Case Studies on Transport Policy 10 (2022) 2025–2043

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

The substitution of short-haul flights with rail services in German air travel markets: A quantitative analysis

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ARTICLE INFO

Keywords:
Sustainability
Short-haul flights
High-Speed Rail
Intermodality

ABSTRACT

In recent years, a ban on short-haul flights for which alternative, more environmentally friendly transportation is available has been on European regulatory agendas, particularly in countries like Germany, with its well-developed high-speed rail (HSR) and a dense network of low-cost, point-to-point airline traffic. This study aims to quantify the potential impact on CO_2 emissions of substituting short-haul flights with rail frequencies in 87 German air travel corridors. Using OAG data on passenger bookings and airline schedules for 2019, as well as current rail travel times, we determine the target flights by looking at the actual proportion of connecting passengers per frequency. We estimate a potential reduction in CO_2 emissions of between 2.7% and 22%, depending on how strict the flight substitution is. However, the social benefits of those carbon emissions might fall short of the travel time losses experienced by the passengers. Increased investment to improve rail speeds and intermodal accessibility appears necessary before the substitution policies can be implemented.

1. Introduction

Aviation has recently come under fire due to its strong growth as a source of carbon emissions in the transportation sector (Baumeister, 2019). That is especially true for short-haul flights, which can generate twice as many emissions per seat-kilometre than long-haul flights (Grimme and Jung, 2018). In Europe, high-profile climate change movements like ‘flygskam’ (flight-shaming) aim to encourage people to stop travelling by plane. Many public authorities at both national and EU levels are currently entertaining the idea of banning short-haul flights and replacing them with less polluting high-speed rail (HSR) options. The flight route between Amsterdam and Brussels, two cities connected by rail in less than two hours, and the recent efforts of Belgian and Dutch politicians to stop these flights (VRT.be, 2019) are paradigmatic examples of this trend. The debate has also spread to countries like Germany or Spain, where the Major of Barcelona pledged to stop using flights if there was a rail alternative under seven hours of travel time.

A tangible example of these policies becoming a reality is the recent move by the French Government, which, as part of the Covid-19 bailout for Air France, requested the carrier to start dropping short-haul frequencies where a rail alternative under 2.5 h existed (Flightglobal, 2020). An interesting exception was that short-haul flights could still be operated in France if they served to connect passengers (referred to as “hub transfers” by the French finance minister). We submit there were two main reasons for this: a) HSR travel may not yet be a substitute for indirect passenger journeys in connection to long-distance destinations, and b) long-haul flights, which are often the pillar of a country’s global air connectivity, may critically depend on indirect passengers being fed to them at the hub airports to ensure sufficient load factors to operate profitably.

Similar conditions were discussed in the wake of Lufthansa’s subsidiary Austrian Airlines’ bailout. Lufthansa’s CEO expressed that the combination of green requirements and economic assistance in France and Austria could become a model for flight substitution within Europe (Küfner, 2020). These extremes have not so far been considered in Germany, but with the Green Party now a member of the coalition government, the environmental sensibilities regarding the future of German aviation are higher than ever (Gruene.de, 2021).

In this context, this paper presents a German case study about the substitution of short-haul flights with rail services. Germany is a suitable country for this type of analysis due to its well-developed HSR network and a large share of domestic, low-cost air traffic. In particular, we aim to answer the following research questions:

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https://doi.org/10.1016/j.cstp.2022.09.001
Received 7 March 2022; Received in revised form 26 August 2022; Accepted 4 September 2022
Available online 7 September 2022

1. How many flights could potentially be banned in Germany without compromising long-haul connectivity? Which airports and airlines would be most affected?
2. How many passengers would switch to rail? What would be their travel time increase? And the carbon savings generated?

Several high-level studies on air-rail substitution have been carried out by aviation agencies (Eurocontrol, 2021), public authorities (Ajuntament de Barcelona, 2020), academics (Baumeister, 2019; Dalkic et al., 2017; Robertson, 2013; Wang et al., 2019 or Avogadro et al., 2021), and even banking firms (e.g. UBS, 2020) that document potential emission savings in the range of millions of tons of CO_2 each year. Still, none of these studies explicitly considers the connectivity aspect, i.e. long-haul, indirect airline travellers cannot entirely switch to rail, which can effectively limit the modal shift caused by flight bans as those passengers would change to other flights.

As per the scope of substitutability between air and rail, there are no strict boundaries regarding distance and travel time. Nevertheless, many studies use a range of 500–600 km as a reference (e.g. Albalate et al., 2013; Chen et al., 2019), which can expand up to 1,000 km in countries with faster HSR services (Zhang et al., 2018). Regarding travel time, Kroes and Savelberg (2019) suggest a range between two and six hours for the strongest substitutability, with business travellers leaning towards the lower end of that scale.

With those reference values, we used data on airline schedules (OAG) and passenger bookings (MIDT) to identify target flights and simulate several scenarios of flight substitution on German routes. We assumed that individual flights must serve a minimum proportion of connecting passengers to be allowed. The results for each scenario indicate the potential passenger shift from air to rail, the increase in travel time for all affected passengers, and the reduction in CO_2 emissions.

The remainder of this paper is structured as follows. Section 2 reviews the existing literature on air-rail competition and the impacts of modal substitution on carbon emissions. Section 3 describes our German case study, the OAG travel datasets and the methodological process. Section 4 presents the quantitative findings while Section 5 discusses their main environmental and policy implications. Section 6 concludes and provides recommendations for future research.

2. Literature review

In short- and medium-distance trips (approximately under 800 km), high-speed trains have a lower energy consumption per seat-km than aircraft when travel itineraries are compared like-to-like (Dalla-Chiara et al., 2017). Seeing how that directly translates into lower carbon emissions, HSR has often been hailed as a more environmentally friendly means of travel and, for the appropriate corridors, a valid substitute for road and air transportation (Givoni and Dobruszkes, 2013).

At the heart of most quantitative analyses on the topic, one typically finds a calculation of modal shift and emission savings arising from a hypothetical substitution of airline travel by rail frequencies (either high-speed or not). For example, the study by Dalkic et al. (2017) concluded that developing the Turkish HSR network to compete with air in medium-distance routes could cause an overall reduction of 452.7 kt CO_2 by 2023. However, this figure also amalgamated the modal shift from cars and buses. For more air-specific results, we looked at the studies from Baumeister (2019) and Baumeister and Leung (2021) about the Finnish air transport network. Even though the country does not have HSR lines, they concluded that a potential substitution of air by non-HSR services could lead to a 95 % emissions reduction, with all routes under 400 km remaining competitive in terms of travel times. Robertson (2013) quantified the emissions reduction at 14 % for his study of the Sydney-Melbourne corridor, and Wang et al. (2019) found it to range between 3 and 5 % for the Chinese domestic air transport network. The more recent study of Avogadro et al. (2021) –the first one to cover 27 European countries– concluded that removing all intra-European flight routes for which other modes were available (with a maximum increase in travel time of 20 %) would lower emissions by 4.72 %, the most impacted countries being, in decreasing order, France, Germany, the UK, Spain and Italy.

This is not to say that there is a universal consensus that the substitution of air by rail would be the ultimate solution to the issue of transport emissions. As noted by Jiang et al. (2021), there is a broader scope of analysis that considers the extra emissions generated by the massive construction projects of rail infrastructure, as well as the different problems of induced demand (Givoni and Dobruszkes, 2013) by which the introduction of new HSR services increases travel demand on the relevant corridors and removes seat capacity from the system that was originally planned to accommodate the shift from airlines. In line with those sceptical views, studies like Transport & Environment (2022) limit the benefits of shifting from air to rail to only a 2–4 % reduction in global emissions, even in the best of scenarios.

Despite those limitations, quantifying the potential traveller shift linked to air-rail substitution remains a key angle in the transport literature, a keystone of which is the broader corpus of studies on air-rail competition that help determine the boundaries of substitutability between the two modes.

Many academics have studied the topic of air-rail competition and modal shifts in Europe and Asia (See, e.g., López-Pita and Robusté, 2005; Park and Ha, 2006; Givoni, 2007; Clever and Hansen, 2008; Jiménez and Betancor, 2012). Most studies did look at the impact on demand, prices, capacities and market shares of air travel after a competing HSR service was introduced (Clewlow et al., 2014). For example, airline traffic on the Paris-Lyon route (450 km) decreased by almost 50 % due to the entry of the high-speed TGV service (Patterson and Perl, 1999). The introduction of HSR on the Madrid-Seville route in the 1990 s caused a decline in the airline market share from 40 % to 13 %, while rail transportation increased from 16 % to 51 % (Park and Ha, 2006). In Germany, the air transport sector experienced a 12 % decline in business after introducing the Intercity Express (ICE) (Vickerman, 1997). Similarly, the HSR connection between Seoul and Busan led to a significant reduction in the frequency of flights between the two cities (Fu et al., 2012). A recent study by Kroes and Savelberg (2019) on the potential for high-speed trains to replace short-haul air traffic at Amsterdam airport showed that between 1.9 and 3.7 million annual air trips could be replaced by 2030, with the Amsterdam-London route being most impacted.

