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STRATEGIC ANALYSIS OF VILNIUS AIRPORT'S GROWTH TRAJECTORY AND NOISE REGULATION COMPLIANCE

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Abstract. Accurate forecasting of future events is essential for managing and optimizing airport activities, facilitating the minimization of adverse environmental impacts. The availability of detailed information about yearly aircraft movements at Vilnius City International Airport (VNO) offers an opportunity to create various scenarios that projects the growth patterns within airport and aviation industry in general. This scientific research paper explores the temporal trajectory of VNO with a focus on forecasting its evolution towards reaching major airport status of 50 000 aircraft movements per year. The study employs quantitative method in forecasting data with cycling origin using the ratio to moving average method also known as Time Series Method (TSM). Calculations are done by Microsoft Excel software with which regression trend line is obtained. Two various scenarios are projected: the continuous use of Terminal 1 (T1) and the introduction of new Terminal 2 (T2). Forecast show that continuous use of T1 will reach threshold of 50 000 flights per year by end of 4th quarter of 2025. For T2 it is projected that 53 110 flights will be done at VNO at the end of the same year T2 is projected to become operational: 2026 4th quarter. These findings underscore the necessity of strategic planning and infrastructure development to accommodate future growth and increase airport efficiency in line with growing demands.

Keywords: Vilnius International Airport, growth patterns, passenger volumes, aviation, regulatory frameworks.

1. Introduction

As the global aviation industry continues to expand and evolve, the growth of airports in major cities poses economic opportunities and environmental challenges alike. VNO, located in a capital of Lithuania stands out as a country's largest airport with highest quantity of flights, passenger volume and cargo traffic. VNO is the second largest airport in Baltic states. First is Latvia's Riga International Airport and third of is Estonia's Tallinn International Airport. Currently, airport has one terminal in use. The construction of Terminal 2 has started in January 2023. Terminal 2 is scheduled to be opened in first quarter of 2025. Opening of the second terminal forecast to double the quantity of passengers from 1200 per hour to 2400. The opening of the second terminal provides not only economic benefits as it significantly impact passenger demand and air traffic for these and directly dependent airports (Evans & Schäfer, 2011), but it also initiates a significant risk to environment and the health of the airport surrounding population. Also, Therefore, accurate forecasts are crucial for timely introduction of measures and regulations to reduce negative environmental impacts of airport related activities.

In European Union environmental noise directive major airport is defined as follows: "major airport" shall mean a civil airport, designated by the Member State, which has more than 50 000 movements per year (a movement being a take-off or a landing), excluding those purely for training purposes on light aircraft. According to this definition Vilnius City Airport has not reached major airport status (Rodríguez-Díaz et al., 2017).

Studies also show that expansion of airports (with increase of amount of flights) has negative impacts to the human health, wellbeing and also the negative impact on the environment (Sahrir et al., 2014).

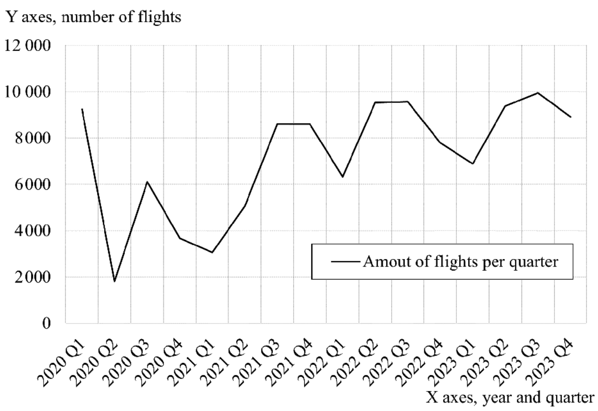

Figure 1. Number of flights at VNO 2020–2023

Figure 1 provides graphical visualization of all flights done at VNO during period of last four years (2020–2023). This data is used for TSM as this method requires most recent data input into calculations.

Environmental noise directive (European Commission [EC], 2002) is considered as one of the main tools of regulating noise impact in European Union (EU). It includes various noise mitigation strategies: higher noise allowance for daytime operations than nighttime operations, planning and zoning of new residential areas and airports, improvements for soundproofing of residential buildings, imposition of taxes or fines on airlines or airports that violate established noise thresholds.

