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IS INCREASING SEAT CAPACITY COMMON PRACTICE OF AIRLINES AT CONGESTED AIRPORTS?

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ABSTRACT

If on the one hand the overall demand for air transport grows, but airport capacity is on the other hand not anymore available at congested airports we would assume that airlines offer flights with more seats in order to cope with demand. Analysis of developments of frequencies and average seat capacity at congested and not yet congested airports has shown that the hypothesis of bigger aircraft in congested situations is valid in most instances, however, not at all airports. London Heathrow is the most congested airport (with the highest capacity utilization index) worldwide, however, average seat capacity did not change in the last five years. San Diego has been the airport with the highest flight volume of a single runway airport, and the average aircraft size grew by roughly 15 seats since 2006. While at the majority of Asian and European airports with high capacity utilization average seat capacity of flights has grown in the past that was not the case at most high volume airports in the US. The objective of the paper is to report on the thorough analysis of the development of average seat capacity at congested airports – as contrasted to the situation at not yet congested airports - and to find out about the reasons for airlines to increase the number of seats at congested airports, by means of statistical analysis reflecting variables like flight volume, degree of congestion and network development.

KEYWORDS: Average seat capacity of flights, efficiency of passenger throughput at constrained and unconstrained airports, causal factors of average seat capacity development, relationship between average seat capacity and market conditions.

TOPIC AREAS: Airline strategy, management and operations; airport demand management & airport-airline relation.

1. Introduction

Capacity constraint analyses of the global airport system have shown (Gelhausen et al, 2013) that in 2008 only a small number of airports have been congested, among them important airports like London Heathrow, New York LaGuardia, and Paris Charles de Gaulle. 10 airports have been identified as capacity critical airports, which handle about 6 % of all flights. This means, too, that the great majority of flights were operated under unconstrained conditions. According to the demand forecasts of the aircraft manufacturing industry and public institutions like ICAO we have to assume that the number of flights will increase in future, probably not as strong as the passenger traffic, measured in Pass-kms, however, given a long term growth rate of around 5 % for the traffic development, a growth rate of 3 % for the flight volume seems not implausible. The number of flights would thus grow by about 30 to 40 % in 10 years. The constraint analysis has demonstrated that traffic conditions at airports, still favourable in 2008, will soon deteriorate, since many more airports will suffer from bottleneck situations. The majority of flights in the main airport network worldwide will be affected by capacity constraints.

The impact of capacity constraints on flight activities can be mitigated by capacity enhancing measures like new runways. Investment options like new infrastructure are more and more subject to public opposition, at least in Europe and the US, since the population in the neighborhood of airports is against higher levels of noise pollution due to more aircraft movements. Interconnecting high speed and regional trains with airports is another investment option relieving the pressure on short distance flights, however, also more and more opposed by the affected population. Options of reorganizing traffic operations are gaining therefore in importance. They may be:

- Increasing prices of landing charges; often not feasible due to fee regulation at airports;
- Using more intensively off-peak times; at hub airports only feasible to a small degree, since incoming and outgoing traffic is time coordinated;
- Diverting traffic to less congested airports; often contradictory to requests of passengers and hub operations;
- Based in technological progress, changing air traffic control (ATC) rules in order to augment the throughput of aircraft movements; this measure will raise capacity probably to a degree which corresponds to the traffic growth of just a few years;
- Using aircraft with higher seat capacity.

Using bigger aircraft and aircraft with higher seat density are measures that airlines use to varying degrees depending on factors like level of airport congestion, airline fleet, network structure, competition with other airlines, etc. The paper will concentrate on this measure and report on statistical analyses regarding the development of average aircraft size (no. of seats per flight) at constrained and unconstrained airports worldwide as well in world regions. A model has been developed which relates average aircraft seat capacity with influencing factors like degree of airport congestion and average flight distance. The structure of the paper is as follows:

- Selection of constrained and unconstrained airports for the analysis of aircraft seat capacity;
- Development of average seat capacity at constrained and unconstrained airports worldwide and in world regions;
- Airport specific developments of average seat capacity;
- Factors causing airlines to raise seat capacity of flights;
- Model relating average seat capacity with influencing factors;
- Conclusions.

2. Selection of Constrained and Unconstrained Airports for the Analysis of Aircraft Seat Capacity

A working hypothesis at the outset of the analysis has been that airlines that want to serve a growing market increase their capacity by offering more seats on existing as well as new routes. At congested airports airlines would do so by deploying bigger aircraft and at uncongested airports by increasing first of all the number of flights. Capacity constraints would hinder airlines from increasing frequencies, whereas at airports with capacity surplus airlines would rather prefer to offer more flights in order to better comply with the needs of travelers, in particular business travelers.

Our analysis of the development of average seat capacity of flights offered should then differentiate between congested and uncongested airports, however would not necessarily have to include all airports worldwide. The global air traffic network consists of several thousand airports, most of which handle only small numbers of aircraft movements. An analysis of traffic distribution in the global network of around 2400 airports, which are part of the international scheduled air traffic, has shown that traffic is very concentrated on a relatively small number of airports (Gelhausen et al, 2013). In 2008, 50 % of the total number of flights has been handled by just 100 airports, corresponding to 4 % of all airports, and 95 % of all flights were concentrated on the top 1000 airports (41 %). Correspondingly, there have been 1400 airports with volumes as low as to account for just 5 % of the total volume.

For the analysis of seat capacity of flights we have selected those airports with a threshold traffic volume of 70 000 air transport movements (ATMs) in 2010. We could have selected other threshold volumes as well. The decision to choose the volume of 70 000 ATMs was influenced by the fact that single runway airports with a volume in that order have a 5 % peak hour volume of around 20 ATMs which corresponds to about 50 % of the hourly capacity of a runway under IFR conditions. Airports with smaller volumes can be seen as airports of rather regional importance without any capacity problems in the near future. In 2010, there were 178 airports worldwide with traffic volumes exceeding 70 000 ATMs, handling about two thirds of the total flight volume.

In order to identify constrained airports in the sample of 178 airports we have applied an approach which has been described in an earlier paper, which deals with the problem of airport constraints and the future capability of airports to cope with the growing traffic (Gelhausen et al, 2013). Based on OAG data, we have calculated for each airport the 5 % peak hour volume and the average daytime hour volume of the year 2010. The ratio of these two volumes has been defined as the capacity utilization index (CUI). Both the 5 % peak hour volume and the CUI are indicators of to what degree the airport is constrained or not. A high traffic volume in the 5 % peak hour indicates congestion in peak times of the day, whereas a high value of the CUI indicates that congestion occurs also during normal traffic hours of the day. If the values of these indicators exceed certain threshold values – in the case of the 5 % peak hour volume depending on the capacity class of the airport (single runway, two parallel runways, etc.) - then the airport can be regarded as an airport with congestion problems over longer operating hours of the year, the duration depending on the value of the thresholds.

