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THE INFLUENCE OF ROAD TRAFFIC NOISE ON APARTMENT PRICES – BIAŁYSTOK CASE STUDY

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Annotation
The article analyzes the correlations between road traffic noise and apartment prices on a local real estate market. The investigated area was a residential estate in the city of Białystok in north-eastern Poland. Real estate transactions concluded in 2015-2016 were analyzed. The analyzed apartments constitute a housing resource on the secondary real estate market and are characterized by similar values of the main attributes which influence apartment prices. The apartments were divided into two size groups based on their floor area: small apartments – 20-40 m² and medium-sized apartments – 40-60 m². Traffic noise levels for the investigated estate were determined based on the local acoustic map. The long-term indicator of average noise level A on every day of the year in view of the time of day (L$_{DWN}$) was used in analyses. The correlations between the dependent variable (apartment price per unit area) and independent variable (road traffic noise) were determined. The study demonstrated that apartment prices decreased with a rise in traffic noise levels. Apartments exposed to lower levels of traffic noise and characterized by a higher standard of living fetched higher prices on the local market. The presented methodology can be a useful tool for local real estate agents and administrators.

Key words
road traffic noise, real estate value, Pearson's correlation coefficient

JEL classification: *C21, Q53, R32*

1. Introduction

Human activities are the main source of noise in a city. Noise is distressing, and it negatively affects the quality of life. The main sources of urban noise are roads, airports, railways and industrial sites (Dubois et al., 2006). Road traffic noise poses one of the greatest environmental problems. It has a negative impact on human health and life in large urban centers. Noise levels higher than 55 dB are a source of discomfort and anxiety for most people. Noise levels in excess of 65 dB are unacceptable and have serious health implications, such as disrupted sleep patterns, irritability, apathy, concentration problems, cognitive problems, stress and disease (circulatory diseases, ear disorders, neurological diseases and psychological disturbances) (Directive 2002/49/EC). High levels of traffic noise contribute to social conflict and increase social and economic costs. Social costs include higher risk of disease and premature death, whereas economic costs include lower work performance and the negative consequences of the decisions made on the real estate market. Noise directly influences the prices of real estate, in particular apartments. The consequences of excessive traffic noise should be studied in greater detail to eliminate the above risks (Szopińska and Krajewska, 2016; Szczepańska, et al., 2015; Brandt and Maenning, 2011; Blanco and Flindell, 2011; Yang and Kang, 2005).

Research into the structure and evolution of landscape is carried out in different fields of science. Landscape undergoes continuous change under the influence of nature and human activities (Aretano et al., 2013; Veteikis et al., 2011). The soundscape concept has been coined by Shafer in the 1970s, and it laid the ground for research into the effects of noise on the surrounding environment. Shafer defines the urban soundscape as a complex sonic environment which testifies to high levels of social and cultural development (Schafer, 1977; Raimbault and

Dubois, 2005). The type and location of social conflicts in the soundscape have to be identified in noise analyses (Bernat, 2016). According to research, the perception of a landscape engages other senses than sight (Liu et al., 2013; Ohrstrom et al., 2006). The second most important sense in this process is hearing which has the potential to register a much wider set of stimuli than touch, smell or taste (Visual landscape design training Manual, 1994). Perceptions of landscape can be classified as "near" when all senses are engaged or as "distant" when the viewer relies only on the sense of sight (Qiu, et al., 2013).

The aim of this study was to analyze the correlations between traffic noise levels and the prices of apartments on a local real estate market between 1 January 2015 and 31 December 2016. Noise is a serious annoyance that influences the decisions of real estate market participants and real estate prices. The results of this study could provide valuable inputs for real estate agents, real estate managers and property appraisers. Providers of real estate services in large urban areas should have substantial knowledge about the correlations between property prices and traffic noise levels.

2. Materials and Methods

The studied area was the city of Białystok in north-eastern Poland. Białystok is the capital and the largest city of the Region of Podlasie. It is the administrative, economic, scientific and cultural center of Podlasie, and a supraregional academic and scientific hub (Fig. 1). Białystok has a population of nearly 300,000 and a relatively high population density of around 2,904 people/km^2 (Białystok Municipal Office, 2018). The city is divided into 28 districts with various roles: residential, industrial and services. As an administrative and metropolitan center, Białystok is characterized by high levels of traffic noise. The local transportation system is composed of national and regional roads that intersect downtown areas and residential estates.

