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NOISE LOAD AT THE AIRPORT M. R. ŠTEFÁNIK IN BRATISLAVA

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Abstract

The aim of the article is to describe the current state of noise pollution at the airport M.R. Štefánik and analyze the change in noise pollution when changing the occupancy level of the airport M.R. Štefánik in Bratislava. Another goal of the article is to design an optimal runway system that would be suitable for the future needs of the airport and to compare the current noise load of the current runway system with an alternative noise load when changing the configuration of the runway system. The article also briefly describes the noise, the factors influencing its spread in various environments, the reasons for the generation of noise in air transport and its negative effects on people or the environment.

Keywords

Noise. Bratislava Airport. Annex 16. Air operations. Runway system.

1. INTRODUCTION

Air transport is currently one of the fastest growing modes of transport, a statement that is particularly true of technological advances in propulsion units. The first aircraft used reciprocating engines, also referred to as propellers. These engines were characterized by a certain noise level, but only after the arrival of jet engines and their mass implementation in civil aviation, work began on certain regulations. In 1971, ICAO adopted the first noise standard under Annex 16. In the following years, this annex was expanded to include other standards and recommendations in new editions, and in 1983 ICAO created CAN and CAEP to help develop new or update existing standards and recommendations. According to ICAO, engine noise decreased by 75% between the 1960s and 2000.

2. CURRENT NOISE STATE AT M.R. ŠTEFÁNIK AIRPORT AND METHODOLOGY OF PREDICTION

2.1. Legislation

The current state of noise pollution at Bratislava Airport is subject to certain regulations by the state under Act no. 355/2007 and Act. no. 649/2007. Act no. 355/2007 Act on the Protection, Support and Development of Public Health and on Amendments to Certain Acts determines the conditions and requirements according to which noise load measurements are to be performed at airports and their surroundings in the territory of the Slovak Republic. [1] Decree of the Ministry of Health no. 549/2007 Coll. details of the permissible values of noise, infrasound and vibration and of the requirements for the objectification of noise, infrasound and vibration in the environment are laid down. [217]

2.2. Description of physical and technical conditions of M. R. Štefánik Airport

M. R. Štefánik Airport is located about 9 km from the center of the capital of the Slovak Republic, near the village of Ivanka pri Dunaji, in the cadastral area of Bratislava-Ružinov. Construction of the airport began in 1947-1948 and regular operation began in 1951. Currently, Bratislava Airport is located in a relatively densely urbanized area, which extends to the west, north, south and east of the airport, which complicates the physical development of the airport due to noise pollution affecting the population and the possible complaints of the population about noise. There is also a small Danube on the southern side of the airport, where due to the existing flora and fauna, there is an increased risk of aircraft colliding with birds that may nest here. [3].

2.3. Correlation and regression analysis

Air transport is generally influenced by many factors, the most important of which we would classify in basic categories such as. socio-economic factors, demand and supply factors, environmental factors and factors of other transport options. Therefore, it is important to say that the quality of each prediction depends not only on the chosen prediction method but also on the variables with which the prediction would work. Also, the quality of the prediction depends on the size of the budget intended to create the prediction or the experience of the people who created the prediction. [4]

From the point of view of airport planning and operation, it is very important to predict the future development of traffic, both in terms of future airport capacity requirements, which the airport should be able to adapt to in time, and in terms of profitability of the arrangements. or, conversely, that the arrangements in question are not unnecessarily exaggerated to such an extent that they are no longer justified and therefore not cost-effective. The methods that are commonly used in aviation to predict the development of traffic at airports can be divided into three main groups: qualitative methods, quantitative methods and decision analysis. In this way, they are divided according to ICAO in document no. 8991 of 2006. [5]

When examining the values of two or more different numerical characters, we can assume that there may be a statistical interdependence between certain variables examined. A possible feature of a certain statistical dependence may be a certain correlation between the given features, for example in the form of a direct ratio, and thus with a linear increase in the numerical value of variable A the numerical value of variable B increases or the value of the variable B. In this case, it is a direct linear statistical dependence. If the higher numerical values of the variable A correspond to the lower numerical values of the variable B and at the same time the higher numerical values of the variable B would correspond to the lower numerical values of the variable A, we speak of an indirect linear statistical dependence. To determine the statistical linear dependence, the correlation coefficient rxy between the values of the variables X and Y is calculated using two alternative relations:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_1-\bar{x})*(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_1-\bar{x})^2*\sum_{i=1}^{n}(y_i-\bar{y})^2}})$$

$$r_{xy} = \frac{n*\sum_{i=1}^{n}x_i\,y_i - \sum_{i=1}^{n}x_i*\sum_{i=1}^{n}y_i}{\sqrt{[n*\sum_{i=1}^{n}x_i^2-(\sum_{i=1}^{n}x_i)^2]*[n*\sum_{i=1}^{n}y_i^2-(\sum_{i=1}^{n}y_i)^2]}}$$

The value of the coefficient describes the correlation intensity of the investigated variables. The correlation coefficient has a value in the range -1 to 1. If the correlation coefficient has a value of 0, it means that it is an independence between the examined values. In the case of other numerical values, it is possible to use the following approximate scheme of the breakdown of the statistical dependence intensity given in Table 1. [6]

Table 1: Breakdown of the intensity of statistical dependence according to the respective value with respect to the interval on which the given value is located. [6]