Airport congestion is not a clear cut phenomenon; the term encompasses the whole transition area between constrained flow conditions at some peak hours to dense traffic conditions with high delays for each aircraft over longer periods of time. For the purposes of differentiating airports with and without capacity problems in this analysis we have defined as threshold values a capacity utilization of around 75 % in the 5 % peak hour and in addition a CUI of 65 %. In the case of a single runway airport this means that the airport is regarded as constrained if the 5 % peak hour volume exceeds 30 ATMs and the normal day hour utilization exceeds 65 % of the 5 % peak hour volume, assuming that the 5 % peak hour volume of 30 and more ATMs reflects a near capacity volume.

As a result we have identified 43 congested and accordingly 135 uncongested airports in the sample of 178 airports worldwide with a traffic volume of more than 70 000 ATMs in 2008 and 2010 respectively. The majority of congested airports (about 50 %) belong to those airports with high traffic volumes and runway systems of three and more runways, only seven single runway airports are regarded as constrained airports. Examples of the high volume airports with capacity constraints are London Heathrow (LHR), Charlotte (CLT), Washington R. Reagan (DCA), Newark (EWR), Istanbul (IST), and Beijing (PEK). Among the single runway airports are San Diego (SAN) and Geneva (GVA), the other constrained airports of this class are Chinese airports. Other airports with capacity problems are Guangzhou (CAN), Munich (MUC) and Jakarta (CGK) in the category of airports with two independent parallel runways, Seattle (SEA), Mexico City (MEX) and London Gatwick (LGW) in the category of airports with two dependent parallel runways, and New York La Guardia (LGA), Delhi (DEL) and Melbourne (MEL) in the category of airports with two crossing runways.

3. Development of Average Seat Capacity at Constrained and Unconstrained Airports Worldwide and in World Regions

The analysis of 178 airports has shown (see Fig. 1) that average seat capacity per flight has grown in the past, in the global network by almost 10 % from 114 seats in 2006 to 125 seats in 2012. In the same time the total number of aircraft movements at more than 3000 airports has increased by 11 % from 58 to about 64 Million, while the number of passengers has grown by 26 % from 4.7 to 5.94 Billion. The number of flights has grown thus weaker than the demand, partly due to the fact that on average more seats per flight have been offered. In addition, the load factor has increased as well. The trend towards bigger aircraft has prevailed already before 2006; in the year 2000 average seat capacity were about 105 seats per flight in the global network. Since 2000 average seat capacity has grown thus by almost 20 % worldwide.

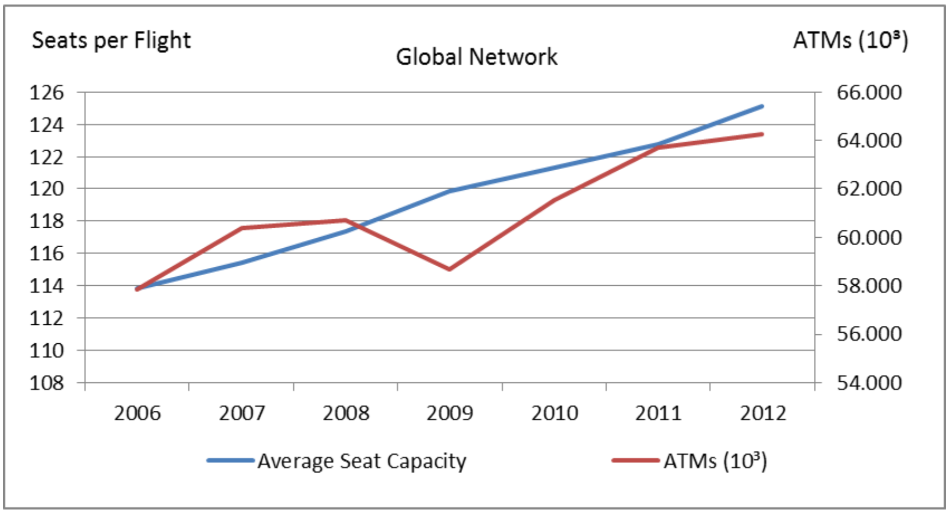

Fig. 1: Average Seat Capacity and Number of Air Transport Movements in the Global Network of 178 Selected Airports 2006 – 2012 (Source: OAG)

If we differentiate between airports with and without capacity problems (with traffic volumes of more than 70 000 ATMs in 2010) we see that in both networks the average seat capacity has increased as well (see Fig. 2 and 3). Average seat capacity has grown by 8.5 % from 130 to 141 seats at the 43 constrained airports and by 9 % from 123 to 134 seats per flight at the 135 unconstrained airports. Airlines have thus deployed in general bigger aircraft into the market, regardless of the constraint situation at airports. As can be seen, air traffic at constrained airports has grown faster than at unconstrained airports, where traffic has gone up and down and did not change in volume very much between 2006 and 2012. One reason for the different developments is the fact that the most important airports including hubs belong to a higher degree to the category of constrained airports than “secondary” airports. The average traffic volume of constrained airports was in 2012 about 370 thousand ATMs, whereas the corresponding volume of unconstrained airports was less than 150 thousand movements. Traffic has concentrated more on hub and other high volume airports in the past, partly because of the concentration of intercontinental traffic on relatively few airports and the need to feed traffic into these hub airports.

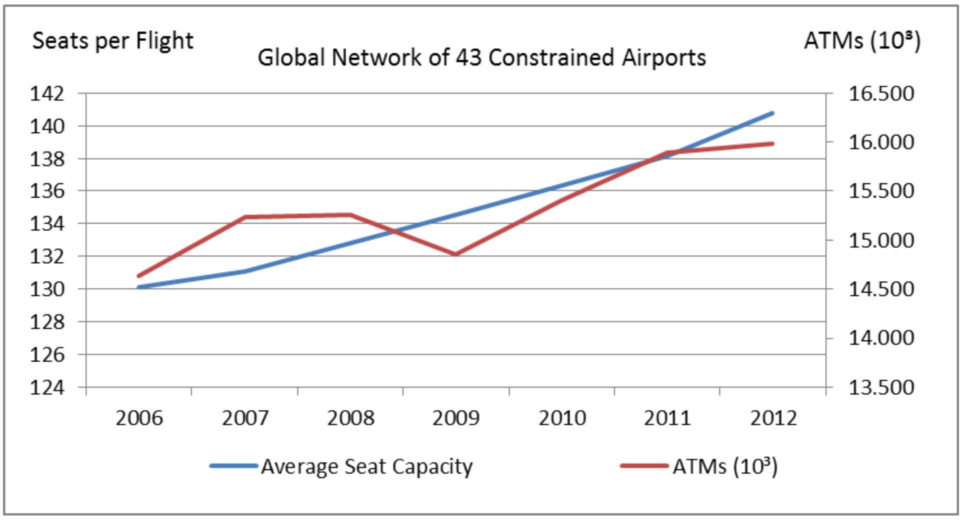

Fig. 2: Average Seat Capacity and Number of Air Transport Movements in the Global Network of 43 Constrained Airports 2006 – 2012 (Source: OAG)

