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IMPLEMENTING NOISE ABATEMENT MEASURES ON AIRPORTS: STATISTICAL ANALYSIS OF THE INFLUENTIAL FACTORS

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Abstract: *It is widely accepted that the most significant local environmental impact associated with the operation of airports arises from the noise generated by aircraft. In order to mitigate negative effect of noise, many airports have introduced a variety of measures. Although there are similarities between airports that are introducing some of the noise abatement measures (NAMs), the number and type of applied measures are very different among them. The research presented in this paper focuses on finding statistical evidence to support hypothesis that there is a significant correlation between implemented NAMs and specific characteristics related to airports. In order to determine the most influential factors for the introduction of NAMs in airport surroundings, logistic regression was used on data set for 246 European airports. For predictor variables, five specific characteristics related to airports (number of runways and aircraft operations, distance from the city and the population of the city that it serves, GDP per capita) and ten NAMs as a dichotomous variables have been used. The results of analyses have shown that there is a significant correlation between implemented NAMs and specific characteristics related to airports but also between NAMs themselves. The results of this research can be used to determine the likelihood of introduction of certain NAM for each airport based on the factors that showed significant correlation with that NAM.*
Keywords: *Air traffic, Airport, Noise Mitigation, Noise Abatement Measure (NAM).*

INTRODUCTION

Major commercial airports generate benefits to their neighboring communities, providing more investment and employment, increasing mobility, as well as providing a strong stimulus to the globalization of the industry, business and long distance tourism [1]–[3]. However, external costs are associated with these benefits and any increase in aircraft movement causes adverse environmental impacts [1]. It is widely accepted that the most significant local environmental impact related to the operation of airports arises from the noise generated by aircraft [4]–[10].
It has been shown that aircraft noise causes annoyance [4], various adverse health effects like hearing loss [11], cardiovascular diseases [12], sleep disturbance [13], etc. Different organizations at the global level and numerous air transport system stakeholders, including aircraft manufacturers, airports, airlines and air navigation service providers are participating in finding solutions to this problem [6].
In September 2001, within the Resolution A33-7 [14], International Civil Aviation Organization (ICAO) has presented the policies and programs based on the so-called "Balanced approach" to aircraft noise management. Balanced approach consists of identifying the noise problem at an airport and then analyzing the various measures available to reduce noise, with the goal of addressing the noise problem in the most cost-effective manner [14]. In the guidelines for the application of a "Balanced approach", ICAO has recognized the need that the solution for noise problem should be discussed separately at each airport in accordance with the particular characteristics of the observed airport [15]. The guidelines are general and do not require an accurate and uniform application for all airports. However, the same solution can be applied if similar noise problems are identified at airports [15]. The Balanced Approach recommends that noise policy should not target single solutions but use any combination of solutions as the most appropriate option to solve the causes of problems [6], [16].
Many airports recognized noise problem long ago and have introduced a variety of measures to reduce its impact [17]–[23]. Since 1992, Boeing maintains a database of airports around the world that implemented measures to reduce noise impacts [24]. The database contains basic information about airports and description of noise abatement measures (NAMs) that they implemented.
Based on data from Boeing's database, Netjasov [6] provided an overview of the measures implemented at airports around the world showing their frequency and diversity. Due to ever-increasing volume of air traffic in the world, it was shown that the number of airports that are facing the problem of noise, as well as the number of airports that are introducing some measures to manage the noise is increasing [6].
Although there are similarities between airports that are introducing NAMs, the number and type of applied measures are very different among them. In addition to all the previous knowledge of the subject, the question that remains open is [6], [7]: what are the most influential factors for introduction of individual measures? The research presented in this paper focuses on finding statistical evidence to support the hypothesis that there is a correlation

between some airports related characteristics and implemented NAMs.

This paper is organized as follows. Section 2 describes methods used in the paper; Section 3 the problem definition; Sections 4 and 5 present the results and discussion; Section 6 gives concluding remarks and future research directions.

