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Optimisation of Flight Movements in Europe

Possibilities for reducing the number of flight movements in Europe, taking the quality of the connections into account

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Abstract

Many current problems in air traffic are related to the number of aircraft movements. Overcrowding in the airspace, difficult coordination at airports, high emissions of noise and pollutants as well as complexity of airlines are side effects of too many aircraft movements.

This study examines the extent to which the number of flight movements in Europe can be reduced without change in transport performance. For this purpose, the number of flight movement for a European network of the 140 most frequently flown serviced routes will be optimised. The reference date is November 17th, 2017.

It shows that with the same passenger transport performance, the number of flight movements can be reduced to 1/3 of the current level (from 2.040 flights per day to 738 flights per day). In some cases, the quality of the connections can even be improved because all flights in the optimised network are coordinated.

This proves that the current air traffic structure has considerable weak points. There are too many redundant aircraft movements. Our proposed reform measures can contribute to the needed reduction in the number of aircraft movements without reducing passenger transport services and travel quality.

[1] The working group is indebted to a large number of experts for their valuable advice, not all of whom can be named here. Special thanks go to Dr. Thomas Maurer and Mrs. Uta Martin for their work on the manuscript.

Optimierung der Flugbewegungszahlen in Europa

Möglichkeiten zur Reduktion der Zahl der Flugbewegungen in Europa unter Berücksichtigung der Verbindungsgüte[2]

Zusammenfassung

Viele aktuelle Probleme im Luftverkehr hängen mit der Zahl der Flugbewegungen zusammen. Überfüllungen im Luftraum, erschwerte Koordination an Flughäfen, hohe Emissionen von Lärm und Schadstoffen sowie große Komplexität der Airlines sind Begleiterscheinungen zu vieler Flugbewegungen.

Die vorliegende Studie untersucht, auf welchen Umfang sich die Zahl der Flugbewegungen in Europa bei unveränderter Transportleistung reduzieren lässt. Dazu wird eine Optimierung der Flugbewegungszahlen für ein europäisches Flugnetz der 140 meistbeflogenen Strecken vorgenommen. Stichtag ist der 17. November 2017.

Es zeigt sich, dass bei gleicher Passagiertransportleistung die Zahl der Flugbewegungen auf 1/3 des gegenwärtigen Niveaus reduziert werden kann (von 2.040 Flügen pro Tag auf 738 Flüge pro Tag). Dabei kann die Verbindungsgüte teilweise sogar verbessert werden, weil alle Flüge des Netzes aufeinander abgestimmt sind.

Das bedeutet: Die gegenwärtige Luftverkehrsstruktur besitzt erhebliche Reserven. Es gibt zu viele Flugbewegungen, die redundant sind.

Es werden im Beitrag Reformmaßnahmen vorgeschlagen, die zu einer Verringerung der Zahl der Flugbewegungen (ohne die Passagiertransportleistungen und Reisegüte zu verringern) beitragen können.

[2] Für wertvolle Hinweise ist der Arbeitskreis einer Vielzahl von Fachleuten zu Dank verpflichtet, die hier nicht alle namentlich genannt werden können. Besonderer Dank gebühren Dr. Thomas Maurer und Frau Uta Martin für deren Arbeit am Manuskript.

Optimisation of Flight Movements in Europe

Table of Contents

List of Figures

List of Tables

1 Problem and Research Question

Anyone who at any given point in time looks at the planes simultaneously in the air over Europe (Figure 1), wonders involuntarily whether this picture represents an efficient and optimal system. It seems obvious that improvements would be conceivable.

Figure 1: Planes over Europe, 2nd October, 2018 at 5:30 pm[3]

The annual passenger volume in Europe rose from 800 to almost 900 million persons per year between 2008 and 2017.[4] Over the same period, the number of aircraft movements within Europe fell from 8 ½ to around 8 million flights per year (Figure 2).

Flight movements and passenger numbers are decoupled from each other.[5] Decoupling the number of flight movements from the growth in passenger numbers and eventually decreasing the absolut number of flight movements has several advantages:

- The complexity of air traffic is declining.
- The airspace is getting safer.
- Airlines control less complex structures.
- Fewer aircraft and crews, especially pilots, are needed.
- The capital commitment might decrease.
- Emissions might fall.[6]
- The noise problem could be relaxed.[7]

[3] The picture is taken from www.flightradar24.com
[4] Statistisches Amt der Europäischen Union (2017).
[5] Umweltbundesamt (2017a), p. 64.
[6] Umweltbundesamt (2017b).
[7] Bundesumweltministerium (2007), p 5.