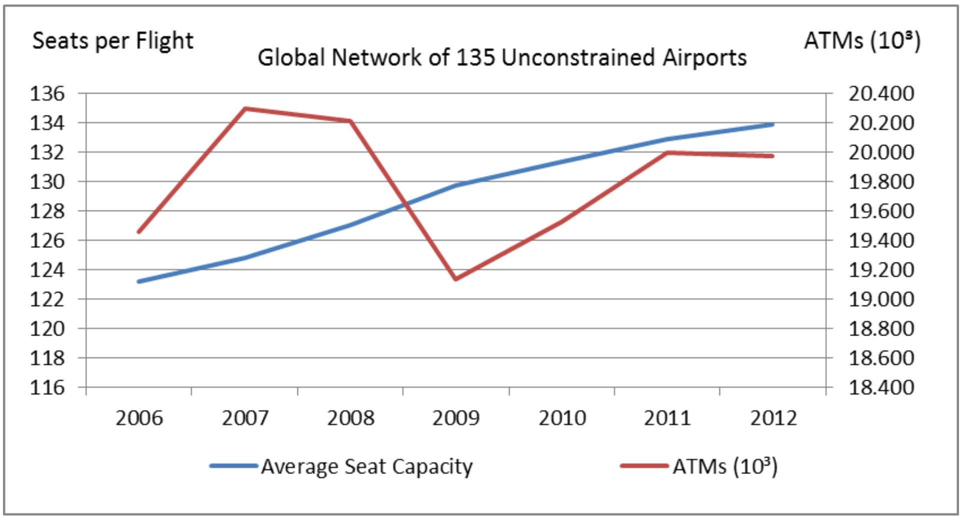

Fig. 3: Average Seat Capacity and Number of Air Transport Movements in the Global Network of 135 Unconstrained Airports 2006 – 2012 (Source: OAG)

Total traffic at the 43 constrained airports amounted to 16 Million ATMs in 2012, while the unconstrained airports handled a volume of 20 Million ATMs. The 43 constrained airports form only a small fraction of the global network (less than 2 % of all airports), however, they handled one quarter of all movements. The traffic share of the 135 unconstrained airports was about 31 %, so that the selected airports altogether handled more than 50 % of total air traffic.

The development of average seat capacity has been analysed at constrained and unconstrained airports in world regions as well. World regions have been defined as

- Africa
- Asia
- Europe
- North America
- South America
- South West Pacific (i. e. Australia)

Table 1 shows the development of average seat capacity per flight at constrained and unconstrained airports by world region.

World Region	Asia	Africa	Europe	North America	Middle East	South America	South West Pacific
Constrained Airports							
Average Seat Capacity:							
2012	171	-	162	112	236	133	170
2006	162	-	148	111	200	132	153
Growth 2012/2006 (%)	**5.5**	**-**	**9.5**	**0.9**	**18**	**0.8**	**11**
No. of ATMs (x10^6):							
2012	3.24	-	3.66	7.64	0.32	0.6	0.52
2006	2.09	-	3.53	7.93	0.19	0.45	0.44
Growth 2012/2006 (%)	**55**	**-**	**3.7**	**-10.4**	**68**	**33**	**18**
Unconstrained Airports							
Average Seat Capacity:							
2012	176	150	135	111	173	133	134
2006	186	143	120	103	181	118	120
Growth 2012/2006 (%)	**-5.7**	**4.9**	**12.5**	**7.8**	**-4.6**	**12.7**	**11.7**
No. of ATMs (x10^6):							
	3.87	0.40	5.55	7.45	0.63	1.47	0.57
2006	2.71	0.32	5.54	8.77	0.37	1.24	0.51
Growth 2012/2006 (%)	**43**	**25**	**0.2**	**-17.8**	**70**	**18.5**	**11.8**

Table 1: Average Seat Capacity and Traffic Volumes at Congested and Uncongested Airports in World Regions 2006 and 2012 (Source: OAG)

The picture of average seat capacity development becomes more diversified if we look into world regions. The average number of seats offered per flight has grown at congested airports in all world regions, however, much more in the Middle East and South West Pacific than in Asia and Europe, and only marginally in North and South America. In Africa no airport has been classified as constrained. Traffic volumes have increased in all regions, except in North America, where the number of flights fell by 10 % between 2006 and 2012. Traffic growth was strongest in the Middle East (+68 %) and in Asia (+55 %). The highest growth of average seat capacity was equally in the Middle East (+18 %), whereas the decline of traffic in North America was accompanied by an average aircraft size the capacity of which did not change over time. In addition, average seat capacity of flights in North America was with 112 seats per flight much smaller than in other regions, in particular smaller than in the Middle East, where the average number of seats offered was 236. It should be noted, that the category of congested airports in the Middle East is represented by just one airport, which is Dubai (DXB). The corresponding values of Asia and Europe were 171 and 162. The low capacity of flights in North America is partly caused by the fact that most of these flights are domestic flights, and domestic routes are typically characterized by higher frequencies (with somewhat smaller aircraft) than international routes.

Average seat capacity increased at uncongested airports in Europe, North and South America, Africa and in South West Pacific, whereas in Asia and the Middle East average aircraft size decreased by about 5 % between 2006 and 2012. Air traffic at uncongested airports has grown in all world regions except in North America, where traffic was down by 18 %. Except in Asia, average seat capacity at unconstrained airports was lower in all world regions than at constrained airports, in particular in Europe, the Middle East and South West Pacific. Average aircraft size was with 111 seats again rather low in North America and was highest in Asia with 176 seats on average.

Summarizing we have found an increase in average seat capacity at congested airports in all world regions and at uncongested airports in most regions except in Asia and the Middle East. The growth varied between 0.8 % at congested airports in South America and 18 % at those in the Middle East, and between -5.7 % at uncongested airports in Asia and almost 13 % at those in Europe and South America.

4. Airport Specific Developments of Average Seat Capacity

If we further specify the analysis of average seat capacity developments in world regions to the level of single airports we see an even more diversified picture. Concentrating first on **constrained airports** we have identified 34 (79 %) out of 43 constrained airports where the average number of seats offered per flight increased between 2006 and 2012. Correspondingly at 9 (21 %) airports average seat capacity declined. At 22 airports both the average seat capacity and the number of ATMs increased, while at 12 airports the average aircraft size increased, although the number of ATMs decreased. The regional distribution of constrained airports where flights on average have grown in seat capacity is as follows

- 11 airports in North America,
- 11 airports in Europe,
- 9 airports in Asia,
- 2 airports in South West Pacific, and
- 1 airport in the Middle East.

On the other side, there have been 5 congested airports with decreasing seat capacity in North America, 2 airports in South America and 2 airports in Asia. None of the congested airports, where the average number of seats offered per flight decreased was found in Europe, the Middle East and South west Pacific.

Among the constrained airports in North America with flight movements with growing seat capacity are Atlanta (ATL), the airport with the highest flight volume, New York (JFK), Denver (DEN), and Los Angeles (LAX). Washington National (DCA), Chicago O'Hare (ORD) and San Diego (SAN), the airport with the highest volume of a single runway airport, are examples of constrained airports with decreasing average seat capacity. In Fig. 4 the development of traffic and average seat capacity at the Chicago O'Hare airport is shown.