METHODS

A. Noise Abatement Measures

According to Boeing database, airports around the world have introduced 18 different NAMs so far [6], [24]. In this research, only the following ten NAMs were analyzed, because data for other measures have not been available for larger sample of airports needed for quantitative research:

1. Noise Abatement Procedures
2. Engine Run-Up Restrictions
3. Preferential Runways
4. Airport Curfews
5. Noise Charges
6. APU Operating Restrictions
7. Noise Level Limits
8. ICAO Annex 16 Chapter 3/Chapter 2 Restrictions
9. Operating Quotas
10. Noise Budget Restrictions.

Analyzing Boeing's database it was found that 603 airports applied some of the NAMs in the year 2009. In 2010, the number of airports increased to 630.

In this paper, a particular emphasis was given on NAMs that European airports applied. According to Boeing's database, the number of European airports that applied some of the NAMs was 231 in 2009 and 246 in 2010.

Comparison of frequency of NAMs at European airports in years 2009 and 2010 is given in Fig. 1. The most common measures applied are Noise Abatement Procedures followed by Engine Run-Up Restrictions. Only seven airports have applied Noise Budget Restrictions.

Distribution of number of NAMs introduced per airport in Europe for years 2009 and 2010 is shown in Fig. 2. From the Fig. 2 it can be seen that in both years, roughly 60% of airports are introducing one to four NAMs and 25% five to six NAMs. Only 1% of the observed airports have implemented all ten analyzed measures.

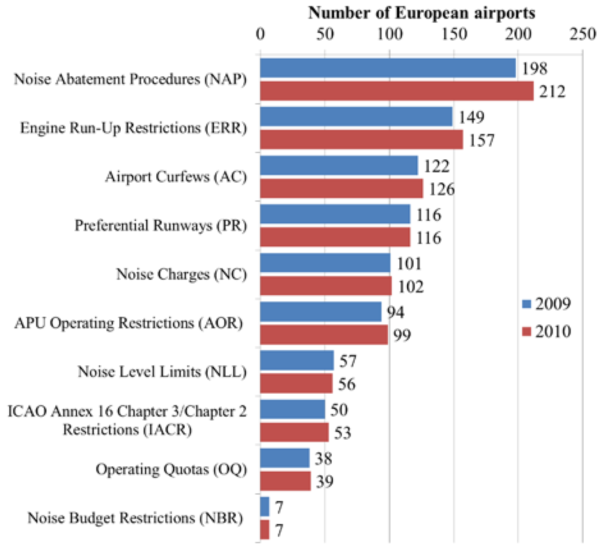

Figure 1 Distribution of number of airports in Europe that introduced certain NAMs in years 2009 and 2010

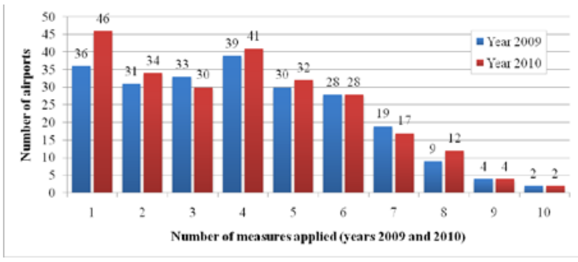

Figure 2 Distribution of number of NAMs introduced per airport in Europe for years 2009 and 2010

B. Data analysis

To predict the necessity of introducing each of the examined NAMs, we used the backward logistic regression analysis, used when the response variable is dichotomous (introduction of a specific NAM). The form of the model is:

$$\log\left(\frac{p}{1-p}\right) = c_0 + c_1X_1 + c_2X_2 + \ldots + c_kX_k \tag{1}$$

where p is the probability that the dependent (response) variable Y=1, X_1, X_2,..., X_k are the predictors, and c_0, c_1,... c_k are regression coefficients.

Logistic regression thus forms a predictor variable (log(p/(1-p)) which is a linear combination of the explanatory variables, later transformed into probabilities by a logistic function.

For predictor variables, we have used five specific characteristics related to airports: number of runways and aircraft operations, distance from the city and the population of the city that it serves, GDP per capita (Section 3) and ten NAMs as a dichotomous variables.