It is important to note that Directives are only binding with regard to the goal that the EU countries must achieve; the means for achieving the goal are up to the individual Member States (EC, 2002). END requires Member States to develop noise maps every five years to determine the exposure to environmental noise, provide information about environmental noise and its effects to the public, and adopt action plans based upon the noise-mapping results to manage noise issues and effects (International Civil Aviation Organization [ICAO], 2004)

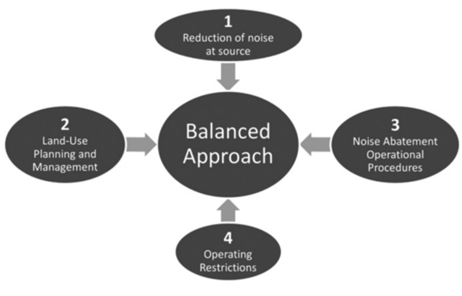

Figure 2. ICAO of balanced approach (source: ICAO, 2004)

Environmental noise includes noise emitted from air traffic, among other sources (Handayani et al., 2023). END only applies to major civil airports, meaning airports with more than 50,000 movements a year (Handayani et al., 2023). For the noise maps, two indicators are used: "L_{den}" for the overall noise level during the day, evening, and night, which is used to describe the annoyance caused by exposure to noise; and "L_{night}" for the sound level during the night used to describe sleep disturbance. However, it is up to the Member States to set limits or target values, or to decide what measures to include in the action plans.

The International Civil Aviation Organization (ICAO, 2004) has set a model called Balanced Approach (BA). This model provides general guidelines for airports for noise mitigation. Figure 2 provides visualization of BA model. This approach is fundamental for noise mitigation for majors airports.

BA is similar to "Green Airport" concept provided by Dalkiran. Concept explains that classifying the impact analysis, affecting each other while focusing on operational or capital investments in the airports (Dalkıran et al., 2021) is similar to BA.

The analysis of the impact of the aircraft activity on surrounding populated areas is based upon a review of the current effective legal acts of the Republic of Lithuania concerning noise effects and other related issues. Main legal documents that are in effect:

- The Law on Public Health of the Republic of Lithuania,
- The Law on Ambient Air Protection of the Republic of Lithuania,
- The Law on Land of the Republic of Lithuania,
- The Resolution No. 343 of the Government of the Republic of Lithuania of 12 May 1992 Regarding the Approval of the Rules for Special Land and Forest Use Conditions,
- The Order No. 4R-193 of the Director of the Civil Aviation Administration of 26 October 2004 Regarding the Approval of the Requirements for Airports.

They also provide general guidelines for sanitary zones, land use and planning in the airport territory. Main purpose of regulations is to ensure that benefits of air travel will be balanced with economic gains and environmental impact.

The increase in aircraft traffic as a consequence of the airport activities expansion directly correlates with nuisance limit.

2. The overview of aircraft movements at VNO during 2017–2023

For correct forecast correct past data and correct interpretation of it is important to get the required results. Data is taken from VNO official website as VNO officials provide all the information about

Table 1. Amounts of flights quarterly at VNO 2017–2023

Year	Jan – Mar, number of flights	Apr – Jun, number of flights	Jul – Sep, number of flights	Oct – Dec, number of flights	Total, number of flights
2017	9325	12037	6895	10996	39253
2018	10280	12734	12740	11439	47193
2019	10254	12711	12685	11790	47440
2020	9246	1827	6105	3679	20857
2021	3062	5067	8598	8598	25325
2022	6335	9525	9577	7796	33233
2023	6894	9386	9956	8920	35156

quantity of passengers and flights yearly. For simpler interpretation of results amounts of flights was divided into yearly quarters. Table 1 is given to show the distribution quantity of flights during 2017–2023. Data is taken from Lithuanian Airport statistics sours (Lithuanian Airports, 2023).

3rd quarter of the year has the highest average amount of flights. More than 9500 flights are done during July–September. It can be associated with vacation period time in the country.

1st quarter of the year has the lowest average amount of flights at VNO – less than 8000. This can be associated with start of the year economics, bad weather and other factors.

The peak of airport activity was reached during the 2019. As shown in Table 1 the total amount of flights during 2019 reached over 47 thousand and over 5 million passengers passed via VNO. However, the following year a drop of 56% (from 47 440 to 20 857) of total flights has been recorded. The quantity of passengers also dropped dramatically: from 5 million to 1.31 million or by 74%. This was due to the COVID-19 pandemic. The decline was one of three times over past twenty years when annual decline in flights and passenger volume was recorded in VNO.