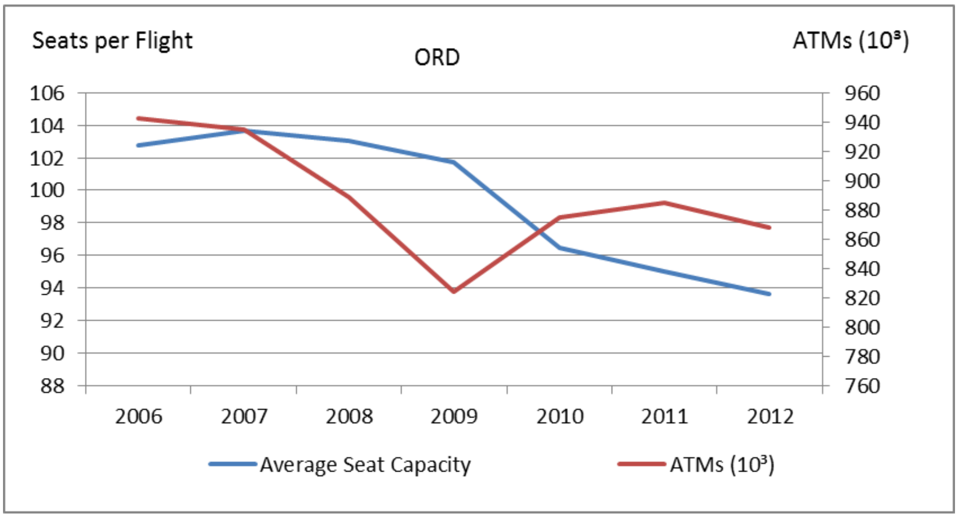

Fig. 4: Average Seat Capacity and Number of Air Transport Movements at Chicago O'Hare Airport (Source: OAG)

Chicago O'Hare is an example of a high volume airport, in fact with the second highest traffic volume worldwide, with a flight supply the average size of which has been rather small. There is no other constrained airport that has with 94 seats per flight movement (in 2012) a lower average seat capacity than Chicago O'Hare. Since 2006 both the traffic volume and average number of seats offered per flight have gone down, the traffic by 8 % and the average size by 9 %.

In Europe the airports London Heathrow (LHR) and Gatwick (LGW), Duesseldorf (DUS), and Frankfurt (FRA) have been constrained among others. The development of flight size and traffic of London Heathrow is shown in Fig. 5.

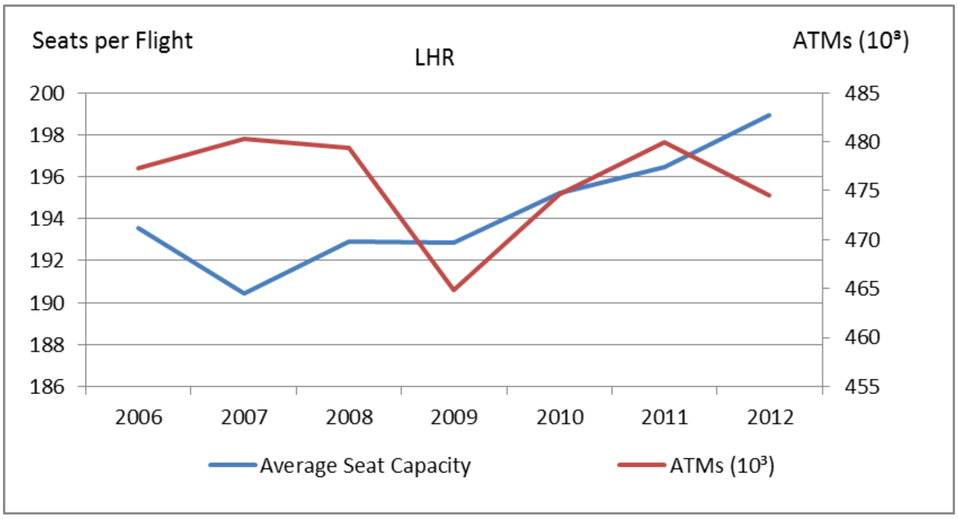

Fig. 5: Average Seat Capacity and Number of Air Transport Movements at London Heathrow Airport (Source: OAG)

The average number of seats offered at London Heathrow is with 199 seats (in 2012) more than twice as high as at Chicago O'Hare. While the traffic volume has slightly decreased between 2006 and 2012 the average number of seats per flight has slightly gone up from 194 to 199 seats. It has been found in the worldwide constraint analysis of airports that London Heathrow is the most constrained one, with a CUI of 85 % in 2012. No other airport has achieved such high capacity utilization, never the less the average seat capacity has increased by only 4 seats per flight on average. One reason for the fact that the seat capacity has not increased stronger is the already rather high average seat capacity – the average in Europe has been 162 seats per flight -, another reason is that, taking advantage of the constraint situation, carriers have increased the number of business class seats in order to raise revenues at the cost of economy class seats, without changing the average size of aircraft.

At no other airport worldwide flights with such a high seat capacity are offered as at Dubai airport, the average number of seats per flight has been 236 in 2012 (see Fig. 6). Dubai airport belongs to those airports where both the traffic and the flight capacity have grown strongly, between 2006 and 2012 by 66 % and 18 % respectively. The high efficiency of passenger throughput at the Dubai hub airport is caused by the fact that the home carrier Emirates is serving primarily intercontinental demand via Dubai by employing wide body aircraft, in particular the A380.

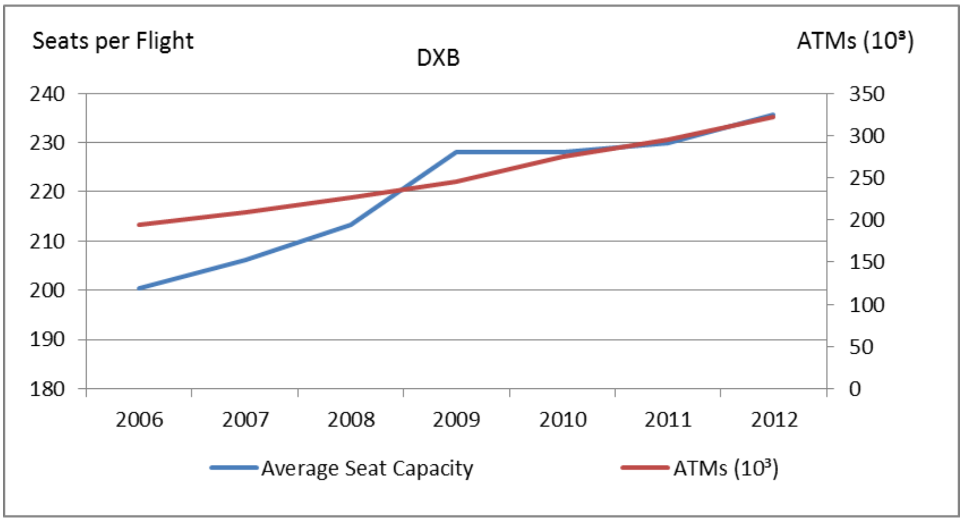

Fig. 6: Average Seat Capacity and Number of Air Transport Movements at Dubai Airport (Source: OAG)

Altogether 135 airports with annual traffic volumes exceeding 70 000 ATMs have been identified as **unconstrained airports**. 107 airports of them – representing almost 80 % - have been served by flights with increasing seat capacity. At 28 airports average seat capacity of flights has gone down between 2006 and 2012. At 63 airports with growing seat capacity the traffic volume has increased as well, whereas at 44 airports traffic has gone down. The regional distribution of unconstrained airports is as follows

- 48 airports in North America, of which 39 airports with increasing and 9 airports with decreasing seat capacity,
- 40 airports in Europe, of which 39 airports with increasing and 1 airport with decreasing seat capacity,
- 25 airports in Asia, of which 14 airports with increasing and 11 airports with decreasing seat capacity,
- 5 airports in South West Pacific, of which 5 airports with increasing seat capacity,
- 5 airports in the Middle East, of which 1 airport with increasing and 4 airports with decreasing seat capacity,
- 9 airports in South America, of which 7 airports with increasing and 2 airports with decreasing seat capacity,

- 3 airports in Africa, of which 2 airports with increasing and 1 airport with decreasing seat capacity.