The value of the correlation coefficient	Level of linear dependence
from - 0.1 to 0.1	Linear independence
from -0.4 to -0.1 or 0.1 to 0.4	Weaker addiction
from -0.7 to -0.4 or from 0.4 to 0.7	Moderate addiction
from -1 to -0.7 or from 0.7 to 1	Strong addiction

Regression analysis has many variants. In principle, regression analysis examines at least two numeric characters X and Y. The task of regression analysis in this case is to model the dependence of variable Y on variable X, where variable X is the cause and variable Y is the consequence, this simple two-variable variant is called single-criteria regression analysis. The relationship between the variables X and Y is expressed by the following formula:

$$y_i = f(x_i) + e_i$$

Where [xi, yi], i = 1, 2, ..., n is n points whose coordinates are expressed by the values of the variable X and the variable Y and ei is a random error also called a residual component or residual. [6] Residue is the error between the predicted value and the observed true value, it is a measure of how far the point is vertically from the regression line. The regression line is sometimes called the line of the best fit because it is the line that fits best when dragged through points, minimizing the distance of actual values from the predicted values, using the least squares method. In connection with the regression analysis, it is important to explain the confidence interval, which represents the proportion of calculated values that contain the actual value of the parameter [7].

However, if we assume or know that the variable Y is influenced by more factors than just one predictor X, it is usually a multi-criteria regression analysis, which can be used to express the effect of several independent variables on the observed indicator at the same time. Multi-criteria regression analysis should include all predictors of X affecting the observed variable Y. The dependence of factors X on the observed variable Y can be determined by correlation analysis or by building a correlation matrix, at the same time factors X must be as independent of each other, otherwise distortion of results. We write the multi-criteria regression analysis in the form [6].

$$y = b_o + b_1x_{1i} + b_2x_{2i} + \ldots.. b_kx_{ki} + e_i$$

Stepwise regression is a specific form of regression analysis that allows you to search a list of possible predictors, while helping to select the ones that provide the best regression model. This procedure is used when it is not entirely clear at the outset which predictors are most suitable for creating a regression analysis model. [8].

In 2019, 26,941 movements (take-offs and landings) of aircraft were handled at the airport out of the total number of movements at Bratislava Airport. Of the total number, there were 14,294 landings and 13,467 takeoffs. In terms of arrivals, the runway was the busiest in the direction of 31, with 11,066 movements. In terms of take-offs, the busiest runway was in direction 04, together with runways in directions 13 and 31. In terms of runways and runways in both directions, runway 13-31 was used for landings in 83.3% of cases. This is mainly due to the fact that the level of equipment with radionavigation approach devices is higher on this runway than on runway 04-22. In terms of take-offs, runway 13-31 was used in 50% of cases. Runway 04-22 was used in take-offs in 50% and on landings in 17% of cases. The noise load was calculated on the basis of a mathematical model of the area based on data from photogrammetry. The control was performed using a georeferenced digital orthophotomap. The calculation of the noise load caused by air traffic was done using the methodology of ECAC Doc. 29. The propagation of noise from ground sources was modeled using the ISO 9613 standard. The verification of the model took place in two phases, in both cases an airplane was used for verification. The calculation is performed for operation for 180 days. The area noise load from air traffic is made by displaying isophone equivalent sound levels A for individual reference time periods of the day. The calculation was also made in individual places in the affected settlements. 6 emission points in built-up areas around Bratislava Airport were determined for the calculation of specific values. At these points, the noise load in dB was calculated. The results of the noise analysis showed that air traffic noise most affects the residential areas of Ivanka pri Dunaji and Most pri Bratislave. Data were provided with the consent of Bratislava Airport by Euroakustik, s.r.o. [9]

3. NOISE LOAD ANALYSIS WHEN CHANGING THE LEVEL OF BTS AIRPORT

3.1. The current state of air transport in Europe and at M. R. Štefánik Airport

The latest published data from Bratislava Airport come from 2020. This year and also in 2021 was strongly marked by the global pandemic Covid-19, which affected air traffic around the world, either by various restrictions aimed at travel to and from high-risk countries, or phasing out. flights for a variety of reasons, including a slowdown in economic activity around the world. Air transport around the world has seen a huge decline in its economic activities. It was no different in Europe. According to data published on the Eurostat website, the number of passengers carried in Europe fell by 73% in 2020 compared to 2019, which accounted for only 277 million passengers carried by air. [10] In 2021, 64.3% of passengers, ie just over 409 million passengers, were carried in Europe compared to the previous pandemic of 2019. [11,12]. In the case of flights to Europe, 5 million flights were made in 2020 and by 2021 there were already 6.2 million flights. Compared to 2021 to 2020, this may seem like a big increase of 20%, but compared to the 11.1 million flights in 2019 in Europe, it is still only 54% more than before the pandemic. period. In the first quarter of 2021, the number of flights compared to 2019 was at the level of 38% to 34%. In the following months, however, with the advent of digital EU-Covid passports, with increasing levels of vaccination in the Member States and the gradual lifting of anti-pandemic measures, the market situation began to change when traveling within the European area. On August 27, there was a peak in the number of flights in Europe, with 26,773 flights. Compared to the peak number of flights performed in 2019, when 37,288 flights were performed, this was 28% less. The market situation remained stable during the winter months, when the pandemic situation in Europe began to deteriorate again. Air traffic in Europe during the winter period was between 75% and 80% of the level of the same period in 2019.