The Cox & Snell R Square and the Nagelkerke R Square values were used to show the amount of variation in the dependent variable explained by the model. The Cox & Snell R^2 is an alternative index of the goodness of fit related to the R^2 value from linear regression. The Nagelkerke R^2 provides a correction to the Cox & Snell R^2, as its maximum value is 0.75 when the variance is at its maximum (0.25), so that the maximum value equals 1.

PROBLEM DEFINITION

The number and type of implemented NAMs differ among airports. In order to analyze characteristics of airports or their surroundings that are leading to different resolution of noise problem, first step in this research was to determine potential measurable factors that are presumed to have influence on introduction of NAMs.

A. Research Starting Point

Netjasov [6] stated that intuitively it is expected that airports with more aircraft operations (landings and take-offs), higher percentage of heavier aircraft in the fleet mix, closer to the settlements, greater population densities surrounding it, will implement more NAMs. However, in many cases, it seems that reasons for noise measure introduction are somewhat different [6]. Some of the reasons may be regulations concerning noise, citizen complaints or level of awareness of environmental protection.

To what extent will the airport surroundings be exposed to noise depends on many factors, and the most important are [25]:

- airport characteristics (number of takeoffs and landings, the distribution of traffic throughout the day and night, etc.),
- fleet mix (types of aircraft that are using the airport),
- the shape and characteristics of departure and arrival procedures, and
- airport location (topography).

Fleet mix, shape and characteristics of departure and arrival procedures, and airport location have a significant impact on the creation and propagation of noise. However, in this study, they have not been taken into account because of the unavailability of operational data and the fact that procedure usage depends on meteorological and/or traffic situation. It is necessary to consider distance from the airport to the city because settlements closer to the airports are more exposed to noise. Airports with more runways have more options for designing different procedures for takeoff and landing in order to reduce noise and because of that, it is decided to consider the impact of number of runways on introduction of NAMs. A number of citizen complaints about noise were not considered because for most airports data are not found in the available databases. GDP per capita is used as a measure of the level of awareness of environmental protection. The assumption is that developed countries, with a higher GDP per capita, are more concerned about the negative impact of noise than less developed countries.

From all of the assumed factors, for further analysis, the following have been adopted:

- number of aircraft operations (take-offs and landings) on the airport,
- number of airport runways,
- distance from the airport to the settlement,
- population in the vicinity of the airport,
- GDP per capita of the country where the airport is located.

B. Design of Database

To determine a functional relationship between proposed factors and implemented NAMs, it is primarily necessary to collect the data about these factors for each airport that has applied at least one of the NAMs.

The basis for this research was Boeing's database of airports that implemented NAMs. The study was conducted on the most recent available data set for year 2010.

The data about the number and type of applied NAMs and number of runways for each observed airport were obtained from Boeing's database [24] (grass runways were excluded). A number of aircraft operations is taken from EUROCONTROL’s STATFOR Interactive Dashboard [26]. STATFOR database takes into account only IFR flights. GDP per capita (in dollars) for every country was taken from World Bank (http://data.worldbank.org/).

For the purposes of this research, proximity to the settlement was defined as the distance from the airport to the center of a city that airport serves. For most airports, website www.distance.to was used for estimation of the distance to the town center. For airports serving several cities, the average distance from the cities was calculated according to the following formula:

$$d_{avg} = \left(\sum_{i=1}^{n} d_i \cdot P_i \right) / \sum_{i=1}^{n} P_i \tag{2}$$

where: d_{avg} is the average distance from the cities, d_i is the distance from city i to the airport, P_i is the population in city i, n is the number of cities.

For most cities, collecting the data about city population was carried out from EUROSTAT.

C. Assumptions and hypothesis

Before analyzing the database and answering the question about the correlation between airports related characteristics and implemented NAMs, it is important to know whether every airport can implement each measure. The assumption is that there are no limitations for airports to apply an NAM.