The substitution between air and HSR can be driven by many variables such as frequency of daily departures, travelling convenience, and prices (Kroes and Savelberg, 2019). However, several studies have noted the pre-eminence of distance and travel time (see Table 1).

Overall, there is a lack of consensus about the scope of competition and substitutability between air and rail in terms of travel time and distance. For Europe, Vickerman (1997) studied multiple air and rail routes in Spain, Germany and France and determined that the most likely scope for air-HSR competition ranges between 200 and 600 km and between one and three hours of travel time. Similar evidence can be found in the study by Cheng (2010) on the Taiwanese rail network and Albalate et al. (2015) across 180 routes in Spain, France, Italy and Germany. Other studies projected HSR as a substitute mode for aviation on trips under 500 km (e.g. Martin and Nombela, 2007; Bilotkach et al., 2010), while González-Savignat (2004) stated that HSR in Spain is a competitive option for trips under three hours. After studying 161 European routes, Dobruszkes et al. (2014) concluded that air and HSR are the strongest substitutes in routes between two and two and a half hours by train, which was also supported by the study by Behrens and Pels (2012) on the Paris-London corridor. D'Alfonso et al. (2016) also investigated the same route and found effective air-HSR competition between 200 and 800 km, as did Kroes and Savelberg (2019). They, in addition, considered HSR a competitive substitute for air travel on trips between two and six hours.

In contrast, Bergantino and Madio (2020), who analysed the Bari-

Table 1
Summary of past literature on thresholds of air-HSR competition.

Authors	Countries Analysed	No. of Routes	Threshold of competition
Janic (1993)	EU-wide (20 cities)	Multiple routes	400–2,000 km
Vickerman (1997)	Spain, Germany & France	Multiple routes	1–3 h 200–600 km
González-Savignat (2004)	Spain	2 routes Madrid-Seville Barcelona-Madrid	3 h
Martín & Nombela (2007)	Spain	187 routes	500 km
Adler et al. (2010)	Europe	Multiple routes	400–2,000 km
Bilotkach et al. (2010)	EU27, Switzerland & Norway	900 routes	500 km
Cheng (2010)	Taiwan	4 routes	1–3 h 200–600 km
Behrens & Pels (2012)	England & France	1 route London-Paris	145 min for leisure travel, 160 min for business travel
Jiménez & Betancor (2012)	Spain	9 routes	3 h 800 km
Dobruszkes et al. (2014)	EU-wide	161 routes	2–2.5 h
Albalate et al. (2015)	Spain, France, Italy & Germany	180 routes	90–180 min 438 miles (ca. 700 km)
D'Alfonso et al. (2016)	England & France	1 route London-Paris	200–800 km
Wan et al. (2016)	China, Japan & South Korea	503 routes	500–800 km
Kroes & Savelberg (2019)	Netherlands	13 routes	2–6 h 800 km
Bergantino & Madio (2020)	Italy	2 routes	500–1,000 km

Rome and Brindisi-Rome routes (Italy), discovered that modal shift from air to HSR is more likely on distances between 500 and 800 km. These findings align with Wan et al. (2016), who studied 503 routes within China, Japan and South Korea. Finally, there is a recent study by UBS (2020) for Europe and China on the acceptance of travel time between different modes, which concluded that leisure travellers are willing to accept a travel time of five to six hours on the train, while business travellers would tolerate up to four hours.

Based on the above, our selection of German routes will cover up to 600 km and six hours of rail travel time to be as comprehensive as possible in our geographical scope.

Despite the broad literature on air-rail competition, we found no study on the implications of a short-haul flight ban (either in Germany or any other country) explicitly accounting for the connectivity problem, whereby short-haul flights cannot be banned if indirect long-haul travellers are not able to switch to HSR. One may argue that airports that are good multimodal platforms (i.e. well integrated with surface transport modes by, for example, having their HSR station) would not need short-haul flights for hub transfers as the medium- and long-haul airline frequencies could be fed passengers by the incoming rail services (Janic, 2011). However, it is also true that most European airports are still far from delivering that level of seamless connectivity across modes. Thus, short-haul flights would still be needed for hub transfers, at least in the medium term. Incorporating this issue into the air-rail substitution analysis, while also quantifying the potential passenger shift using airline bookings data, are the main novelties of our approach.

3. Data and methodology

3.1. Case study and datasets

Between 2008 and 2019, the German air transport sector grew from 166.3 to 226.9 million annual travellers –a 36.44 % increase. Low-Cost Carriers (LCCs) took key shares in short-haul domestic and international markets during that time. The high incidence of LCCs, especially at secondary airports such as Berlin, Duesseldorf, and Hamburg, hints at the existence of air transport markets in Germany that rail services could potentially replace.

According to figures published by the International Union of Railways (UIC, 2021), the total length of the German HSR network is 1,571 km (as of 2020) and thus takes third place in Europe behind Spain (3,487 km) and France (2,735 km). The German HSR network, operated by Deutsche Bahn (DB), was developed from pre-existing infrastructure and launched in 1990 (Cheng, 2010). A prime example of an HSR-induced modal shift is the Munich-Berlin route. Since 2017, when the Intercity-Express (ICE) high-speed services reduced travel time from six to four hours, rail replaced air as the primary means of transport between the two cities. While this modal shift mainly stems from the convenience afforded to travellers who arrive directly at city-centre railway stations, it could also be partly driven by the willingness of German travellers to accept somewhat longer travel times to be more environmentally friendly (UBS, 2020).

We selected 87 non-stop flight routes out of 21 German airports for our case study. These are mostly domestic flights, but the sample also includes short-haul connections to 17 destinations in Austria, Belgium, the Czech Republic, Denmark, Luxembourg, the Netherlands, Poland, and Switzerland. See Table 2 for a complete list of the airports included. The routes are all under 600 km, and rail alternatives (both HSR and non-HSR) take less than six hours. If a lower threshold of three hours is set, the number of sample routes would decrease to fifteen. The shortest route, with only 135 km, is between Munich (MUC) and Nuremberg (NUE), with the fastest rail travel time of 1 h 01 min, and the longest with 599 km is between Hamburg (HAM) and Munich (MUC) with a rail travel time of 5 h 37 min.

Fig. 1 illustrates the sample routes served out of Frankfurt and Munich airports (see Appendix A for the other routes).

Table 3 shows the seating capacity of these potentially replaceable routes served by the German airports in 2019. A potential ban on short-haul flights could affect an estimated 32 % of Germany's annual capacity (around 42 million airline seats). Thus, the mentioned political debate about replacing short-haul flights could drain a sizable share of the German airports' traffic and, thus, their aeronautical revenues. Around 4 million of those seats are routes requiring less than three hours of rail travel time (<3h), which would most likely be banned first. Only Frankfurt serves roughly 1.6 million of them (about 4 % of the airport's offered seat capacity). Nevertheless, Muenster/Osnabruck with 18 %, and Nuremberg and Leipzig/Halle with 13 % account for the highest proportion of potentially replaceable seats on routes with less than three hours of rail travel time.

Table 2
Airports included in the study.

Region	*Airports*
Germany	Berlin (TXL/SXF), Cologne/Bonn (CGN), Dortmund (DTM), Dresden (DRS), Duesseldorf (DUS), Frankfurt (FRA), Friedrichshafen (FDH), Hamburg (HAM), Hannover (HAJ), Karlsruhe/Baden-Baden (FKB), Leipzig/Halle (LEJ), Mannheim (MHG), Muenster/Osnabrück (FMO), Munich (MUC), Nuremberg (NUE), Paderborn/Lippstadt (PAD), Saarbrucken (SCN), Stuttgart (STR) and Westerland (GWT).
Europe	Amsterdam (AMS), Basel/Mulhouse (BSL), Brussel (BRU), Copenhagen (CPH), Gdansk (GDN), Geneva (GVA), Graz (GRZ), Innsbruck (INN), Linz (LNZ), Luxembourg (LUX), Paris (CDG/ORY), Prague (PRG), Salzburg (SZG), Strasbourg (SXB), Vienna (VIE), Warsaw (WAW), Zurich (ZRH).