Other two instances where number of passengers dropped were influenced by global and local factors. In 2009 reduced amount of airport activity was due to global economic crisis and in 2017 reduced amount of flights was due to runway reconstruction. These events are impossible to predict with TSM therefore it is important to note limitations of these forecasts.

3. Impact of increased amount of flights on noise

As mentioned before, legal framework for noise control in Republic of Lithuania is regulated by noise control law. Noise limit values are provided in different document called Lithuanian Hygiene Standard.

This law sets noise limits which can be calculated by Equation (1):

$$L_{den} = 10\lg\left(\frac{12\times 10^{\frac{L_{day}}{10}} + 4\times 10^{\frac{L_{evening}+5}{10}} + 8\frac{L_{night}+10}{10}}{24}\right), \quad (1)$$

where L_{den} – day-evening-night noise indictor defined as 24 hours total A-weighted sound level; L_{day} – day noise indicator defined as A-weighted sound level during day time (from 6:00 to 18:00); $L_{evening}$ – evening noise indicator is defined as A-weighted sound level during evening time (from 18:00 to 22:00); L_{night} – night noise is one of the indicators defined as A-weighted sound level during night time (from 22:00 to 6:00)

As is shown in Equation (1) $L_{evening}$ and L_{night} gives higher values to noise indicators due to the potential risk of sleep disturbances.

According to Lithuanian Sanitary Standard HN 33:2011 "Acoustic noise, noise limit values for residential and public buildings and their environment" L_{den} and L_{day} cannot be higher than 65 dBA, $L_{evening}$ more than 60 dBA and L_{night} 55 dBA for residential building affected by transport noise. According to these limit values noise contours are drawn. Each noise value is linked with Lithuanian regulations and define an area, which is considered as "affected" in terms of noise limits in that area. Highest amount noise limits values currently affected are confined inside VNO territory. There are various factors impacting overall L_{den} values: type of aircraft, flight frequency, flight paths and operations, airport infrastructure, time of the day etc.

Because one of the factors impacting L_{den}, L_{day}, $L_{evening}$ and L_{night} is the amount of noise events (in this case amount of aircraft movements), noise maps contour and area impacted by higher values of noise metrics is most likely to increase accordingly to the increase of aircraft movements at airport.

Studies and research done about the impact of increased airport traffic suggests various results. According to 2010 Vilnius International Airport Master Plan (VIAMP) done by international business and strategy consulting firm ALG: Global (ALG) by 2030 due to air traffic increase area of L_{den} values between 55–65 dBA has increased by 49% (3,49 km^2). This increase was modelled using the data from 2010 flights traffic information. It showed the amount of flights during day-time, evening-time, night-time and type of aircraft that was used. Figure 3 provides visualization of noise affected areas increase due to increased amounts of flights. This increase in area affected by noise advocates the importance of appropriately planned airport-area development (Siska, 2014).

As noise generated by aircrafts depends on various unpredictable factors (such as type aircraft, flight paths, landing procedures, weather conditions etc.) it is very problematic to predict exact noise area increase. Therefore, for comparison data for increased area affected by airport noise has been taken from above mentioned ALG studies. Amount of flights during 2010 was 26 094. Projected amount of flights by 2030 in ALG scenario was 55 257 which is increase by 111,76%. Following this logic it can be assumed that scenario when Vilnius airport area affected by 55–65 dBA will increase 2,9 km^2.

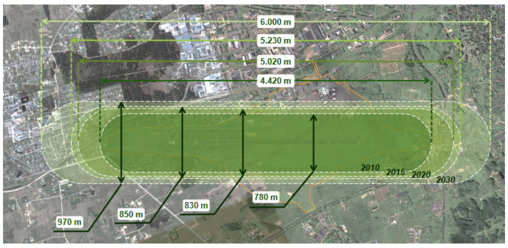

Figure 3. Noise affected area regarding air transport noise (source: Vilniaus oro uostas, 2012)

4. Methods

It can be presumed that data in first table is of the cycling origin. For forecasting a quantitative method is used. To get the wanted results ratio to moving average method is used. Firstly, for correct TSM calculation it is required to have these values: four quarter moving average value, centered average value and percentage of the average.

Four quarters moving average is calculated by adding the latest four quarters of data (in this research paper four latest quarterly amounts of flights). Mathematical expression of moving average is given in Equation (2) and data calculated is taken from Table 1.

$$a_n = \frac{Y_n + Y_{n+1} + Y_{n+2} + Y_{n+3}}{4}, \quad (2)$$

where a_n – four quarters moving average; $Y_{n;n+1...n+3}$ – the data value of calculated quarter.