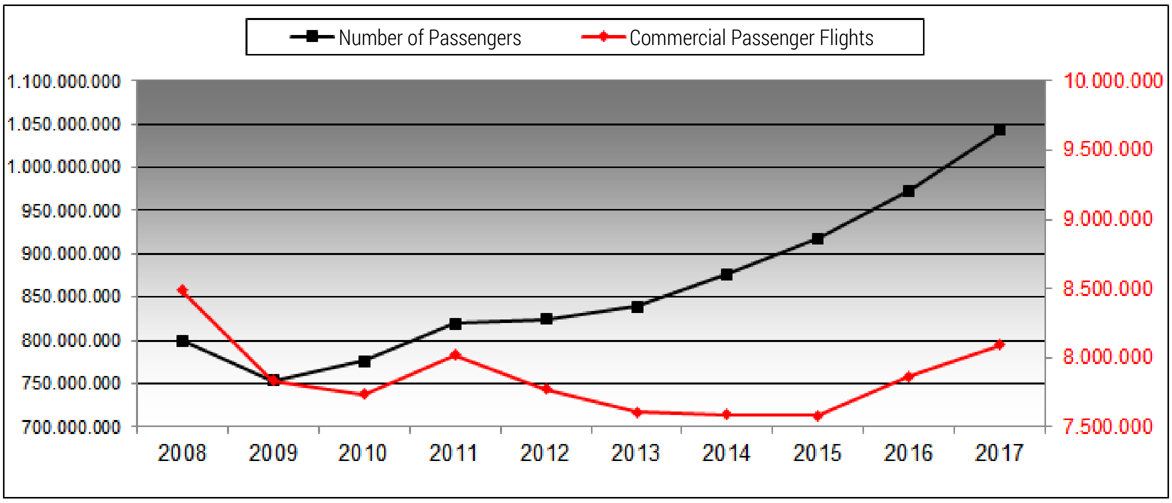

Figure 2: Number of passengers (upper line) and Commercial Passenger Flights (lower line) in Europe

In the past, decoupling of growth in passenger numbers from aircraft movements was achieved through higher capacity utilisation and the use of larger aircraft. The deployment of a Boeing 747-400 by Lufthansa on the short-haul route between Frankfurt am Main (FRA) and Berlin Tegel (TXL) following the insolvency of the airline Air Berlin in 2017 was spectacular.[8] Other modes of transport are also relying on larger units: The German railways, for example, are planning ICE-trains with 13 railcars (ICE 4), which will carry 913 passengers. In road freight traffic, the overlong "EuroCombi" is being considered. On average, European air traffic transports only around 150 passengers in one means of transport.

Many current problems in air traffic are related to the number of aircraft movements. Only a few of these should be mentioned:

- Overcrowding in airspace contributes to delays and risks.
- The ever-increasing number of passengers with unchanged aircraft sizes inevitably leads to ever more difficult complexity on the ground, in the air and in the organisation of air traffic for airlines and air traffic control.
- The use of a smaller number of large aircraft tends to cause fewer emissions of pollutants compared with many small aircraft.
- Fewer aircraft movements reduce the noise problem caused by take-offs, landings and overflights at low altitudes.
- Fewer aircraft movements ease the shortage for pilots.
- The manufacturers Boeing and Airbus are working at full capacity and are postponing a mountain of orders for smaller aircraft. Turning to larger aircraft could have a relaxing effect.

If air traffic is to continue to grow, then reducing the number of aircraft movements in absolute terms or relative to the number of passengers carried is an unavoidable "must". The question is how to promote and support this development.

[8] Kurpjuweit, K. (2017).

The Aviation Working Group of Technical University of Chemnitz has turned its attention to this question. In a first study, (i) the potential for reducing aircraft movements was to be determined and (ii) incentives to achieve the objective were to be considered. The two research questions were:

1. By what amount can the number of flight movements in Europe be reduced under the maxim of taking all passengers willing to travel into account?
2. What incentives are necessary in order to get closer to this goal in practice?