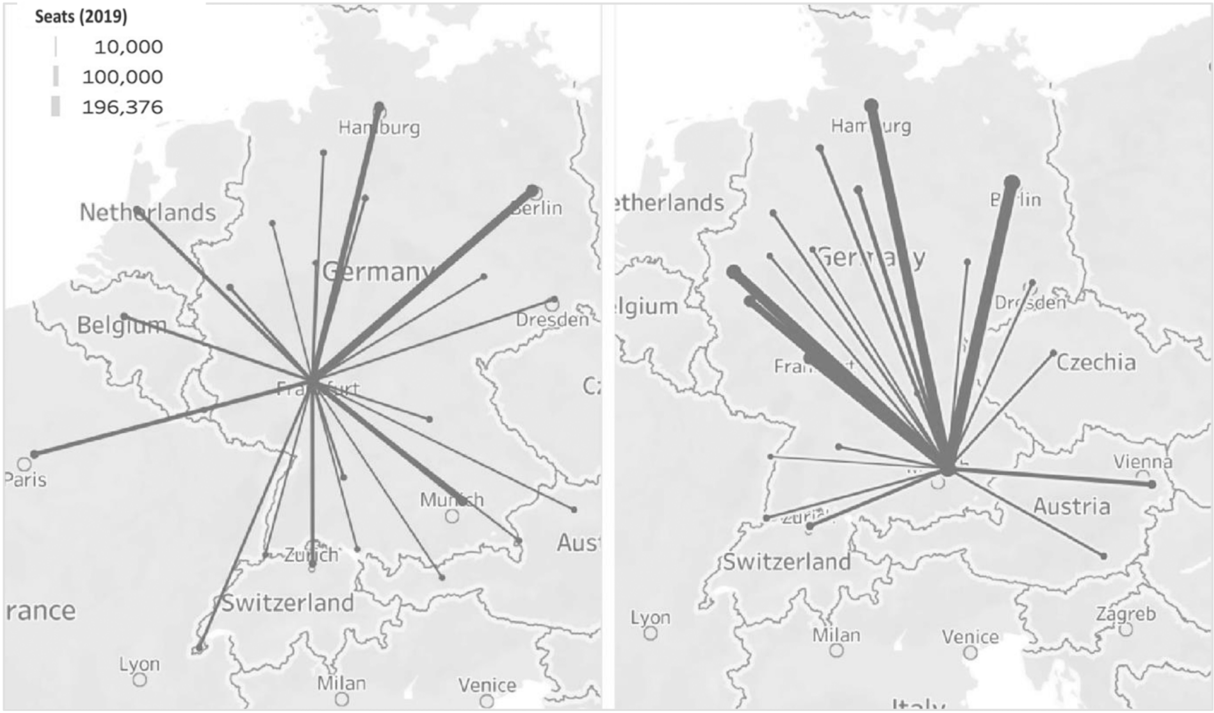

Fig. 1. Sample Air Routes from Frankfurt (left) and Munich (right) *Source: OAG Traffic/Schedules Analyser.*

Table 3
Potentially replaceable seat capacity at German airports (2019).

Airport	*<3h*	*3–6 h*	*Total affected*	*% <3h*	*% 3–6 h*	*% Total*	*Total*
Frankfurt	1,599,766	7,170,680	8,770,446	4 %	16 %	19 %	45,138,204
Stuttgart	599,079	2,206,198	2,805,277	7 %	27 %	34 %	8,227,337
Duesseldorf	496,026	3,754,304	4,250,330	3 %	23 %	26 %	16,657,207
Nuremberg	353,302	478,665	831,967	13 %	18 %	32 %	2,625,615
Hannover	272,129	687,577	959,706	7 %	18 %	24 %	3,928,407
Munich	263,821	8,249,972	8,513,793	1 %	26 %	27 %	31,856,630
Leipzig/Halle	205,336	366,486	571,822	13 %	23 %	37 %	1,560,112
Muenster	120,244	203,718	323,962	18 %	31 %	50 %	650,181
Paderborn	53,550	112,722	166,272	12 %	25 %	37 %	454,096
Berlin (TXL)	31,395	6,191,213	6,222,608	0 %	40 %	40 %	15,466,202
Berlin (SXF)	5,054	283,024	288,078	0 %	4 %	5 %	6,398,601
Hamburg	765	4,221,939	4,222,704	0 %	38 %	38 %	11,238,168
Cologne/Bonn	220	2,522,410	2,522,630	0 %	33 %	33 %	7,754,187
Mannheim	–	29,836	29,836	0 %	89 %	89 %	33,695
Bremen	–	766,347	766,347	0 %	52 %	52 %	1,485,304
Dresden	–	516,116	516,116	0 %	49 %	49 %	1,048,833
Friedrichshafen	–	123,416	123,416	0 %	41 %	41 %	303,070
Saarbrucken	–	40,888	40,888	0 %	15 %	15 %	277,566
Westerland	–	8,994	8,994	0 %	9 %	9 %	97,360
Dortmund	–	143,856	143,856	0 %	9 %	9 %	1,569,646
Karlsruhe	–	70,056	70,056	0 %	9 %	9 %	782,083
Total	**4,000,687**	**38,148,417**	**42,149,104**	**4 %**	**28 %**	**32 %**	**157,552,504**

Source: OAG Schedules Analyser.

Table 4 provides a similar analysis from the airline perspective. The most potentially replaceable short-haul capacity (under three hours of alternative rail time) is served by Lufthansa (3.7 million seats, which amounts to 4 % of the carrier's operations at the selected airports). This proportion increases to 29 % if we consider the sample routes between three and six hours of alternative rail time.

We collected a flight-level dataset to understand how passengers used these potentially replaceable flights in Germany. A sample week was chosen from the monthly average of departing seats out of the 21 selected German airports in 2019 (Fig. 2). Since April was the closest month to the annual average, its first week (1st to 7th) was selected as the sample week for the analysis.

Our method requires data on passenger bookings and airline schedules to study a potential air-rail modal shift on the selected routes. The Market Information Data Transfer (MIDT) dataset provides information on airline bookings and travel itineraries involving any of the 87 chosen flights. Only travel itineraries with up to one flight connection are included to simplify the analysis. Overall, the demand dataset contains slightly above 184 thousand individual passenger trips in 64.4 thousand itineraries. The original MIDT data sets are supplied by OAG Traffic Analyser, which processes data from Global Distribution Systems (GDS) like Amadeus, Galileo or Sabre with an additional adjustment of tickets

Table 4
Potentially replaceable seat capacity at German airports according to airline (2019).

Airlines	*<3h*	*3–6 h*	*% <3h*	*%3–6 h*
Lufthansa	3,714,420	22,676,620	4 %	29 %
SWISS	366,937	1,893,272	7 %	45 %
KLM	329,968	2,450,630	9 %	75 %
Eurowings	62,412	11,898,446	0 %	35 %
TUIfly	12,474	9,072	0 %	0 %
Tunisair	8,388	2,260	2 %	3 %
Onur Air	1,938	4,911	0 %	1 %
Corendon Airlines	1,134	8,019	0 %	1 %
Total	4,497,671	38,943,230		

Source: OAG Schedules Analyser.

purchased by direct-sale channels made by the data provider.

Our global airline schedules data comes from the OAG Schedules Analyser and covers from the 1st to the 7th of April 2019. This dataset contains 272 thousand unique records of scheduled passenger flight departures. Of those, approximately 5.7 thousand refer to the 87 selected routes. Finally, we collected data on the fastest rail travel times between the selected routes from the booking platform Omio.com (2020) or Google Maps' Directions API. Additional travel time information was also gathered from Google Maps.

3.2. Methodology

We follow a five-step methodological process. First, the demand and supply datasets are combined using a flight-connections algorithm (adapted from Piltz et al., 2018) to match the passenger bookings with seats in the actual flights during the sample week. That allows us to determine each flight's load factor and indirect connectivity level. The second step consists of defining a regulatory threshold of minimum percentage of passenger connections (the 'hub transfers') for airlines to be allowed to operate a given short-haul flight. We define four scenarios for such minimum connectivity threshold: 10 %, 35 %, 60 % and 80 %, leading to increasingly stringent conditions to operate in the selected routes. In the third step, we apply the respective thresholds to the schedules dataset to determine which flights should be banned. The fourth step involves relocating the affected passengers from the banned flights into new travel itineraries according to a predetermined list of travel modes, including rail, direct, and indirect flights. Finally, the outcome of his relocation step allows us to calculate the impact on travel times and emission savings, primarily from the expected switch of airline passengers to the low-emissions rail alternative.

Despite the limited geographical scope of the selected routes, it is worth remembering that these potentially replaceable flights serve a wide diversity of global city-pair markets, defined by the true points of origin and destination of the passengers' itineraries revealed by the passenger bookings data. These origin and destination points may not always coincide with a flight's arrival and departure airports. This only occurs for non-stop passengers (referred to as origin–destination "OD" passengers from now on). In Fig. 3, these passengers are the ones that travel between MUC and FRA airports using precisely the MUC-FRA flight segment. However, the aircraft seating capacity in that segment is shared by different types of connecting passengers. Some travellers may have started their journey from another airport before arriving in Munich (for example, Bangkok-BKK in Fig. 3). These are referred to as "Connection-Feeding" passengers since the arriving BKK-MUC frequency "feeds" travellers into the MUC-FRA segment. The third passenger category comprises passengers who began their travel in MUC, then connected in Frankfurt onto a flight to an onward destination (for example, Doha-DOH in Fig. 3). These are known as "Connection-Onward" travellers.

The main reason to separate passengers according to the type of travel itinerary is that not all travellers affected by a flight ban necessarily belong to that city-pair OD market. In other words, the presumed rail alternative may not exist for connecting travellers whose short-haul flight is banned, and they cannot transfer to/from their long-haul frequencies. Our data shows that the global connectivity of German airports is making substantial use of these short-haul feeding/onward services. An average of 17 % of passenger bookings to Asia-Pacific destinations depend on them, and this value increases to 24 % and 25 % for the Latin American and North American markets.

