Determination of Traffic Noise on the Selected Area of the City of Zabrze

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INTRODUCTION

The problem of excessive noise is one of the basic problems of the modern world. The main sources of noise, affecting the whole population, are, at the moment, mainly the sources generally referred to as communicational. These include:

a) Road noise sources.
b) Railway (railway and tramway) noise sources.

The problem of analysing the impact of traffic noise is closely related to the issue of creating and operating strategic acoustic maps. The Directive of the European Parliament and the Council of Europe from 2002 and 2015 (Directive 2002/49/Ec, Commission Directive (EU) 2015/996) obliges the EU Member States to prepare strategic noise maps. Each city within the European Union was obliged to create such a map and to update it every 5 years. Unfortunately, the Strategic Map is designed to show annual average values and does not take into account a number of momentary and local factors. The Strategic Map also does not provide possible ways of eliminating excessive noise. The Programme of Environmental Protection against Noise for the City, developed on the basis of the Strategic Map, also treats noise in the city in a "global" way and the

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solutions proposed therein are aimed at noise reduction in the largest possible area, taking into account the sources of greatest noise impact. No noise reduction solutions are proposed for small limited areas exposed to noise from local noise sources.

METHODOLOGY OF RESEARCH

The article is a substantive summary of research conducted by the Institute of Production Engineering of the Silesian University of Technology in Zabrze, covering the determination of ways to reduce traffic noise in the selected area of the city of Zabrze using measurement and simulation methods. This topic has been repeatedly addressed by the authors in a number of works (Boczkowski, 2016; Boczkowski, 2017; Kaźmierczak et al., 2021; Kuboszek, 2017a; Kuboszek, 2017b; Kuboszek 2017c; Pradela et al., 2014). The analysis was conducted within the Project Based Learning (PBL) project (PBL project, 2020). which aimed at teaching a selected group of students teamwork, synthesizing information from various sources, making decisions and taking responsibility for them, planning and organizing work and appropriate time management.

The aim of the project was to map the acoustic field of the selected area of the city of Zabrze and to determine ways of reducing traffic noise using measurement and simulation methods. The above goal was realised by performing the following activities:

a) Selection of the area of the city of Zabrze subject to analysis.
b) Identifying the main sources of traffic noise in the study area.
c) Measurement of traffic volume.
d) Carrying out 24-hour acoustic measurements in selected reference points.
e) Obtaining map documentation (GIS layers) of the selected area.
f) Building a simulation model and simulating acoustic phenomena according to the method described in ISO 9613-2.
g) Identification of ways to reduce noise in a selected area.
h) Simulation analysis of proposed solutions' influence on acoustic field taking into account their multivariate character.

The paper presents the first part of the completed project including the selection of research area, analysis of the structure and use of buildings in a specific area of the city of Zabrze. It also presents the results of both road and rail (in this case tramway) traffic intensity surveys as well as 24-hour acoustic measurements. Additionally, a comparison is made between the obtained measurement values and the values obtained from the Strategic Acoustic Map of the City of Zabrze performed as part of the 3rd round of mapping in 2017.

Definition of the study area

Conducting acoustic surveys within PBL project by a relatively small group of students (6 people) naturally limited the scope of conducted research. The time that the research group was able to devote to the project meant that the research could be carried out in a limited area of the city of Zabrze. After analysing the

map of Zabrze city, the area limited by the following streets was selected: Korfantego Avenue, Gdańska Street, Mikulczycka Street, Maria Skłodowska-Curie Street (Fig.1).