Whereas at most of the Asian airports traffic has grown strongly in the past, most of the North American airports had to report traffic declines. Average seat capacity of flights went up at all but one European airport, while in the Middle East most airports were served by flights with decreasing seat capacity, although traffic went up strongly at these airports. An example is Bahrain (BAH) airport, where traffic went up by 68 % between 2006 and 2012, but average seat capacity dropped from 175 to 142 by 19 %, the highest loss encountered by any airport (see Fig. 7).

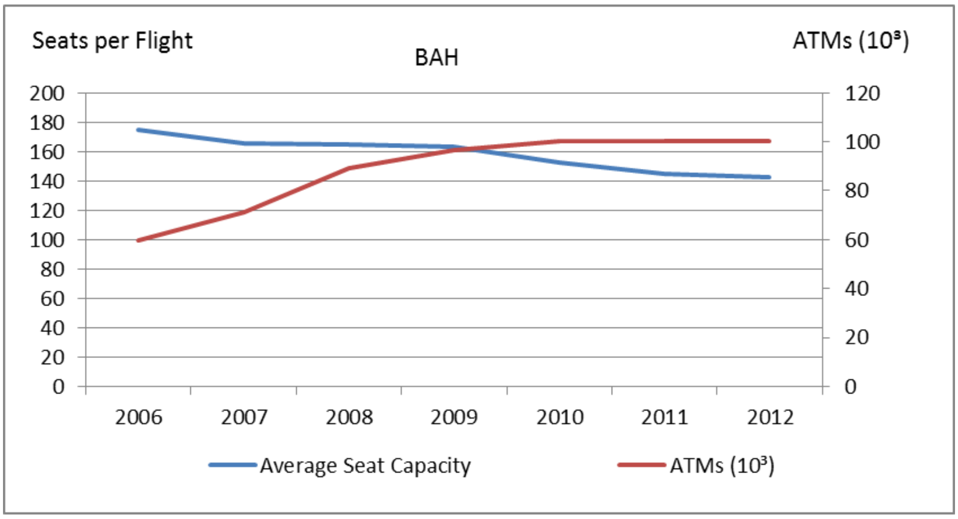

Fig. 7: Average Seat Capacity and Number of Air Transport Movements at Bahrein Airport (Source: OAG)

Another exceptional example is Milwaukee (MKE) airport in the US, where traffic fell by 35 %, however, the number of seats offered per flight increased from 67 to 97, thus by 45 %, the strongest increase of all airports (see Fig. 8). This growth is not typical for North American airports, at most airports the increase in average seat capacity was rather small; on average seat capacity in North America stayed almost constant with 112 seats per flight over the 6 year period.

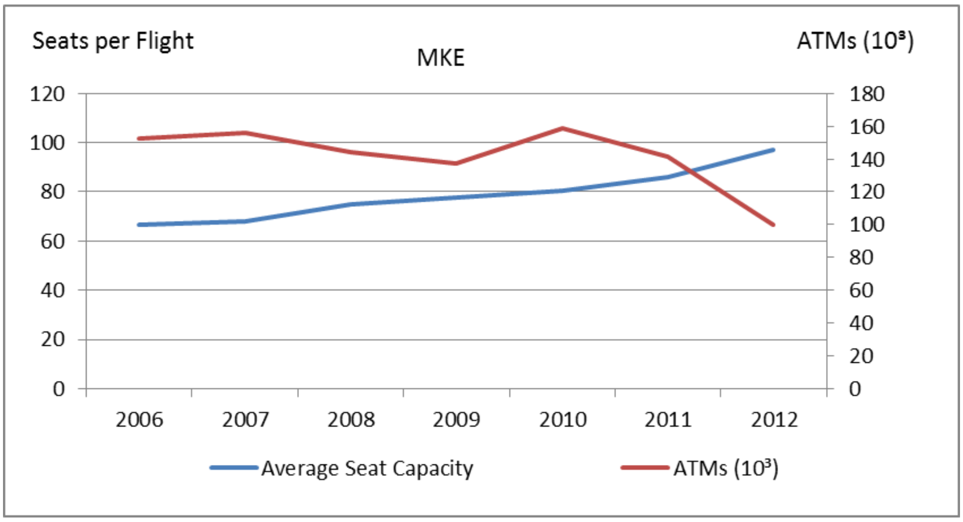

Fig. 8: Average Seat Capacity and Number of Air Transport Movements at Milwaukee Airport (Source: OAG)

In summarizing we can state that in almost 80 % of all constrained airports airlines have increased average seat capacity of flights in recent years. The reasons for enlarging seat capacity may have varied depending on the airport specific situation, one reason was, however, the lack of airport capacity, so that increasing seat capacity per flight was one option to cope with demand in bottleneck conditions. On the other hand, we have found that also in 80 % of all unconstrained airports airlines have chosen the option to offer bigger seat capacity per flight. Clearly, lack of airport capacity did not play a direct role her, but may be an indirect role, when the other airport of the flight stage has been constrained. Other reasons played a decisive role as well, since at only 20 % of all airports airlines have scheduled flights with declining seat capacity over time.

5. Factors Causing Airlines to Raise Seat Capacity of Flights

As mentioned, lack of slot availability at constrained airports is a main reason for airlines to increase the number of seats per flight in order to cope with growing demand. So far we have only indirectly seen this relationship by having analysed average seat capacity at congested airports being positively correlated with the traffic volume (see Fig. 2). If we were able to show that seat capacity is functionally related with a measure of congestion, we could directly demonstrate that there is also a causal relationship between flight capacity and airport congestion. Such an indicator of airport constraints at congested airports is the capacity utilization index (CUI). In Fig. 9 we see the positive correlation between average seat capacity and the CUI in the global network of 43 constrained airports. With increasing level of capacity utilization the number of seats offered per flight is growing as well. For the network of unconstrained airports such a relationship exists in a similar way, however, not as strongly, since the CUI is a true indicator of high capacity utilisation only where the 5 % peak hour volume has values near capacity, that is primarily at constrained airports and at unconstrained airports with rather high traffic volumes.

