Environmental Capacity and Sustainability of European Regional Airports: A Case Study

Nicola Gualandi, Luca Mantecchini, and Davide Serrau

***Abstract*—**Airport capacity has always been perceived in the traditional sense as the number of aircraft operations during a specified time corresponding to a tolerable level of average delay and it mostly depends on the airside characteristics, on the fleet mix variability and on the ATM. The adoption of the Directive 2002/30/EC in the EU countries drives the stakeholders to conceive airport capacity in a different way though. Airport capacity in this sense is fundamentally driven by environmental criteria, and since acoustical externalities represent the most important factors, those are the ones that could pose a serious threat to the growth of airports and to aviation market itself in the short-medium term. The importance of the regional airports in the deregulated market grew fast during the last decade since they represent spokes for network carriers and a preferential destination for low-fares carriers. Not only regional airports have witnessed a fast and unexpected growth in traffic but also a fast growth in the complaints for the nuisance by the people living near those airports. In this paper the results of a study conducted in cooperation with the airport of Bologna G. Marconi are presented in order to investigate airport acoustical capacity as a de-facto constraint of airport growth.

***Keywords*—**Airport acoustical capacity, airport noise, air traffic noise, sustainability of regional airports.

I. Introduction

AIRPORT capacity has always been perceived as the maximum number of aircraft operations during a specified time corresponding to a tolerable level of average delay [2]. The introduction of the Directive 2002/30/EC by the European Commission changes the scenario since imposes a cut off in aircraft movements in Community airports in case of noise generated by air traffic exceeds acoustic limits for a given area.

In Europe acoustic airport capacity is more stringent than physical capacity especially in regional airports, and this is mainly due to the house developing that has encroached on the territories near those airports. Acoustical capacity represents the first boundary to the expansion of airports. In many European regional airports the surplus of physical capacity, mainly dependant on the low level of traffic and on the high performance geometrical characteristics, can not be exploited unless acoustical capacity is efficiently managed.

Aircraft capacity can be defined as the maximum number of aircraft movements in an average day for traffic and meteorological conditions that generates a ground noise level equal to the maximum permitted by the acoustic zonings for a given area that surrounds an airport.

In general the more non urbanized areas surrounds the airport the easier the airport can accommodate future traffic growth, but local variables such as the number of evening and night movements and the type of aircrafts strongly affect airport acoustical capacity.

This paper contains the results of a study aimed to quantify the variables that affect airport capacity.

II. The Regulatory Scenario

Noise generated by different means of transport is recognized to be one of the most serious concerns for people living in urban areas. It's well accepted that the annoyance caused by air transport is higher than the annoyance caused by other means of transport. A survey conducted by IATA in 2003 pointed out that in Europe between 1.63 and 2.21 millions of people are exposed to aircraft noise.

The adoption of the Directives 2002/49/EC and 2002/30/EC by the European Parliament establishes a new scenario in noise management measures and in particular with regard to noise generated by air transport. The Directive 2002/49/EC introduces a common noise indicator for all the activities with the aim of providing a basis for developing Community measures to reduce noise emitted by major sources. The introduction of the common indicator Lden will significantly increase the impact of noise policies in airport management, since it introduces a weight of 5 dB for aircraft movements within evening period and a weight of 10 dB for night movements. The evening 5 dB penalty is likely to highly affect the overall noise measure because of the high level of traffic in airports during this period. A study that we conducted in cooperation with the airport of Bologna to understand how the introduction of the new regulatory scenario affects airport noise, has shown that in comparison with the former Italian noise indicator Lva, the introduction of Lden penalizes airport infrastructures because for a given level of traffic and for a given day-evening-night distribution

N. Gualandi is with the DISTART Transportation, Faculty of Engineering, University of Bologna, Viale Risorgimento 2 40136 Bologna, Italy (e-mail: n.gualandi@ unibo.it).

L. Mantecchini is with the DISTART Transportation, Faculty of Engineering, University of Bologna, Viale Risorgimento 2 40136 Bologna, Italy (e-mail: luca.mantecchini@unibo.it).

D. Serrau is with the Airport of Bologna G. Marconi, Via Triumvirato 84 40132 Bologna, Italy (e-mail: serrau@bologna-airport.it).

the Lden is around 2 dB higher than the former noise metric Lva. In the case noise limits remain the same (65 dB for residential areas and 75 dB for industrial areas) the aim of the European Commission to reduce noise annoyance is realized, but on the other hand airports are strongly penalized.