Table 5 breaks down passenger traffic per airport (OD vs Connections) in the selected short-haul routes during the chosen week (April 1st-7th, 2019). Some German airports have more connections than others. Thus, a blanket approach to regulating short-haul flights would not be appropriate. For example, with only 27 % of connections at Cologne/Bonn, the travel itineraries passing through that airport are less dependent on short-haul frequencies than, e.g., Frankfurt, where the percentage of connections is 82 % and, thus, deserving of a higher level of protection for its feeding/onward services.

An airport-specific approach to flight bans might be insufficient as well. Table 6 shows the top- and bottom-five routes according to the proportion of connecting itineraries in the MIDT data. While the Stuttgart-Munich non-stop flight serves 95 % of connections, that share is only 8 % for the longer Hamburg-Stuttgart flight segment. A flight ban aiming to protect hub connections at Stuttgart should treat these routes differently. Moreover, our data also shows that passenger connectivity levels fluctuate widely throughout the day, even within the same routes, with rush hours for connections at Stuttgart found at 05:00, 10:00 and 13:00, and an even larger number of connecting waves at Frankfurt airport. This is caused by the airports' underlying hub structure, with synchronised waves of arriving and departing flights, which, in turn, causes those specific frequencies to carry more indirect traffic as passengers take advantage of the hub-and-spoke structure of airline networks to reach a wide variety of indirect destinations. Thus, if flight bans must be selective to protect long-haul connectivity, they would need to be implemented at a flight-number level to prioritise the short-haul frequencies arriving or departing during the respective airports' high-

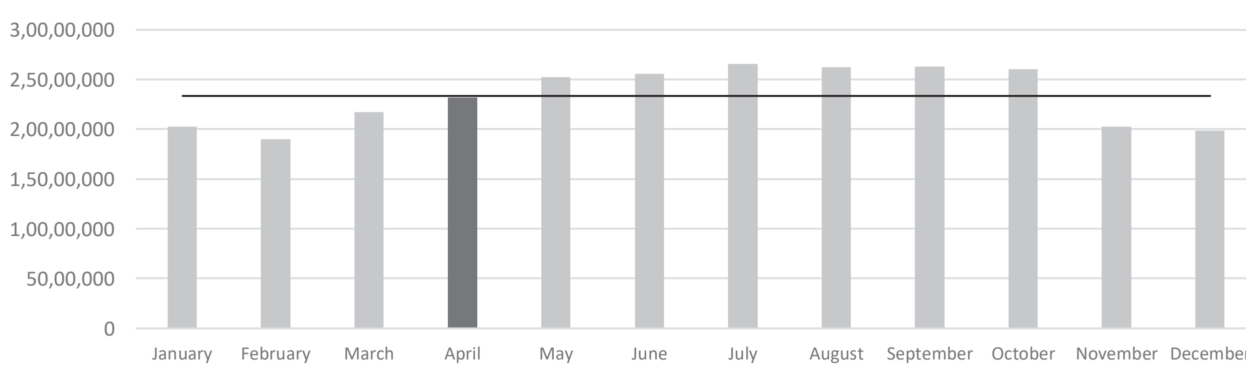

Fig. 2. Monthly departing seats at German airports in 2019 *Source: OAG Schedules Analyser.*

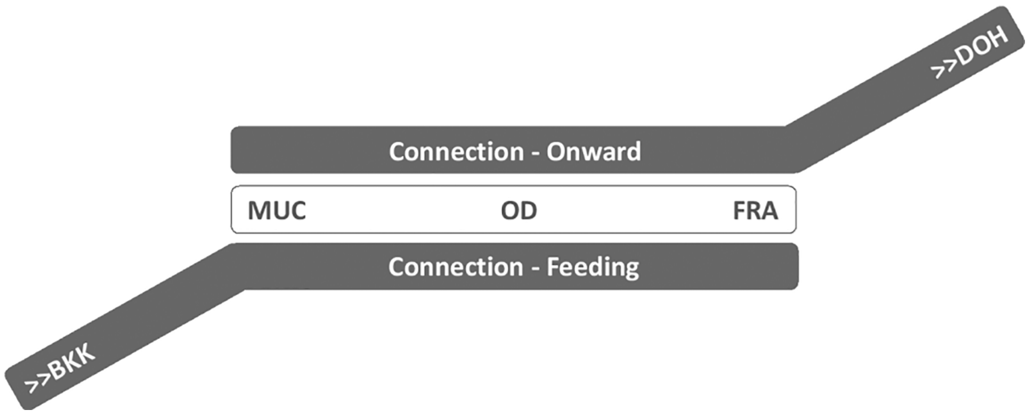

Fig. 3. Different types of passenger itineraries.

Table 5
Breakdown of passenger traffic in the selected routes (weekly-two-way passengers).

Airport Name	*Code*	*OD*	*% OD*	*Connection*	*%Connection*	*Grand Total*
Berlin	SXF	5,589	100 %	1	0 %	5,590
Berlin	TXL	70,524	70 %	30,838	30 %	101,362
Cologne/Bonn	CGN	32,376	73 %	11,807	27 %	44,183
Dresden	DRS	2,479	25 %	7,271	75 %	9,750
Dortmund	DTM	532	30 %	1,256	70 %	1,788
Duesseldorf	DUS	41,004	52 %	37,957	48 %	78,961
Friedrichshafen	FDH	258	10 %	2,232	90 %	2,490
Karlsruhe	FKB	991	74 %	352	26 %	1,343
Muenster	FMO	1,650	29 %	4021	71 %	5,671
Frankfurt	FRA	39,301	18 %	184,760	82 %	224,061
Westerland	GWT	72	39 %	114	61 %	186
Hannover	HAJ	4,756	25 %	14,371	75 %	19,127
Hamburg	HAM	39,123	54 %	32,819	46 %	71,942
Leipzig/Halle	LEJ	4,077	36 %	7,344	64 %	11,421
Mannheim	MHG	573	98 %	10	2 %	583
Munich	MUC	58,460	34 %	114,251	66 %	172,711
Nuremberg	NUE	4,382	31 %	9,727	69 %	14,109
Paderborn	PAD	724	24 %	23,01	76 %	3,025
Saarbrucken	SCN	346	92 %	29	8 %	375
Stuttgart	STR	30,081	60 %	19,958	40 %	50,039

Source: OAG Traffic Analyser.

Table 6
Top-5 and bottom-5 routes according to the percentage of connections (weekly 2-way passengers).

Rank	*Flights*	*OD*	*OD%*	*Connection*	*Connection %*	*Grand Total*
1	Nuremberg-Munich	114	3 %	4,177	97 %	4,291
2	Nuremberg-Frankfurt	248	4 %	5,905	96 %	6,153
3	Stuttgart-Frankfurt	434	5 %	8,311	95 %	8,745
4	Stuttgart-Munich	255	5 %	4,554	95 %	4,809
5	Amsterdam-Duesseldorf	318	6 %	5,143	94 %	5,461
Rank	*Flights*	*OD*	*OD%*	*Connection*	*Connection %*	*Grand Total*
83	Hamburg-Stuttgart	15,948	92 %	1,359	8 %	17,307
84	Berlin (TXL)-Stuttgart	24,346	93 %	1,813	7 %	26,159
85	Berlin (TXL)-Cologne	29,040	95 %	1,489	5 %	30,529
86	Berlin (SXF)-Salzburg	1,090	100 %	0	0 %	1,090
87	Berlin (SXF)-Cologne	3,232	100 %	0	0 %	3,232

Source: OAG Traffic Analyser.

connectivity windows. For the reasons above, we employed a flight-number-level approach and individually analysed each of the 5.7 thousand short-haul departures in our sample week.

We define the share of connecting passengers as a hypothetical metric to guide the substitution of short-haul flights at German airports. By setting a minimum share of connections as the requirement to ban or allow individual flight frequencies, valuable long-haul connectivity can be protected. Four ad-hoc scenarios are presented in this study (10 %, 35 %, 60 % and 80 %). A 10 % threshold, for example, would mean that only frequencies that can demonstrate that 10 % or more of their seat capacity is used for connections would be allowed to operate. Table 7 indicates how many sample flights would be banned in each case. Imposing only a 10 % minimum threshold would wipe out approximately 1.2 thousand flights, and the number of banned flights would increase to approximately 4.8 thousand for the strictest 80 % scenario.

Besides the connectivity thresholds, there is an extra consideration before labelling a flight as "banned". Most flights are return trips, with an aircraft initially departing from its base airport and travelling back

Table 7
Number of banned flights for different regulatory thresholds. 1–7 April 2019.

Scenario	*Connectivity Threshold*	*Weekly flights banned*
1	10 %	1,195
2	35 %	2,390
3	60 %	3,585
4	80 %	4,780

Source: OAG Traffic Analyser.

after a short turnaround at the destination airport. It is generally easy to identify the "paired flights" as they typically have consecutive flight numbers. These paired flights will only be marked as "banned" if both legs are below the given connectivity threshold. This condition allows us to be conservative when banning flights (to protect airline connectivity) and also minimises disruption to airline operations since it would be challenging (from a fleet management perspective) to operate particular routes in one direction only.