2. Methodology

This study examines these two questions. The procedure is as follows:

- The study is based on annual statistical data from Eurostat and data from a separate survey of all aircraft movements in Europe on a reference date 17th November, 2017. These data provide information on all individual flights, the number of passengers carried, the desired routes and aircraft utilisation.
- These data are used to filter out the most important routes on which more than 1 million PAX travel transported each year. This results in 140 routes with 33 destinations for which we create an optimised flight plan with a reduced number of flight movements (Figure 3).
- The optimised flight schedule ensures that all passengers could reach their destinations on the reference date.
- In the optimised flight plan, the passengers travel with the smallest aircraft to fit all passengers in order to achieve a high capacity utilisation of the aircraft. A secondary condition is the guarantee of a minimum duration of use of the aircraft per day.[9] The average aircraft operating time of the (manually calculated) flight plan is 8:02 hours per day.
- The current system of hubs and spokes will be maintained.
- The *minimum connect time* (MCT) of all airports is observed.
- The *maximum available connect time* (MACT) of the travellers is observed.
- The maximum capacities of the airports with regard to permissible aircraft sizes are observed.
- Night bans are observed.

The reduction in the number of aircraft movements is achieved with three measures:

- Exploiting the potential of large aircraft
- Full use of the hub and spokes system
- Aggregation of flights within a time frame

[9] The system can also be easily maximized for the service life of aircraft. Then the secondary condition is the degree of utilization. As a general rule, maximizing the flight duration per day tends to require larger aircraft that can be used anywhere.