Fig. 1: Białystok on the map of Poland and a map of the Region of Podlasie

Source: own elaboration

Detailed analyses were performed in the residential district of Antoniuk which occupies the central part of Białystok (Fig. 2). Antoniuk has an area of 218.7 h, which accounts for 2.14% of the city's area. The district is situated in the proximity of national and regional roads with high levels of vehicular traffic. The section of the regional road intersecting Antoniuk is a transit route for heavy-duty traffic. Traffic volumes are also high on county and municipal roads which perform residential functions and provide the local inhabitants with access to other parts of the city (commuting, public transport). A railway line constitutes the north-eastern boundary of the analyzed district. Antoniuk borders the city center with a well-developed service sector in the south-east, and other districts with a predominantly residential function in the north-west. The northern part of the district is occupied by allotment gardens and a small undeveloped area. Antoniuk has a predominance of high-rise apartment blocks,

mostly five-storey buildings made of prefabricated elements and concrete slabs, arranged in perpendicular lines. The discussed district abounds in public utility buildings (schools, kindergartens, churches), retail and service outlets. Apartment buildings create a homogeneous residential structure, which contributes to the reliability of analytical results. All of the analyzed buildings date back to the 1970s.

Fig. 2: Location of the analyzed district in Białystok

City boundaries
Antoniuk estate
National roads
Regional roads
Municipal roads
County roads

0 0.5 1km

Source: own elaboration based on the acoustic map of Białystok

The analysis was carried out with the use of the acoustic map of Białystok. The acoustic map of Białystok has been developed in line with the provisions of Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. Polish cities are obligated to develop acoustic maps pursuant to the provisions of the Environmental Protection Law (2001). A fragment of the acoustic map relating to the district of Antoniuk is presented in Figure 3.

Fig. 3: Acoustic map of the analyzed district in Białystok

Source: own elaboration based on http://www.gisbialystok.pl/imap/?locale=pl&gui=new&sessionID=167663
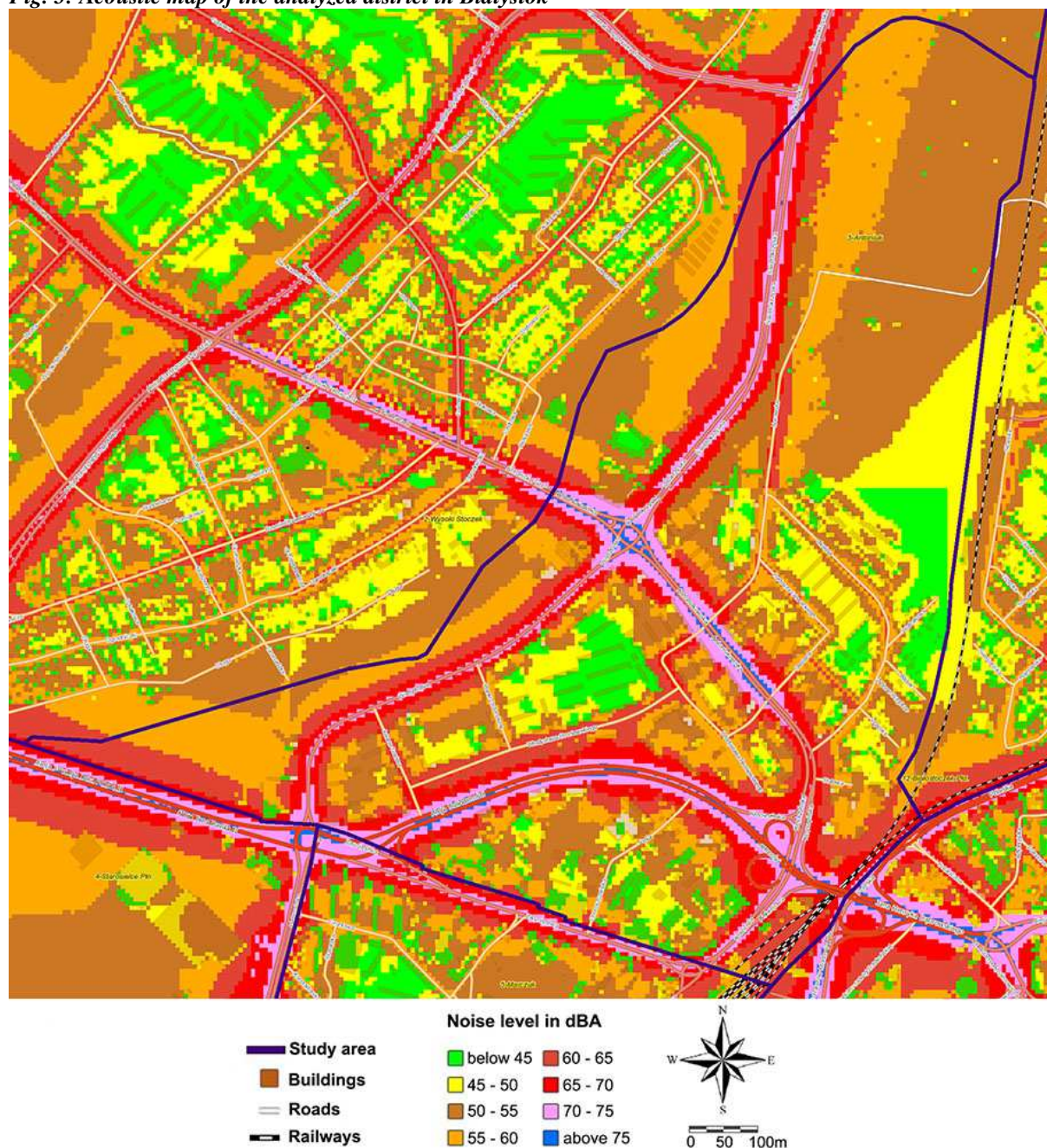
The research methodology was based on the assumption that a building's location relative to busy roads is an important attribute for prospective buyers. The study was conducted in several stages:

1. Selection of apartments. Apartments with the same legal status, similar floor area, situated in buildings erected in the same technology were selected to produce uniform samples and to minimize the influence of other price-forming factors. The analyzed apartments were situated in buildings dating back to the 1970s, and they were in similar technical condition. The apartments differed significantly only in terms of their detailed location, namely their location relative to a noisy traffic route. Significant fluctuations in local real estate prices resulting from changes in business cycles or the passage of time were not observed in the analyzed period. The time trend for the analyzed set of real estate transactions was set at 0%. These assumptions were validated during consultations with real estate agents and preliminary analyses of transaction databases.
2. The selected apartments were divided into two size groups:
   - small apartments <20-40 m^2>,

- medium-sized apartments <40-60 m²>.

Small and medium-sized apartments are predominant in the analyzed estate. Larger apartments were not analyzed due to a very small number of transactions in this size category in the analyzed period.

3. The prices of the analyzed apartments and prices per unit area in €/m² were determined based on the data in the Register of Real Estate Prices and Values (RREPV) kept pursuant to the provisions of the Regulation of the Minister of Regional Development and Construction (Journal of Laws, 2016, item 1034). The register is a public data repository kept by a county governor, and it contains information about the prices of property indicated in notarial deeds and in valuation reports developed by real estate appraisers. The prices stated in notarial deeds were converted to Euro (€) based on the exchange rate quoted by the National Bank of Poland on 31 December 2015. The above date was chosen because it marks the middle point of the analyzed period during which fluctuations in apartment prices were not observed on the local real estate market.

4. Traffic noise values expressed in decibels were read from the acoustic map. The long-term indicator of average noise level A (L_{DWN}), determined on every day of the year in view of the time of day, was calculated with the use of the below formula:

$$L_{den} = 10\lg\left[\frac{12}{24}10^{0,1L_{day}} + \frac{4}{24}10^{0,1(L_{evening}+5)} + \frac{8}{24}10^{0,1(L_{night}+10)}\right]$$

where:

L_{day} – long-term indicator of average noise level A, expressed in decibels (dBA), determined during the day throughout the year (from 6 a.m. to 6 p.m.),

$L_{evening}$ – long-term indicator of average noise level A, expressed in decibels (dBA), determined during the evening throughout the year (from 6 p.m. to 10 p.m.),

L_{night} – long-term indicator of average noise level A, expressed in decibels (dBA), determined during the night throughout the year (from 10 p.m. to 6 a.m.).

5. The distribution of apartment prices per unit area (€/m²) relative to traffic noise levels was presented in a scatter plot.

6. The presence of linear correlations was determined between apartment prices per unit area and traffic noise levels. Pearson's correlation coefficient describes the statistical relationships between the dependent variable (apartment price per unit area) and the independent variable (road traffic noise). The value of the correlation coefficient points to the strength of the relationship between the analyzed variables, and the direction of that relationship is denoted by the (+/-) sign.

