METHODICAL APPROACH TO DETERMINING THE CAPACITY UTILISATION OF AIRPORTS: THE DEVELOPMENT OF THE EUROPEAN AIR TRAFFIC SYSTEM BETWEEN 2008 AND 2012

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Abstract

The global air transport system has seen significant growth rates over recent decades. The exponential increase in passenger numbers were only interrupted by periods of stagnation caused by the negative effects of unpredictable crises. In the future, the total number of aircraft movements is expected to grow further at rates between 4 and 5% per year. As seen in the past, the growth of the air transportation sector is highly asymmetric, which means that it varies strongly from region to region. This forecasted increase in demand is mainly caused by the augmented travel needs of the world's population and the rising wealth of its peoples. Because airports and, more precisely, the runway systems usually represent the bottleneck of the entire air transport system, this paper will focus on these elements. Due to local constraints, many airports haven't been able to expand their infrastructure at the same speed traffic has grown. Therefore, more and more airports are operating close to their maximum capacity. This development is confirmed by continuously increasing average delays.

This paper demonstrates a methodical approach which allows the determining of the degree of capacity utilisation of an airport. The Basic Load Index (BLI) and the Peak Load Index (PLI) were defined as indicators for the capacity situation of an airport. The required parameters were calculated based on Official Airline Guide (OAG) data. This method was then applied to a selection of 75 European airports. The analysis revealed that the vast majority of airports have a low to medium capacity utilisation. Only a few airports face significant capacity constraints. The three airports with the highest capacity utilisation in 2012 were London Heathrow airport, Frankfurt airport and Istanbul Atatürk airport. The years 2008 and 2012 were compared in order to analyse the impact the Eurozone crises had on the capacity utilisation of the European airport system. It was possible to show that the overall capacity utilisation was slightly reduced between the years 2008 and 2012. Nevertheless, some airports developed in a manner totally contrary to the trend of the overall system. The best example of this is the Istanbul Atatürk Airport. Its traffic numbers went up nearly 40% during this period and caused a strong increase in capacity utilisation.

Based on this study, further analysis taking the forecasted traffic growth numbers into account could reveal possible future bottlenecks of the global air transport system.

Keywords

Airport Capacity Utilisation, Capacity Constrained Airports, Air Traffic Forecasts, Capacity Coverage Charts

Nomenclature

ATM	Air Traffic Management	LP	Light Prop Aircraft
BLI	Basic Load Index	MTOW	Maximum Take-Off Weight
BRU	Brussels Airport	MP	Medium Prop Aircraft
CCC	Capacity Coverage Chart	NB	Narrow Body Aircraft
DRC	Declared Runway Capacity	OAG	Official Airline Guide
FRA	Frankfurt Airport	PLI	Peak Load Index
IST	Istanbul Atatürk Airport	RJ	Regional Jet Aircraft
LHR	London Heathrow Airport	TK	Turkish airlines
LIN	Milan Linato Airport	WB	Wide Body Aircraft

1. INTRODUCTION

1.1. Air traffic growth

Over recent decades, the air traffic system has seen significant growth (see FIGURE 1). The development was interrupted only by periods of stagnation which were due to the negative effects of unpredictable crises like the Gulf crises in the early 1990's or the most recently encountered financial crisis (Pompl 2002, p. 2) (The World Bank 2014). The need for transportation continues to be closely linked to the wealth of a population (Vermeeren 2004, p. 28). As continents developed very differently over recent decades, air traffic system growth was also very different, or "asymmetric."
As far as the future is concerned, the air transportation system is seen as the most appropriate mode of transportation for covering medium to long distances within a minimal period of time. Megatrends like globalisation will additionally stimulate demand.
Major stakeholders in the aviation industry project an overall growth of passenger numbers of between 4 and 5% per year for the upcoming 20 to 30 years (ACI 2011, p. 5) (Airbus 2013, p. 44) (Boeing 2013, p. 5) (Embraer 2012, p. 7) (ICAO 2007, p. 2).

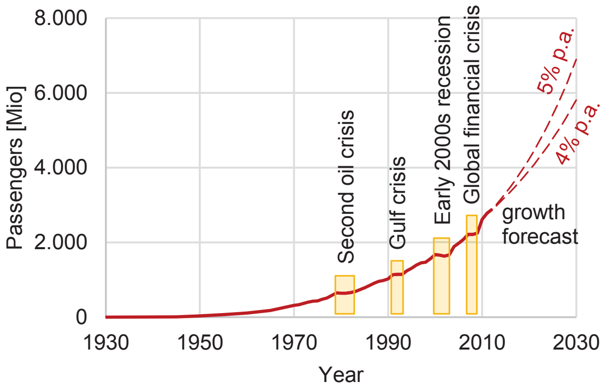

FIGURE 1 The historical development of the air transport passenger numbers and projected growth (Pompl 2002, p. 2) (The World Bank 2014)

1.2. Air traffic system capacity limitations

As air traffic demand increases, the number of flights increases as well. The trend toward operating larger planes with a higher number of available seats tends to slow down growth in aircraft movements. Examples of this are the largest commercial aircraft ever built, the Airbus A380, or the Canadair Regional Jet, which was built to replace smaller short haul aircrafts and offer advantages on the price per seat. However, this development has not been able to compensate for the rise in demand on its own.
As in every technical system, the air transport system is limited in its capacity, as well. Hence, the possibility of accommodating additional flights is exploited at a certain time. The subsystem which determines the capacity of the overall air transport system is that with the smallest single capacity. For the air transport system, this is usually the airport system. When considering airports, the runway system can be seen as the system bottleneck (Feron 1997, S. 10) (Schubert 2014).