It was concluded that there are no infrastructure requirements for implementation of *APU operating restrictions*, because, in addition to fixed ground power unit (GPU), there are mobile GPUs that can be transported near aircraft. The primary requirement for airports is to have GPU equipment, which every airport has but maybe not for all aircraft stands.

Every airport should be able to impose some operating restrictions like *Airport Curfews*, *Noise Budget Restrictions*, *Operating Quotas* or *ICAO Annex 16 Chapter 3/Chapter 2 Restrictions*. In some cases, restrictions may not be economically feasible if they apply to aircraft that make the dominant traffic at the airport. In some cases, *Engine Run-Up Restrictions* require some additional infrastructure (run-up area or maintenance hangars) where pilots are allowed to perform run-up checks of their aircraft [7], [15].

The development of appropriate *Noise Abatement Procedures* should also include obstacle clearances [27]; this implies that some airports may not be able to implement every proposed Noise Abatement Procedure, but they should be able to develop some of their own based on local conditions [15].

Noise charges are usually based on the excess of allowed noise values at certain points of the noise monitoring system. Also, noise charges can be imposed on every aircraft via landing or departure fees.

Noise level limit could be defined as a maximum noise level per flight or as a contouring parameter for the noise management policy [28]. In the second case, noise monitoring system is not needed because compliance with maximum noise level can be checked with noise calculation software.

Every airport can impose *Preferential Runway* based on the noise impact on nearby settlements if meteorological conditions permit. Flight safety should be the determining factor in runway selection when implementing noise abatement operational measures [15].

Although, sometimes there are necessary conditions for introduction of certain NAMs, the general conclusion is that in most cases, every airport can introduce every measure in one or the other way.

But, the question that remains is: on what basis can we decide which airports will introduce which NAMs? That also implies following questions:

- Does the introduction of specific NAMs entail the introduction of other NAMs?
- Can a specific NAM be a precondition for the introduction of other NAMs?
- Is there any logical connection between implementation processes of different measures?

Some measures for the reduction of noise, such as the introduction of quieter fleets, the application of noise abatement operational procedures and the use of operating restrictions, may provide the benefit of a reduction or a modification in the noise-affected area surrounding an airport, but without complementary land-use measures, the anticipated benefits over the long term will not be achieved and, consequently, the return on their costs may be lost [15]. This means that any beneficial effects that may be accomplished by the use of these measures should be preserved whenever possible through the application of complementary measures relative to land-use planning and management [15].

According to the identified noise problem at an airport, operating restrictions may be a part of the set of measures to be implemented to alleviate the noise problem. However, ICAO encourages States not to apply operating restrictions as a first resort, but only after consideration of the benefits to be gained from the other three principal elements of the Balanced Approach [15]. That is why some measures are more widespread than others [29]. For example, at 86% of the major European airports noise abatement procedures are in use, while, at only 3% of the observed European airports, noise budget restrictions are in the place [24].

Every airport has the freedom to implement any measure or combination of the measures, to address the noise problem in the most cost-effective manner. It should be noted that cost-benefit analysis for certain measure is not the same for every airport, due to different airport characteristics (fleet mix, traffic volume, surrounding population, etc.) On that basis, it was presumed that the airports will implement similar measure or combination of the measures if they have the same airport characteristics (and assuming similar noise problems).

Based on the presented research starting points, hypothesis that will be examined in this study are the following:

1. The introduction of specific NAMs entails the introduction of other NAMs.
2. There is a significant correlation between implemented NAMs and particular characteristics related to airports:
   a. Airports with more aircraft operations are more likely to introduce some of the NAMs.
   b. Airports with more runways are more likely to introduce some of the NAMs.
   c. Airports that are closer to the settlement are more likely to introduce some of the NAMs.
   d. Airports surrounded with more population are more likely to introduce some of the NAMs.
   e. Airports located in counties with higher GDP per capita are more likely to introduce some of the NAMs.