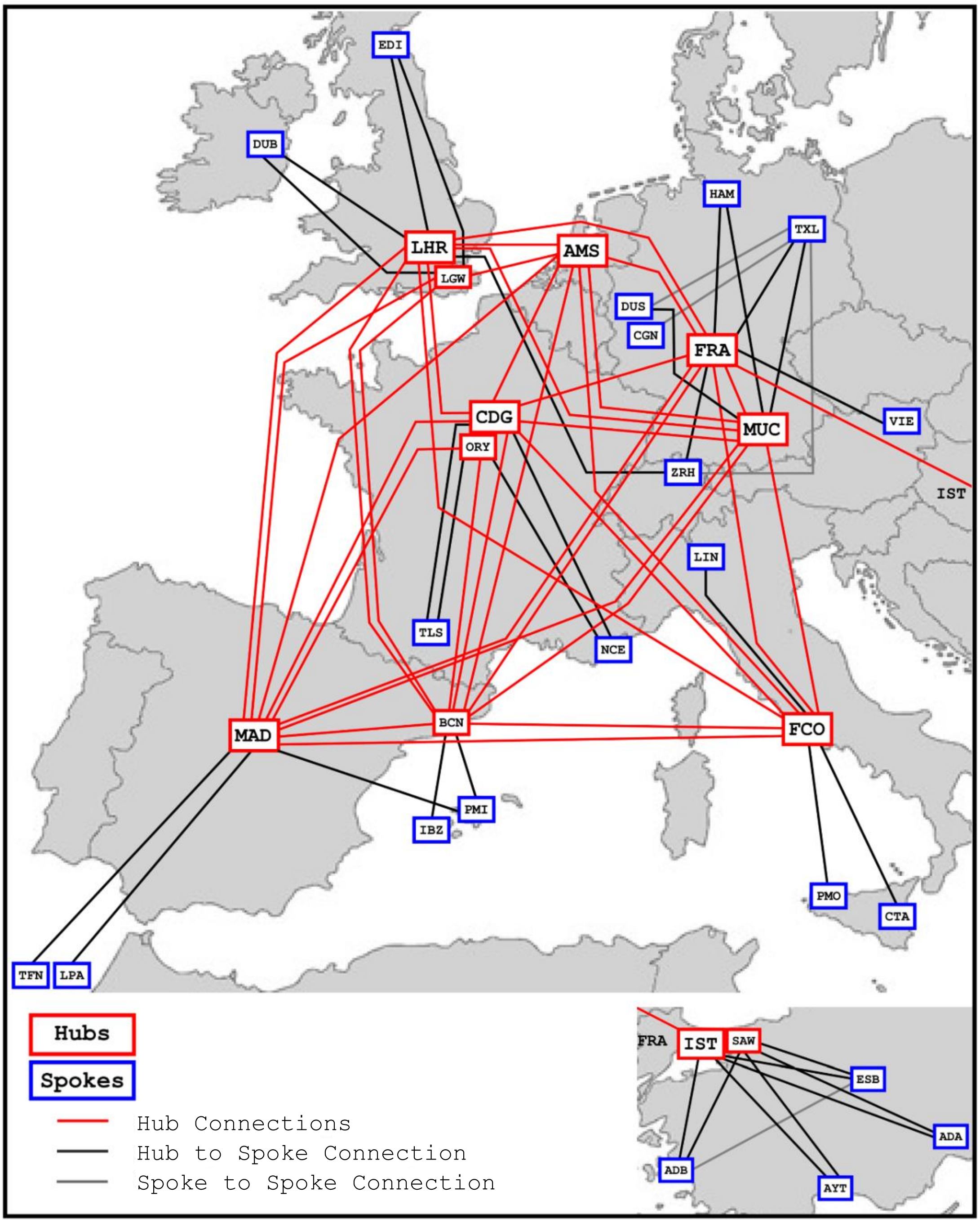

Figure 3: Considered complete flight network

Aggregated trips between two airports are the key to reducing the number of flight movements. Instead of travelling e.g. from Frankfurt to London (or from Paris to Toulouse) with two aircraft of different airlines in quick succession, sometimes at intervals as short as 10 or 15 minutes, these flights are combined into one flight.

This combination or aggregation requires a decision about the new departure time. Railways demonstrate that a regular rhythm of one or two hours is sufficient to adequately satisfy travel needs. We take this concept up. The aimed rhythm for air traffic can be derived from the wave structure of air traffic in the hub and spoke system. A typical hub has 4 to 5 waves distributed throughout the day. This means that travellers can reach their destinations at the spokes every 3½ to 4 hours. More frequent departures at the spokes do not make sense because they only would extend the waiting time at the hubs until the departure of the next wave. Based on the typical wave structure at hubs, we divide the day into five time frames that correspond to the following travel needs[10]:

- Time frame 1 corresponds to travel that takes place as early as possible in the day to conduct business meetings or other activities at the destination in the morning.
- Time frame 2 corresponds to trips that start comfortably in the morning without getting up early and arrive at their destination at around noontime.
- Time frame 3 represents trips that take place in the afternoon, e.g. to be at the destination in time for an evening event.
- Time frame 4 corresponds to trips that are performed after the end of a working day. Night flight restrictions may apply.
- Time frame 5 represents night travel. Night flight restrictions must be taken into account.

[10] Thießen, Jahn, Troll (2005), p. 10f.

3. Results

What are the results we achieved?

The optimised flight schedule is based upon the maxim that there can be flights from any of the 33 airports to any other in any time frame. More detailed information on the procedure can be found in a long version of this study which can be obtained at our website (please find the link in the appendix). Below we present results, and then reform proposals. Table 1 summarises the results:

	Initial situation		1. case: no restrictions	
	Total number of flights at the reference date	Ø PAX per flight	Number of flights	Min. PAX per flight
(Initial) total:	2040		698	
% of initial total:	100%		66%	
Average # of flights per day and route	29,14	140	9,97	409
% of initial avg.	100%		66%	292%

	2. case: restriction aircraft size		3. case: aircraft size and runway	
	Number of flights	Min. PAX per flight	Number of flights	Min. PAX per flight
Case total:	708		738	
% of initial total:	65%		64%	
Average # of flights per day and route:	10,11	404	10,54	387
% of initial avg.	65%	288%	64%	276%

Table 1: Overall results: Number of flights and passengers per flight

Table 1 shows 4 quadrants. The starting position is shown in the upper left quadrant. For the reference date (17 Nov 2017), we recorded that were 2,040 flights on the 140 individual routes. On average, there were 29 flights between two destinations carrying 4,034 people. Each flight carried an average of around 140 PAX.

The remaining three quadrants show the results of the optimizations in the form of three treated cases.