Flight delays are caused by various reasons. One important reason is airport capacity shortage (Eurocontrol 2011). More and more airports around the world are operating close to their maximum capacity and hence exhibit increasing average delays (ADB Airfield Solutions 2014, p. 49) (Busacker 2005, p. V) (Garcia/Mavris 2000, p. 1) (Mavris/Garcia 2000, p. 2) (Rieder 2013). Forecasts preview that the development of the global airport system will not be able to keep up with increasing passenger demand (ADB Airfield Solutions 2014, p. 42-48) (Eurocontrol 2013b, p. 7). This would have a highly negative impact on the entire air transportation sector, as capacity shortages will directly influence growth (Butler 2008, p. 1) (Eurocontrol 2013a, p. 20) (Eurocontrol 2013c, p. 21). The global trade system, of which the air transport system is an important component, will also be negatively impacted (ADB Airfield Solutions 2014, p. 5).
The most obvious solution for the mismatch of airport capacity and passenger demand is the expansion of the airport infrastructure and, more precisely, of the runway infrastructure. This isn't possible for the majority of airports. Principal reasons for this are lack of available areas, public opposition and high investment needs (ADB Airfield Solutions 2014, p. 37) (Bonnefoy et al. 2005, p. 29) (Heumer 2013) (Luft- und Raumfahrt 2013, p. 33). Due to these challenges, the airport system in certain regions of the world will not change substantially in the near future (Bonnefoy 2008, p. 57).

1.3. Factors affecting the capacity of a runway system

As explained in the previous paragraph, runway system capacity is limited and, in most cases, determines the total airport capacity. However, this capacity isn't a constant over time. It is a function of numerous factors which could be classified into the following categories (Neufville/Odoni 2003, p. 376)

- The number and geometric layout of the runway configurations in use
- Separation requirements between aircraft imposed by the Air Traffic Management (ATM) system
- Visibility, cloud ceiling and precipitation
- Wind direction and strength
- Mix of aircraft using the airport
- Mix of movements in each runway and sequencing of movements
- Type and location of taxiway exits from the runway
- State and performance of the ATM system
- Noise related and other environmental considerations and constraints

A particularly convenient way to summarize the range of capacities at an airport is the Capacity Coverage Chart (CCC). It also provides information about the frequencies at which various levels of capacity are available (Neufville/Odoni 2003, p. 402).
The maximum number of movements which can theoretically be handled by a runway system is called "saturation capacity". This value is based on the assumption of infinite demand. This would lead to an unacceptable level of delay (Neufville/Odoni 2003, p. 446). Practical capacity is introduced in order to limit average delay to a reasonable level. It is set around 80% to 90% of the saturation capacity. Over recent years, 4 minutes has been set as an acceptable level of delay. This value can only be attained under optimal operational

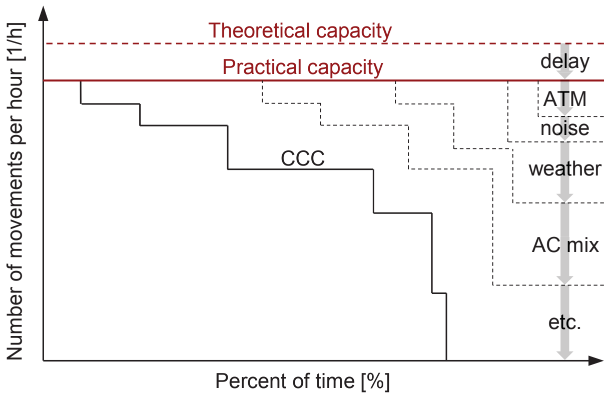

FIGURE 2 A schematically representation of a Capacity Coverage Chart (CCC)

conditions. As described above, numerous factors reduce the capacity which can be ultimately realized. In FIGURE 2, it is shown how the CCC evolves based on the saturation – also called "theoretical capacity".

1.4. Challenging air traffic demand forecasts taking into account airport capacity limitations

Air traffic demand forecasts are a crucial tool for many stakeholders in the air transport industry. Usually, they utilize scenario methods to derive possible developments in future passenger demand.
The final results are then used to evaluate future business activities. For example, they serve as an input for aircraft manufacturers to plan their production capacities and develop new models matched as closely as possible to future customer needs.
This research is based on the hypothesis that capacity shortages in the airport system will have an effect on the development of traffic numbers. The objective of the research is to challenge these forecasts, while taking airport capacity limitations into account, and evaluating whether they are feasible or not.
This paper focuses on the methodical approach to determining the capacity utilisation of an airport. The method is then applied to 75 major European airports. The results are used to classify them according to their degree of capacity utilisation. The capacity situation of these airports in 2008 and 2012 are furthermore compared.

2. EVALUATING THE DEGREE OF CAPACITY UTILISATION OF AN AIRPORT

The key enabler of the objective of the research presented in the previous chapter is the method for determining the degree of capacity utilisation of an airport. Parameters were defined and calculated in order to draw conclusions based on the airport's capacity situation. The two selected assessment parameters are the Basic Load Index (BLI) and the Peak Load Index (PLI), defined later in this chapter. The input parameters needed for this method could be classified into the following three categories (compare FIGURE 3):

- Air traffic demand
- Airport infrastructure
- Operational framework

All three have a direct impact on the degree of capacity utilisation. Obviously, the air traffic demand has to be defined before any analysis. Apart from the mere number of aircraft movements, information about the aircraft type is important, as well. As planes all have individual take-off and landing performances, they have an important influence on the runway throughput.
The airport infrastructure (in use) defines how many runways are available for operations. As shown in the previous section, this has an important impact on the airport throughput. It is therefore an important input parameter for the capacity utilisation analysis.
The operational framework defines the sequences with which aircraft operations take place. For example, the minimum wake vortex separations define the minimum distance or time between two aircrafts during the approach and departure segment. A great deal of effort is put into the development of systems which are intended to improve the operational framework. Wake vortex prediction and monitoring systems are thought to reduce the danger of encountering turbulence caused by a preceding aircraft. In addition, the effective separations are intended to be reduced. 4D navigation systems are developed to increase precision and augment flexibility in routing the aircraft. As a consequence, flight distances can be reduced. Additionally, densely populated areas can be avoided and the noise exposure of the population can thus be minimized.