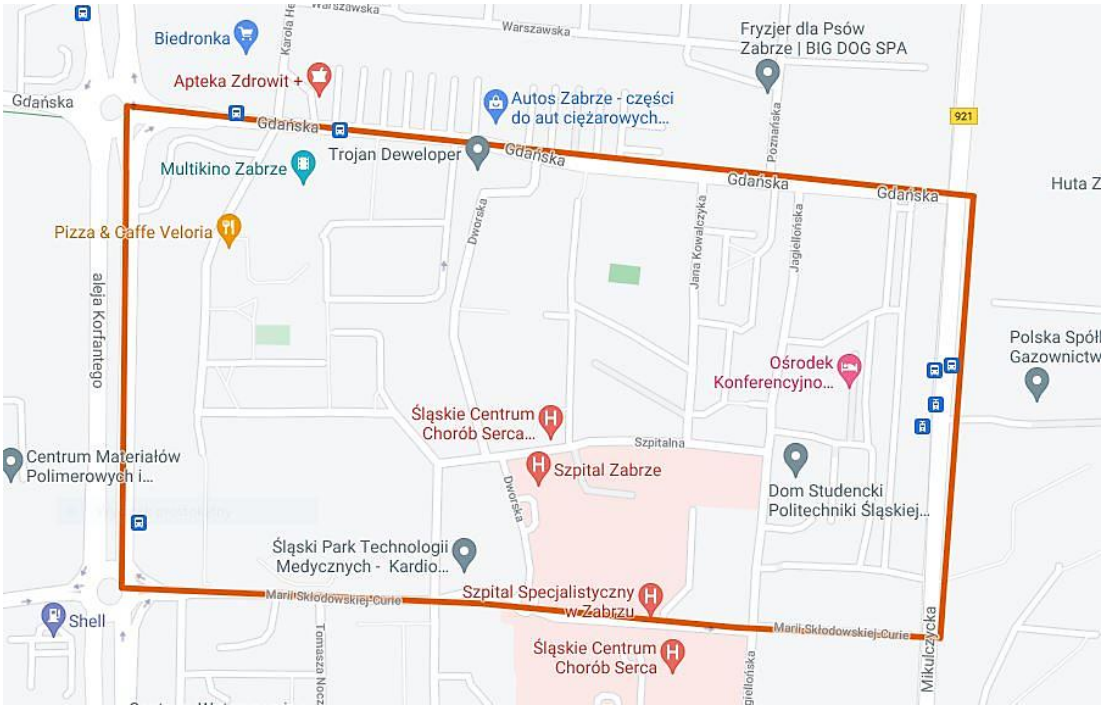

Fig. 1 Map of the study area

Source: own work

The choice of this study area was motivated by the fact that it is a very heterogeneous part of the city. The buildings can be distinguished between residential, commercial and special buildings such as a hospital. The roads surrounding the study area have different cross-sections. Korfantego Avenue is a dual carriageway road with a wide green belt, Mikulczycka Street is a single carriageway road with an additional tram track. Maria Skłodowska-Curie Street on the one hand is a housing estate road, but on the other is an access road to the Silesian Centre for Heart Diseases. It is also important that the Alaska Student House, which is the place of residence for students of the Organisation and Management Faculty, is located in the study area.

Building layer inventory

An inventory of the buildings in the study area was carried out in order to precisely determine the height (number of storeys) and purpose of the buildings. These data were used in simulation studies, which are not part of this publication. Table 1 contains sample data collected on buildings located at Maria Skłodowska-Curie Street. Additionally, a complete photographic documentation of the buildings in the study area was made.

Table 1 Inventory of buildings on Maria Skłodowska Curie Street

Street	home number	building type	number of floors
Marii Skłodowskiej-Curie	22-22c	high-rise building	12
Marii Skłodowskiej-Curie	20-22c	high-rise building	12
Marii Skłodowskiej-Curie	34	Research Institute	ok 2/3
Marii Skłodowskiej-Curie	26	gastronomy building	1
Marii Skłodowskiej-Curie	24A-24E	commercial and service building	1
Marii Skłodowskiej-Curie	24	commercial and service building	1
Marii Skłodowskiej-Curie	18-18C	high-rise building	12
Jana Kochanowskiego	26	two-storey building	2
Marii Skłodowskiej-Curie	16-16d	high-rise building	12
Marii Skłodowskiej-Curie	14-14d	high-rise building	12
Marii Skłodowskiej-Curie	12-12d	high-rise building	12
Marii Skłodowskiej-Curie	10c	Medical outpatient clinic	3
Marii Skłodowskiej-Curie	10a	commercial and service building	1

Source: own work

Selection of measuring points

In the first stage of work, a very detailed analysis of the study area was made in terms of the possibility of conducting 24-hour observations of vehicle traffic and noise level measurements. Technical limitations (possibility of using only one sound pressure level meter) and limited number of PBL project contractors resulted in decision to measure at 4 points. Location of measurement points is shown in Fig. 2.