- Case 1 *"Long-term optimum":* The first case is an optimised flight plan without restrictions that reflects the possibilities that can be achieved in the long run. We assume that there are enough large aircraft to carry all passengers in a time frame and a route at once and that all airports have invested in the necessary infrastructure. In this case, the number of flights in Europe between the destinations of the network can be reduced from 2,040 per day to 698, equal to a reduction of 66%. The average number of passengers per flight rises from 140 to 409.
- Case 2 *"Current aircraft size":* In the second case the restriction of the aircraft size was introduced. We assume that the corresponding number of passengers must be carried by aircraft of current sizes. In

fact, this restriction only has an effect on a single flight connection; for all others, the aircraft of available sizes are sufficient. The exception is the route between the Istanbul-Atatürk (IST) hub and the Spoke Izmir-Adnan Menderes (ADB). Each flight would have to carry 1,092 passengers, which is not possible with the existing aircraft sizes and requires an additional aircraft. For this reason, a third aircraft was used in shuttle flight to realize the connection. By using this third aircraft between IST and ADB, the number of flight movements in the entire network increases slightly to 708 flights per day. On average, around 404 passengers are carried per flight. Compared to the initial situation, this corresponds to a 65% reduction in flights.

- Case 3 *"Short-term solution":* The third case reflects a solution which could be realized possibly in the not too far future. It is assumed that no airport can immediately invest in runway projects and that only the currently available aircraft sizes can be used. This limitation was noticeable for four connections: IST-ADB, IST-ESB, SAW-ADB and SAW-ESB. A third aircraft each had to be used in shuttle flights to relieve the load. For the IST-ADB connection, only the size of the three aircraft already in use (see case 2) had to be adapted. Overall, the total number of aircraft movements in the network is reduced to 738, starting from the initial case. On average, there are around 387 passengers in each aircraft. Compared to the initial data, flight movements can thus be reduced by 64% and the average number of passengers per flight increased by 276%.

The following table shows how the optimized flight plan affects individual airports. We show Frankfurt, Munich and Berlin as examples.

Utilisation of airports before and after optimization of flight movements for the reference date and the network				
	Initial Situation		*Optimized Case*	
	PAX	Flight movements	PAX	Flight movements
Frankfurt	40.372	308	40.776	118
Munich	38.528	298	38.948	100
Berlin	23.484	182	23.614	50
Total	**102.384**	**788**	**103.338**	**268**

Table 2: Utilization of airports before and after optimization – examples

As Table 2 shows, the number of travellers (PAX) remains roughly unchanged after optimization, while the number of flight movements falls significantly. [11] [12]

[11] Minor discrepancies are also due to slight differences in the data because most of the data come from the actual European flight schedule of the reference date, while some come from Eurostat annual data. This is particularly true for aircraft utilisation, which is only available as an annual average. If this average load factor is used to make calculations for the specific reference date, there may be slight discrepancies.

[12] The former is due to the fact that the basic structure of the hubs and spokes system remains unchanged during optimization, so that Berlin does not lose any travellers as a spoke and the hubs in Munich and Frankfurt remain integrated into the routes. At some

The average aircraft operating time is 8:02 h per day. We calculated the flight plan manually. The value can certainly be significantly increased if optimization programs, triangular flights or more complicated flight paths are used.[13]

One important point concerns the *aircraft*. In our analysis, we have only considered the aircraft *sizes*, not the aircraft *types* themselves. Currently, wide-body aircraft with take-off weights of 136 t and above are not designed for short-haul flights. Their design has been optimized for long flights with few take-offs and landings. Although these aircraft types could also be used in the flight plan presented here, this would not be economical in the long run. New designs are therefore required for increased short- and medium-haul operations. Of course, this is in no way an argument against the concept presented here and is not something that could not be realized in the medium term. The fact only proves how the two remaining competitors on the aircraft manufacturer market have adapted to very specific air traffic concepts. We make suggestions as to which aircraft size classes should be used in the new designs in order to achieve a good compromise between universal applicability (i.e. long service life per day) and high utilization per flight.

The following Table 3 shows the aircraft *sizes* required in the optimized flight plan:

A320 neo	6
A321 neo	14
A330-800 neo	2
A340-600	4
A350-800	10
A350-900	20
A350-1000	34
Boeing 737-700	1
Boeing 787-8	6
Boeing 747-8	8
747-400D	20
A380	18
Total	**143**

Table 3: Aircraft *sizes* needed in the optimized flight plan
using the example of conventional types (left column) and their number (right column)

points in the optimized flight schedule, direct flights, which are offset by flights via hubs, are also eliminated. This may result in slightly different PAX numbers.