After acquiring four quarters moving averages it is possible to calculate centered averages. They are calculated according to Equation (3):

$$A_n = \frac{a_n + a_{n+1}}{2}, \quad (3)$$

where A_n – centered average; $a_{n;n+1}$ – the values of moving averages.

Percentage of the average is calculated simply by dividing centered average according to the quarter calculated and multiplied by 100 to receive the percentages. Table 2 provides the calculated values of each quarter accordingly. It is important to note that seasonal index is used for further calculations when TSM of future forecasts is used according to the quarter calculated.

Table 2. Seasonal index calculations

Year	Q1	Q2	Q3	Q4	Sum
2020			72.75	110.7	
2021	156.43	112.82	78.39	89.63	
2022	132.38	88.28	87.48	108.1	
2023	122.72	92.14			
Average	137.18	97.75	79.54	102.8	417.28
X cor.	0,96	0.96	0.96	0.96	
Index	131.67	93.84	76.36	98,70	400.6

After getting values for seasonal values of every quarter's seasonal index it is possible to calculate variables and draw regression trend line. Simplified data table is shown in Table 3. The simplification is explained with … symbol where x is equal to x_{n+1} and y is taken from Table 1 with respective values to quarterly amounts of flights depending on year selected.

Table 3. Variables for regression analysis

x	y	$x*y$	x^2
1	9246	9246	1
2	1827	3654	4
3	6105	18 315	9
…	…	…	…
16	8920	142 720	256
$\sum x$	$\sum y$	$\sum x * y$	$\sum x^2$
136	114571	1084863	1496
$\frac{\sum x}{n}$	$\frac{\sum y}{n}$		
8.5	7160.69		

TSM two different scenarios were modelled: T1 operated without any major restrictions or events that could impact the current calculated average achieved over 2020–2023 time period and the start of T2 operated starting from 2025 Q1. Regression analysis is calculated by Equation (4):

$$y = a + bx, \tag{4}$$

where y – dependent variable; a – the dependent variable intercept; b – coefficient of explanatory value; x – explanatory variable.

b is a coefficient of explanatory value which is calculated according to Equation (5):

$$b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - \left(\sum x\right)^2}, \tag{5}$$

where x – amount of quarters per year; y – dependent variable; n – number of time periods; x – explanatory variable.

a – is a dependent variable intercept and is calculated according to Equation (6):

$$a = \frac{\sum x}{n} - b\left(\frac{\sum y}{n}\right). \tag{6}$$

After everything is calculated specific regression Equation (7) allows to select and decide the data in specific quarter where by choosing the quarter number (x) and multiplying in by its quarters seasonal index amount of flights can be calculated:

$$y = 4385.45 + 326.5x. \tag{7}$$

With calculations from Equation (7) it is possible to calculate the predictions both for T1 and T2. However, the difference between both predictions is the amount of passengers transfer volume. From data interpretation it is taken that increased quantity of passengers will increase amount of flights by 1.5 times, so predictions for T2 is calculated accordingly.

As shown in study about Spanish air traffic and passengers amount increases in the number of "low-cost passengers" positively affects airport efficiency (Fernández et al., 2018). As low cost passengers would be able to use T2 more conveniently and quickly this would lead to more increase in numbers of passengers and therefore increase in flights amount.

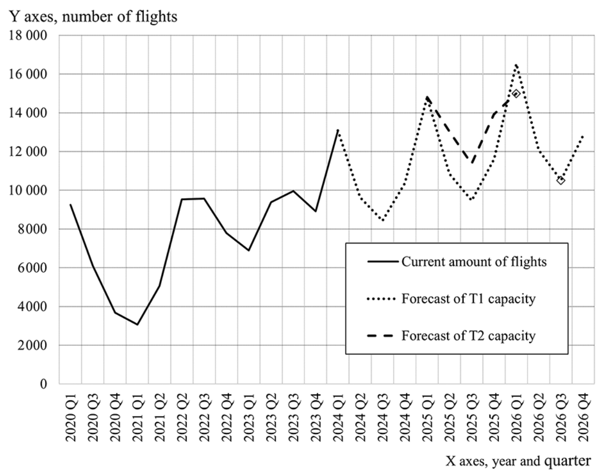

Figure 4. Visualization of T1 and T2 forecasts

For T1 scenario it is calculated that yearly amounts of 50 000 flights would be reached by end of 4th quarter of 2026. Total amount of flights in 2026 in T1 is projected to reach 51 948 flights.