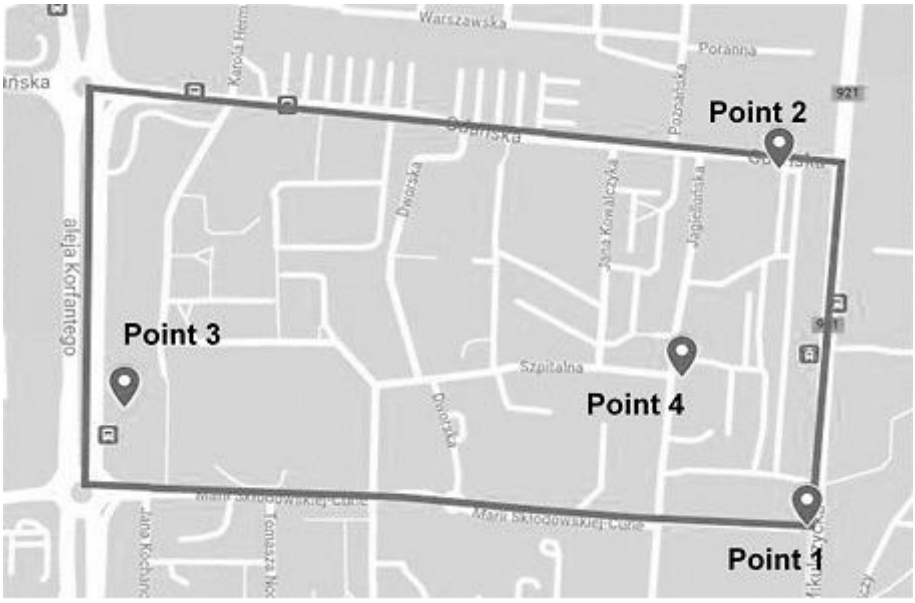

Fig. 2 Location of measuring points

Source: own work

The selection of measurement points was guided by the possibility of ensuring safety of persons performing the measurements as well as of the measurement

equipment set up. Additionally, the selected measurement points provided the possibility of easy observation of vehicle traffic on the analysed roads.

RESULTS OF MEASUREMENTS

The research and observations carried out within the framework of the PBL project included the measurement of sound pressure levels with simultaneous counting of vehicles moving along selected streets. Acoustic measurements were made with a class I sound meter type SVAN 945A. In measurement points 1-3 from 4:00 to 22:00, the measurements were made using the method of direct continuous measurements in limited time (Dz.U.2011), while from 22:00 to 4:00 the method of direct noise measurements using sampling (Dz.U.2011) was applied. At measurement point 4, located in the direct vicinity of the "Alaska" student dormitory, a full 24-hour measurement was made using the continuous measurement method in a limited time.