3. Results and Discussion

In line with the proposed methodology, the evaluated apartments were divided into two size groups. Apartment prices per unit area were given in EUR (€) per 1 m². The basic information about the analyzed real estate market with a division into small and medium-sized apartments is presented in Table 1. A preliminary analysis revealed that prices of group I apartments were higher by 148 €/m². The price spread in group I was significantly higher, and the minimum and maximum prices of group I apartments were higher than in group II. The above is a characteristic feature of the Polish real estate market due to a much higher demand for smaller apartments. In this approach, apartment prices are generally lower and more acceptable for buyers. Noise levels were highly similar for the analyzed set of transactions. Based on the acoustic map, the maximum noise level for both groups was 73 dB, and the minimum noise level was only 1 dB higher for group I apartments (44 dB). The above indicates that the evaluated set of transactions was homogeneous in terms of market prices.

*Tab. 1: Basic information about the local apartment market*

	Group I – small apartments <20-40 m²>	Group II – medium-sized apartments (40-60 m²>
Number of transactions	37	38
Number of buildings	25	25
Average price per unit area [€/m²]	889	741
Min/Max price [€/m²]	668/1 154	557/909
Price spread [€/m²]	486	352
Min/Max noise [dB]	44/73	43/73
Noise spread [dB]	29	30

Source: own elaboration based on the Register of Real Estate Prices and Values and the acoustic map of Białystok.

In the following stage, the correlations between apartment prices (in two groups) and traffic noise were presented in a scatter plot (Fig. 4 and Fig. 5). In group I, apartment prices decreased by 6.31 €/m² per 1 dB increase in traffic noise. In group II, the observed decrease was much smaller, and it was determined at 2.63 €/m² per 1 dB increase

in traffic noise. The Noise Sensitivity Depreciation Index (NSDI) is one of the most popular indicators which illustrates the percent change in real estate price induced by 1 dB increase in traffic noise. The value of the NSDI has been determined in the range of 0.08% to 2.22% in various countries (Blanco and Flindell, 2011). In this study, NSDI reached 0.5% in group I and 0.3% in group II. These results are consistent with the trends observed on other local real estate markets.

Fig. 4: Distribution of apartment prices per unit area in group I relative to traffic noise levels L_{DWN}
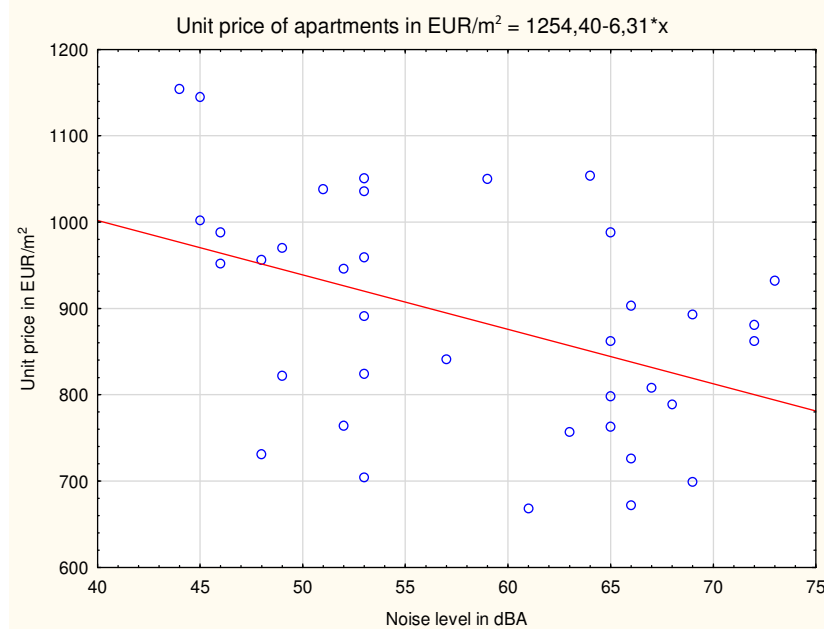
Source: own elaboration