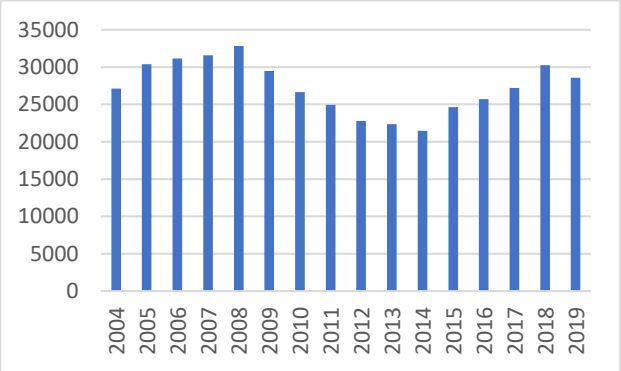
Slovakia and its neighboring countries recorded similar results in the number of flights performed. Slovakia recorded a 52% decrease in air traffic, Hungary recorded a 54% decrease, the Czech Republic recorded a 55% decrease, Poland a 46% decrease and Austria recorded a 52% decrease in air traffic. [13].

3.2. Development and current status of passenger numbers at BTS Airport since 2004

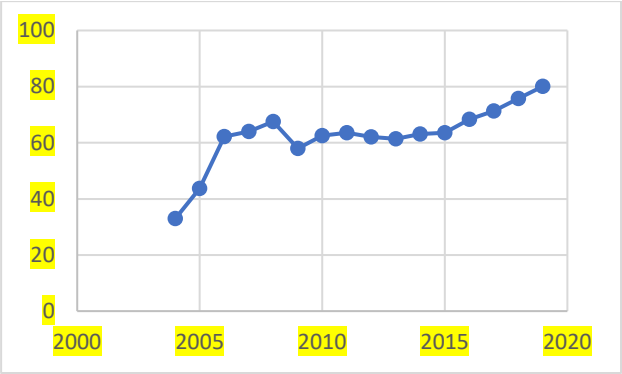
I divided the passengers at M. R. Štefánik Airport into 2 categories, according to the type of transport they used: scheduled air transport and non-scheduled passenger air transport. From 2004 to 2008, the airport saw a steady increase in the number of passengers handled. During this period, the number of passengers transported in scheduled air transport increased. In 2009, there was a decrease in the number of regular passengers, which was mainly due to the global economic crisis, which took place this year and due to which three airlines terminated operations at the airport: SkyEurope Airlines, Seagle Air and Air Slovakia. In the following years, the number of regular passengers handled continued to decline, while the share of passengers transported by non-scheduled air transport remained at roughly the same levels throughout the period, starting to increase slightly in 2010. The number of regular passengers decreased until 2014. Between 2010 and 2014, several airlines ended up at the airport, which resulted in a declining trend of passengers carried until 2014. 2014 was characterized by a stabilization of the total number of passengers compared to 2013, when less than 18,000 more passengers were carried. From 2015 to 2018, M. R. Štefánik Airport again saw a steady increase in the number of regular passengers, which also manifested itself in 2019, but where it was slowed down in recent months, and later in 2020 as a result of the impending pandemic Covid-19 and with it against pandemic measures, artificial flight disruptions, etc. there was a decrease in passengers and flights handled. The number of non-scheduled passengers during this period remained at approximately the same or similar level from 400,000 to 500,000, with the highest number of non-scheduled passengers being in 2017, when they reached 569,481. this number appeared to exceed 2 000 000 passengers, but there has been a sudden drop in passenger traffic in recent months. [14]

3.3. Development of aircraft movements from 2004 to 2019

The number of movements in the period under review between 2004 and 2019 developed similarly to the number of passengers handled in the same period. From 2004 to 2008, the number of movements gradually increased. The year 2009 was also as critical for the number of flights handled at M. R. Štefánik Airport as for the number of passengers handled. The number of flights handled in 2009 decreased by 11% due to the consequences of the global economic crisis and the collapse of several airlines operating at M. R. Štefánik Airport. The years 2010, 2011 and 2012 were characterized by a gradual decrease in flights handled from 10% to 7% compared to the previous year. The period between 2012 and 2014 was characterized by a gradual slowdown in the decrease in flights handled by 2% between 2012 and 2013 and by 5% between 2013 and 2014. In 2015, the number of flights handled increased by 14%. The following period from 2016 to 2018 was also characterized by a gradual increase in the number of flights handled, when in 2019 there was again a decrease in the number of flights handled due to the incipient pandemic at the end of the year. What is important to say, however, is that the load capacity utilization factor (load factor) either increased or remained at approximately the same level throughout the period under review between 2004 and 2019.



Picture 1: number of movements at the airport at M. R. Štefánik airport between 2004 and 2019. (number of take-offs and landings) [14]



Picture 2: Seat capacity utilization factor between 2004 and 2019 (average number of passengers per landing / take-off) [14, the autor]

3.4. Prediction of the development of air traffic at the airport M.R. Štefánik

I developed a forecast of air traffic at M. R. Štefánik Airport on the basis of historical data on airport occupancy in terms of checked-in passengers. Using regression stepwise analysis and correlation analysis, I identified the key indicators (predictors) that most affected the development of the number of passengers handled in the period from 2004 to 2019, when due to the global situation in connection with the outbreak of Covid-19 pandemic occurred in recent months. decline in the air transport market in Europe but also worldwide. Based on the determination of the given significant predictors, I subsequently created a model of prediction of the future development of passengers at M. R. Štefánik Airport for a long-term period using multi-criteria regression analysis. I set the long-term horizon until 2050. Both models have 3 possible development scenarios, namely the scenario with low, medium and high growth. In the following subchapters, I explained and described the results of individual analyzes and models, including individual predictors, the reasons for their selection, determination and their predictions, as well as the processed scenarios for the future development of air transport in terms of the number of passengers handled.