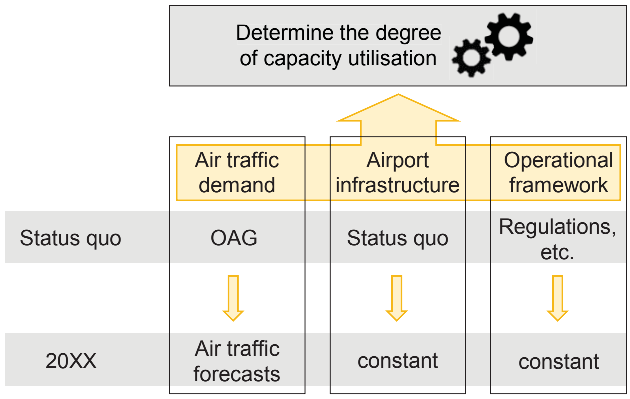

FIGURE 3 Input parameters for the analysis of the capacity situation of an airport at the status quo and for a growth potential analysis

For the analysis of the current airport system, the traffic demand is extracted from flight statistics published by Official Airline Guide (OAG). The operational year of the air traffic industry is divided into two seasons. The summer season begins on the 1st of April and ends on the 30th of September. The winter season covers the remaining months of a year. All flights planned at the beginning of these periods are listed in the OAG database. Because it isn't updated over the course of a season, there is no guarantee that the flight was ultimately operated. Also, flights which were not planned at the beginning of a season were not covered. A comparison of the OAG data and real flight data has shown that about 90% of all movements were covered. As airports handle more aircraft movements, these numbers match even better. For the purposes of this method, this data coverage is sufficient.
The impact of the airport infrastructure and the operational framework on airport capacity must be derived separately

for each airport and each study case.
In addition to the input parameters for a status quo analysis, FIGURE 3 shows the set for a future growth potential analysis. The aim is to identify the maximum capacity of the existing airport system within the currently prevailing regulations and systems. Hence, the input parameters, airport infrastructure and operational framework, were kept unchanged, whereas the future traffic demand situation is derived from air traffic forecasts.

2.1. Categories of indicators for the degree of capacity utilisation of an airport

In the context of this paper, an airport is considered capacity constrained when the number of aircraft movements within a certain period reaches a level close to the maximum capacity. A measure to quantify the degree of capacity utilization has to be defined in order to compare the situation at different airports.
To determine the degree of capacity utilisation, different indicators can be considered which allow conclusions to be made about the airport's capacity situation. An overview of existing indicators was given by (Schinwald/Hornung 2014). These could be classified into the following five categories:

- Flight delays
- Slot utilisation/requests
- Average aircraft size
- Price of landing charges
- Traffic performance measures

Some of these indicators are not very appropriate for this analysis. One reason could be that the indicator is influenced by other effects apart from the number of movements. An example of this is the pricing of the landing charges. Certainly it is an efficient measure to regulate demand during periods of high traffic loads. Following the basic market mechanism, as the price goes up, demand declines. Unfortunately, it couldn't be ruled out that other effects such as, for example, increased aircraft handling costs are not responsible for rising landing charges.
The other indicators might be very accurate, but the required data is not available for the airports to be analysed. An example of this is the category of "flight delays". It is almost impossible to extract the amount of delay which is due to a shortage of airport capacity. Therefore, this indicator isn't adequate for this analysis, either.
(Schinwald/Hornung 2014) defined two parameters which could be used as reliable indicators for the degree of capacity utilisation of an airport. They originate from the category of "traffic performance measures". These two were adopted for this analysis and are presented in the following section.

2.2. The Basic and Peak Load Indexes as indicators for the degree of capacity utilisation of an airport

The assessment of the capacity situation of an airport is based on the following two indicators:

- How much of the available capacity is already used. The parameter which reflects this information is the Basic Load Index.
- How much of the time the airport operates in traffic peaks. The parameter which reflects this information is the Peak Load Index.

Calculating the BLI and PLI on the basis of CCC requires the setting of three parameters: the reference capacity, the lower and the upper capacity threshold.

One effective measure to avoid excessive demand at an airport is the coordination of movements. The operational time is split into slots, which can then be allocated to airlines to perform a take-off or landing. The maximum number of movements which can be scheduled within one hour is called the Declared Runway Capacity (DRC). It is defined as the maximum number of movements which can be handled by the system under good weather conditions, without exceeding an average delay of 4 minutes (Neufville/Odoni 2003, p. 448). From an operational point of view, the DRC of a runway system should equal at least the number of movements within a typical peak hour. Various definitions of this typical peak hour can be found in the literature. Usually either the $30^{th}/300^{th}$ busiest hour of a year or the 5% peak hour movements are considered. However, the last two criteria often lead to almost the same results (Norman et al. 2011).
The analysis of 75 major European airports has revealed that the 5% peak hour criterion correlates the best with the DRC. Therefore, the 5% peak hour movements will be set as the reference capacity. This value is then used to calculate the theoretical number of aircraft movements which can be handled by the airport within a certain period.
Some of the airports operate 24h a day; others are closed during the night. Usually this is either due to absence of demand or night flying restrictions. In order to not distort the results, these hours of low or even no demand are filtered out. Analysis by (Schinwald/Hornung 2014) have shown that the lower threshold should be set at 15% of the DRC.
Traffic demand at an airport usually varies greatly over the course of the day. Especially at hub airports, arrivals and departures are coordinated with each other in order to minimize passenger connecting times. The distribution of aircraft movements therefore follows a wave form. The peaks could then result in very high traffic loads. In order to capture these peaks, the upper threshold should be set to 80% of the DRC (Schinwald/Hornung 2014, p.8).
With these three parameters set, the BLI is defined as the quotient of the number of flights above the lower threshold