Fig. 5: Distribution of apartment prices per unit area in group II relative to traffic noise levels L_{DWN}
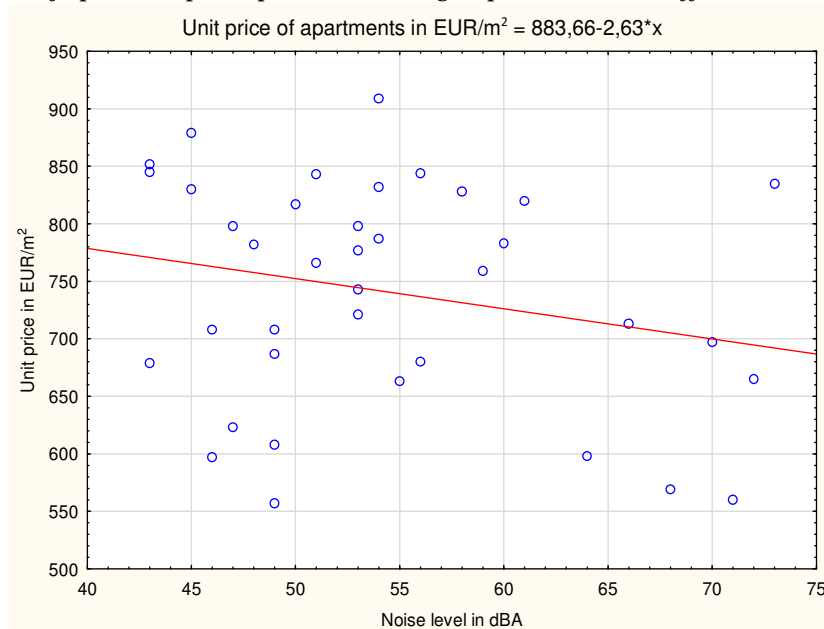
Source: own elaboration

Pearson's correlation coefficient was calculated in the next step of the analysis. It was determined at -0.44 in group I, which points to a relatively significant correlation between the examined variables. A negative value implies that the prices of apartments per unit area decreased with a rise in traffic noise levels. Somewhat different results were noted in group II where the correlation coefficient reached -0.23, suggesting a minor correlation between the analyzed factors in the studied period. However, a negative value of the correlation coefficient points to a decrease in apartment prices with a rise in traffic noise in the immediate vicinity. These results validate NSDI values which were lower in group II. The above could be attributed to the influence of other factors on the final price of larger

apartments. Traffic noise also decreased the prices of larger apartments and their attractiveness for potential buyers. In the analyzed cases, larger floor area was the decisive attribute, whereas noise was a secondary factor in the decision-making process. In the group of smaller apartments with a higher price per unit area, buyers were more likely to focus on the standard of living and pay greater attention to noise levels in the vicinity.

The estimated apartment prices at minimum and maximum traffic noise levels registered in the acoustic map are presented in Table 2. The acceptable noise levels were included for comparative purposes. According to the Regulation of the Minister of the Environment of 2012, the average acceptable long-term noise level for urban zones in cities with a population higher than 100,000 is 70 dB.

Tab. 2: Estimated apartment prices per unit area

	Group I – small apartments <20-40 m^2>	Group II – medium-sized apartments (40-60 m^2>
Regression equation	Y = 1254.40 – 6.31X	Y = 883.466 – 2.63X
Pearson's linear correlation coefficient	-0.44	-0.23
Estimated apartment price per unit area [€/m^2]		
For X=44/43 dB	977	771
For X=70 dB	813	700
For X=73 dB	794	692
Estimated spread of apartment prices [€/apartment]		
For X=44/43 dB	19 540 – 39 080	30 840 – 46 260
For X=70 dB	16 260 – 32 520	28 000 – 42 000
For X=73 dB	15 880 – 31 760	27 680 – 41 520

Source: own elaboration

Conclusions

The results of the study validate the hypothesis that high traffic noise levels in the urban environment influence the prices of apartments on the local real estate market. The owners of apartments situated in the proximity of the most arduous sources of noise (roads, tram lines, railway lines, industrial plants, airports) are particularly exposed to noise discomfort. Residential property is a special category of real estate because it should be place of daily rest and recreation. These functions are considerably disturbed in urban space, and potential buyers search for apartments situated far from sources of noise. However, noise is not the only factor that compromises the standard of living in urban areas, and the buyers' decisions are also influenced by other factors, such as pollution, smog or crime. Functions that are typically associated with residential areas, including location (availability of services, retail outlets, transportation, public administration, schools, jobs), finishing standards and construction technology, also influence the prices of apartments. According to the literature, traffic noise is an equally important or even the key determinant of the attractiveness and prices of residential property.

Acoustic maps are a valuable source of information about the risks associated with the development of transportation systems in cities. The results of studies investigating apartments contribute vital data for market analyses and the formulation of recommendations for urban planning. Traffic noise is one of the greatest threats to harmonious living in cities, and it should be taken into account in the urban planning process. Traffic noise in residential areas should also be kept to a minimum to protect the inhabitants' health. Noise analyses contribute valuable data for urban management, and their results should be used to identify the correlations on the local apartment markets and minimize the threats associated with high levels of traffic noise.

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