Once the vector of banned flights is obtained, the next step is determining the optimal travel alternative for the affected passengers. By optimal, we understand 'travel-time minimising' due to the lack of information on airfares for the sample itineraries, which precludes us from using a more comprehensive measure of 'generalised travel cost' as a guiding criterion. Alternative travel options are only considered within the same travel day as the original travel itineraries. A prioritised list of alternative travel modes is employed for each type of affected passenger. OD passengers are assigned to the fastest rail service on the route (either HSR or non-HSR). The small proportion of passengers in short-haul, time-inefficient connections (for example, HAM-FRA-MUC) will be relocated to non-stop flights (i.e. HAM-MUC) if not banned in the previous stage. If banned, the second choice would be a non-stop rail service; if that is not available, passengers will be moved into the fastest connecting flight within the same travel day. Passengers in medium- or long-haul connections (e.g. MUC-FRA-MIA) will be moved to the relevant non-stop flight (i.e. MUC-MIA), and the second option is the fastest connecting flight within the same travel day. In such case, for layovers in FRA longer than three hours, we assign these passengers to a multimodal, air-rail itinerary, assuming there would be enough time for those travellers to transfer between the rail station and the airport.

Considering the above criteria, our algorithm also checks that the number of passengers allocated to each alternative travel option does not exceed the available seat capacity of the flights that continue to operate under each scenario.

3.3. Measurement of impacts

Comparing the baseline and relocated travel records allows us to measure the impacts of the proposed substitution of short-haul flights. First, we measure the number of OD passengers that could potentially switch to rail services (Rail switch) –interpreted as the required increase in rail capacity to accommodate the affected passengers. Second, we record the number of banned flight segments and the number of passengers that switch to alternative air travel options (Airline switch). Third, we calculate the percentage increase in travel time with respect to the passengers' baseline itineraries, accounting for both rail switch and airline switch passengers. Finally, we measure the potential CO_2 emission savings caused by passengers switching from air travel to rail. Flight emissions are calculated in relation to the number of banned flights using the well-known Carbon Emissions Calculator provided online by the International Civil Aviation Organization (ICAO, 2016). As per the rail emissions, we use the reference values provided by DB's emissions calculator (DB.com, 2022). This allows us to account for different train types across our sample routes (from HSR to diesel trains).

Regarding the calculation of travel times, we assume that all passengers originate and terminate at a fixed point in each city, chosen as a representative "city-centre" location and must access and egress either the airport or the central rail station using public or private transport (Dobruszkes, 2011). Total travel time has six components: waiting, access, lead time, trip, waiting, and egress.

$$TravelTime = Waiting + Access + LeadTime + Trip + Waiting + Egress$$

Waiting times refer to the time spent at the public transport point (e.g. bus stop, metro station), waiting for the next service to arrive during the access or egress stages. This is calculated as half the peak frequency of the relevant public transport service. Access and egress times refer to travelling between the start/endpoint and the airport or rail station. Using average traffic conditions, waiting and access/egress times are obtained from Google Maps. Passengers must always arrive with sufficient lead time to check in to their flights or clear security, which is set at 10 min for rail services. For air itineraries, lead times depend on the size of the departure airport (similarly to Jenu et al., 2021): 90 min for large hubs (i.e. Frankfurt and Munich) and 60 min for all other airports. Flight times are taken from OAG Schedules. For rail, we always consider the fastest available travel time between the cities to reflect a situation of increased investment in said corridors.

All relevant metrics are annualised by multiplying the results for our sample week by 52.

4. Results

4.1. All routes

Table 8 shows the annualised results for the selected 87 routes. Around 41.2 million passengers travelled in itineraries involving short-haul flights in 2019. A 10 % connections threshold to allow short-haul flights to operate would decrease air traffic by 14.8 % to around 35.1 million travellers. In the most severe scenario (80 %), only 22.7 million passengers would still fly, which translates into an overall decline in air traffic of around 47 %. Overall, considering an average intra-EU airfare of €130 (Airliners.de, 2019), the airline's total revenue losses could range between €784 million to €2.5 billion, which carriers might seek to recover from long-haul markets.

Most of the affected passengers would switch to rail. The demand for rail services would increase between six and 19.4 million annual passengers (depending on the scenario). Considering that DB served around 150 million long-distance travellers in 2019 (DB.com, 2020), substituting short-haul flights by rail could potentially increase DB traffic by between 4 % and 13 %. Thus, if policymakers ever contemplate these policies, they must be phased in to meet the drastically increased demand.

The affected passengers (both rail switch and airline switch) would experience an increase in travel time of between 80 % and 90 %, representing an average of three and a half to four extra hours compared to their baseline itineraries. This increase in travel time might be acceptable for leisure travellers but could be problematic for business trips.

Banning between 53 and 272 thousand annual flights would cause annual net CO_2 savings between 587.2 thousand to roughly 2.9 million tonnes, representing between 2.7 % and 22 % of the current air travel emissions, a proportion consistent with the estimates of previous studies for other countries and markets.

4.2. Major routes

The results for the Munich (MUC) and Frankfurt (FRA) corridor are shown in Table 9, with a full schedule of flight bans for the sample week provided in Appendix B. Overall, the route MUC-FRA served around 1.5 million passengers in 2019, and it is the third busiest itinerary in the sample. Both airports being hubs, they handle many connecting passengers. Thus, if a 10 % threshold is imposed, all frequencies in this corridor would be protected. By introducing the second and third substitution levels, air traffic will be reduced by 12 % and 25 %, respectively. Only when the strictest connectivity requirements are

Table 8
Summary of results: all routes (2019).

Scenario	Baseline	10 %	35 %	60 %	80 %
Original Itinerary (pax)	41,167,620	35,067,604	29,333,408	21,231,028	11,737,492
Rail Switch (pax)	–	6,031,688	10,822,344	15,773,888	19,383,364
Banned flights	–	52,988	109,408	187,356	271,908
Airline Switch (pax)	–	68,328	1,011,868	4,162,704	10,046,764
Travel Time Inc. (%)	–	88 %	89 %	84 %	84 %
Net CO2 Savings (t/year)	–	587,264	1,204,634	2,062,966	2,938,392

Table 9
Summary of results: Munich-Frankfurt Route (2019).

Scenario	Baseline	10 %	35 %	60 %	80 %
Original Itinerary (pax)	1,500,564	1,500,564	1,319,408	1,119,378	177,960
Rail Switch (pax)	–	–	150,941	248,341	571,115
Banned flights	–	–	1,456	2,808	9,048
Airline Switch (pax)	–	–	30,215	132,845	751,489
Travel Time Inc. (%)	–	–	36 %	34 %	33 %
Net CO2 Savings (t/year)	–	–	12,587	24,277	78,237

implemented, air traffic drops by 88 %, with the peculiarity that most affected travellers will not switch directly to rail but to alternative flights. This is due to the relatively high proportion of medium- and long-distance itineraries, certainly higher than other sample routes, thus highlighting the importance of this corridor as an essential feeding route within Lufthansa's dual-hub strategy. A much lower average travel time increase compared to other routes makes the MUC-FRA corridor a natural choice for further HSR and intermodal developments to carry out the substitution policies.

A more gradual modal shift is seen in the Munich (MUC)-Hamburg (HAM) route, the second busiest in the sample. Results are shown in Table 10 and Appendix B. The longer distance between the two cities leads to high airline switch as opposed to rail to secure the fastest connection. Indeed, the increase in travel time ranges between 110 % and 113 %, meaning almost four extra hours of travel. Thus, airlines might exploit the limited seat capacity and adjust their short-haul fares to the business segment, so leisure travellers in this corridor would be pushed towards the (presumably) cheaper rail option. At any rate, the number of passengers moving to rail can go up to 1.1 million, meaning a substantial increase in rail demand on the route. Such a sharp rise cannot realistically be attained in the short term and would require a significant long-term capacity investment. The banned flights would create annual CO_2 savings of between 9.4 and 216 thousand tonnes.

Table 10
Summary of results: Munich-Hamburg Route (2019).

Scenario	Baseline	10 %	35 %	60 %	80 %
Original itinerary (pax)	1,709,084	1,644,760	1,165,788	478,296	27,040
Rail Switch (pax)	–	63,024	445,744	863,200	1,053,884
Banned flights	–	676	5,668	12,012	15,392
Airline Switch (pax)	–	1,300	97,552	367,588	628,160
Travel Time Inc. (%)	–	113 %	111 %	111 %	110 %
Net CO2 Savings (t/year)	–	9,479	79,491	168,473	215,885

A high OD route is Frankfurt (FRA)-Berlin (TXL). It was the busiest sample route, with around 2.2 million passengers in 2019 (Table 11). Introducing the strictest scenario (80 %) would only leave 940 thousand annual passengers using airline travel (a 57.3 % reduction). Looking at the flight-level data shown in Appendix B, a low-cost carrier like EasyJet would be entirely banned from the route. In contrast, the flag carrier Lufthansa would be more protected due to its hub-and-spoke network structure that facilitates connections. The savings in CO_2 would amount to 40 up to 176 thousand annual tonnes.