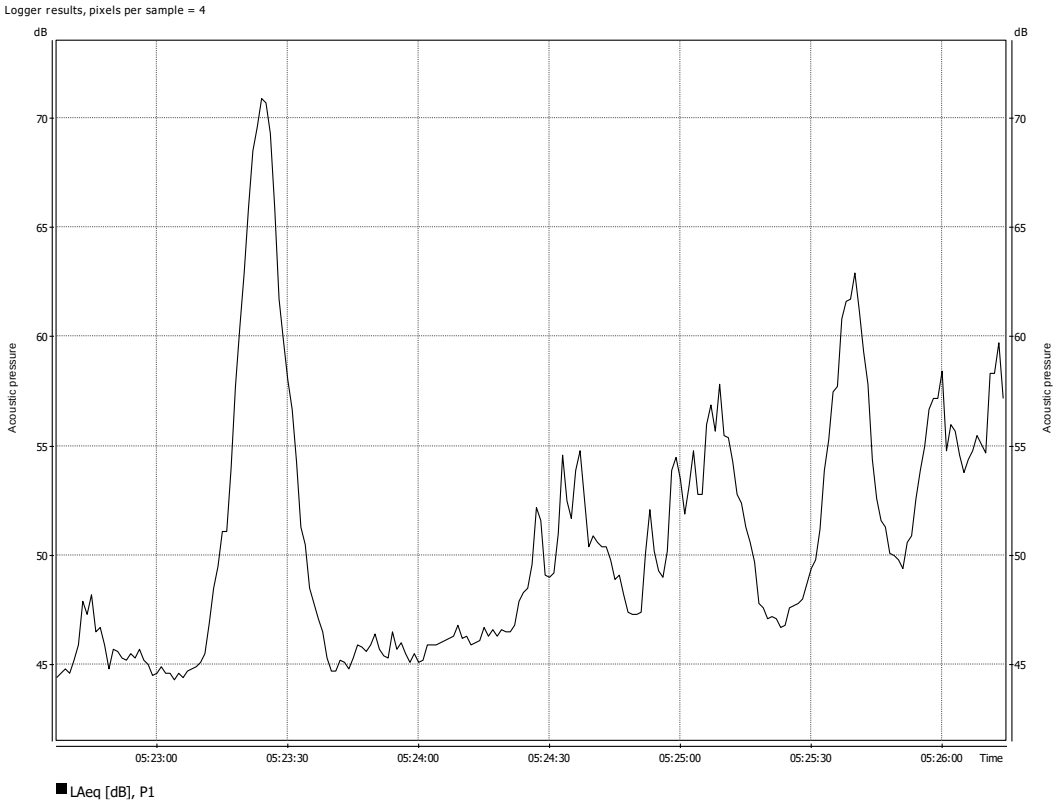

Fig. 3 Graph of sound pressure level

Source: own work

At this point, full registration of traffic along Jagiellońska and Szpitalna Streets was made with the use of video recording equipment. As a result of the measurement, one-second sound pressure level values were obtained. An exemplary fragment of the sound pressure level course is presented in Fig. 3. The obtained values were used for calculating one-hour equivalent values of L_{Aeq} and allowed estimating the values of L_{DWN} indices (Dz.U.2011).

Results of traffic volume measurements on selected streets

Traffic volume and noise level measurements were made in four measurement areas marked on Fig. 2. Measurements were performed from 4:00 to 22:00 in 6-hour sections. In order to maintain consistency of the obtained results, measurements were made from Monday to Friday. The weekend period is characterized by a different structure of vehicle traffic and is usually not taken into account in measurements of vehicle traffic which are to be used to create noise maps by simulation methods.

Table 2 Traffic volume on Korfantego Avenue

Point 3 - Korfantego Avenue								
Lp.	Measurement time		Direction 1			Direction 2		
			Cars	Trucks	Buses	Cars	Trucks	Buses
2	04:00	05:00	44	5	4	42	12	3
3	05:00	06:00	225	11	5	265	19	7
4	06:00	07:00	396	12	13	279	27	11
5	07:00	08:00	567	18	2	434	40	2
6	08:00	09:00	503	29	2	472	41	6
7	09:00	10:00	422	41	5	406	42	4
8	10:00	11:00	484	26	0	357	29	0
9	11:00	12:00	437	39	2	577	35	4
10	12:00	13:00	516	27	1	502	33	3
11	13:00	14:00	678	25	5	592	27	5
12	14:00	15:00	708	39	2	761	35	3
13	15:00	16:00	951	77	2	935	54	5
14	16:00	17:00	707	22	2	794	21	4
15	17:00	18:00	701	24	7	710	12	5
16	18:00	19:00	624	16	14	621	9	16
17	19:00	20:00	503	6	2	472	7	3
18	20:00	21:00	353	8	3	334	17	3
19	21:00	22:00	254	9	3	242	11	3

Source: own work

During the measurements all vehicles traveling in two directions in the designated study area were counted. The vehicles were divided into light vehicles – passenger cars, and heavy vehicles – trucks. Additionally, vehicles such as buses, ambulances and motorbikes were also counted. Sample data on vehicle traffic volume on Korfantego Avenue are presented in Table 2. Fig. 4 shows the results of traffic volume measurements on streets running next to the measurement points. Analysing the obtained diagrams, it may be stated that automobile traffic on the streets under study exhibits the characteristics typical of medium-sized cities. Mikulczycka street, which is the main access road to the city centre from the north, shows increased traffic of heavy vehicles after 5:00 and 9:00 a.m. It is connected with increased movement of delivery vehicles to commercial establishments located in the centre. A similar phenomenon, however on a smaller scale, can be observed in Gdańska Street, which diverts part of the traffic from Mikulczycka Street to the west and bypasses the city centre through Korfantego Avenue.