RESULTS

First, we predicted the introduction of *Airport Curfews*, based on the set of the predictor variables mentioned above. The Cox & Snell R Square and the Nagelkerke R Square values are 0.278 and 0.371 respectively, showing the amount of variation in the dependent variable explained by the model. Table I lists the results of the last step of Backwards Binary Logistic regression model.

TABLE I
AIRPORT CURFEWS LOGISTIC REGRESSION MODEL

	Regression coefficients	Wald test	Sig.
Number of airport runways	-0.531	4.852	0.028
Engine Run-Up Restrictions	0.948	8.420	0.004
ICAO Annex 16	2.074	17.002	0.000
Noise Charges	1.177	13.687	0.000
Preferential Runways	1.095	11.864	0.001
Intercept	-1.129	8.827	0.003

Table I shows that the factors that significantly affect the introduction of Airport Curfews are number of airport runways and the following NAMs:

TABLE III
APU OPERATING RESTRICTIONS LOGISTIC REGRESSION MODEL

	Regression coefficients	Wald test	Sig.
GDP per capita (in thousands)	0.034	10.403	0.001
Airport Curfews	0.823	5.830	0.016
Engine Run-Up Restrictions	1.578	18.221	0.000
Noise Abatement Procedures	1.206	5.650	0.017
Noise Charges	-0.702	4.092	0.043
Preferential Runways	1.333	17.860	0.000
Intercept	-4.671	39.178	0.000

Engine Run-Up Restrictions, ICAO *Annex 16 Chapter 3/Chapter 2 Restrictions*, *Noise Charges*, and *Preferential Runways*. The negative regression coefficient for the independent variable number of airport runways indicates that airports with more runways are less likely to introduce Airport Curfews. Positive regression coefficients for independent variables Engine Run-Up Restrictions, ICAO Annex 16 Chapter 3/Chapter 2 Restrictions, Noise Charges and Preferential Runways indicates that airports that have introduced this NAMs are more likely also to introduce Airport Curfews. The highest coefficient is obtained for ICAO Annex 16 Chapter 3/Chapter 2 Restrictions showing that this NAM has the greatest influence on the introduction of Airport Curfews compared to other NAMs.
Table II shows the classification accuracy. As can be seen, 98 airports that had not introduced this NAM are also predicted not to introduce it, and 93 airports that had introduced it are predicted to do so; 22 airports that had not introduced Airport Curfews are predicted to introduce it, and 33 that had, are predicted not to. These airports had been incorrectly classified. The overall classification accuracy is 77.6%.

TABLE II
AIRPORT CURFEWS CLASSIFICATION TABLE

	Airport Curfews		
Observed	Predicted		% Correct
	0	1	
0	98	22	81.7
1	33	93	73.8
Overall %			77.6

Prediction of introduction of *APU Operating Restrictions* was done in the same way. The Cox & Snell R Square and the Nagelkerke R Square values are 0.264 and 0.357 respectively, showing the amount of variation in the dependent variable explained by the model. Table III shows the results of the last step of Backwards Binary Logistic regression model.
From Table III it can be seen that the factors that significantly affect the introduction of APU Operating Restrictions are *GDP per capita* (in thousands), *Airport Curfews*, *Engine Run-Up Restrictions*, *Noise Abatement Procedures*, *Noise Charges*, and *Preferential Runways*.
The negative regression coefficient for independent variable Noise Charges indicates that airports that introduced this NAM are less likely to introduce APU Operating Restrictions. The positive regression coefficient for independent variable GDP per capita (in thousands) indicates that airports with higher GDP per capita of the country where they are located are more likely to introduce APU Operating Restrictions. Also, positive regression coefficients for Airport Curfews, Engine Run-Up Restrictions, Noise Abatement Procedures and Preferential Runways indicate that airports that have introduced this NAMs are more likely also to introduce APU Operating Restrictions. The highest coefficient is obtained for Engine Run-Up Restrictions showing that this NAM has the highest influence on the introduction of APU Operating Restrictions compared to other NAMs.
Table IV shows the classification accuracy for APU Operating Restrictions. As can be seen from Table IV, 115 airports that had not introduced this NAM are also predicted not to introduce it, and 64 airports that had introduced it are predicted to do so; 32 airports that had not introduced APU Operating Restrictions are predicted to introduce it, and 35 ones that had, are predicted not to. These airports had been incorrectly classified. The overall classification accuracy is 72.8%.