The adoption of the Directive 2002/30/EC pose a serious threat for the growth of airport infrastructure since it establishes rules and procedures regarding the introduction of noise-related operating restrictions at Community airports.

The introduction of measures aimed at reducing the noise nuisance from aircraft at airport with particular noise problems is a key point in the development of a sustainable air transport policy. The policy approach adopted by this Directive to noise management is based on the ICAO balanced approach. The balanced approach concept of aircraft noise management comprises four basic principles that airports should adopt to limit noise nuisance and requires a carefully assessment of all different options to mitigate noise. Those four principles are: the reduction of airplane noise at source, land-use planning and management measures, noise abatement operational procedures and operating restrictions. The last two decades have witnessed tremendous improvements in the construction of aeronautic engines in regard with efficiency and noise reduction, but it's not likely that such improvements will reduce aircraft noise in the near future. In case of short or medium term planning is not easy for an airport authority reduce noise nuisance by a land-use planning, even if it appears one of the best solutions aimed at reducing noise impacts and at the same time it guarantees a sustainable growth of airports. Many noise sensitive airports in Europe already adopt noise abatement procedures and noise management measures at the point that a further benefit is difficult to obtain. A reduction in the number of movements is a likely solution that airports could be forced to consider in the short term planning in case of non environmental compatibility.

The framework outlined above push airport operators to consider airport acoustical capacity as a mean that could limit the growth of air traffic in the European airports and could generate negative impacts for the economic activities in airport's catchment areas.

III. Airport Acoustical Capacity

Environmental impacts constitute the single most important impediment on the future growth of air transport industry [7], in addition EUROCONTROL has recognized that unless airport environmental capacity if effectively managed, environmental issues will form an increasingly significant constraint on European airports development and operation [5]. The IATA Environmental Reporting Survey of the 2001, concluded that for airlines environmental issues are considered of similar importance to commercial factors such as employment generation, building new alliances and developing air routes networks.

Noise and environmental impacts not only represent an annoying consequence of aviation for people living near the airports but also a serious threat to aviation itself.

Several definitions have been given in technical literature for airport acoustical capacity. On June 2000 environmental capacity was the theme of a workshop held at Heathrow Airport with the aim of working on a definition of environmental capacity. The meeting came up with the following definition: "environmental capacity represents the extent to which the environment is able to receive and tolerate, assimilate, or process outputs derived from airport activities (SCAN-UK 2000). Thomas [5] using a more pragmatic approach, gave a definition where environmental capacity is not directly defined, although the environmental component constraining capacity is recognized as the impact of airport operations upon the local environment and upon the lives of residents of local communities. Upham et al. [11] have defined the environmental capacity of an airport as the capacity of the environment both human and non human, to tolerate the impacts of airport activities.

From an airport manager prospective the concept of airport acoustical capacity grows in importance since represents the number of aircrafts that can be handled in a given period of time that generates a ground noise level compatible with acoustic zonings for areas near the airports.

The cap on movements the Dutch Government posed in 1997 at Amsterdam Schiphol due to environmental factors, that limited the theoretical capacity of the airport of around 650.000 slots per year to 360.000 slots per year is an example of how environmental issues influence airport capacity.

A study conducted by the authors of this paper has shown that the acoustical capacity of the Bologna airport G. Marconi is around the two third of the physical capacity.

The adoption of a different approach that links directly airport acoustical capacity with more measurable variables such as the number of airplane movements has been used in this study.

Airport acoustical capacity is defined as the maximum number of aircraft movements in an average day for traffic and meteorological conditions that generates a ground noise level equal to the maximum tolerable by acoustic zonings for the areas that surround a given airport.

Airport capacity as defined above is strictly dependant on a series of variables that can be divided into endogenous variables and exogenous variables. Endogenous variables strongly depend not only on the traffic and its characteristics but also on the airport characteristics such as layout or airport surface. Exogenous variables on the other hand, derive from the interaction between airports and the communities and are strongly dependant on the type of dwellings and on the regulatory scenario.