[13] With very few exceptions (due to night flight restrictions), it is also possible, for example, to use the aircraft over the night on medium and long-haul flights and thus further improve the load factor of the aircraft. For this reason, the total utilisation of the aircraft can only be determined within the established flight network. Example route FRA-TXL: aircraft 1 arrival 22:00 in FRA; 22:00 plus 0:45 MCT = 22:45 earliest take-off. Machine must start 08:50 from FRA to TXL again, i.e. 08:50 minus 0:45 MCT = 08:05 latest arrival from night flight. Therefore, possible time for long distance: from 22:45 h to 08:05 h = 09:20 h. I.e. destination may be minus the MCT of the destination airport (e.g. 1h) 08:20 h:/2 = 04:10 h maximum flight time away. Total load could be increased by 08:20 h.

4. Reforms

The question arises as to what *reforms* are necessary and what *incentives* are needed ore useful to be put in place in order to move closer to the goal of reduced aircraft movements in practice.

Three groups of incentives are conceivable or necessary: One group starts with the (i) handling of slots and hourly corner values. A second group (ii) helps airlines to bear the business risk of investing in large aircraft with high seating capacity. The third group (iii) aligns the behaviour of passengers.

a. Slots

Reduce slots and hourly reference figures.[14] The hourly corner values[15] of the airports are reduced. Fewer slots are offered at the airports, especially at the hubs. The slots will be offered at a greater time interval. This increases the probability of punctuality. It also forces the airlines to use larger aircraft to take all passengers willing to travel in one period in one wave.

Encourage size-based fees. Airports have long been charging fees that take into account the size of aircraft. In the future, large aircraft with large passenger capacity should benefit from significant fee advantages to encourage switching to larger aircraft. Smaller aircraft will pay the standard rate or increased charges.

Internalisation of external effects.[16] A variant of size-dependent charges exists if the charges per flight are designed in such a way that they fully cover the external costs of flying. This creates a monetary incentive to reduce the number of flight movements.

Less passenger-related fees. Airports currently share in the business risk of airlines by waiving fees for aircraft with low load factors. This spurs airlines on to offer additional flights because they have to pay little for low load factors. This is counterproductive. Such graduated charges reward the increase in the number of flights and should be dropped.

Punish failure to comply with slots. Airlines that do not use slots due to delays or other problems pay penalties. This will result in airlines only making safe schedules. Punctuality increases. The hub and spoke system proves its functionality. The time frame concept is sufficient because passengers reach their destinations in time. There is little demand for additional direct flights.

b. Airline Support

The purchase or lease of larger aircraft may constitute an economic risk in the phase of the system's start. As useful as larger aircraft are for the system as a whole, their purchase is risky for the individual airline. In other sectors, the trend towards size is already in full swing. The aviation industry has been hanging on to small aircraft for too long. The difficulties of the A380 are due to wrong structures in the airline industry. How can airlines be helped to shoulder the economic risk of large aircraft?

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[14] Lufthansa-Chief Carsten Spohr made such a suggestion. Helmut Breidenbach, President of the Bundesvereinigung gegen Fluglärm (BVF) agreed in October 2018.

[15] Hourly reference figures.

[16] Bickenbach, Soltwedel, Wolf (2007), p. 109.

Punishment for idle capacity costs. When airports adapt to larger aircraft in order to be able to quickly channel large numbers of passengers through the handling process in a batch, small aircraft with few passengers lead to underutilization of the systems set up. These airlines must be punished for this. Airlines with small aircraft have to pay a surcharge for too few passengers.

Newcomer airlines that want to skim pensions on individual routes with small aircraft without great risk should not receive any support. Only airlines that operate large aircraft with the prospect of a good workload are eligible for support. Incentive systems must be changed accordingly.

Air transport agreements. Large airlines with sufficient financial strength who invest in large aircraft must be protected from ruinous competition among themselves. Not all Airlines altogether are able to operate large aircraft on all routes. Where air traffic agreements are negotiated bilaterally, air rights can be divided by negotiation. Within the EU, the Commission must create or allow appropriate regulations to encourage airlines to turn to large aircraft without unbearable competition risk to reduce the number of aircraft movements.

c. Travellers' Behaviour

The behaviour of travellers can also be used to enforce the new system. There are considerable misguided incentives here at the time being.

Facilitate airline integration. Currently, many airlines have set the course in such a way that travellers fly with only one airline or airline group. This is suboptimal because travellers cannot use the entire network. Rather, they only use the part of the network operated by a particular airline or airline group - which is always less than the whole. If you travel from Frankfurt to Inverness, you cannot combine your best flight from Frankfurt to London with one airline and your best flight from London to Inverness of another airline. The industry makes it unattractive to combine flights of different airlines. This is outdated and not progressive. Combining airlines in one trip must be facilitated just in rail transport.

