATM network. As with almost all networks, constraints or disruptions introduced at different places may have different outcomes in terms of network performance. In order to better understand these network effects, the analysis considered the relationship between Union-wide HFE and en route ATFM delays per flight occurring in different Member States.

53 In terms of the impact on Union-wide HFE, average delays per flight in Germany, France, Poland, Spain (Canarias and Continental), Hungary, Slovakia, Cyprus, Italy, the Netherlands, and Estonia are the most significant in the analysis. Delays in Germany show the highest impact (one minute of average delay per flight increased Union-wide HFE by 0.11 percentage points).

54 Delay per flight occurring in Spain Canarias, Slovakia, and Estonia show an inverse relationship with HFE (one minute of average delay decreased HFE by 0.04, 0.09, and 0.14 percentage points respectively). The reason for this relationship between delays occurring in States at the border of the SES area and SES-wide HFE requires further investigation.

55 Figure 5 (next page) provides a geographical representation of the States where local delays have the most significant impact on Union-wide HFE.

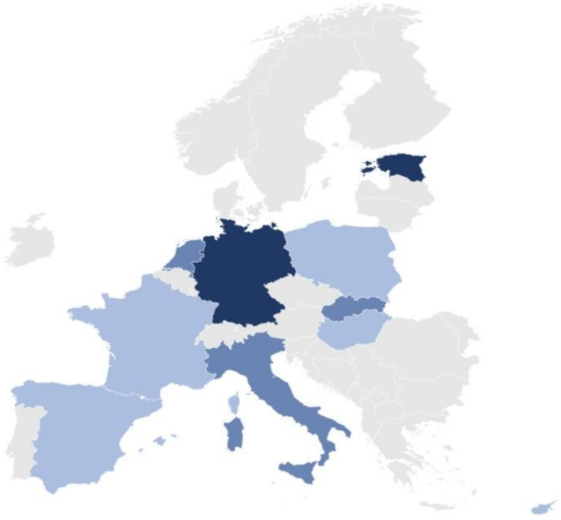

Figure 5 – Significant Member States in the Union-wide regression model (Source: PRB elaboration). Member States in darker shading have a stronger impact (higher coefficient) on Union-wide HFE.

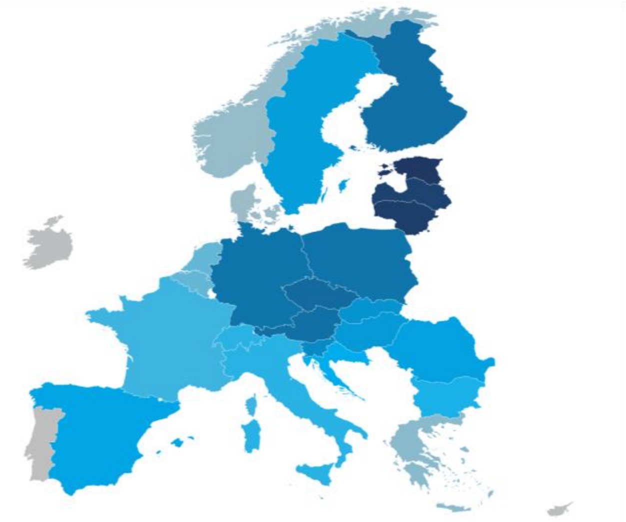

Figure 6 – The strength of the Member State-level regression models expressed by the R^2 value (Source: PRB elaboration). Member States in darker shading have a stronger relationship (higher R^2 value) between capacity underperformance and horizontal flight inefficiency.

4.4 Member State-level assessment

56 In order to understand the local specificities, the analysis examined the relationship between the HFE of each Member State and average en route ATFM delays per flight occurring in the network. The results showed significant differences in how strongly en route ATFM delays explained variation in HFE across Member States.

57 The analysis concludes that the relationship between the Member State HFE and en route ATFM delays in the network is strongest in Estonia, Lithuania, and Latvia, where 65-68% of HFE variation is explained by variations in the delays per flight in other Member States. In contrast, in Ireland, Portugal (Lisboa FIR) and Cyprus only 5-6% of HFE variation is explained by variations in en route ATFM delays per flight generated in other Member States.

58 For a group of Member States (Germany, Poland, Czech Republic, Austria located in Central Europe, and Finland), 51-55% of the variation in HFE is explained by variations in en route ATFM delays per flight. Figure 6 presents the strength of the relationship between HFE and ATFM delays.[23]

59 Delays in Cyprus, Germany, France, and Poland are found to significantly influence HFE in more than 20 Member States, whereas some other Member State-level delays were only significant for a single other Member State (e.g. Bulgaria, Latvia, Norway). This suggests a wider network effect of the interdependencies. Delays generated in a specific area may have a spill-over effect which has an impact well beyond neighbouring countries.