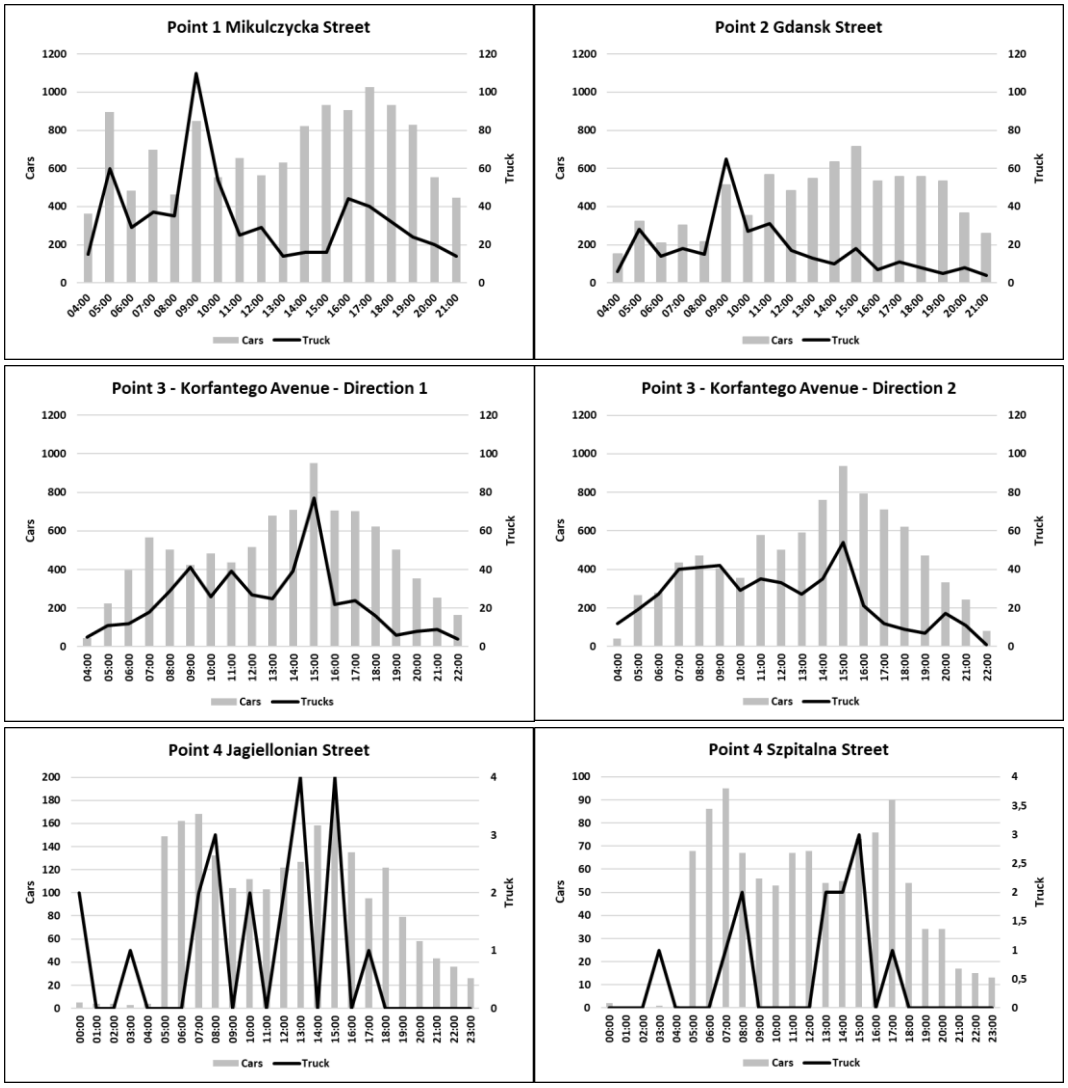

Fig. 4 Traffic volume on observed streets

Source: own work

Korfantego Avenue is the main axis of movement of the inhabitants of the northern part of Zabrze to work in the city centre. This can be seen on the diagrams (Section 3) as increased passenger vehicle traffic around 07:00 and 15:00. A similar increase in passenger vehicle traffic can be observed on Mikulczycka St. around 05:00. This is probably related to the need for workers to get to the factories located in the industrial zones on the northern outskirts of the city. In some of these plants, the first shift starts at 6:00.