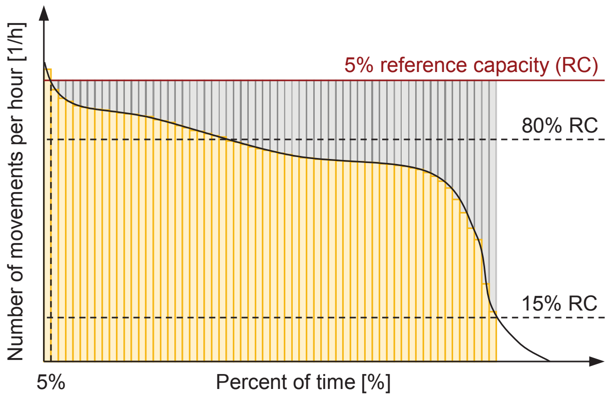

FIGURE 4 Capacity Coverage Chart illustrating the data from which the PLI is calculated

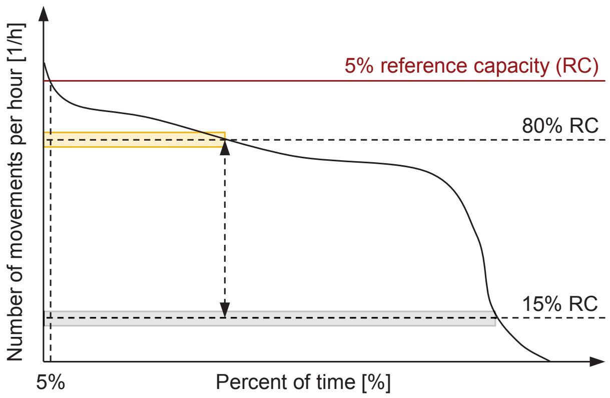

FIGURE 5 Capacity Coverage Chart illustrating the data from which the PLI is calculated

and the theoretical maximum number of flights within the same period (see FIGURE 4).
The PLI is defined as the quotient of the time the airport is operating above the upper threshold and the time the airport is operating above the lower threshold (see FIGURE 5).

2.3. Classification of airports

A 2D scatter plot is used to classify airports with regard to the degree of capacity utilisation. The Peak Load Index is plotted as a function of the Basic Load Index. The higher the parameters, the higher the capacity utilization. The degree of capacity utilization thus increases from the lower left corner to the upper right corner of the diagram (see FIGURE 7).
A certain border from which an airport is capacity constrained could not be set. However, the diagram allows one to compare airports and therefore draw conclusions about the individual capacity utilisation situation.

2.4. Process of data analysis

As indicated above, the data used are flight statistics published by OAG. This raw data includes numerous flight entries which are not operating in reality. Since airlines joined into alliances, such as the “star alliance” or “one world” members, they sell flights under codeshare agreements. This means that one physical flight is offered several times by various airlines.
These so-called code share flights have to be eliminated before the data is processed (see FIGURE 6). Then the airports to be analysed are filtered, the flights have to be extracted and sorted. The evaluation of the data and the

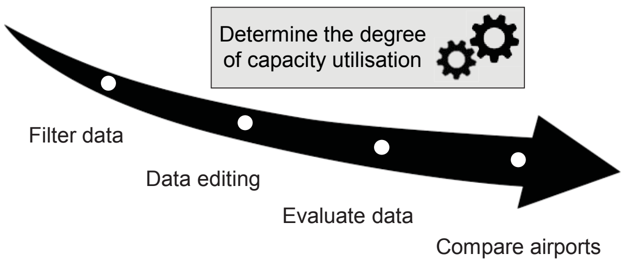

FIGURE 6 Steps along the process of data analysis for determining the degree of capacity utilisation of airports

calculation of the parameters follow. These results then allow the classification and comparing of airports according to their degree of capacity utilisation.

3. CASE STUDY OF MAJOR EUROPEAN AIRPORTS

As Europe is one of the richest continents in the world, the travel activity is very high, as well. Its air traffic system has developed over almost an entire century. Due to significantly growing passenger numbers in the past, the system is facing more and more capacity constraints. As for future development, growth is expected to decline but still remain positive. In addition, it is expected that the infrastructure of the European airport system will not substantially change in the near and mid-term future. This makes the European air transport system a very appropriate use case for a capacity utilisation analysis.
As a result of the US real estate crisis, which started in 2008, the European financial market was heavily destabilized, as well. A period of recession which was later called the Eurozone crisis followed, beginning in early 2009. It still affects the entire industrial sector today.
The years 2008 and 2012 were compared to examine the influence this crisis had on the capacity utilisation of the airport system. With regard to the air transport system, which has developed over decades, a period of 4 years is a relatively short period. However, the economic development which had a strong impact on passenger demand makes it very interesting to analyse these years.
The 75 European airports subject to these study are listed in Appendix 1.

3.1. Capacity utilisation of major European airports in 2012

The results of the analysis of the capacity indicators BLI and PLI for the year 2012 are plotted in FIGURE 7. The airport Münster-Osnabrück was identified as the one with the smallest capacity utilisation. It is characterized by a BLI value of 41% and a PLI value of 12%. By contrast, the airport London Heathrow was identified as the one with the highest capacity utilisation. With a BLI of 86% and a PLI of 88%, it outranges the next airport in the ranking by about 10% and 20% respectively. The largest European airport according to passenger numbers (Airport Council International 2007, p. 17) is very well known for its extensive capacity utilisation. It therefore represents an