Using correlation analysis, I searched for cross-correlations and discarded data sets that were too high a cross-correlation - values of correlation coefficients at the level of 0.95 and more. Subsequently, the remaining values were retained and entered into the stepwise analysis.

Using the stepwise method (forward selection and backward elimination), the algorithm evaluated, based on the values of the examined numerical series of possible predictors, that the model of regression analysis predicts all movements at the airport (number of movements at BTS airport - take-offs and landings) includes three predictors of selected indicators: the number of passengers handled at Bratislava Airport, the Human Development Index and the number of IFR flights in Slovakia. These three predictors were characterized by very low p values and mean values. Standard Error in regression analysis indicates how accurate the model is - the higher the numerical value of the standard error, the more accurate the model, and vice versa, the smaller the numerical value of the standard error, the more accurate the model. This error expresses how accurate the estimated values are in relation to the real values and it is up to the analyst to assess whether the error is already too large or is tolerable for the model. I performed the stepwise regression method in the MATLAB program environment. The equation of the linear regression analysis based on the performed forward selection and back elimination has the following form:

$$y = x_1 * 0{,}0076 - x_2 * 164838 + x_3 * 16{,}7896 + 144231{,}2269$$

where x1 is the total number of passengers handled at M. R. Štefánik Airport, x2 is the value of the human development index and x3 is the number of IFR flights performed in Slovakia.

The residual errors of the model ranged from 1835 to -1395.79. These values express the direct difference between the predicted numerical values of the performed movements and the actual measured values of the performed movements. With the numbers in the estimates of the performed movements at the airport of M. R. Štefánik, the model ranged in the deviations from 0.01% to 17%. The model showed the highest values of deviations when predicting the total number of passengers handled in the first 3 years of the observed period, while predicting the total number of passengers handled during the remaining observed period, the model showed deviations from 6% to 0.01%.

Using forward selection and back elimination and correlation analysis, I selected and identified individual predictors based on which I subsequently made a regression prediction. Individual predictors were selected by comparing several models of regression analyzes using different combinations of predictors. The combination of the predictors "number of IFR flights", "Human Development Index" and "Number of passengers" was chosen on the basis of a certain assumption of the author and subsequently also the results of the regression analysis. The regression analysis, where these variables were chosen as predictors, had the lowest average value of the residual error (deviation) of the predicted values compared to the actual ones. The average error value was 0.04%. To calculate the estimate of future values of the monitored variable number of movements at the BTS airport, it was necessary to determine the future development of individual predictors. I determined the future development of predictors independently or took over from the forecasts of certain institutions in terms of medium and long term. I set the long-term horizon from 2019 to 2050.

I took over the predictor "number of IFR flights in Slovakia" from Eurocontrol predictions issued for the period between 2021-2027 and 2021-2050. [15,16]

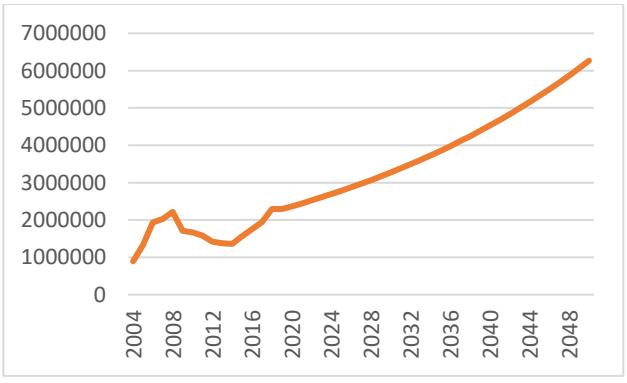
Eurocontrol predicts IFR flights in 3 scenarios - high growth, medium growth and low growth. Eurocontrol's forecasts take into account current and future challenges for air transport and its development. The forecast for the period from 2021 to 2027 takes into account the effects of the global Covid-19 pandemic in terms of epidemiological factors, factors affecting the aviation industry and macroeconomic impacts on gross domestic product. The prediction assumes three possible scenarios, where all three have specified factors influencing the epidemiological situation in the countries from which the specific impacts on air traffic will develop. The scenario with a high (fast) course assumes the end of the effects of the pandemic in the middle of 2023, and thus the return of air traffic to pre-pandemic values in 2019. The scenario with a medium level of development assumes the end of the pandemic by the end of 2023. In the course of this work, it is important to look at the possible development of future IFR flights in Slovakia, as well as the expected development of passengers at airports. Rapid

and medium-sized scenarios assume that airports will be able to return to their pre-pandemic performance. The slow-moving scenario assumes that airports will have difficulty operating as in the pre-pandemic period. According to the IATA forecast, from 1 March 2022, a gradual return to pre-pandemic values of passengers carried within the European internal market is expected in 2022, when the number of passengers carried should reach 86% of the number of passengers carried in 2019 and 105% in 2024. [17]