Finally, the Berlin (TXL)-Stuttgart (STR) route is a paradigmatic example of loss of connectivity (Table 12). With 1.4 million annual travellers, introducing the first substitution level (10 %) would reduce traffic to almost 217 thousand passengers (an 84 % reduction). Only 130 thousand passengers (a 90.4 % reduction) remain flying in the second scenario. None of the original itineraries would survive the third and fourth substitution levels. Rail switch ranges from 916 thousand (10 %) to 1.3 million annual passengers (60 % and 80 %). Passengers would face an average increase in their travel time of 108 % (nearly-four and a half hours).

Besides the threatened Berlin-Stuttgart connection, other small airports such as Mannheim, Cologne/Bonn or Saarbruecken would experience a substantial loss of air connectivity due to their high dependency on the Berlin and Hamburg hubs. However, other smaller routes, including several linking German cities to Amsterdam, are almost 100 % protected due to their high proportion of flight connections.

Full details about the level of protection against flight bans for all sample routes are shown in Appendix A.

5. Discussion

Overall, the potential modal shift caused by the substitution of short-haul flights by rail services in Germany could lead to significant carbon savings, in line with previous studies such as Robertson (2013) or Baumeister (2019). Considering the social costs of carbon in Germany (valued at €77.13/ton CO_2 as per DEFRA, 2006), the lower emissions would amount to savings between €45 and €227 million per year. However, these benefits might fall short compared to the costs of travel time lost. Using the median values of €10/h and €12/h for in-vehicle

Table 11
Summary of results: Frankfurt-Berlin (TXL) Route (2019).

Scenario	Baseline	10 %	35 %	60 %	80 %
Original Itinerary (pax)	2,200,276	1,740,908	1,625,416	1,073,956	149,604
Rail Switch (pax)	–	459,368	548,808	859,976	1,260,064
Banned flights	–	3,900	5,408	10,556	17,108
Airline Switch (pax)	–	–	26,052	266,344	790,608
Travel Time Inc. (%)	–	71 %	69 %	68 %	68 %
Net CO2 Savings (t/year)	–	40,045	55,534	108,411	175,709

Table 12
Summary of results: Berlin (TXL)-Stuttgart Route (2019).

Scenario	Baseline	10 %	35 %	60 %	80 %
Original itinerary (pax)	1,360,268	209,924	79,300	–	–
Rail Switch (pax)	–	1,143,324	1,229,904	1,272,440	1,272,440
Banned flights	–	7,176	10,036	11,128	11,128
Airline Switch (pax)	–	7,020	51,064	87,828	87,828
Travel Time Inc. (%)	–	111 %	110 %	108 %	108 %
Net CO2 Savings (t/year)	–	98,019	137,114	152,040	152,040

time and access/egress times provided by Roman et al. (2014), we estimate losses between €218 million (10 % threshold) to €1.05 billion in the strictest scenario. While we do not assert whether the emission savings and travel time goals should have the same or different weightings, it seems clear, given the large difference, that a substantial improvement in rail speeds and intermodal connectivity is needed before these substitution policies can be realistically implemented.

At the current rail speeds, the modal shift would also distort the European Commission's Flightpath2050 vision of having 90 % of intra-European travellers able to complete their door-to-door journey within 4 h (EC, 2011). This goal might constrain the scope of the substitution in the medium-term and effectively limit the chosen air corridors to those with rail alternatives under 2.5 or 3 h, instead of the broader 6-hour threshold we employ here.

Another interesting aspect of our results is the large amount of 'airline shift', i.e. air passengers shifting to alternative airline services if their original frequency is cancelled. Even though we do not monitor those effects here, passengers may choose to connect in other jurisdictions where short-haul flights are not banned if alternative connections are unavailable at the original hub. To the extent this behaviour can cause an increase in short-haul frequencies in those corridors, we might end up facing a problem of carbon leakage (emission shifting to other countries), thus defeating the purpose of the short-haul flight substitution in the first place (Oxera, 2022). In our German case study, airports like Amsterdam or Zurich might absorb the increased demand for short-haul hub connections. The evident implication is that country-specific actions, such as those initiatives seen in recent years, might be intrinsically flawed and a European-wide approach is necessary.

From an airport perspective, the short-haul slots liberated by the substitution process will not be the high-value ones arriving or departing during the airports' high-connectivity windows. It would make the most sense for airlines to retain precisely those to feed their high-yield, long-haul segments. Thus, highly congested hubs hoping that the substitution process would free up valuable slot capacity might find those benefits limited. In airports heavily dependent on short-haul feeding and without seamless intermodal integration, there may also be implications for long-haul route development if the flight bans severely curtail the feeding frequencies. A chicken-or-egg problem may appear if a new long-haul flight is proposed when no other long-haul connections operate at the airport. The long-haul frequency may require short-haul feeding to run profitably, but these short-haul frequencies may be banned because of the lack of long-haul frequencies in the first place.

Finally, in extreme situations, the lack of medium- or long-haul frequencies at certain times on hub airports can lead to forced "ghost" hours on feeding airports. Depending on their size and dependence on hubs, this can lead to either the demise of the small airport operator or severe problems with efficiently utilising airport capacity.

6. Conclusions

This paper conducted a quantitative analysis of the potential effects of substituting short-haul flights with rail services in German air travel markets. In total, 87 routes were analysed using airline schedules and passenger bookings data from April 2019. We defined four substitution scenarios, each involving minimum shares of connecting passengers (10 %, 35 %, 60 % or 80 %) to allow short-haul flights to operate within Germany. The aim is to protect Germany's long-haul connectivity when short-haul routes are crucial in serving feeding/onward services to/from global destinations.

Depending on the scenario, rail demand can potentially increase between six and 19.4 million passengers per year across the German and European rail networks –a percentage increase of between 4 % and 13 % with respect to DB's traffic in 2019. In total, the number of banned short-haul flights would range between 53 and 272 thousand per year, reducing air travel-related CO_2 emissions between 2.7 % and 22 %. However, passengers would face significant travel time increases by switching to the rail alternative, which might prove highly inconvenient for business and leisure travellers. Thus, it seems evident that any process of air-rail substitution in Germany must follow a substantial improvement in HSR speeds, capacities, and multimodal integration.

A blanket approach (with country-wide thresholds) does not appear suitable if these flight bans are ever implemented. Instead, it should be done in a more targeted fashion with route-specific thresholds, maybe first in a pilot route and later extended to others. Perhaps the Munich-Frankfurt corridor could be chosen as the pilot one due to the relatively low travel time increase of rail versus flying. Another way to implement the connectivity regulations could be to require airlines serving short-haul frequencies to block a proportion of their seats for indirect travellers to/from medium- and long-haul destinations. It would then be up to the airlines to decide which flights to keep and remove based on profit-maximising criteria. Short-haul flights without good connectivity will tend to disappear over time as airlines are forced to operate with empty seats, pushing up airfares and decreasing demand simultaneously. However, while network airlines might be able to adapt to those restrictions at their main hubs, this raises questions about low-cost carriers and their predominantly point-to-point business model that currently dominates intra-European air travel.

It is also worth remembering that flight connections depend on passenger choice. Travellers are known to disregard inline connectivity restrictions to transfer flights across unrelated airlines in what is known as 'self-help hubbing' or 'self-connectivity' (Suau-Sanchez et al., 2016). The recent popularity of this phenomenon raises another fundamental question: will the ability to operate short-haul flights depend on an airline's ability to feed passengers into another, possibly rival long-haul carrier at the same airport? Those incentives may lead dominant long-haul carriers to engage in exclusionary practices to prevent non-allied operators from accessing the desirable time slots needed to feed passengers into their long-haul frequencies at the expense of their short-haul flights. Thus, some regulatory oversight would be desirable to ensure fair and non-discriminatory access to the feeding slots for long-haul frequencies if sufficient competition is to be secured.

The conclusions arising from our quantitative analysis must be taken with caution, given our approach's evident limitations. First, we do not consider the carbon emissions from the much-needed capacity increases to accommodate the potential modal shift to rail. On the other hand, we do not take into account the non-CO_2 impacts of aviation either, such as sulphur dioxide or particle emissions, which also negatively affect air quality (EEA, 2020). This means our estimates of the potential environmental benefits might undershoot the real ones. From a technical perspective, the different flight substitution scenarios should be run incrementally to build each successive simulation upon the updated connectivity figures resulting from the passenger relocation results from the previous ones. That was, unfortunately, not computationally feasible at this stage. In addition, we do not model travel behaviour, which can be affected by airfares and other factors, such as the development of teleworking alternatives in the wake of the Covid-19 pandemic that can motivate business passengers to avoid travel. Finally, by not integrating high-speed rail capacities and timetables in our simulation algorithm, we cannot model intermodal travel itineraries (rail + flight) in sufficient detail either. That would allow us to analyse scenarios of total flight bans in the routes with the highest levels of connectivity and realistically assess how much of the modal shift could be absorbed with both current and projected levels of rail capacity. These improvements are left for future research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A Summary of sample routes and protection levels at different levels of indirect connectivity