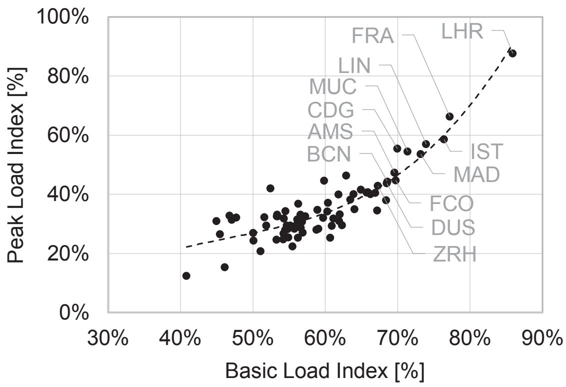

FIGURE 7 BLI over PLI for major European airports in 2012

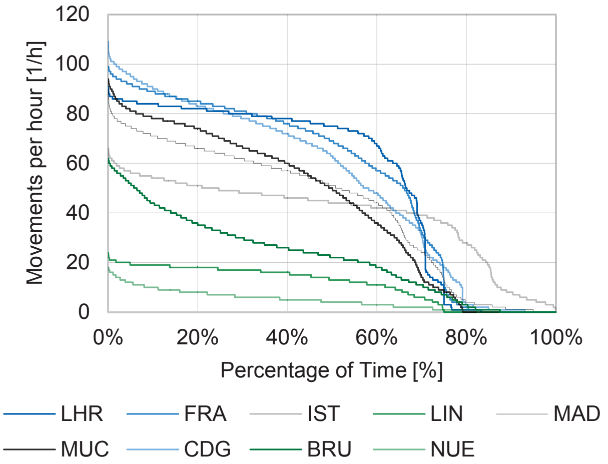

FIGURE 8 CCC for a selection of airports

industry benchmark case, which was proven by this study. Between these two extremes, the distribution follows an exponential trend. The vast majority of the airports are located in the lower part of the diagram and therefore characterised by a low to medium capacity utilisation. However, it is a continuous trend, where no clear groupings of airports could be observed. Nor is it possible to define a certain threshold for capacity constrained airports.

The difference in capacity utilisation between airports becomes very obvious if the shapes of the respective CCC are compared: analysing, for example, the Istanbul Atatürk airport and Brussels airport (see FIGURE 8). They both have maximum throughput capacities per hour at about the same size. In the case of Istanbul Atatürk airport, the traffic level in the CCC declines slowly. Therefore, the system very often encounters these traffic loads. Whereas, in the case of BRU, the traffic level declines very rapidly. Hence, these hours, with a demand close to the maximum capacity, are a rare case. The same effect could be observed when comparing Nuremberg and Milan Linate airports (see FIGURE 8).

At European airports, it is very common that traffic is strongly reduced during the night. This could be either due to night flight restrictions or a lack of demand. This fact can be seen very clearly in the CCC, as well (see FIGURE 8). About 20% to 25% of the time, or 5 to 6 hours a day, the number of aircraft movements is very low. Istanbul Atatürk airport marks an important exception. Traffic levels remain elevated even at night.

FIGURE 9 plots the development of the BLI and PLI as a function of the airport size. Both indicators show a clear upward trend. In the case of the PLI, the correlation is even slightly stronger. Especially the large airports which very often serve as hub airports, have a higher than average capacity utilisation.

An interesting study case is found in the Milan Linate airport (LIN). It is one of the two airports near Milan. It is the closer one and therefore very popular. It is mainly used for domestic and short-haul international flights to metropolitan destinations within Europe. The maximum number of scheduled commercial movements per hour is limited to 18 (SEA 2012, p. 4-12). The data analyses revealed that it has the 4th highest capacity utilisation indicators, while the number of movements in 2012 is less than a quarter of the movements at London Heathrow or Frankfurt airport. This goes completely against the trend

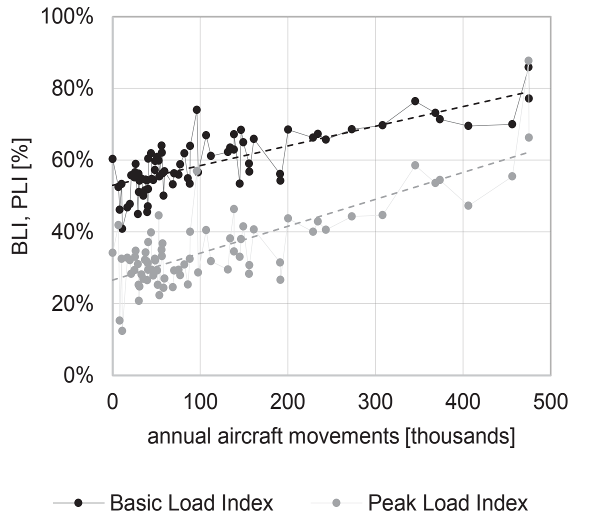

FIGURE 9 BLI and PLI as a function of the annual aircraft movements for the selected 75 European airports (OAG 2012)

of the other airports. The special situation of this airport, with a very limited maximum number of movements per hour and a rather significant passenger demand, results in this situation of very high capacity utilisation.

3.2. How capacity utilisation changed for major European airports from 2008 to 2012

As described above, the Eurozone crisis not only influenced the financial markets, but also the entire European air transportation industry. The demand for air travel decreased, putting some extra pressure on the industry. More and more stakeholders had problems keeping their businesses economically viable. The expected reaction of the market to such a development would be a consolidation in order to reduce the number of players in the market and increase overall profitability. Although consolidation of the airline industry was softened by governmental financial subventions, some players vanished from the market.

The overall number of aircraft movements for the 75 airports subject to this study decreased by 3.6% from 2008 to 2012 (Official Airline Guide 2008) (Official Airline Guide 2012). Also, the weighted average BLI and PLI decreased. With a decline of -2.7% the PLI fell almost twice as much as the BLI (-1.4%). This is simply due to the fact that statistically more flights take place during peak hours than during off-peak hours. Therefore, the PLI reacts more sensitively to changes in passenger demand. This makes it the more sensitive indicator for short term changes, whereas the BLI is more suited to determining the overall capacity utilisation from a long term perspective. Both together provide a very accurate image of the capacity utilisation situation of an airport.