Eurocontrol's long-term forecast for 2022 to 2050 does not take into account the Russian invasion of Ukraine, but assumes that this conflict will affect air transport developments in the medium rather than the long term. The prediction is based on pre-pandemic air traffic performance and focuses its prediction on the period after the end of the global Covid-19 pandemic. This prediction is also based on three different scenarios. The high-growth scenario assumes high economic growth in a world with a high level of globalization, with intensive support in investing in sustainable technologies and promoting green-sustainable aviation. The medium-growth scenario also appears to be the most likely and is characterized by medium-term economic growth, with regulations focusing on the environmental, social and economic aspects of air transport and its sustainability. This scenario is based on current trends in air transport and also on likely trends in air transport in the future. The low-growth scenario is characterized by slow economic growth in terms of flight conditions, higher prices for conventional aviation fuel and also sustainable aviation fuel, together with higher charges for air pollution. It also counts on limited investments in new technologies, or delays in starting these investments compared to previous scenarios. This scenario is based on the assumption that energy prices will be particularly high and at the same time there would be a strong economic downturn during the 30 years of forecast. [16] IFR flights within the airspace of the Slovak Republic are partly responsible for the generation of movements at M. R. Štefánik Airport, in cases where there are fewer such flights, due to the correlation coefficient between the observed variable "movements at BTS airport" and the predictor "number of We can expect that with the decrease in the number of IFR flights, there is a slight increase in movements at M. R. Štefánik Airport. In practice, we could explain this by the fact that under adverse external environmental conditions, some flights are forced to change from VFR to IFR or such flights are planned in advance as IFR, so some of these flights will not go to M. R. Stefanik Airport.

The correlation coefficient of the predictor "Human Development Index" with the observed variable "movements at the BTS airport" is - 0.4456, which means a weaker negative linear dependence. This means that the worse the HDI, the slightly higher the value of the number of movements made at the BTS airport. At first glance, this doesn't make much sense in general, if we look at it: "The healthier, more educated and richer the population, the more likely it is that such a population can afford to buy a ticket and fly, which should increase and the number of movements. Such an assumption, from my point of view, is correct only to a certain extent in the case of BTS airport. BTS Airport has been characterized by a steady increase in scheduled air traffic over the last 5 years. The providers of these services were, in most cases, low-cost companies that carried the majority of passengers to or from BTS. Such companies are characterized by a high load factor. An excellent example is Ryanair. In view of this, I think that the higher HDI is a sign that, on the one hand, the purchasing power of the population is increasing (better education usually has a positive effect on possible earnings) and the population's willingness to travel, as young people or people without more serious health complications healthier population). Thus, the higher HDI has a positive linear dependence with the predictor "PAX together", but looking at the types of companies that provide their services at BTS and the level of their provision, this may result in a slight reduction in the number of movements at BTS due to increasing HDI, as these low-cost airlines are trying to make the most of their services and therefore prefer to provide fewer flights instead of providing more flights with a slightly lower load factor, for example at 80%. , regularly and with a much higher load factor, bordering on 90%, as in the case of Ryanair. I predicted the HDI until 2050 on the basis of the trend continuation method, while the average year-on-year growth from 2020 to 2025 is 0.39%, and I kept this growth for the growth of this index until 2050. I estimate this increase partly on the basis of Eurocontrol forecasts, which in both scenarios predict either strong or stable average economic growth, while the scenario with low economic growth has so far proved to be the least likely. By 2050, according to my estimates, the HDI should reach 0.9215.

The predictor "Number of passengers handled" and the observed variable "movements at BTS airport" have a correlation coefficient of 0.5895. The correlation coefficient indicates the mean positive linear relationship between the observed variable and the predictor. In practice, this finding could be explained by the simple principle "the more potential passengers, the greater the offer - flights - airport movements". This assumption only applies to a certain extent, because most services at BTS are provided by low-cost carriers, which, due to their business models, try to make the most of their flights compared to traditional carriers. I based the prediction of the total number of passengers handled on the basis of predictions of annual percentage increases of air passengers in terms of long-term prediction (until 2050) from companies and organizations: Boeing, Airbus, The Air Transport Action Group, ICAO, International Clean Transport Council (The International Council on Clean Transportation (ICCT) averaging values for the same type of scenario (low, medium, high). This long-term growth at BTS is based on the assumption that trends in air transport will remain unchanged in the future and that BTS will maintain the same position on the regional market in the total number of passengers handled. The estimated year-on-year increase in passengers at Bratislava Airport by 2050 is 3.3%.



Picture 3: Priemerný medziročný alternatívny nárast cestujúcich na letisku Bratislava do roku 2050.

3.5. Scenario of the development of the number of movements at the M. R. Štefánik Airport for the long term

Based on the development of Eurocontrol scenarios, I created scenarios for the development of the number of movements at M. R. Štefánik Airport for a long time horizon. Horizon has 3 scenarios, and these scenarios are directly derived from the IFR predictions of Eurocontrol flights, my predictions of the human development index and the average defined annual growth of passengers at M. R. Štefánik Airport. The short-term scenarios have been developed for the recovery period from the global Covid-19 pandemic, and the long-term scenarios reflect alternative developments in the post-global pandemic period up to 2050. Scenario 2 is the most probable, given the development of air traffic so far compared to the IFR prediction of Eurocontrol flights.