Flight (one-way)	*Ban Status*
Amsterdam-Bremen	Protected
Amsterdam-Duesseldorf	Protected
Amsterdam-Frankfurt	Protected at 10-60%, partial substitution at 80%
Amsterdam-Hamburg	Protected at 10-35%, partial substitution at 80%
Amsterdam-Hannover	Protected
Amsterdam-Stuttgart	Mostly protected at 10-35%, partial substitution at 60%, nearly totally banned at 80%
Bremen-Frankfurt	Protected
Bremen-Munich	Protected at 10-35%, partially protected at 60%, partial substitution at 80%
Bremen-Stuttgart	Mostly protected at 10%, banned at 35-80%
Brussels-Frankfurt	Protected at 10-60%, partial substitution at 80%
Brussels-Stuttgart	Mostly protected at 10-35%, banned at 60-80%
Basel/Mulhouse-Duesseldorf	Partially protected at 10-35%, banned at 60-80%
Basel/Mulhouse-Frankfurt	Protected
Basel/Mulhouse-Munich	Protected at 10-35%, gradually banned between 60-80%
Paris (FR)-Duesseldorf	Mostly protected at 10-35%, gradually banned at higher levels.
Paris (FR)-Frankfurt	Mostly protected at 10-60%, partial substitution at 80%
Paris (FR)-Stuttgart	Mostly protected at 10-60%, partial substitution at 80%
Cologne/Bonn-Dresden	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%
Cologne/Bonn-Hamburg	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%
Cologne/Bonn-Leipzig/Halle	Partially protected at 10-35%, banned at 60-80%
Cologne/Bonn-Munich	Protected at 10%, partial substitution at 35-60%, banned at 80%
Cologne/Bonn-Zurich	Protected at 10%, banned from 35-80%
Cologne/Bonn-Berlin	Partially protected at 10-35%, banned at 60-80%
Cologne/Bonn-Berlin	Banned
Copenhagen-Hamburg	Protected 10-35%, partially protected at 60%, banned at 80%
Dresden-Frankfurt	Protected
Dresden-Munich	Protected
Dresden-Cologne/Bonn	Partially protected at 10%, partial substitution at 35%, totally banned at 60-80%
Dortmund-Munich	Protected at 10-60%, mostly banned at 80%
Duesseldorf-Amsterdam	Protected
Duesseldorf-Basel/Mulhouse	Partially protected at 10-35%, banned at 60-80%
Duesseldorf-Frankfurt	Protected
Duesseldorf-Hamburg	Protected at 10%, partially closed at 35%, banned at 60-80%
Duesseldorf-Leipzig/Halle	Protected at 10%, partial substitution at 35%, mostly banned at 60-35%
Duesseldorf-Luxembourg	Banned
Duesseldorf-Munich	Mostly protected at 10%, partial substitution at 35%, mostly banned at 60-80%
Duesseldorf-Nuremberg	Mostly protected at 10%, partial substitution at 35%, mostly banned at 60-80%
Duesseldorf-Paris (FR)	Mostly protected at 10%-35%, afterwards gradually substituted
Duesseldorf-Stuttgart	Protected at 10%, partial substitution at 35%, banned at 60-80%
Duesseldorf-Zurich	Protected at 10%, partial substitution from 35-80%
Duesseldorf-Berlin	Partially protected at 10%, mostly banned at 35-80%
Friedrichshafen-Frankfurt	Protected
Karlsruhe/Baden-Baden-Berlin	Partially protected at 10-35%, banned at 60-80%
Muenster/Osnabrueck-Frankfurt	Protected
Muenster/Osnabruck-Munich	Protected at 10%, partially protected at 35%, mostly banned at 60-80%
Muenster/Osnabruck-Stuttgart	Protected at 10%, banned at 35-80%
Frankfurt-Amsterdam	Protected at 10-60%, partial substitution at 80%
Frankfurt-Basel/Mulhouse	Protected
Frankfurt-Brussels	Protected at 10-60%, partial substitution at 80%
Frankfurt-Friedrichshafen	Protected
Frankfurt-Geneva	Protected 10-35%, partially protected at 60%, partial substitution at 80%
Frankfurt-Hamburg	Mostly protected at 10%, gradually banned at 35-60%, mostly banned at 80%
Frankfurt-Hannover	Protected
Frankfurt-Innsbruck	Protected at 10-35%, partial substitution at 60%, banned at 80%
Frankfurt-Leipzig/Halle	Mostly protected
Frankfurt-Linz	Protected
Frankfurt-Luxembourg	Protected
Frankfurt-Muenster/Osnabruck	Protected
Frankfurt-Munich	Protected 10-35%, partially protected at 60%, banned at 80%
Frankfurt-Nuremberg	Mostly protected
Frankfurt-Paderborn/Lippstadt	Protected
Frankfurt-Paris (FR)	Protected at 10-35%, partial substitution at 60-80%

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(*continued*)

Flight (one-way)	*Ban Status*
Frankfurt-Salzburg	Protected at 10-60%, partial substitution at 80%
Frankfurt-Stuttgart	Protected
Frankfurt-Zurich	Protected at 10-60%, partial substitution at 80%
Frankfurt-Berlin	Mostly protected at 10%, partial substitution at 35-60%, mostly banned at 80%
Frankfurt-Bremen	Protected
Frankfurt-Dresden	Protected 10-35%, mostly protected at 60%, partial substitution at 80%
Frankfurt-Duesseldorf	Protected
Gdansk-Berlin	Banned
Graz-Munich	Protected
Geneva-Frankfurt	Protected at 10-60%, partial substitution at 80%
Westerland-Hamburg	Mostly protected at 10-35%, banned at 60-80%
Hannover-Amsterdam	Protected
Hannover-Munich	Mostly protected at 10-35%, partial substitution at 60%, mostly banned at 80%
Hannover-Stuttgart	Partially protected at 10-35%, banned at 60-80%
Hannover-Frankfurt	Protected
Hamburg-Amsterdam	Protected at 10%, mostly protected at 35-60%, mostly banned at 80%
Hamburg-Copenhagen	Protected 10-35%, partial substitution at 60%, mostly banned at 80%
Hamburg-Mannheim	Banned
Hamburg-Munich	Mostly protected at 10%, partial substitution at 35-80%
Hamburg-Nuremberg	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%
Hamburg-Saarbrucken	Banned
Hamburg-Stuttgart	Partially protected at 10%, banned at 35-80%
Hamburg-Westerland	Protected at 10%, partial substitution at 35-60%, banned at 80%
Hamburg-Cologne/Bonn	Mostly protected at 10%, banned at 35-80%
Hamburg-Duesseldorf	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%
Hamburg-Frankfurt	Protected at 10%, partial substitution at 35-60%, mostly banned at 80%
Innsbruck-Frankfurt	Protected
Leipzig/Halle-Munich	Mostly protected
Leipzig/Halle-Stuttgart	Partially protected at 10%, banned at 35-80%
Leipzig/Halle-Cologne/Bonn	Partially protected at 10-35%, banned at 60-80%
Leipzig/Halle-Duesseldorf	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%
Leipzig/Halle-Frankfurt	Protected
Linz-Frankfurt	Protected
Luxembourg-Duesseldorf	Banned
Luxembourg-Frankfurt	Protected
Mannheim-Berlin	Banned
Mannheim-Hamburg	Banned
Munich-Basel/Mulhouse	Protected at 10-35%, partial substitution at 60%, banned at 80%
Munich-Graz	Protected
Munich-Muenster/Osnabruck	Protected 10-35%, partial substitution at 60%, banned at 80%
Munich-Nuremberg	Protected
Munich-Paderborn/Lippstadt	Protected at 10-35%, partial substitution at 60%, banned at 80%
Munich-Prague	Protected at 10-60%, mostly protected at 80%
Munich-Stuttgart	Protected
Munich-Vienna	Protected at 10%, partial substitution at 35%, mostly banned at 60-80%
Munich-Zurich	Protected at 10-35%, partial substitution at 60-80%
Munich-Berlin	Mostly protected at 10%, partial substitution at 35-60%, banned at 80%
Munich-Bremen	Protected 10-35%, mostly protected at 60%, partial substitution at 80%
Munich-Cologne/Bonn	Protected at 10%, partial substitution at 35-60%, banned at 80%
Munich-Dortmund	Protected at 10-60%, mostly banned at 80%
Munich-Dresden	Protected at 10-60%, mostly banned at 80%
Munich-Duesseldorf	Mostly protected at 10%, partial substitution at 35%, mostly banned at 60-80%
Munich-Frankfurt	Protected at 10%, partial substitution at 35-60%, mostly banned at 80%
Munich-Hamburg	Mostly protected at 10%, partial substitution at 35%, mostly banned at 60-80%
Munich-Hannover	Mostly protected at 10-35%, partial substitution at 60%, mostly banned at 80%
Munich-Leipzig/Halle	Mostly protected
Nuremberg-Vienna	Protected at 10%, partial substitution at 35%, banned at 60-80%
Nuremberg-Zurich	Mostly protected
Nuremberg-Duesseldorf	Mostly protected at 10%, partial substitution at 35-60%, banned at 80%
Nuremberg-Frankfurt	Protected
Nuremberg-Hamburg	Mostly protected at 10%, partial substitution at 35, banned at 60-80%
Nuremberg-Munich	Protected
Paderborn/Lippstadt-Frankfurt	Protected
Prague-Munich	Protected at 10-60%, partial substitution at 80%
Stuttgart-Amsterdam	Mostly protected at 10-35%, partial substitution at 60%, banned at 80%
Stuttgart-Brussels	Protected 10-35%, partial substitution at 60%, banned at 80%
Stuttgart-Muenster/Osnabrueck	Protected at 10%, banned at 35-80%
Stuttgart-Paris (FR)	Protected at 10-35%, partial substitution at 60%, mostly banned at 80%
Stuttgart-Zurich	Protected
Stuttgart-Berlin	Partially protected at 10%, mostly banned at 35%, banned at 60-80%
Stuttgart-Bremen	Mostly protected at 10%, banned at 35-80%
Stuttgart-Duesseldorf	Protected at 10%, partial substitution at 35%, banned at 60-80%
Stuttgart-Frankfurt	Protected
Stuttgart-Hamburg	Partially protected at 10%, banned at 35-80%
Stuttgart-Hannover	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%
Stuttgart-Leipzig/Halle	Mostly protected at 10%, partial substitution at 35%, banned at 60-80%