Graphs of traffic intensity on Jagiellońska and Szpitalna streets show that these are typical residential streets. From 24:00 to 5:00 traffic practically ceases. Between 5:00 and 8:00 there is an increase in traffic connected with employees commuting to work. Between 14:00 and 17:00 there is an increase in traffic connected with residents returning home.

The results of acoustic measurements

As a result of measurements and calculations, values of equivalent sound pressure level averaged in one-hour sections were obtained. The obtained results are presented in Table 3 and by means of diagrams on Fig. 5.

Table 3 Equivalent sound pressure level L_{Aeq} dB

Measurement time		Equivalent sound pressure level LAeq dB			
		Point 1	Point 2	Point 3	Point 4
4:00	05:00	56,0	56,9	48,0	47,4
5:00	06:00	58,9	60,9	54,0	54,3
6:00	07:00	60,5	63,6	55,1	56,5
7:00	08:00	61,8	63,1	59,1	57,1
8:00	09:00	62,0	63,5	56,8	56,7
9:00	10:00	61,1	64,2	56,2	57,1
10:00	11:00	61,8	65,8	59,4	57,4
11:00	12:00	62,4	65,9	57,6	57,1
12:00	13:00	62,8	65,9	57,2	57,3
13:00	14:00	63,0	65,8	58,0	57,5
14:00	15:00	63,3	65,7	58,1	58,3
15:00	16:00	63,9	64,6	59,4	58,9
16:00	17:00	61,7	64,4	57,2	57,0
17:00	18:00	61,4	77,3	56,8	57,7
18:00	19:00	61,8	63,5	59,1	57,2
19:00	20:00	60,4	64,3	55,9	56,9
20:00	21:00	60,1	62,0	54,0	54,6
21:00	22:00	58,6	61,6	52,7	53,5