In creating a scenario with medium growth of IFR flights in Slovakia for the long term, I use Eurocotrol's forecast for the period 2019 to 2050. This scenario is based on the assumption that the Covid-19 pandemic did not affect world markets as much as in Scenario 1, with the world economy and with it, air transport will recover from this crisis as early as 2024 and also from the assumption that the next economic growth will be stable and without major complications. The average year-on-year increase in IFR flights is set at 1.2% of the number of IFR flights in Slovakia in 2019, which were 821, which is 220 IFR flights more than in the previous scenario. According to estimates, the average growth of IFR flights in Europe and also in Slovakia should be accompanied by a certain degree of implementation of new technologies, which are friendly to refueling or emissions.

Table 2: Values for calculating the number of movements at BTS airport in 2050 with the average growth of IFR flights

Variable name	Value of average year-on-year growth in %	Initial value in 2019 and final value in 2050	
Number of IFR flights in Slovakia	1,2 %	562	821
Human development index	0,39 %	0,826	0,9158
Number of passengers handled	3,3 %	2 290 242	6 266 014

The resulting value of movements at M. R. Štefánik Airport in 2050 was predicted to be 54,406 movements with a medium growth of IFR flights.

3.6. Characteristics of San Diego airport and comparison with Bratislava airport

San Diego International Airport (San Diego International Airport) is an international airport in United States of America. It is located in the state of California, in the city of San Diego, about 3.2 km from the part of the city "Downtown San Diego", while the airport itself is located practically in the city center as well, which has similar or perhaps worse opportunities in terms of ability to physically expand in space as Bratislava Airport. I chose San Diego Airport because it has a similar regional geography to BTS Airport, has a partially similar runway system to BTS Airport, and has a higher number of flights and passengers than BTS Airport should have in the future. The airport is located in an area with a high level of urbanization. It has one runway, in which the axis of the trajectory is a densely built-up and populated area of the city of San Diego in both directions. The airport itself is surrounded on the north, east, west, and in part south by boroughs of San Diego. The second reason for the choice was the similarity of the technical parameters of the track system. San Diego Airport has one runway with a length of 2865 x 61 m, the runway surface is made of asphalt and the runway capacity is defined by the code PCN 75 / F / A / W / T. Compared to the runways at Bratislava Airport, this is a different type of surface (flexible), which is more demanding for regular maintenance. In this particular case, however, the runway at San Diego Airport has a payload advantage over runways at Bratislava Airport. In the case of track length, the difference is minimal and does not have a significant effect on operating performance. Both Bratislava Airport and San Diego Airport use VOR, ILS, DME and LOC radio navigation and landing systems. [18,19] The third reason for selection is the operating performance of both airports. At this point, I compare the current operating performance of San Diego Airport (from 2019) with the alternative operating performance of Bratislava Airport in the predicted period in 2050. According to the observed prediction from scenario 2, M. R. Štefánik Airport should handle approximately 54,406 movements with approximately passengers. , exceeding the limit of 6 mil. In 2019, San Diego Airport handled 231,354 movements, of which approximately 208,000 movements were operated by commercial companies and 12 thous. movements were operated by companies focused on the business model of air taxi. [20]

4. PROPOSAL FOR THE SOLUTION OF RUNWAYS AT BRATISLAVA AIRPORT FOR ALTERNATIVE OCCUPANCY OF THE AIRPORT IN THE FUTURE

From a comparison of the technical and physical parameters of the mentioned airports, I conclude that San Diego Airport and Bratislava Airport are very similar in certain respects. Both airports have a problem if they are to expand physically, as they are located in places with a high degree of urbanization, which complicates the expansion of both airports in terms of noise to the inhabitants living in the immediate vicinity of both airports. There is also a problem with the lack of space as such, San Diego Airport can probably try to expand only in the red marked area in Figure no. 7, while Bratislava Airport has slightly better conditions in terms of free space where it is located, but at the current rate of expansion of the surrounding municipalities, the already small space decreases more and more each year, which again increases the problem of noise in location and its negative impact on the population, thus increasing the negative relationship of the local population to the possible physical expansion of the airport. However, from the point of view of Bratislava Airport's operating capacities compared to San Diego Airport's operating capacities, it is very likely that Bratislava Airport will not have to significantly expand its runway system, as it should be able to handle an alternative number of movements compared to San Diego Airport's performance and runway configuration. from all three scenarios I've worked out. From the point of view of operating costs, however, I believe that M. R. Štefánik Airport does not need two runways for its operation. In this regard, I base both the comparison with San

Diego airport and the distribution of arrivals and departures on the individual runways, which are given in Chapter 2. The operating costs of maintaining two runways, I estimate, can be significantly higher than the operating costs of maintaining one runway. expensive. However, Bratislava Airport did not provide me with information including the airport's finances, so I was not able to verify this cost hypothesis.