(*continued on next page*)

(*continued*)

Flight (one-way)	*Ban Status*
Stuttgart-Munich	Protected
Berlin-Cologne/Bonn	Banned
Berlin-Salzburg	Banned
Salzburg-Berlin	Protected at 10%, banned at 35-80%
Salzburg-Frankfurt	Protected
Salzburg-Berlin	Banned
Berlin-Cologne/Bonn	Partially protected at 10%, mostly banned at 35-80%
Berlin-Duesseldorf	Partially protected at 10%, mostly banned at 35-80%
Berlin-Frankfurt	Mostly protected at 10%, partial substitution at 35-60%, mostly banned at 80%
Berlin-Gdansk	Banned
Berlin-Karlsruhe/Baden-Baden	Partially protected at 10%, partial substitution at 35-60%, banned at 80%
Berlin-Mannheim	Banned
Berlin-Munich	Mostly protected at 10%, partial substitution at 35%, mostly banned at 60%, banned at 80%
Berlin-Salzburg	Protected at 10, partial substitution at 35-80%
Berlin-Stuttgart	Partially protected at 10%, partial substitution at 35%, banned 60-80%
Berlin-Warsaw	Protected at 10-35%, partial substitution at 60% and totally at 80%
Vienna-Munich	Protected at 10-35%, partial substitution at 60-80%
Vienna-Nuremberg	Protected at 10%, partial substitution at 35%, banned at 60-80%
Warsaw-Berlin	Protected at 10-35%, partial substitution at 60%, banned at 80%
Zurich-Cologne/Bonn	Protected at 10%, partial substitution at 35-80%
Zurich-Duesseldorf	Protected at 10%, partial substitution at 35-80%
Zurich-Frankfurt	Protected at 10-60%, partial substitution at 80%
Zurich-Munich	Protected at 10-35%, banned at 60-80%
Zurich-Nuremberg	Mostly protected
Zurich-Stuttgart	Protected

Source: *OAG Schedules*

Appendix B Schedule of flight bans for selected routes

Table B1. Munich to Frankfurt flights (1-7 April 2019)

MUC-FRA		10%							35%							60%							80%						
Flig	Dep.	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
LH	05:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
LH	06:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
LH	06:	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1			0	0	0	0	0		
LH	07:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	0
LH	08:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0
LH	09:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
LH	10:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
LH	11:	1	1	1	1	1			1	0	1	1	0			0	0	0	0	0			0	0	0	0	0		
LH	12:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0
LH	13:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1
LH	14:	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1			0	0	0	0	0		
LH	15:	1	1	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH	16:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0
LH	17:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1
LH	18:	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1			1	1	1	1	1		
LH	19:	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flights		0	0	0	0	0	0	0	2	2	2	2	3	2	1	4	5	3	5	5	3	2	1	1	1	1	1	9	9

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

Table B2. Munich to Hamburg flights (1-7 April 2019)

MU		10%							35%							60%							80%						
Flig	De	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
LH2	04:	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EW	04:	1	1	1	1	1	1		1	0	1	0	1	1		0	0	0	0	0	0		0	0	0	0	0	0	
LH2	05:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1
LH2	05:	1	1		1				1	1		1				0	1		0				0	0		0			
LH2	06:	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1			0	0	0	0	0		
LH2	06:			1	1	1	1	1			1	1	1	1	1			0	0	0	1	0			0	0	0	0	0
LH2	07:	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH2	08:	1	1	1	1	1			1	1	1	1	1			0	0	1	0	0			0	0	0	0	0		
EW	08:	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
LH2	09:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0
LH2	11:	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EW	11:	1	1	1	1	1		1	0	0	0	1	0		0	0	0	0	0	0		0	0	0	0	0	0		0
LH2	12:	1				1		1	1				1		1	0				0		0	0				0		0
LH2	13:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0
EW	13:				1	1		1				0	0		1				0	0		0				0	0		0
LH2	14:	1	1	1	1	1			1	1	1	1	1			0	0	0	0	0			0	0	0	0	0		
LH2	14:	1	1	1	1	1		1	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
LH2	15:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH2	15:	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH2	16:	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	0	0	0	0	0		0
LH2	16:	1		1	1	1		1	1		1	1	1		1	0		0	0	1		0	0		0	0	0		0
EW	17:	1	1	1	1	1		0	0	1	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
LH2	17:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0
LH2	17:		1		0	0				1		0	0				1		0	0				0		0	0		
LH2	18:	1	1	1	1	1		1	1	1	0	1	0		1	0	0	0	0	0		0	0	0	0	0	0		0
LH2	19:	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flights		0	0	0	1	1	0	1	6	5	6	9	9	3	8	1	1	1	2	2	8	1	2	2	2	2	2	1	1

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

Table B3. Frankfurt to Berlin (TXL) flights (1-7 April 2019)

FRA-TXL		10%							35%							60%							80%						
Flight No	Dep. Time	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
LH 172	04:15:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U2 5540	04:20:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH 170	04:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0
LH 174	05:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0
LH 38	06:15:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1
U2 5542	06:30:00	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
LH 176	06:45:00	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1			0	1	0	1	0		
LH 178	07:45:00	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	0	0	0	0		0	0
LH 180	08:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0
U2 5544	08:45:00	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0
LH 182	09:45:00	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1			1	1	1	1	0		
LH 184	10:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
LH 186	11:45:00	1	1	1	1	1		1	0	1	1	1	1		1	0	0	0	0	0		1	0	0	0	0	0		0
LH 188	12:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
U2 5546	13:05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LH 190	13:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
LH 166	14:15:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH 192	14:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0
LH 168	15:15:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH 194	15:45:00	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LH 196	16:15:00	1	1	1	1	1		1	0	0	1	1	0		0	0	0	0	0	0		0	0	0	0	0	0		0
LH 198	16:45:00	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
U2 5552	17:10:00	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
LH 200	17:45:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
LH 44	18:15:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
U2 5554	18:30:00				0	0		0				0	0		0				0	0		0				0	0		0
LH 202	19:15:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0
Flights banned		5	5	5	5	5	4	5	7	7	6	6	7	5	8	14	16	13	16	15	13	13	25	24	25	24	25	20	23

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

(*continued*).

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

Table B4. Stuttgart to Berlin (TXL) flights (1-7 April 2019)

STR-TXL		10%							35%							60%							80%						
Flight No	Dep. Time	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
U25602	04:10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EW2002	04:20:00	1	1	1	1				0	0	0	1				0	0	0	0				0	0	0	0			
EW2014	04:25:00						1							1							0							0	
EW2012	05:05:00	0	0	1	0	1		1	0	0	0	0	0		1	0	0	0	0	0		0	0	0	0	0	0		0
EW8001	06:15:00	0	1	1	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
U25592	06:20:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EW8017	07:50:00							0							0							0							0

EW2010	08:05:00	1	1	1	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
EW2000	08:10:00						1							0							0							0	
EW2008	09:00:00	1	1	1	1	1			0	1	1	0	0			0	0	0	0	0			0	0	0	0	0		
EW8003	10:10:00	1	0	0	1	1			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
U25594	10:10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EW2018	12:30:00	1	1	1	1	1	1		1	0	0	1	1	1		0	0	0	0	0	0		0	0	0	0	0	0	
U25596	13:00:00	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
EW2004	13:20:00	1			1			1	0			0			1	0			0			0	0			0			0
EW2058	14:30:00							1							0							0							0
EW20	14:5			0	0	1	1				0	0	0	0				0	0	0	0				0	0	0	0	

(*continued*).

06	0:00																												
EW8005	14:50:00	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
EW2020	16:20:00	1	0	1	0	1	1		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
U25598	17:05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EW2016	17:15:00							0							0							0							0
EW8007	18:50:00	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
U25600	18:55:00	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0
Flights banned		10	11	10	13	10	5	10	16	15	16	16	15	8	11	17	16	17	18	16	10	13	17	16	17	18	16	10	13

(*continued*).

Note: Light blue indicates the flight is allowed, red means the flight is banned. Source: OAG Schedules.

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