Analysis of the change in annual aircraft movement for each airport shows that the larger airports tend to contribute more to the reduction than the smaller ones (see FIGURE 10). Despite the decline of overall air traffic numbers, there are several airports which encountered growth in traffic within this time period. The best example of this is the Istanbul Atatürk Airport, which has almost doubled its total number of aircraft movements. The

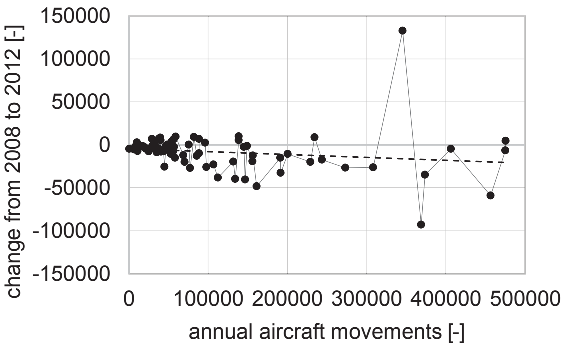

FIGURE 10 change in annual movements from 2008 to 2012

development of Turkish Airlines is mainly responsible for this. The airline uses the airport as their main hub airport.

FIGURE 11 plots the development of the BLI and PLI as a function of the annual aircraft movements per airport. It could be confirmed that reduction of the PLI is more important than decline of the BLI. Decrease in the PLI tends to be stronger for the larger airports. Contrarily, no significant trend could be observed for the change in the BLI as a function of the annual aircraft movements.

A closer investigation of the development of the three most capacity-critical airports is presented in the following section.
With an increase of 38% compared to the year 2008, Istanbul Atatürk airport was by far the fastest growing airport investigated within this study (Official Airline Guide 2008) (Official Airline Guide 2012). The shape of the CCC of 2008 and 2012 are very similar but with an offset of almost 20 movements per hour (see FIGURE 12). The long, flat ramp at the beginning of the CCC indicates a high capacity utilization and is reflected in the BLI and PLI.
As traffic demand is expected to grow further and the capacity utilization will increase at the same time, additional runways are planned to be built. This will give the airport further growth possibilities. It is expected that

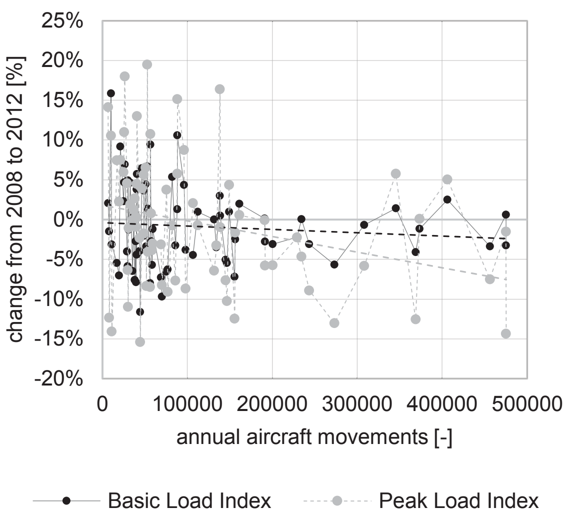

FIGURE 11 change in BLI and PLI from 2008 to 2012

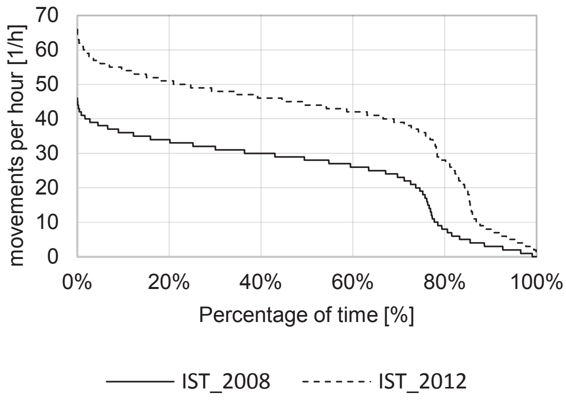

FIGURE 12 comparison of the CCC of IST in 2008 and 2012

these measures are still not enough to accommodate the future air traffic demand. Therefore, a completely new airport with a total annual passenger capacity of over 100 million is already under construction.

The total number of aircraft movements at the Frankfurt Airport did not change significantly from 2008 to 2012. An overall increase of 5000 flights has been monitored (Official Airline Guide 2008) (Official Airline Guide 2012). Due to the new runway, which went operational in 2011, the maximum hourly capacity was increased significantly. The DRC in 2008 has been set to 83 and went up by 2012 to 96 movements per hour. As a result, new slots were available during periods of high demand. Airlines moved flights into these periods in order to respond the best possible way to passenger demand. This effect can also be seen in FIGURE 13, as the traffic load during the high demand periods increased and contrarily for periods of medium demand.
Additionally, the effect of the night flight regulation, which was introduced between 2008 and 2012, can be clearly seen. For the last 25% of the time in the CCC, traffic decreased, which makes the nights a time with a very limited number of movements. Thus, the airport follows the trend of the majority of European airports (see FIGURE 8).

The total number of aircraft movements at London Heathrow airport decreased about 1% from 2008 to 2012 (Official Airline Guide 2008) (Official Airline Guide 2012).

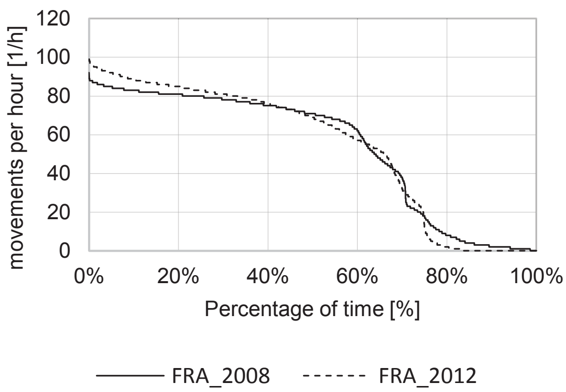

FIGURE 13 comparison of the CCC of FRA in 2008 and 2012

The CCC in FIGURE 14 shows no significant change in the shape of the curve. This is confirmed by BLI increasing slightly by about 1% and a PLI reduction of 2%. The reduction in PLI may not necessarily be caused by shrinking demand. As the average aircraft size went up at LHR in order to offer more seats per flight, the maximum throughput of the runway system declined. Hence the number of slots per hour went down, as well.