5. COMPARISON OF ALTERNATIVE NOISE LOADS WHEN CHANGING THE LEVEL OF BTS AIRPORT AND WHEN CHANGING THE RWY CONFIGURATION

The work aimed to determine the change of alternative noise load at M. R. Štefánik Airport when changing the number of movements performed at the airport, and to determine the change of alternative noise load when changing the runway system depending on the alternative needs of future operations. In cooperation with Euroakustik s.r.o. I developed maps of alternative noise loads at Bratislava Airport with the predicted number of movements according to scenario 2. The number of movements was predicted to be 54,406 for 20506. The noise load of the airport is measured throughout the year and is divided into 2 half-year periods. As M. R. Štefánik Airport does not have the same level of occupancy during these two monitored periods, the calculation was performed for the six-month period, which has a higher occupancy level. In 2019, 16,501 flights were recorded during the busier period. The calculation for the predicted half-year period with a higher occupancy rate was determined on the basis of the percentage of flights from the busier half-year period 2019 to the total number of flights in 2019. Based on this percentage of flights in the summer half-year 2019, I calculated that while maintaining current trends movements at M. R. Štefánik Airport, 27,203 movements will be performed at Bratislava Airport in the summer of 2050. The ratio of the number of flights in the summer of 2019 and 2050 was determined by a numerical coefficient of 1.6948. Based on the assumption of maintaining the current trends of commercial air transport at the airport M. R. Štefánik using aircraft, I recalculated the number of movements in individual noise categories recorded on individual runways of Bratislava Airport from 2019 by a coefficient of 1.6948, and thus determined the approximate number of movements in specific noise categories at year 2050 on individual tracks. In the calculation, the emission noise parameters of the aircraft were considered as for the state in 2019. The values of alternative noise in 2050 using the current runway system range from 35 dB to 65db and more dB, depending on the monitored location and time for which it was given calculation done. The values of alternative noise in 2050 using the changed runway configuration range from 35 dB to 65 dB and more dB, depending on the monitored location and time for which the calculation was made.

6. CONCLUSION

From the produced noise maps it follows that the alternative noise load in 2050 will be similar in intensity to the current state of noise load at Bratislava Airport in the case of all monitored periods and both mentioned configurations of runway systems in this work. The assumption is that, based on the forecast, in the next 10 to 15 years there will be a reduction in noise emission parameters, especially for airplanes with jet propulsion units from about 4-7 dB, depending on the category and flight operation. This means that the future noise intensity could actually be a few decibels lower. The areas affected by noise in 2019 during the observed period "day" and "evening" do not differ much in size from the potentially affected areas in 2050, while maintaining the current configuration of the runway system. Municipalities that are not affected by noise pollution caused by air traffic at Bratislava Airport in 2019, but by 2050 should already be in one of the extended areas of noise, I will call "newly affected municipalities" for the rest of the work. In the case of the reference period "evening" in 2050, there should be a slight expansion of the area affected by airport noise to the north-east of the airport and the noise intensity in this extended area would be in the range of 45-55 dB. In the case of the monitored period "night", compared to the current noise load in the vicinity of Bratislava Airport, there will be a significant expansion of areas in all directions, noise pollution caused by aviation, not only within the territorial scope but also in some places there will increase . According to the forecast, the newly affected municipalities with noise intensity from 35-45 dB should include: Zlaté Klasy, Hviezdoslavov, partly Mierovo, Bernolákovo, western part of Pezinok, partly Viničné, Šenkvice, Kráľová pri Senci, Senec, Slovak Tomb, Veľký Biel, Čakany and Malinovo. The intensity of noise pollution would increase for the municipalities of Chorvátsky Grob, Most pri Bratislave and Ivanka pri Dunaji from the current 35-45 dB to 45-50 dB, and for the municipality of Miloslavov it would increase from the current 35-45 dB to 50-55 dB. Depending on the configuration change from the current system to the one-runway system in the 13/31 direction, the extent of the area affected by noise pollution as well as the intensity of noise pollution in some places would change. Some places originally affected by the noise load arising from the flight activity on runway 04/22 would no longer be affected at all during the monitored period "day" and "evening". Such municipalities include: Ivanka pri Dunaji, Zálesie, Chorvátsky Grob, Bernolákovo. The newly affected municipalities in the monitored time periods "day" and "evening" would include the following municipalities: Čierna Voda (western part of the municipality), Bratislava Rača, Bratislava Ružinov in the Trnávka part. These municipalities would be affected by the lowest noise intensity in the range of 35 - 45 dB. Regarding the estimated noise intensity and the extent of the affected area in the observed time "night", we see a big change in both cases. The extent of the area affected by noise pollution from Bratislava Airport has expanded in this time interval in practically all directions from Bratislava Airport to a certain extent. In comparison with the territorial range of noise during the time intervals "day" and "evening", the following municipalities added to the territorial range of noise in the time interval "night": Hviezdoslavov, Kvetoslavov, Mierovo, Thursday on the Island, Čakany, Zlaté Klasy, Tomášov, Malinovo, Zálesie, Ivanka at the Danube, northwestern Bernolákova, Chorvátsky Grob, southwestern Slovenský Grob, Čierna Voda and Marianka with noise intensity in the range from 35 - 45 dB. Bratislava Vajnory and Rača, where the noise intensity increased to 45-50 dB, and Miloslavov, where the noise intensity increased to 50-55 dB, are among the inhabited areas where the noise load intensity has increased. There was also an increase in the intensity of noise along the axis of the runway in the direction of 13 to 60 and more dB, in the area between Bratislava Airport and Miloslavov. Based on the results of the prediction of future movements at M. R. Štefánik Airport in 2050 and subsequent comparison with the current performance of San Diego Airport, which has only one runway at the current number of aircraft