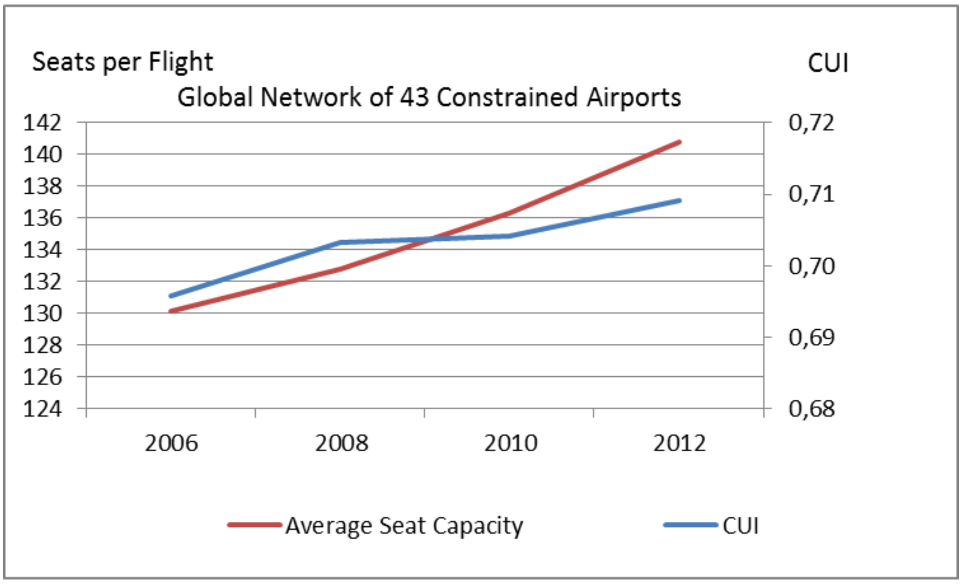

Fig. 9: Average Number of Seats per Flight and Airport Capacity Utilisation Index (CUI) in the Global Network of 43 Congested Airports 2006 – 2012 (Source: OAG)

As numerous examples of airports, particularly in North America have shown, there is also an incentive for airlines to offer more seats in bigger aircraft without increasing the frequency on economic grounds. Unit costs of bigger aircraft are lower than of smaller aircraft. Based on data of the US air traffic market in 2006, as provided by The Airline Monitor (ESG Aviation Services, 2007), one can show the relationship between cost per seat mile and aircraft size, by which unit costs fall sharply from about 16 US Cents to 6 Cents when the seat capacity of an aircraft goes up from about 40 seats (e. g. EMR-135) to about 150 seats (e. g. A-320). If aircraft get bigger unit costs go only marginally down as is shown in Fig. 10.

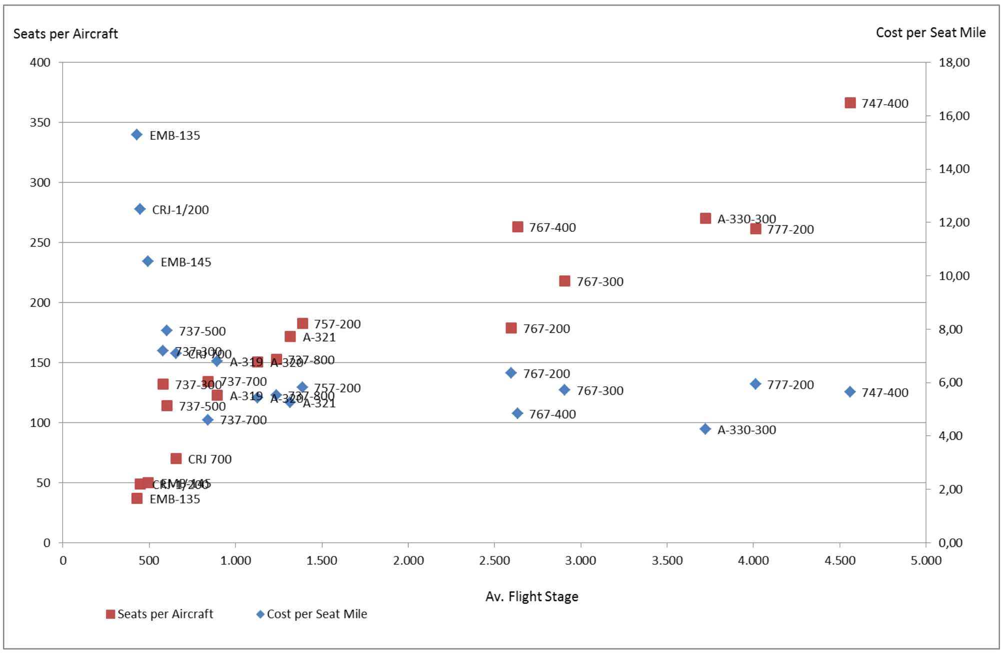

Fig. 10: Relationship between Unit Cost, Average Flight Stage and Aircraft Size (Seats per Aircraft) in the US Market 2006 (Source: The Airline Monitor)

If sustainable levels of load factor and frequency are achieved and demand continues to grow airlines have an economic interest to schedule aircraft with higher seat capacity rather than increase frequency, in constrained airport conditions even more than in unconstrained conditions.

In Fig. 10 the relationship between aircraft seat capacity and average flight stage in the US air traffic market is shown, too. As can be seen there is a clear tendency of employing bigger aircraft types on longer routes. If more flights on longer routes are offered at an airport then the average seat capacity of all flights is likely to go up. At the same time unit costs go down, particularly in the short and medium distance range.

The question is then, did average flight distances go up at congested and uncongested airports? As can be seen in Fig. 11 and 12, this was the case in both networks. An increase in average flight distance may therefore be regarded as a factor describing the tendency of employing aircraft with higher seat capacity at lower unit cost.

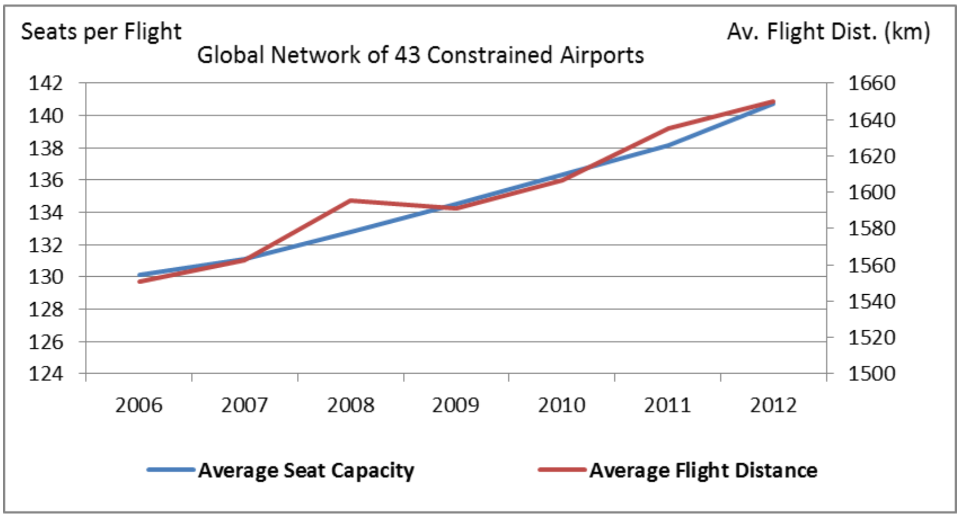

Fig. 11: Average Flight Distance and Average Seat Capacity per Flight in the Global Network of 43 Constrained Airports 2006 -2012 (Source: OAG)