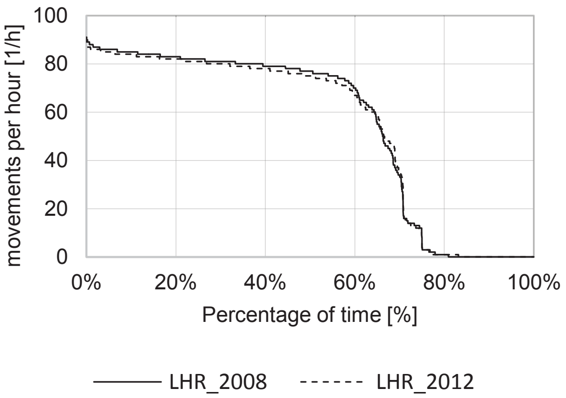

FIGURE 14 comparison of the CCC of LHR in 2008 and 2012

4. METHODICAL CHALLENGES

The method presented in this paper allows the determining of the degree of capacity utilisation of an airport. The basis for this evaluation is OAG traffic data. Because OAG data is based on flight schedules, it does not match 100% with the real air traffic. It isn't a problem for larger airports, but might be for the smaller ones. Results could be falsely skewed because of the relatively small number of total operations, which leads to high sensitivity of the BLI and PLI to missing aircraft movements.
London Heathrow airport is one of the world's busiest airports. Its BLI/PLI has been calculated to 86%/88% for the year 2012. Still, these values are more than 10% away from the theoretical maximum utilisation. This is even more the case for the BLI than as for the PLI. It is due to the fact that the maximum available capacity has been equalled to the reference capacity for the entire time of operations. This is an approximation which overestimates the available capacity. In reality, the maximum available capacity follows a stepwise trend (see FIGURE 2). Some of the capacity limiting parameters such as weather couldn't be foreseen. But there are others, like the aircraft mix or arrival-departure ratio, which could possibly be taken into consideration. This might further increase the accuracy of the presented method.
In this paper, the European airport system was taken as a study case to determine the capacity situation. This is a status quo analysis where the traffic movements are provided by OAG data. This analysis further allows the determining of the growth potential for existing systems. Analysing growth scenarios for future air traffic systems needs to transfer not only the individual air traffic demand for each airport into the future but also to consider changes to the airport infrastructure as well as to the operational framework. Both are input parameters for the presented method and have an important impact on the maximum runway capacity.

5. CONCLUSION AND OUTLOOK

The European air traffic system, which was analysed for this paper, has developed over almost an entire century. Due to traffic growth in the past decades, more airports than ever operate close to their maximum capacity. Analysing the distribution of the traffic reveals that only a small number of airports handle the vast majority of aircraft movements in Europe.
Most of the 75 airports subject to this analysis are characterised by moderate to low capacity utilisation. Only a small number of them face significant capacity constraints. The 7 airports with the highest capacity utilisation in 2012 are:

- London Heathrow Airport (LHR)
- Frankfurt Airport (FRA)
- Istanbul Atatürk Airport (IST)
- Milan Linate Airport (LIN)
- Madrid Barajas Airport (MAD)
- Munich Franz Josef Strauß Airport (MUC)
- Paris Charles de Gaulle Airport (CDG)

Comparing the situation of 2012 and 2008 shows a slightly reduced overall capacity utilisation. The reduction in air traffic movements which led to this fact was mainly caused by the impact of the Eurozone crisis which began in 2009. Nevertheless, some airports developed in a manner totally contrary to the trend of the overall system. The best example of this is the Istanbul Atatürk Airport. Its traffic numbers went up nearly 40%. This extraordinary growth was mainly caused by the fast expansion of the Turkish flag carrier, Turkish Airlines (TK). Being the airport with the 6th highest capacity utilisation in 2008, it became 3rd in the rankings for 2012. Another airport which encountered a significant change in traffic movements is the Madrid Barajas airport. The total traffic volume went down by about 11.2%. In the four year period, it declined from the 3rd position in the capacity utilisation ranking down to the 5th.
The results of the capacity utilisation analysis show that there isn't a specific point from which an airport is capacity-constrained. In most cases, it is a slow process which begins with moderate demand levels, which increase gradually. The traffic peaks continue growing until no more slots are ultimately available. An excellent example for the utilisation of almost all the available resources is London Heathrow Airport. However, not only the large airports can face significant capacity constraints. Despite the fact that Milan Linate airport has less than a quarter of the annual aircraft movements of London Heathrow, its capacity utilisation is very high.

Future studies in this field will need to analyse the growth potential of the airport system. Comparing these numbers to traffic forecasts will help to identify future bottlenecks.

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Appendix 1: BLI –PLI values for the 75 major European airports