TABLE IV
APU OPERATING RESTRICTIONS CLASSIFICATION TABLE

	APU Operating Restrictions		
Observed	Predicted		% Correct
	0	1	
0	115	32	78.2
1	35	64	64.6
Overall %			72.8

Prediction of introduction for eight other NAMs was done in the same way. Due to that, the summary results of the last step of Backwards Binary Logistic regression models and classification accuracy for this eight NAMs are shown in Table VI. Summary results of the Cox & Snell R Square and the Nagelkerke R Square values and overall percentage of classification accuracy for ten NAMs are shown in Table V.
It can be seen from table V that the highest values of the Cox & Snell R^2 and the Nagelkerke R^2 (0.359 and 0.555 respectively) were obtained for ICAO Annex 16 Chapter 3/Chapter 2 Restrictions. This means that independent variables that significantly affect the introduction of ICAO Annex 16 Chapter 3/Chapter 2 Restrictions explaining around 55% of the variation in the dependent variable.

TABLE V
SUMMARY RESULTS OF BACKWARDS BINARY LOGISTIC REGRESSION MODELS FOR TEN NAMS

	Model Summary		Classification Table
Measure name	Cox & Snell R Square	Nagelkerke R Square	Overall Percentage
Airport Curfews	0.278	0.371	77.64
APU	0.264	0.357	72.76
Engine Run-Up	0.235	0.322	79.27
ICAO Annex 16	0.359	0.555	89.02
NAP	0.097	0.176	86.18
NBR	0.072	0.318	97.60
Noise Charges	0.196	0.264	72.00
Noise Level Limits	0.179	0.272	78.90
Operating Quotas	0.276	0.474	88.60
Pref. Runways	0.179	0.239	67.50

The overall classification accuracy of this model is 89.02%. The lowest values of the Cox & Snell R^2 were obtained for Noise Abatement Procedures and Noise Budget Restrictions. The overall classification accuracy ranges from 67.5% for Preferential Runways up to 97.6% for Noise Budget Restrictions. The values of Cox & Snell R^2 and the Nagelkerke R^2 must be taken into account when interpreting the results concerning the factors that significantly affect the introduction of certain NAMs.

DISCUSSION

Table VII shows the influence of independent variables on NAMs observed. Sign + presents positive dependency with significance $p<0.05$, while sign ++ presents positive dependency with significance $p<0.01$. Sign - presents negative dependency with significance $p<0.05$. Independent variables that are not marked do not significantly affect the introduction of NAMs.

We have already discussed the factors that significantly affect the introduction of Airport Curfews and APU Operating Restrictions. From Table VI and VII it can be seen that the factors that significantly affect the introduction of *Engine Run-Up Restrictions* are number of aircraft operations (in thousands), Airport Curfews, APU Operating Restrictions and Operating Quotas, all having the positive influence. The factors that significantly affect the introduction of *ICAO Annex 16 Chapter 3/Chapter 2 Restrictions* are a number of airport runways, Airport Curfews, Noise Charges, Noise Level Limits and Operating Quotas.

Noise Abatement Procedures are positively affected with population and APU Operating Restrictions. Positive dependency between Noise Abatement Procedures and population indicates that airports that are surrounded by more population are likely to implement some Noise Abatement Procedures to reduce the noise level on the ground or to change the route that flies over a large part of the population. Negative dependency was obtained for Airport Curfews, which means that airports that have introduced Airport Curfews are less likely to introduce Noise Abatement Procedures. However, taking into account the low values of the Cox & Snell R Square and the Nagelkerke R Square (0.097 and 0.176 respectively) these results are not relevant.