Source: own work

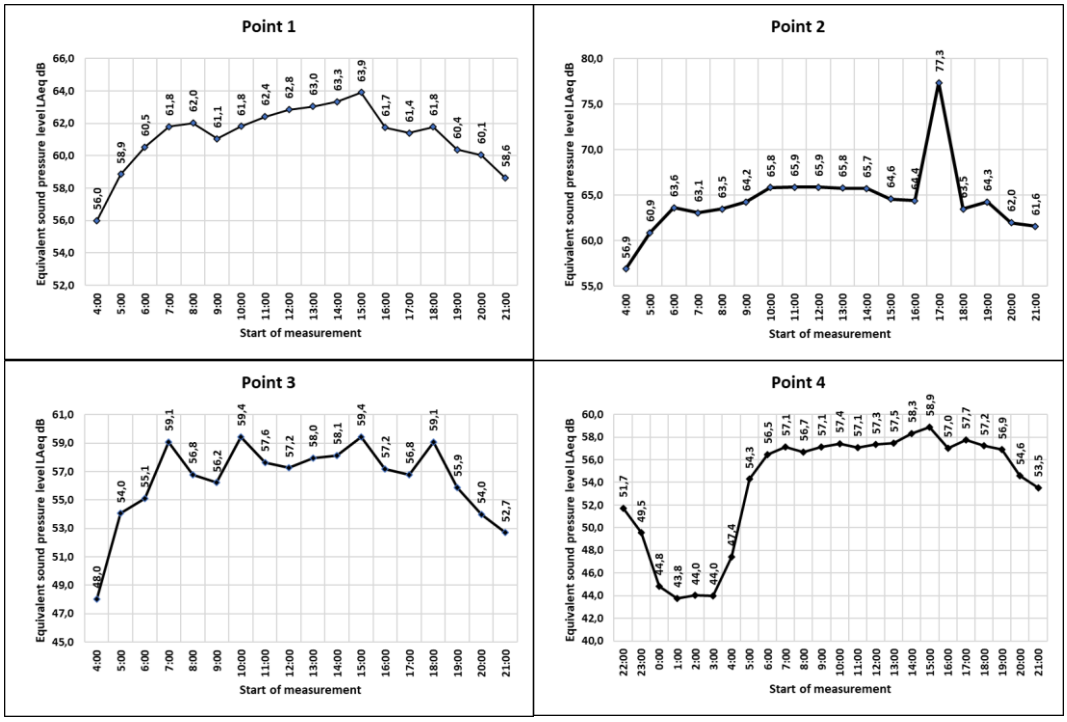

Fig. 5 Equivalent sound pressure level L_{Aeq} dB

Source: own work

The analysis of the obtained results shows a quite obvious conclusion that the obtained values of sound pressure levels are in close correlation with the intensity of vehicle traffic. The values measured in Point 3 at Korfantego Avenue show the maximum values at 7:00, 10:00 and 15:00, which coincides with increased traffic of inhabitants to and from work. Values in point 4 between 24:00 and 4:00 (practically no vehicle traffic) drop to approx. 44 dB, which means that this is the acoustic background value in this area. An anomaly in the obtained results is the value of equivalent sound pressure level obtained in measurement point 2 after 17:00. The obtained value (77.3 dB) is definitely higher than the average level in this point oscillating around 65 dB. An explanation for this phenomenon is the complex traffic situation in the area of the intersection of Mikulczycka and Gdańska Streets. There are no traffic lights at this intersection, those driving on Mikulczycka street have priority of driving. Increased traffic on Mikulczycka street at around 17:00 hrs causes traffic jams for cars driving on Gdańska street towards the east. Lack of fluent vehicle traffic has resulted in the recording of increased noise.

The values of sound pressure equivalents were used to determine the long-term noise indicator L_{DWN}. L_{DWN} is the A-weighted long-term average sound level in decibels (dB) over all the days of the year, taking into account the daytime period (6:00 to 18:00), the evening period (18:00 to 22:00) and the night time period (22:00 to 6:00). (Dz.U.2011) The L_{DWN} is determined from formula (1):

$$L_{DWN} = 10 \lg\left[\frac{12}{24}10^{0,1L_D} + \frac{4}{24}10^{0,1(L_W+5)} + \frac{8}{24}10^{0,1(L_N+10)}\right] \quad (1)$$

where:

L_D, L_W and L_N denote the long-term average sound level A expressed in decibels (dB), determined during all times of the day, evening and night of the year.

As the measured values are not long-term values, the calculated values of L_{DWN} (Table 4) should be treated as indicative.

The obtained L_{DWN} values can be compared with the corresponding values extracted from the Strategic Noise Map of the City of Zabrze performed as part of the 3rd round of mapping in 2017 (UM Zabrze 2017).

Table 4 L_{DWN} value obtained from measurements and Strategic Noise Map of Zabrze

	Indicator Ldwn dB			
	Point 1	**Point 2**	**Point 3**	**Point 4**
Calculated value	65,3	68,8	60,2	58,8
Strategic noise map of Zabrze	65 - 70	65-70	60-65	60-65

Source: own work, UM Zabrze 2017

Comparison of obtained results indicates correctness of conducted measurements. It also shows that L_{DWN} values obtained as a result of short term

acoustic measurements do not differ significantly from values obtained by simulation during creation of Strategic noise map of Zabrze. The strategic noise map also allows us to obtain information on land use (UM Zabrze 2017) and noise limits assigned to those areas. Analysis of this thematic layer of the Noise Map shows that measurement points 1, 2 and 4 lie in the zone marked as "Areas of multi-family housing and collective residence" for which admissible value of long-term average sound level L_{DWN} is 68 dB (Dz.U.2012). Point 2 is located in the area designated as "Areas of nursing homes", for which the admissible value of L_{DWN} index is 64 dB. In view of the above it may be stated that only at measurement point 2 located at Gdańska Street a slight exceeding of permissible values was registered. It should be remembered, however, that the calculated L_{DWN} values are indicative.

CONCLUSION

The realisation of the described research work was connected with the Project Based Learning (PBL) project conducted by the Institute of Production Engineering of the Silesian University of Technology in Zabrze, whose aim was to teach a selected group of students teamwork, synthesising information from various sources, making decisions and taking responsibility for them, planning and organising work and proper time management. The correctness of the obtained measurement values, their completeness indicates that the objectives of the project were fulfilled. It should be noted that the implementation of the project coincided with the period of restrictions related to the COVID-19 Pandemic, which clearly hindered the implementation of the intended activities. Despite this, all measurement activities were carried out.

The obtained measurement data (traffic density on selected streets, measured levels of acoustic pressure in measurement points) were used for further studies consisting in creation of acoustic field maps using simulation methods and analysis of influence of various methods of road noise reduction on the acoustic climate of the city.

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Keywords: Strategic acoustic map, traffic noise, Project Based Learning