	2008		2012		evolution	
	BLI	PLI	BLI	PLI	BLI	PLI
BRU	57,0%	32,4%	54,3%	26,6%	-2,8%	-5,8%
SXF	56,5%	22,7%	60,9%	29,3%	4,4%	6,5%
DRS	46,6%	20,8%	55,8%	28,3%	9,2%	7,5%
ERF	52,2%	24,1%	60,3%	34,1%	8,1%	10,0%
FRA	80,5%	80,6%	77,2%	66,3%	-3,3%	-14,4%
FMO	44,0%	26,4%	40,8%	12,3%	-3,1%	-14,1%
HAM	62,3%	35,9%	62,3%	29,5%	0,0%	-6,5%
CGN	58,2%	33,0%	54,9%	25,3%	-3,3%	-7,7%
DUS	71,6%	49,5%	68,5%	43,7%	-3,1%	-5,8%
MUC	72,5%	54,4%	71,4%	54,5%	-1,2%	0,1%
NUE	56,3%	29,1%	51,9%	29,4%	-4,4%	0,2%
LEJ	54,7%	29,8%	47,7%	32,1%	-7,0%	2,3%
SCN	50,4%	27,8%	52,4%	41,9%	2,0%	14,1%
STR	60,4%	37,3%	56,6%	28,6%	-3,8%	-8,7%
TXL	64,0%	37,2%	64,9%	41,5%	1,0%	4,3%
HAJ	53,2%	25,1%	59,9%	44,6%	6,7%	19,5%
BRE	51,9%	22,1%	56,6%	33,1%	4,7%	11,0%
TLL	53,4%	27,4%	45,5%	26,5%	-7,9%	-0,9%
HEL	59,3%	32,4%	56,8%	30,7%	-2,5%	-1,7%
MAN	66,2%	40,8%	59,0%	28,3%	-7,2%	-12,5%
LPL	56,6%	27,0%	50,1%	26,9%	-6,5%	-0,1%
LTN	60,6%	27,7%	53,3%	24,6%	-7,3%	-3,1%
SOU	57,0%	31,6%	54,3%	31,8%	-2,7%	0,2%
LHR	85,3%	89,2%	85,9%	87,6%	0,6%	-1,5%
ABZ	59,0%	36,0%	56,3%	36,8%	-2,8%	0,8%
AMS	67,1%	42,3%	69,6%	47,3%	2,5%	5,0%
DUB	73,9%	48,2%	68,4%	37,9%	-5,5%	-10,3%
CPH	68,5%	42,2%	66,3%	40,0%	-2,2%	-2,3%
LUX	48,0%	23,9%	54,5%	27,8%	6,4%	3,9%
SVG	53,6%	26,8%	57,3%	32,5%	3,6%	5,6%
KRK	50,2%	26,3%	54,8%	28,1%	4,6%	1,9%
KTW	52,3%	25,3%	46,8%	32,8%	-5,5%	7,4%
WAW	71,4%	38,5%	66,9%	40,5%	-4,5%	2,0%
ARN	56,0%	31,5%	56,2%	31,5%	0,1%	-0,1%
VNO	52,9%	23,4%	55,2%	29,3%	2,3%	5,9%
LPA	66,0%	37,5%	56,3%	29,2%	-9,7%	-8,3%
TFS	43,3%	26,9%	47,1%	31,3%	3,8%	4,4%

	2008		2012		evolution	
	BLI	PLI	BLI	PLI	BLI	PLI
TFN	72,0%	43,4%	64,0%	35,0%	-8,0%	-8,5%
ALC	55,8%	28,2%	50,1%	24,3%	-5,7%	-3,8%
BIO	65,8%	42,2%	61,9%	39,9%	-4,0%	-2,4%
BCN	74,3%	57,3%	68,6%	44,3%	-5,7%	-13,1%
MAD	77,3%	66,2%	73,2%	53,6%	-4,1%	-12,6%
AGP	52,1%	26,7%	53,4%	32,5%	1,3%	5,7%
PMI	58,4%	40,7%	53,4%	33,1%	-5,1%	-7,6%
VLC	66,3%	44,8%	54,7%	29,4%	-11,6%	-15,4%
MRS	53,4%	24,9%	63,9%	40,0%	10,6%	15,1%
CDG	73,3%	63,0%	70,0%	55,4%	-3,4%	-7,5%
ATH	67,0%	41,4%	63,5%	38,1%	-3,5%	-3,3%
HER	49,0%	26,4%	45,0%	30,9%	-4,0%	4,5%
CFU	37,5%	21,9%	53,3%	32,5%	15,9%	10,5%
SKG	51,2%	31,0%	51,6%	32,2%	0,4%	1,2%
BUD	65,1%	37,1%	58,8%	28,0%	-6,3%	-9,1%
BRI	55,5%	25,9%	54,2%	24,8%	-1,3%	-1,1%
CTA	61,7%	33,7%	59,7%	32,0%	-2,0%	-1,8%
PMO	62,1%	31,6%	54,5%	34,2%	-7,6%	2,6%
CAG	62,1%	31,6%	56,2%	25,2%	-5,9%	-6,4%
MXP	63,9%	40,1%	65,9%	40,7%	2,0%	0,6%
BGY	58,1%	30,0%	56,9%	27,0%	-1,2%	-3,0%
TRN	54,7%	24,1%	60,4%	37,1%	5,7%	13,0%
LIN	69,6%	48,2%	74,0%	57,0%	4,3%	8,7%
BLQ	52,6%	22,4%	62,0%	33,2%	9,4%	10,8%
VCE	62,5%	25,6%	56,0%	29,4%	-6,5%	3,8%
CIA	46,2%	31,7%	51,1%	20,7%	4,9%	-11,0%
FCO	70,4%	50,5%	69,7%	44,7%	-0,7%	-5,8%
NAP	64,1%	33,6%	60,7%	25,2%	-3,4%	-8,4%
FLR	52,0%	16,8%	58,9%	34,7%	6,9%	18,0%
PRG	60,2%	32,5%	61,1%	31,8%	1,0%	-0,7%
VIE	68,8%	49,5%	65,7%	40,6%	-3,1%	-8,9%
OPO	54,1%	26,4%	55,5%	22,3%	1,3%	-4,1%
LIS	59,9%	30,0%	62,9%	46,3%	3,0%	16,4%
SJJ	47,6%	27,6%	46,1%	15,2%	-1,5%	-12,4%
GVA	66,7%	35,5%	67,2%	34,5%	0,5%	-1,0%
ZRH	67,2%	47,5%	67,3%	42,9%	0,1%	-4,7%
IST	75,0%	52,8%	76,4%	58,6%	1,4%	5,7%
KBP	56,6%	31,7%	61,9%	30,9%	5,4%	-0,8%