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TABLE VI
SUMMARY RESULTS

ICAO Annex 16 Chapter 3/Chapter 2 Restrictions

	Regression coefficients	Wald test	Significance
No. of airport runways	0.812	8.541	0.003
Airport Curfews	1.897	11.975	0.001
Noise Charges	0.981	4.959	0.026
Noise Level Limits	1.344	9.027	0.003
Operating Quotas	2.488	25.790	0.000
Intercept	-5.408	46.897	0.000

Operating Quotas

	Regression coefficients	Wald test	Significance
No. of airport runways	-0.710	5.193	0.023
Population	0.000	6.712	0.010
Engine Run-Up Restr.	1.646	5.494	0.019
ICAO Annex 16	2.635	30.755	0.000
Noise Level Limits	0.965	4.109	0.043
Intercept	-3.549	22.364	0.000

ICAO Annex 16 Chapter 3/Chapter 2 Restrictions

Observed	Predicted		% Correct
	0	1	
0	188	5	97.4
1	22	31	58.5
Overall %			89.0

Operating Quotas

Observed	Predicted		% Correct
	0	1	
0	196	11	94.7
1	17	22	56.4
Overall %			88.6

Engine Run-Up Restrictions

	Regression coefficients	Wald test	Significance
No. of aircraft operations	0.014	9.957	0.002
Airport Curfews	0.662	4.395	0.036
APU	1.075	9.962	0.002
Operating Quotas	1.424	4.745	0.029
Intercept	-0.791	10.829	0.001

Noise Level Limits

	Regression coefficients	Wald test	Significance
No. of aircraft operations	0.005	5.380	0.020
ICAO Annex 16	1.605	18.330	0.000
Preferential Runways	0.810	5.180	0.023
Intercept	-2.451	63.956	0.000

Engine Run-Up Restrictions

Observed	Predicted		% Correct
	0	1	
0	62	27	69.7
1	24	133	84.7
Overall %			79.3

Noise Level Limits

Observed	Predicted		% Correct
	0	1	
0	176	14	92.6
1	38	18	32.1
Overall %			78.9

Noise Abatement Procedures

	Regression coefficients	Wald test	Significance
Population	0.002	6.849	0.009
Airport Curfews	-0.926	4.996	0.025
APU	1.484	8.859	0.003
Intercept	1.230	15.185	0.000

Noise Charges

	Regression coefficients	Wald test	Significance
Number of operations	0.008	12.167	0.000
GDP per capita	0.026	7.587	0.006
Airport Curfews	1.166	15.714	0.000
Intercept	-2.428	29.470	0.000

Noise Abatement Procedure

Observed	Predicted		% Correct
	0	1	
0	0	34	0.0
1	0	212	100.0
Overall %			86.2

Noise Charges

Observed	Predicted		% Correct
	0	1	
0	117	27	81.3
1	42	60	58.8
Overall %			72.0

Preferential Runways

	Regression coefficients	Wald test	Significance
No. of airport runways	0.833	12.326	0.000
Airport Curfews	0.808	7.826	0.005
APU	1.087	13.758	0.000
Intercept	-2.159	28.344	0.000

Noise Budget Restrictions

	Regression coefficients	Wald test	Significance
No. of airport runways	0.973	7.148	0.008
Preferential Runways	17.864	0.000	0.996
Intercept	-22.581	0.000	0.995

Preferential Runways

Observed	Predicted		% Correct
	0	1	
0	96	34	73.8
1	46	70	60.3
Overall %			67.5

Noise Budget Restrictions

Observed	Predicted		% Correct
	0	1	
0	239	0	100.0
1	6	1	14.3
Overall %			97.6

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TABLE VII
DEPENDENCY BETWEEN INDEPENDENT VARIABLES AND NAMS OBSERVED