TABLE I
VARIABLES THAT AFFECT ACOUSTICAL CAPACITY

Endogenous variables	Exogenous variables
Fleet mix	Regulatory scenario
Traffic	Type of dwellings
Day/Evening/Night distribution	Position of dwellings
Load factor	Meteorological conditions
Airport layout	Distance runway dwellings
Runway length	
Airport surface	

In essence, the understanding of these variables is paramount for airport managers in order to obtain a gain in acoustical capacity, or an increase in the number of operation within a given noise contour. This paper analyses the impact of endogenous variables on noise since those variables are easier to manage and modify by airport operators.

IV. Analysis of the Variables

A. *Presentation of the Case Study*

The airport of Bologna represents a prototypal case study of regional airport for traffic characteristics, physical infrastructures and environmental issues. The traffic is mostly composed by a combination of normal carriers (ex flag carriers) such as Alitalia, British Airways, KLM, Air France, Lufthansa among the others, and low-cost carriers that link the airport of Bologna with a lot of destination in Europe. The percentage of charter flights represent another important part in the total air traffic, linking the airport G. Marconi with many long haul destinations. The fleet mix is mostly dominated by mid size aircrafts such as Md 80 series aircrafts, Airbus A-319 and A-320, and Boeing 737 aircraft series. The percentage of day, evening and night movements is respectively the 84%, 9%, and 7%, in the year 2005, by the definition of day evening and night period contained in Decreto n. 194 August 2005 that absorbs European Directive n. 49/2002. Day evening and night period are set respectively from 8 am to 8 pm, from 8 pm to 10 pm, and from 10 pm to 8 am.

The Airport of Bologna, like many similar airports in Europe, is likely to be seriously constrained by environmental factors in the short medium term due to the proximity with the suburbs of the city of Bologna. This awareness has pushed the airport infrastructure management to adopt a series of measures in order to reduce and mitigate noise pollution. The airport is provided with a noise monitoring system made up of nine monitoring terminals (NMT), located in noise sensitive areas around the airport. This system permits to record every single noise event generated by each flyover and associates automatically the noise to the aircraft responsible. The following analysis has been conducted using the noise data recorded by the two noise terminals located in proximity of the runways ends during the entire year 2005. The terminals in question are the NMT 1 and NMT 6 and are located respectively at 860 m from threshold number 12 and at 1000 m from the threshold number 30.

Take off noise and landing noise are considered separately in the next sessions.

Fig. 1 Location of the Noise Monitoring Terminals

B. *Characterization of Take-Off Noise*

Take-off represents the most critical phase of flight in many aspects, especially with regard to noise emissions. Aircraft propulsion systems are without doubt the major source of noise during this phase since an high thrust is necessary. The importance of understanding the variables that affect noise during take-off is essential for an airport management because in general the higher the number of take-off airplane in a given direction the lower is airport acoustical capacity in that direction.

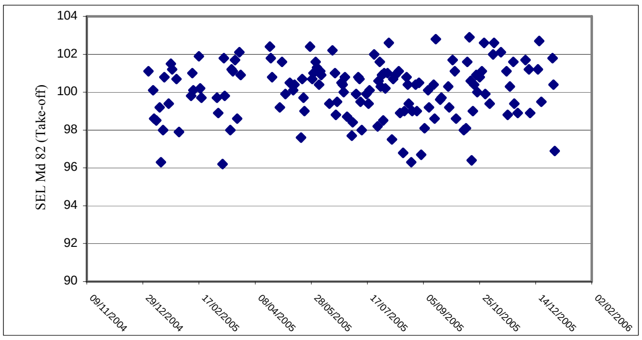

Fig. 2 SEL per period of the year

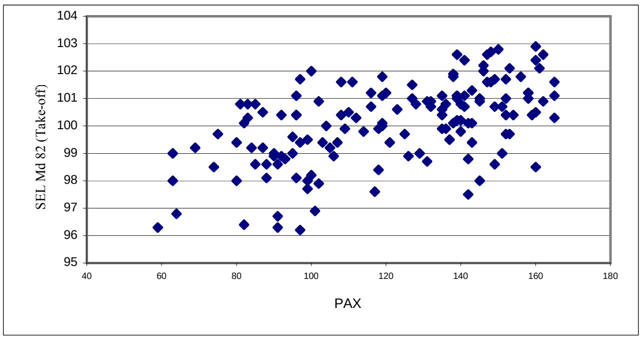

Fig. 3 SEL in function of the number of passengers

A first analysis conducted on the noise data related referred to a singular type of aircraft on one route, shows on one hand that in area near the airports noise is not influenced by meteorological conditions, but on the other hand shows a light relation between SEL and number of passengers. The analysis repeated for other types of aircraft shows the same results.