handled at the airport, I conclude that Bratislava Airport has a system of runways with sufficient capacity to handle the predicted number of future movements. However, in view of the operating costs of the current runway system, I would suggest canceling the runway in direction 04/22, as the airport would be able to handle the predicted number of movements without much difficulty, even according to the noise load using only one runway. the current assumption that the predicted noise values, during the day and at night, do not exceed the permitted noise limits. Given the estimated number of passengers in 2050, while the current trends in air transport continue, I also think that the airport is able to handle the predicted number of passengers in the number of 6 mil. per year, even if the airport terminal was originally designed to handle 5 mil. passengers per year. [21] The current airport terminal was completed in 2012, and there are currently various technologies for speeding up passenger check-in at the airport, such as automated baggage weighing and check-in systems, or passengers themselves, etc., which were just starting in 2012. they were not in the world or at all. Using various similar smart innovations, it is in my opinion very likely that the given estimated number of passengers in 2050 will be able to handle without major complications.

REFERENCES

[1] Slov-Lex: 355/2007 Z. z. [online]. Available on the Internet: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2007/355/20211229 (citované 3.4.2022)

[2] Slov-Lex: 549/2007 Z. z. [online]. Available on the Internet: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2007/549/20090701 (citované 3.4.2022)

[3] Google: Google maps. [online]. Available on the Internet: https://www.google.com/maps/@48.1678782,17.2058592,13.79z (citované 9.4.2022)

[4] A. Kazda - B. Caves: Airport Design and Operation. [online]. Available on the Internet: https://books.google.sk/books?id=rVtGCgAAQBAJ&pg=PA23&hl=sk&source=gbs_toc_r&cad=3#v=onepage&q&f=false (citované 10.4.2022)

[5] ICAO: Manual on Air Traffic Forecasting [online]. Available on the Internet: https://www.icao.int/MID/Documents/2014/Aviation%20Data%20Analyses%20Seminar/8991_Forecasting_en.pdf (citované 11.4.2022)

[6] doc. Ing. Vladimír KONEČNÝ, PhD. 2018. Ekonomická analýza v podniku cestnej dopravy a zasielateľstva: Návody na cvičenia. Žilina: Žilinská univerzita v Žiline. 2018. 193 s. ISBN 978-80-554-1470-6

[7] 7_22Internet archive: Introductory statistics by Illowsky, Barbara [online]. Available on the Internet: https://archive.org/details/IntroductoryStatistics_201904/page/n419/mode/2up (citované 13.4.2022)

[8] R. Sims, 2016. A Review and Application of Aviation Forecasting for Airport Planners: Master of Science. University of North Dakota, 2016. 41s [online]. Available on the Internet: https://commons.und.edu/theses/397/ (citované 11.4.2022)

[9] Ing. Milan Kamenický. 2020. Letisko M.R. Štefánika - Bratislava: Plošná hluková záťaž z leteckej prevádzky v roku 2019: posudok. Bratislava: Euroakustik s.r.o., 2020. 23 s.

[10] Eurostat: Air passenger transport decreased by 73% in 2020 [online]. Available on the Internet: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20211206-1 (citované 15.4.2022)

[11] Statista: Number of passengers carried by air in the European Union from 2008 to 2020 [online]. Available on the Internet: https://www.statista.com/statistics/1118397/air-passenger-transport-european-union/ (citované 15.4.2022)

[12] Statista: Year-on-year passenger traffic change of commercial airlines in Europe from 2013 to 2022* [online]. Available on the Internet: https://www.statista.com/statistics/658701/commercial-airlines-passenger-traffic-change-europe/ (citované 15.4.2022)

[13] Eurocontrol: Charting the European Aviation recovery: 2021 COVID-19 impacts and 2022 outlook [online]. Available on the Internet: https://www.eurocontrol.int/sites/default/files/2022-01/eurocontrol-think-paper-15-2021-review-2022-outlook_0.pdf (citované 15.4.2022)

[14] Letisko M. R. Štefánika: Ročné správy [online]. Available on the Internet: https://www.bts.aero/o-letisku/press/rocne-spravy/ (citované 16.4.2022)

[15] Eurocontrol: EUROCONTROL Forecast Update 2021-2027 [online]. Available on the Internet: https://www.eurocontrol.int/publication/eurocontrol-forecast-update-2021-2027 (citované 20.4.2022)

[16] Eurocontrol: EUROCONTROL Aviation Outlook 2050 [online]. Available on the Internet: https://www.eurocontrol.int/sites/default/files/2022-04/eurocontrol-aviation-outlook-2050-report.pdf (citované 21.4.2022)

[17] IATA: Air Passenger Numbers to Recover in 2024 [online]. Available on the Internet: https://www.iata.org/en/pressroom/2022-releases/2022-03-01-01/ (citované 21.4.2022)

[18] Letové prevádzkové služby: AIP Letecká informačná príručka [online]. Available on the Internet: https://aim.lps.sk/eAIP/eAIP_SR/AIP_SR_valid/html/LZ-AD-2.LZIB-sk-SK.html (citované 21.4.2022)

[19] San Diego International Airport [online]. Available on the Internet: http://www.airnav.com/airport/KSAN (citované 21.4.2022)

[20] San Diego International Airport: air traffic report summary. Calendar year 2019. [online]. Available on the Internet: https://www.san.org/Portals/0/Documents/Air%20Traffic%20Reports/2019_Year_in_Review.pdf?ver=2020-02-27-144247-470 (citované 22.4.2022)