60 The varying level of delay impact on the HFE of other Member States can broadly be explained by traffic flows and the scales of delays faced. Germany and France accommodate the major traffic axes in the 'core' of the network while Cyprus and Poland accommodate traffic flows between western Europe and the far/Middle East. Airspace users avoiding delays in this airspace can have more significant upstream/downstream impacts on HFE in other Member States.

61 Similarly to the Union-wide analysis, delays in some Member States on the borders of the SES have an inverse relationship with the HFE of many Member States. When delays in Spain Canarias, Slovakia, and Estonia had a significant impact on the HFE of another Member State, this almost always had a beneficial impact on the HFE of other Member States. Figure 7 (next page) shows an overview of how frequently the delay occurring in

---

[23] This is demonstrated by the strength of the regression model.

Member States had significant impacts on the local HFE.

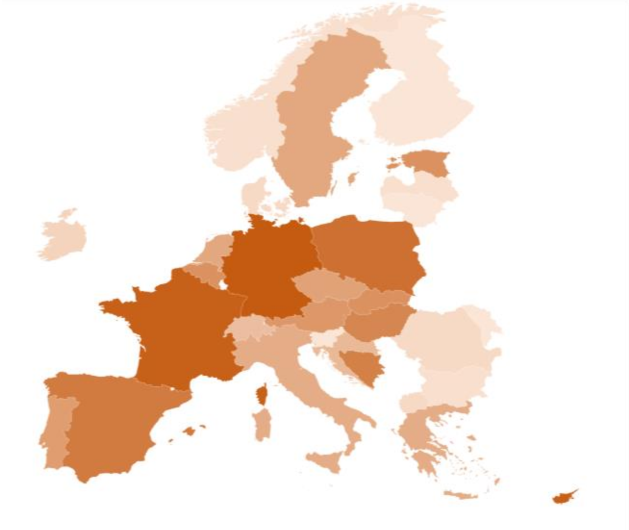

Figure 7 – Frequency of Member State-level en route ATFM delay having a significant impact in the Member State-level regression models (Source: PRB elaboration). A darker shading indicates that the en route ATFM delays of the Member State influenced HFE performance in other Member States.

5 CONCLUSIONS

62 The study shows that en route ATFM delay has a negative effect on horizontal flight efficiency. The impact varies according to a number of factors including the cause of delay, the location of the delay, the length of delay, and the season and where the HFE is measured.

63 **Conclusion 1:** Delay causes have a varying impact on HFE depending on the season due to the nature of the disruption they cause. Table 2 summarises the impact that a minute of delay per flight for each delay reason has on HFE:

Delay reason	Summer HFE impact	Winter HFE impact
Non-ATC capacity	1.23 pp	2.9 pp
Events	0.45 pp	0.49 pp
Weather	0.14 pp	0.34 pp
ATC disruption	0.12 pp	0.18 pp
ATC staffing	Negligible	0.28 pp
ATC capacity	Negligible	0.19 pp
Non-ATC disruption	Negligible	Negligible

Table 2 – Summary of the impact that a minute of delay per flight has on HFE by delay reason and season (Source: PRB elaboration).

64 **Conclusion 2:** Without any delays, the Union-wide HFE is estimated to be on average around 2.6% within the sample, suggesting that this amount of HFE is attributable to other factors than delay (e.g. inefficient route networks, airspace restrictions, airspace user route preferences).

65 **Conclusion 3:** Delays occurring in different Member States have a varied effect on Union-wide HFE, with delays in Germany, Italy, and the Netherlands having on average the larger (more detrimental) impact on Union-wide HFE.

66 **Conclusion 4:** HFE at a local level is influenced, to varying degrees, by en route ATFM delays in other Member States. Those with HFE impacted heavily by delays in other Member States include Estonia, Lithuania, and Latvia. Those whose HFE is not impacted very much include Ireland, Portugal (Lisboa FIR), and Cyprus.

67 **Conclusion 5:** The local HFE in the Member States of the SES area tend to be sensitive to en route ATFM delays in a relatively small number of other States (Germany, France, Cyprus, and Poland).

68 **Conclusion 6:** The impact of delays on HFE can be related to both the cause of the delay and the location. ATC strikes were also found to cause significant underperformance on specific days, with delays up to eight minutes per flight and HFE up to 4% measured across all flights on the given strike day.