However the variable that affects the most airport acoustical capacity in this phase is the type of aircrafts. The analysis of noise data events recorded by NMT 6, during the year 2005, shows that the distribution of SEL per each type of aircraft is normal. Every aircraft has been then characterized by its SEL mean value, its standard deviation, and its coefficient of variation.

TABLE II
SEL MEAN VALUES PER AIRCRAFT TYPE, TAKE-OFF

Aircraft	SEL	Number of cases	CV
A 319	90	612	0.33
A 320	93	788	0.41
B 737-300	91.8	571	0.40
B 737-400	94	864	0.50
B 737-500	91	892	0.37
B 737-800	93.7	425	0.45
Md 82	99.8	2335	0.40
ATR 72	84.4	331	0.41
CRJ2	84.5	642	0.32
F 100	93.6	795	0.37
B 462	89.5	289	0.46

The data emphasize the poor noise performance of marginal ICAO Chapter III aircraft, in the study the Md 80, which is characterized by a mean value of SEL 10 points higher than the A-319 and in general several decibels higher than similar aircrafts.

In order to quantify the differences among aircrafts in regard with noise it has been introduced an *Aircraft Noise Equivalent Factor*, which is given by the ratio between the SEL of a given aircraft with the SEL of the noisiest one in a fleet mix. The analysis on the real values of SEL recorded and this index are important because they give an average value of aircraft performances in regard with the single event noise.

TABLE III
AIRCRAFT NOISE EQUIVALENT FACTOR

Aircraft	ANEF Value
ATR 72	0.02
Crj 2	0.03
B 462	0.09
A 319	0.1
B 735	0.13
B 733	0.15
A 320	0.2
B 738	0.24
F 100	0.24
B 734	0.26
Md 82	1.00

This ratio shows easily how some types of aircraft are less noisier than others, for instance a single event of an A-319 is 0.01 of an event generated by a Md 82. SEL is measured indeed in a logarithmic scale and an increase of 3 dB corresponds to a doubling of the acoustic sensation perceived. By introducing ANEF is possible to obtain a single value index that expresses the noise performance of an aircraft in relation with one another in a more comprehensible way.

Even if this analysis gives important information on the single event flyover it is not exhaustive to link different aircrafts with acoustical capacity, because capacity generally refers with cumulative noise metrics and specifically in Europe with Lden. This phase has been conducted by simulating with INM the noise generated by a given number of different aircrafts and than measuring the area or the length of the 65 dB noise contour, that identifies the acoustical capacity for residential areas. Fig. 4 contains an example of INM noise contours referred to take-off movements.