For T2 scenario it is calculated that yearly amounts of 50 000 flights would be reached by the end of 4th quarter of 2025 at the same year it is planned to become operational. Total amount of flights in 2025 in T2 is projected to reach 53 110 flights.

Figure 4 shows the trend line of forecasted flights regarding the T1 and T2. It can be concluded that in both cases by 2026 regulations regarding airport environmental impact must be reviewed and updated.

5. Limitations of TSM

Time series methods often assume that the underlying data is stationary, meaning that statistical properties such as mean and variance remain constant over time. However, real-world data may exhibit trends, seasonality, or other non-stationary patterns, which can affect the accuracy of forecasts. In last two decades such events like global pandemic which led to aviation practically starting from scratch (Kitsou et al., 2022) and global economic crisis have impacted airport activities all around the globe in such way that TSM could not have predicted. Other factor like geopolitical situation and natural disasters can also influent the amount of flights globally.

Time series methods are generally better suited for short to medium-term forecasting horizons (Wang et al., 2017).

Therefore, four year data has been used for forecast calculations. It is important to understand these possible changes and calculate the forecasts accordingly to the actual situations and depend on these type of forecasts with caution and critical thinking.

6. Results

1. According to data from VNO two most likely scenarios for T1 and T2 have been projected with TSM.

2. It has been projected that T1 natural growth of passengers and quantity of flights would reach more than 50 000 flights per year by the end of 2026. T2 would reach threshold 50 000 annual flights on the first year it is projected to become operational: by the end of 2025.

3. For major airports various stricter noise regulations are applied. Procedures on restrictions on flight

times, measuring of noise limits L_{den} and L_{night} drawing of noise maps must be improved at VNO for not violating the noise thresholds in projected forecasts.

7. Conclusions

1. The anticipated increase in airport traffic suggests a correlated rise in noise levels (as shown in VIAMP prepared by ALG), necessitating stricter measures to mitigate the impact of airport noise on the surrounding communities.

2. Analysis of noise regulations, including the European Union's Environmental Noise Directive (END) and the International Civil Aviation Organization's (ICAO) Balanced Approach, highlights the need for measures to reduce noise impacts on communities surrounding VNO, especially as VNO approaches the threshold for major airport status.

3. The study shows the importance of aligning noise regulations and mitigation strategies with forecasted airport growth, emphasizing the need for updated policies and measures to manage noise impacts effectively.

4. Limitations of the TSM approach, such as its sensitivity to external factors and short-to-medium-term forecasting, focuses on the necessity of incorporating flexibility and critical thinking into future forecasting endeavors to take into account unforeseen events and changes in aviation direction.

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VILNIAUS TARPTAUTINIO ORO UOSTO VYSTYMOSI PROGNOZAVIMAS IR TRIUKŠMO RIBINIŲ DYDŽIŲ VERTINIMAS

S. ZAVADSKAS, R. GRUBLIAUSKAS, V. VAIŠIS

Santrauka. Tikslus ateities įvykių prognozavimas yra būtinas siekiant valdyti oro uostų veiklą ir mažinti jos neigiamą poveikį aplinkai. Taikant kiekybinius metodus atliktas tyrimas leidžia prognozuoti VNO plėtros trajektoriją siekiant įgyti didelio oro uosto statusą ir viršyti 50 000 skrydžių per metus. Modeliuojami du scenarijai: tik esamo pirmojo terminalo (T1) naudojimas ir naujo antrojo terminalo (T2) atidarymo įtaka. Prognozės rodo, kad 2025 metų ketvirtą ketvirtį T1 pasieks 50 000 skrydžių ribą, o T2 galėtų pasiekti 53 110 skrydžių kiekį iki 2026 metų ketvirto ketvirčio, t. y. planuojamo T2 atidarymo. Straipsnis aktualus, nes didesnio pralaidumo oro uostai sukelia daugiau triukšmo, todėl jiems reikalingas griežtesnis triukšmo reguliavimas dėl galimo didesnio poveikio aplinkinėms bendruomenėms ir aplinkai.

Reikšminiai žodžiai: tarptautinis Vilniaus oro uostas, augimo modeliai, skrydžių srautai, reglamentas.