		Dependent variables									
		AC	AOR	ERR	IACR	NAP	NBR	NC	NLL	OQ	PR
Independent variables	Number of aircraft operations (in thousands)			++				++	+		
	GDP per capita (in thousands)		++					++			
	Number of airport runways	-			++		++			-	++
	Average distance										
	Population-all cities (in thousands)					++				++	
	Airport Curfews (AC)		+	+	++	-		++			++
	APU Operating Restrictions (AOR)			++		++					++
	Engine Run-Up Restrictions (ERR)	++	++							+	
	ICAO Annex 16 Chapter 3/Chapter 2 Restrictions (IACR)	++							++	++	
	Noise Abatement Procedures (NAP)		+								
	Noise Budget Restrictions (NBR)										
	Noise Charges (NC)	++	-		+						
	Noise Level Limits (NLL)				++					+	
	Operating Quotas (OQ)			+	++						
	Preferential Runways (PR)	++	++						+		

The only factor that significantly affects the introduction of *Noise Budget Restrictions* is a number of airport runways; this means that airports that have more runways are likely to implement Noise Budget Restrictions. However, this analysis could be questionable because only seven airports have introduced this measure.

The factors that significantly affect the introduction of *Noise Charges* are a number of aircraft operations (in thousands), GDP per capita (in thousands) and Airport Curfews; this means that airports with more aircraft operations and higher GDP per capita of the country they are located are likely to introduce Noise Charges. In addition, airports that have introduced Airport Curfews are likely to introduce Noise Charges. The factors that significantly affect the introduction of *Noise Level Limits* are a number of aircraft operations (in thousands), ICAO Annex 16 Chapter 3/Chapter 2 Restrictions and Preferential Runways. Airports that have introduced these two NAMs and had more aircraft operations are likely to introduce Noise Level Limits.

The factors that significantly affect the introduction of *Operating Quotas* are a number of airport runways, the population in all cities (in thousands), Engine Run-Up Restrictions, ICAO Annex 16 Chapter 3/Chapter 2 Restrictions and Noise Level Limits. Negative dependency was shown for a number of airport runways, which means that airports with more runways are less likely to introduce Operating Quotas. Airports surrounded with more population are more likely to introduce this NAM. Positive dependency is shown for Engine Run-Up Restrictions, ICAO Annex 16 Chapter 3/Chapter 2 Restrictions and Noise Level Limits indicating that airports that have implemented these three NAMs are likely to implement Operating Quotas.

The factors that significantly affect the introduction of *Preferential Runways* are a number of airport runways, Airport Curfews, and APU Operating Restrictions. Airports with more runways are likely to implement Preferential Runways. Positive dependency with these two NAMs indicates that airports that have implemented Airport Curfews and APU Operating Restrictions are likely to implement Preferential Runways.

CONCLUSION

Analysis of noise abatement measures, presented in this paper has shown that there is a significant correlation between NAMs implemented at European airports and specific characteristics related to airports.

The research was conducted based on data from Boeing's database for the year 2010 for 246 European airports. For each airport, data on number of runways and aircraft operations, distance from the city and the population of the city that it serves, GDP per capita of the state in which airport is and the number of introduced NAMs were collected.

The results obtained by logistic regression have shown that there are correlations between some airport related characteristics and NAMs introduced. It was shown that airports with more aircraft operations are likely to introduce Engine Run-Up Restrictions, Noise Charges, and Noise Level Limits. Airports with higher GDP per capita of the country where they are located are more likely to introduce APU Operating Restrictions and Noise Charges. It was shown that a number of airport runways has negative dependency with Airport Curfews and Operating Quotas, which means that airports with more runways are less likely to implement these two NAMs. Positive dependency was shown between a number of airport runways and ICAO Annex 16 Chapter 3/Chapter 2 Restrictions, Noise Budget Restriction, and Preferential Runways. The population surrounding

airport has positive dependency with Noise Abatement Procedures and Operating Quotas while the average distance from airport to the city center did not show any correlation with NAMs observed.
The results obtained by logistic regression also showed that introduction of specific NAMs entail the introduction of other NAMs. All significant correlations obtained between NAMs are positive, except between APU Operating Restrictions and Noise Charges and between Noise Abatement Procedures and Airport Curfews.
The results of this research can be used as a directive during airport developing planning process to determine the likelihood of introduction of certain NAM on certain airports, based on the factors that showed significant correlation with considered NAM.

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