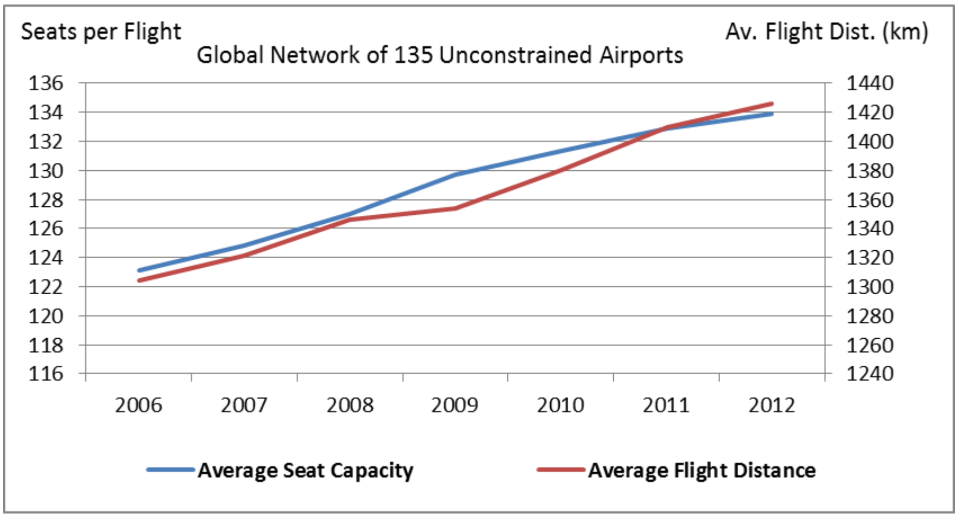

Fig. 12: Average Flight Distance and Average Seat Capacity per Flight in the Global Network of 135 Unconstrained Airports 2006 -2012 (Source: OAG)

We have assumed, that the number of seats per flight is also dependent on the degree of competition between airlines at an airport. To test this hypothesis we have calculated for each airport the HHI-coefficient (Hirschmann-Herfindahl-Index) (Ehmer and Berster, 2002), which represents a measure of airline concentration at an airport. The analysis has shown that at the 43 constrained airports the HHI has slightly gone up by 2.5 % from 2950 in 2006 to 3025 in 2012, while the average seat capacity has increased by 8.5 % from 130 to 141 seats (see Fig. 2). Airline concentration has thus grown at the cost of competition along with an increase in seat capacity. While this result is confirming the hypothesis, the development at unconstrained airports went otherwise; the HHI decreased by 4.4 % from 2810 to 2685, whereas the average seat capacity went up by 9 % from 123 to 134 seats per flight (see Fig. 3). While airline competition gained, flights with more seats were offered, probably because other factors like lower unit costs and network changes were more decisive.

So far we have seen that the development of average seat capacity of flights is positively correlated with traffic volume, although not at all airports as examples like London Heathrow and Milwaukee have shown, with average distance of flights and the degree of congestion at already constrained airports. The relationship between seat capacity and distance stands for the fact that airlines use bigger aircraft at lower unit cost on longer flight stages. Other factors may cause airlines to schedule otherwise, depending for instance on local conditions, aircraft availability and airspace and airline regulation. For forecasting on a network level seat capacity of flights a model has been developed that incorporates the generally important factors as they have been derived in this chapter.

6. Model Relating Average Seat Capacity with Influencing Factors

The estimated model is linear and takes the form:

$$\mathrm{AVGSEATS}_i = \mathrm{CONST} + \sum_j \beta_j * x_{ij}$$

The dependent variable *AVGSEATS*$_i$ is the average number of seats per flight at airport i. The independent variables comprise a constant term, CUI, average flight length and several region specific constants. Observations are weighted by the number of flights at the airport. Table 2 shows the model estimation results. *AVGFL* describes the average flight length in km at an airport (OAG, 2012). *NA* (North America), *EUR* (Europe), *ASIA* (Asia), *MEAST* (Middle East) are binary variables that take a value of 1, if an airport belongs to the region and 0 otherwise. *CUI* is the capacity utilisation index and theoretically takes values between 0 and 1; however, in real world applications *CUI* is typically limited to values between 0.4 and 0.85 (London Heathrow). A likelihood-ratio-test shows that discriminating the *CUI* coefficient between airports operating near or at their capacity limit and airports that have ample capacity reserves ("test model") is not significant (-2*(LogL(final model) – LogL(test model)) = 0.134). All variables are significant at the <=1% level, except for the EUR variable (<=5% level). Model fit (R^2) is 75.8%. This is a reasonable value given the complex task of explaining average airport size with a rather simple model, however, we have to consider that there remains a significant part of variation in the data observed that the model cannot explain. Nevertheless, the model is sufficient for the problem studied in this paper. A variable for the HHI has the expected negative sign, but is not statistically significant different from zero (t-statistic of -0.553). A variable for the number of passengers (*PASS*) at an airport is highly correlated with the *CUI* and *AVGFL* variables, reaching values of 0.5445 and 0.5817, respectively. A likelihood-ratio-test shows that including *PASS* is significant at the 5% level, but not at the 1% level. The test value is 5.44 and the critical values are 3.84 (5%) and 6.63 (1%), respectively. However, *PASS* is omitted from the final model setup, because explanatory power increases only marginally (ΔR^2 = 0.58%) and variance of the parameter estimates increases.

Variable	Coefficient		R^2	# of obs.
CONST	57.6845812	***	75.82%	224
CUI	61.8579267	***		
AVGFL	0.02539032	***		
NA	-23.9042594	***		
EUR	9.89872101	**		
ASIA	30.4363804	***		
MEAST	37.6541034	***		

*** Significant at the <=1% level
** Significant at the <=5% level

Table 2: Estimation results (final model)

The estimation results of Table 2 show that average number of seats offered per flight increases by around 6 seats per 0.1 increases in CUI value. Another important factor determining average aircraft size is average flight length: Average number of seats offered per flight increases by around 2.5 seats per 100 km increases in average flight length at an airport. Finally, there are regional differences: Average number of seats per flight tends to be lower in North America than in Europe or even Asia and the Middle East: There is more domestic traffic with smaller aircraft at a higher frequency in North America and more long-haul and intercontinental traffic with larger aircraft in Asia and the Middle East. Europe is somewhere in-between those two types.