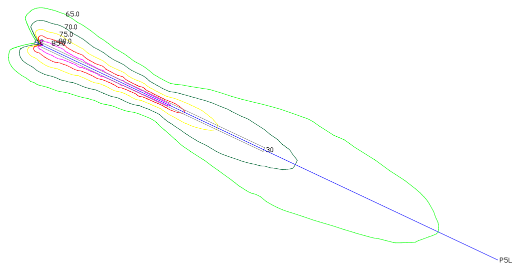

Fig. 4 Example of INM take off noise contours

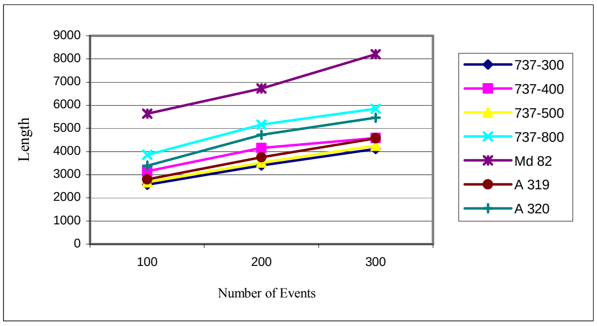

Fig. 5 Length of the 65 dB noise contour simulated with INM, day

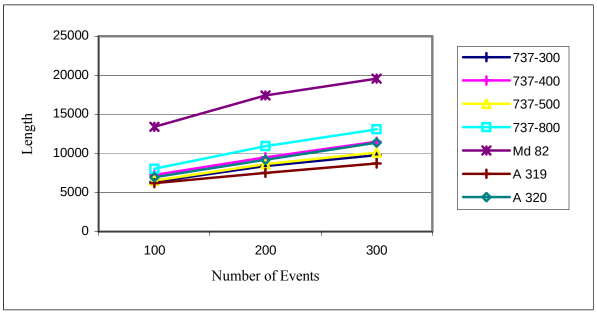

Fig. 6 Length of the 65 dB noise contour simulated with INM, night

The diagrams above show that for a given number of flyovers there is a high variability in the length and area of the noise contours. It is significant to note that the length of the noise contour generated by 100 Md 82 movements is almost equal to the one generated by 500 A-319 movements, which represents a five time increase in capacity. This confirms the reduction in airport capacity caused by marginal Chapter III aircrafts.

TABLE IV
DAY-EVENING-NIGHT RATIO MOVEMENTS LENGTH

Aircraft	Evening/Day	Night/Day	Night/Evening
B 737-300	1,90	2,47	1,30
B 737-400	1,77	2,31	1,30
B 737-500	1,88	2,44	1,30
B 737-800	1,62	2,08	1,29
Md 82	1,77	2,38	1,34
A 319	1,98	2,21	1,12
A 320	1,98	2,21	1,12

TABLE V
DAY-EVENING-NIGHT RATIO MOVEMENTS AREA

Aircraft	Evening/Day	Night/Day	Night/Evening
B 737-300	1,90	2,47	1,30
B 737-400	1,77	2,31	1,30
B 737-500	1,88	2,44	1,30
B 737-800	1,62	2,08	1,29
Md 82	1,77	2,38	1,34
A 319	1,98	2,21	1,12
A 320	1,73	2,06	1,19

The ratio between the length of the 65 dB noise contour generated by a certain number of movements between two different time periods for a given type of aircraft, gives an indication about the penalty of some decibels that are added to movements in cumulative noise metrics that rebounds on a lost in acoustical capacity. The same analysis repeated by using the areas within 65 dB noise contours shows the same results. The areas interested by a given sound level is an effective instrument for the planning process of airports since it allows to understand the portion of ground interested by a certain noise level.

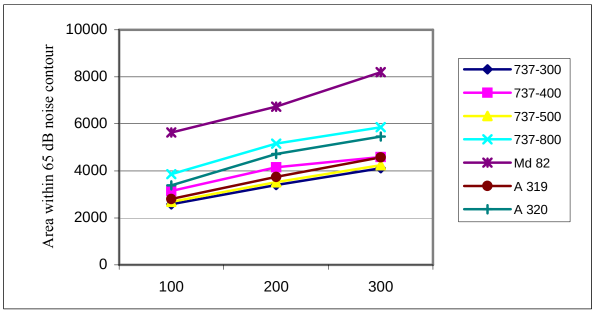

Fig. 7 Area of the 65 dB noise contour simulated with INM, day

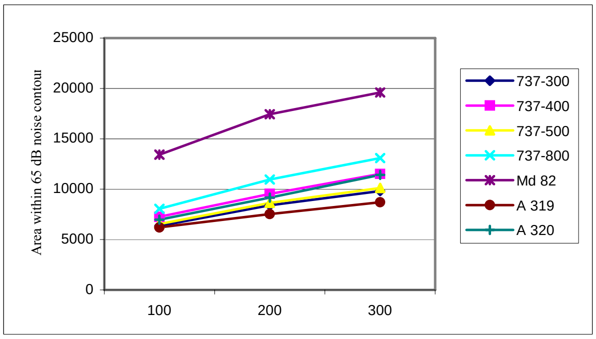

Fig. 8 Area of the 65 dB noise contour simulated with INM, night

The analysis shows that, as in the case studied before, a low number of Md 82 produces effects comparable with a much higher number of other aircrafts. It is worth noting that the area within 65 dB noise contour generated by 100 Md 82 is larger than the one generated by 500 Boeing 737-500.

C. Characterization of Approach Noise

Approach noise is mainly dependant on two factors the geometrical characteristics of airplanes and the configuration that airplanes have on approach with flaps and sluts lowered and the gear extracted. The turbulence due to the gear represents the principal noise source in landing, some experiments aimed to analyze the sources of airplane noise in landing pointed out that the gear extracted accounts for a 10 dB increase in noise indeed.