Mileage bonus. Last but not least, it is also the system of mileage credits that leads travellers to look at their trips not according to the main service, but (also) according to the additional service. This is especially true for business travellers as business trips are paid for by the company and the privatised mileage credit therefore has an incredible value for the traveller. The passenger gains on each trip, whether it is necessary or not and whether the chosen route is optimal or not.

Advanced travel procedures. For an efficient and optimized overall system, it must be easier for travellers to change airlines during a trip. There are many different models for this. In rail traffic, to give one example, it is absolutely usual to start a journey with a regional railway company, change to another company (e.g. Deutsche Bahn) at a changeover station and to continue with a (different) regional companies train at another changeover station.[17] Only in this way the huge railway network can be used efficiently. The aviation industry, on the other hand, operates its anachronistic system of managing everything via its own lines. It has set up a network, but no one can take full advantage of it. This leads to duplication and tripling of redundant flights (Figure 1). It is therefore necessary to demand that the air transport industry should adopt systems similar to

[17] Practically everywhere, where there are networks, the use by several providers is usual. This applies to the Internet as well as many other networks. In international money transfes, for example, the client does not care which correspondent bank a transfer is routed through. And also the banks have nothing against it, if foreign correspondent banks are involved.

those of the railways, where every traveller can use the entire network. To this end, each participating provider of a partial route or partial service must be fairly remunerated, but on the other hand no obstacles must be created for the traveller to change carriers within the network. *Once this has been achieved, the door will be wide open to reducing the number of aircraft movements in Europe.*

5. Summary

The present proposal involves a radical reorientation of air transport organisation. In view of the world climate changes, such a reorientation is inevitable. In contrast to other innovative proposals, the present one does not take any business away from anyone. There will be no reduction in the number of passengers - the existing passenger flows are simply distributed in a different way. The question is how this could be done in practice. The answer certainly requires further consideration. This article only outlines rough lines of thought on how the gradual approach to optimal utilisation of partial routes and available transport capacities can be achieved – e.g. via a common IT platform for booking all commercial airlines and distributing ticket revenues.

- First of all, the necessary reduction in the number of aircraft movements should become a political objective. IATA, booking portals such as Amadeus and others must be involved.
- Ad hoc incentives to merge flights could be installed to launch the system. This can be initiated, for example, simply by reducing the number of slots in loaded hours at airports. No competition policy objections should be raised against agreements between airlines regarding the allocation of capacity in slot-reduced periods. There are models for this: the state itself, for example in the case of international air transport agreements, constantly makes such allocations. Treaties following Brexit could serve as first examples.
- Ultimately, an airline should receive the license for a certain route in a certain time window. Competition and quality assurance can be guaranteed, as in rail transport, by concessions on individual routes that are limited in time.
- An alternative would be to charge high taxes to internalise the negative externalities of aircraft movements. The airlines would then automatically optimise the number of aircraft movements ro reduce these penalties. This alternative seems to be less attractive for airlines.
- The next step would be to make it easier for passengers to combine airlines within a single booking. IATA could be commissioned to develop such a system for charging ticket prices. There should be fixed rules for the distribution of travel revenue between carriers that have concessions on certain routes. In rail transport, this has already been implemented throughout Europe. Also, air transport groups have such partial service charges. All related problems have already been identified and largely solved.
- Reservations via booking platforms such as Amadeus would eject entire routes, quote total prices and make bookings for all partial routes (just as for rail traffic), analogous to rail information.
- In addition, travellers could also book and change bookings directly with the airlines as before. The information computer of an airline would then probably take its own preferences into account and, for example, prefer or suggest travel options with as high a proportion of its own airline as possible.

In summary, there are numerous ways to start the new system. Many of the problems involved have already been solved. Others need further considerations. Politicians should give the start to proceed with more detailed analyses.

Note

This article is an abridged version of a longer study. The full study contains further explanations of the methodology and the optimization process (in German language). It further contains all data of the optimized flight plans for 140 European routes and airports involved.

The full study can be downloaded using the following link:

https://www.tu-chemnitz.de/wirtschaft/bwl4/pub/Nollau_Thiessen_DE.pdf

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