Model #	Model name	R^2	Log-Likelihood
1	CUI	12.22%	-1124.478
2	AVGFL	31.86%	-1096.118
3	CUI + AVGFL	37.69%	-1086.086
4	REGIONS	52.08%	-1056.693
5	REGIONS + CUI	56.34%	-1046.253
6	REGIONS + AVGFL	74.32%	-986.802
7	FINAL MODEL	75.82%	-980.061

Table 3: Comparison of models

Table 3 shows the estimation results of different models that include only a subset of the explanatory variables and of the final model (#7) of Table 2. Here, we have to keep in mind that the estimators in models #1 to #6 are potentially biased, because some explanatory variables are missing. Table 3 displays the share of linear variance (R^2) in the estimation data set that is explained by the (sub)models. All models include a constant term (*CONST*). However, a model including only a constant term has an R^2 of virtually 0 and therefore is omitted from Table 3. Model #1 comprises a constant term and the *CUI* variable. Model #2 is composed of a constant term and the *AVGFL* variable. Model #3 comprises a constant term and the *CUI* and *AVGFL* variables. Model #4 includes a constant term and the region-specific binary variables. Equally, models #5 and #6 comprise a constant term, region-specific variables, the *CUI* variable and the *AVGFL* variable, respectively. Table 3 illustrates that the largest part of the linear variance (52.08%) in the estimation data set is explained by the region-specific variables *NA*, *EUR*, *ASIA* and *MEAST* if we do not account for overlapping of explanatory power of variables. Accordingly, *AVGFL* and *CUI* account for 31.86% and 12.22%, respectively, of the linear variance that is explained by the submodels. However, if we take a look at the last three models in Table 3 we see a rather large increase of R^2 if we include the *AVGFL* variable (+22.24 percentage points), but only a small increase in R^2 if we include the *CUI* variable (+4.26 percentage points and +1.50 percentage points, respectively). From this observation we conclude that there is a rather small part of linear variance in the estimation data set that is explained only by the *CUI* variable.

The most important variable for explaining average number of seats per flight at airport in this model is the average flight length at an airport (*AVGFL*), followed by region-specific characteristics and then capacity utilisation at an airport (*CUI*). Nevertheless, despite the rather small share of the linear variance in the estimation data set that is exclusively explained by the *CUI* variable a likelihood-ratio-test shows that the *CUI* variable is still highly significant.

7. Conclusions

Using bigger aircraft and aircraft with higher seat density are measures that airlines use to varying degrees depending on factors like level of airport congestion, airline fleet, network structure, competition with other airlines, etc. The paper reports on statistical analyses regarding the development of average aircraft size (no. of seats per flight) at constrained and unconstrained airports worldwide as well as in world regions.

A working hypothesis at the outset of the analysis has been that airlines that want to serve a growing market increase their capacity by offering more seats on existing as well as new routes. At congested airports airlines would do so by operating bigger aircraft and at uncongested airports by increasing first of all the number of flights. Capacity constraints would hinder airlines from increasing frequencies, whereas at airports with capacity surplus airlines would rather prefer to offer more flights in order to better comply with the needs of travelers, in particular business travelers. The analysis has shown that the first part of the hypothesis is correct in most instances while the second part is only valid in the minority of cases; also at most uncongested airports aircraft size has gone up in the past.

Based on an analysis of 5 % peak hour volumes and day time capacity utilization of airports worldwide we have identified 178 airports with annual volume exceeding 70,000 ATMs in 2010; 43 of them were classified as constrained and correspondingly 135 as not constrained airports. Total traffic at the 43 constrained airports amounted to 16 Million ATMs in 2012, while the unconstrained airports handled a volume of 20 Million ATMs. The 43 constrained airports form only a small fraction of the global network (less than 2 % of all airports), however, they handled one quarter of all movements. The traffic share of the 135 unconstrained airports was about 31 %, so that the selected airports altogether handled more than 50 % of total air traffic.

The analysis of 178 airports has shown that average seat capacity per flight has grown in the past, in the global network by almost 10 % from 114 seats in 2006 to 125 seats in 2012. In the same time the total number of aircraft movements at more than 3000 airports has increased by

11 % from 58 to about 64 Million, while the number of passengers has grown by 26 % from 4.7 to 5.94 Billion.

If we differentiate between airports with and without capacity problems (with traffic volumes of more than 70 000 ATMs in 2010) we see that in both networks the average seat capacity has increased as well. Average seat capacity has grown by 8.5 % from 130 to 141 seats at the 43 constrained airports and by 9 % from 123 to 134 seats per flight at the 135 unconstrained airports. Airlines have thus operated in general bigger aircraft, regardless of the constraint situation at airports.

The picture of average seat capacity development becomes more diversified if we look into world regions. The average number of seats offered per flight has grown at congested airports in all world regions, however, much more in the Middle East and South West Pacific than in Asia and Europe, and only marginally in North and South America. Average seat capacity of flights in North America was with 112 seats per flight much smaller than in other regions, in particular smaller than in the Middle East, where the average number of seats offered was 236. The low capacity of flights in North America is partly caused by the fact that most of these flights are domestic flights, and domestic routes are typically characterized by higher frequencies (with somewhat smaller aircraft) than international (and intercontinental) routes.

Average seat capacity increased at uncongested airports in Europe, North and South America, Africa and in South West Pacific, whereas in Asia and the Middle East average aircraft size decreased by about 5 % between 2006 and 2012. Except in Asia, average seat capacity at unconstrained airports was lower in all world regions than at constrained airports, in particular in Europe, the Middle East and South West Pacific. Average aircraft size was with 111 seats again rather low in North America and was highest in Asia with 176 seats on average.

Summarizing we have found an increase in average seat capacity at congested airports in all world regions and at uncongested airports in most regions except in Asia and the Middle East. The growth varied between 0.8 % at congested airports in South America and 18 % at those in the Middle East, and between -5.7 % at uncongested airports in Asia and almost 13 % at those in Europe and South America.

If we further specify the analysis of average seat capacity developments in world regions to the level of single airports we see an even more diversified picture. In almost 80 % of all constrained airports airlines have increased average seat capacity of flights in recent years. The reasons for enlarging seat capacity may have varied depending on the airport specific situation, one reason was, however, the lack of airport capacity, so that increasing seat capacity per flight was one option to cope with demand in bottleneck conditions. We have found out that with increasing degree of capacity utilization (CUI) the number of seats offered per flight has gone up as well. On the other hand, we have seen that also in 80 % of all unconstrained airports airlines have chosen the option to offer bigger seat capacity per flight. Other reasons than airport congestion played a decisive role for increasing average seat capacity, since at only 20 % of all airports airlines have scheduled flights with declining seat capacity over time.

If sustainable levels of load factor and frequency are achieved and demand continues to grow airlines have an economic interest to schedule aircraft with higher seat capacity at lower unit costs rather than increase frequency, in constrained airport conditions even more than in unconstrained conditions. There is a clear tendency of employing bigger aircraft types on longer routes. We have seen that average flight distances have gone up at both congested and uncongested airports. An increase in average flight distance may therefore be regarded as a factor describing the tendency of employing aircraft with higher seat capacity at lower unit cost. Other factors may cause airlines to schedule otherwise, depending for instance on local conditions, aircraft availability and airspace and airline regulation. For forecasting on a network level seat capacity of flights a model has been developed that incorporates the generally important factors as they have been derived in this paper.

The estimated model is a linear function relating average seat capacity per flight as the dependent variable with a constant term and the independent variables CUI, average flight distance and region specific constants. The estimation results show that average number of seats offered per flight increases by around 6 seats per 0.1 increases in CUI value and by around 2.5 seats per 100 km increase in average flight length at an airport. Finally, there are regional differences: Average number of seats per flight tends to be lower in North America than in Europe or even Asia and the Middle East.

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