The analysis conducted is aimed to quantify the variables that affect noise in this phase and it is based upon the data collected by the noise monitoring terminal number 1 that is located at 860 m from the runway threshold mainly used for landings. The data show that approach noise is not dependent both on meteorological conditions and on the weight of aircrafts. The analysis of data shows that the distribution of frequency of SEL per type of aircraft recorded by the NMT1 is clearly normal. It is possible to identify each aircraft by the mean value of the SEL and its standard deviation.

TABLE VI
SEL MEAN VALUES PER AIRCRAFT TYPE, LANDING

Aircraft	Mean SEL	Number of cases	CV
A 300	92.6	134	0.34
A 318	87	119	0.20
A 319	87.5	451	0.33
A 320	87.5	656	0.30
A 321	87.7	65	0.39
Md 82	89.4	2033	0.48
B 737-300	90.8	356	0.32
B 737-400	90.6	664	0.33
B 737-500	90.7	519	0.33
B 737-800	89	268	0.26
B 767-300	91.2	146	0.54
B 757-200	89.1	51	0.31
B 462	85.4	173	0.33
CRJ 2	84.8	971	0.29
ATR 45	85.4	227	0.44
ATR 72	86.3	817	0.58
RJ 85	86	222	0.30
F 100	85.3	478	0.46
E 135	83.2	195	0.33

The analysis of data shows that there is less variability among marginal ICAO Chapter III airplane and newer one.

Noise contours generated by aircraft landings differ from take-off noise contours since they are stretched. It is possible to characterize the endogenous variables that affect noise in landing by valuating the distance of 65 dB noise contour from the threshold used for landing.

By simulating with INM an high number of landings in different period of the day it is possible to observe that most of the aircrafts has comparable performances. However this study has shown that landing in evening and night periods represent a serious limitation. Indeed that the ratio between the length of the noise contour generated by a given number of aircraft in the evening period and in night period, and the one generated by day movements for a given type of aircraft is respectively 3.32 and 4.60 (case of an A-319). This represents a serious constraint on the evening and night landing, because with the same acoustical capacity, a smaller number of aircraft can be accommodated in comparison with day movement.

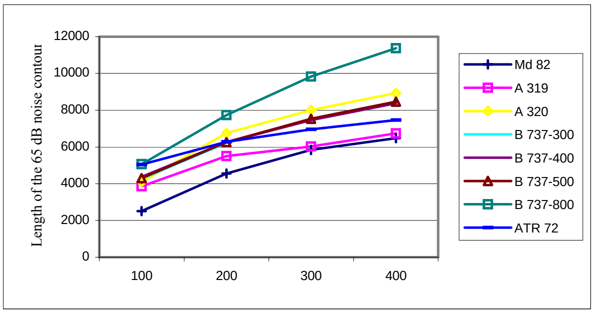

Fig. 9 INM landing simulations evening

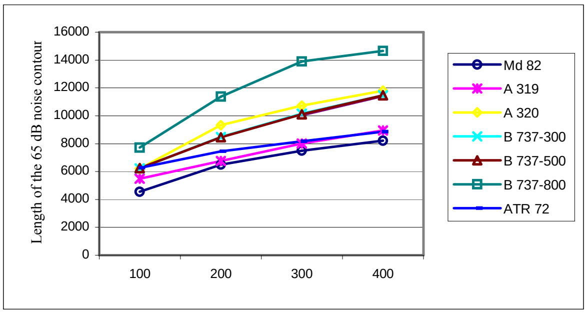

Fig. 10 INM landing simulations night

V. Conclusion

Airport acoustical capacity is likely to affect soon the growth of regional European airports as well as of hub airports.

Many factors affect airport acoustical capacity, if on one hand exogenous factors are difficult to modify in order to gain capacity in the short-medium term, a modification in endogenous factors represents a way to increase airport acoustical capacity.

The type of aircraft seems to represent the most critical variables in influencing airport acoustical capacity, especially during take-off phase, the presence of marginal ICAO Chapter III aircrafts is a strong limitation for the expansion of airports, especially at regional level, since they can drain acoustical capacity faster than newer aircrafts. The analysis shows a light relation between the load factor. The day-evening-night distribution is another important parameter in determining acoustical capacity because of the 5-10 dB weight to the movements within evening and night period. A redistribution of movements into the day-evening-night period can lead to a high increase in capacity.

Airport acoustical capacity is a limited resource that airport planners and managers have to handle in order to maximize the gains stemming from an increasing in traffic but a deep analysis on the variables is strongly recommended.

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