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DOI: 10.35117/A_ENG_22_12_03

Measurements of traffic parameters and conditions in traffic noise research

Abstract: The level of traffic noise depends mainly on road traffic parameters such as: traffic volume, share of trucks in traffic and vehicles speed. Traffic conditions determined by such parameters as, for example, the average travel speed, average delays at the intersection and the number of vehicles stops are also important. Their particular importance is revealed especially in the case of bad traffic conditions and a significant reduction of traffic flow. The paper presents selected methods of measuring road traffic parameters, and in particular - traffic conditions on the example of research on their impact on the noise level in the vicinity of the street and intersections. The results of these tests are also presented, determining the impact of such parameters on traffic noise as: instantaneous speed, sectional speed, average delays at the intersection entry, the number of vehicle stops, volume to capacity of the entry ratio.

Keywords: Traffic noise; Traffic conditions; Traffic parameters; Measurement methods

Introduction

The impact of vehicle traffic and its relationship with road geometry and traffic organization on the noise level in their surroundings has been and still is the subject of many studies conducted around the world. This is due to the seriousness of the problem of traffic noise and its significant impact on people's health and quality of life and work. These studies are often associated with the development of new or improvement of existing models and methods of noise forecasting in the vicinity of roads, which are necessary to control the acoustic climate and prevent the impact of excessive noise levels.

The basic traffic parameters that affect road noise are: traffic intensity, vehicle speed, and the share of heavy goods vehicles. The type of surface on which vehicles move and the geometry of the road, including mainly its longitudinal inclinations, also have a large impact on noise emissions. Additional factors influencing road noise are traffic conditions categorized by the so-called levels of freedom of movement (PSR) and determined by such measures as average travel speed, percentage of the time of driving in a column, and traffic density - for sections of inter-junction roads or average time losses - for road intersections. The existing calculation methods and models take into account the above factors to varying degrees, especially those related to capacity and traffic conditions, thus affecting the accuracy of noise forecasts. This, in turn, affects the correctness of designing methods or devices protecting against excessive road noise and thus on investment costs.

The impact of traffic conditions is the subject of relatively few studies, e.g., due to the problem of measuring traffic conditions. However, the impact of these factors on road noise levels is significant. In the work [2], it was found that the noise level increases with the increase in traffic intensity, but this regularity occurs only up to the value of the so-called maximum traffic intensity; after exceeding it, the vehicle speed decreases successively as the density of the traffic flow increases. This phenomenon causes a decrease in the freedom of movement (determined by levels from "A" to "F," where "F" corresponds to the worst traffic conditions), thus affecting the values of the road noise level. In certain states of saturation with vehicle traffic, the decrease in freedom of movement even results in a reduction in noise levels. The study [4] showed that the deterioration of traffic conditions from the level of freedom of movement "B" to "C" and from "B" to "D" reduces road noise levels by 1.3÷1.7 dB and 2.0 dB, respectively. 2.3 dB. Similar results were obtained in [3], where it was found that the road noise levels increase with the increase in traffic intensity only up to the levels of freedom of movement "B" and "C", while in the case of PSR "D", "E," and "F" the increase in traffic does not cause a significant increase in noise and in some cases even results in its reduction at a limited speed of vehicles. Therefore, in the work [2], noise levels obtained based on existing noise forecasting models that do not take into account the impact of traffic conditions were found to be higher, even by about 2÷3 dB, compared to the results of field measurements obtained under worse traffic conditions.

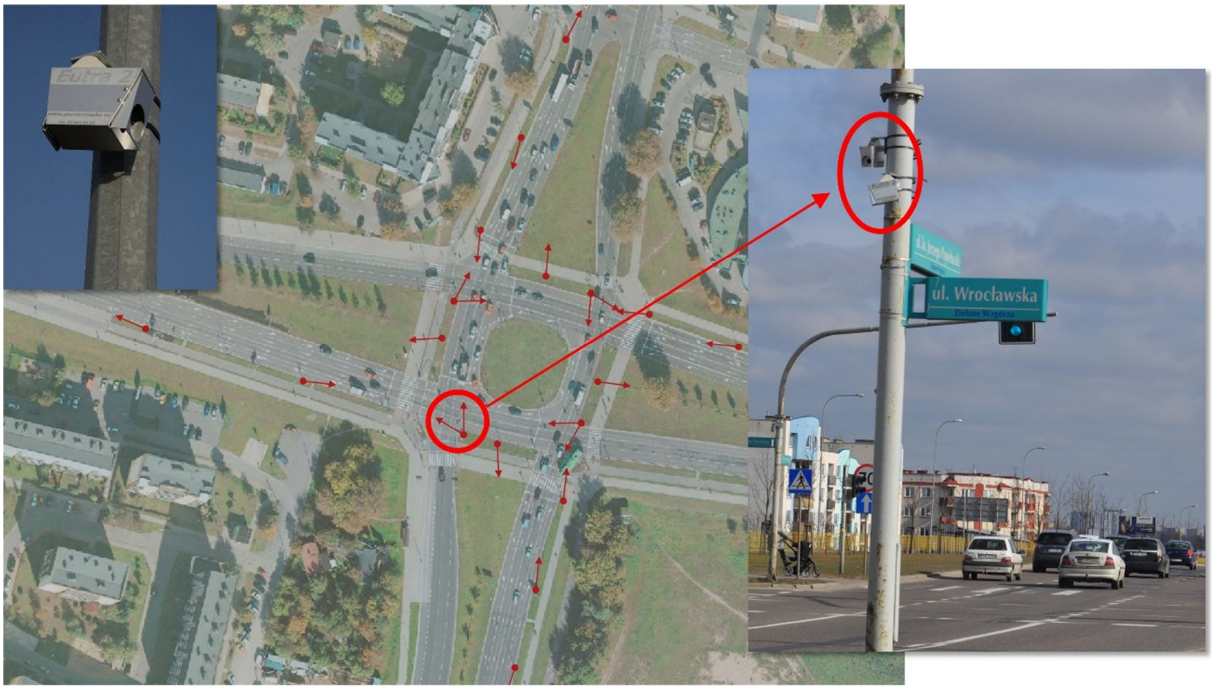
The article presents various methods of measuring parameters and traffic conditions in road noise research to reconstruct the impact of these factors on noise as faithfully as possible.

Measurements of traffic conditions at intersections and their impact on road noise

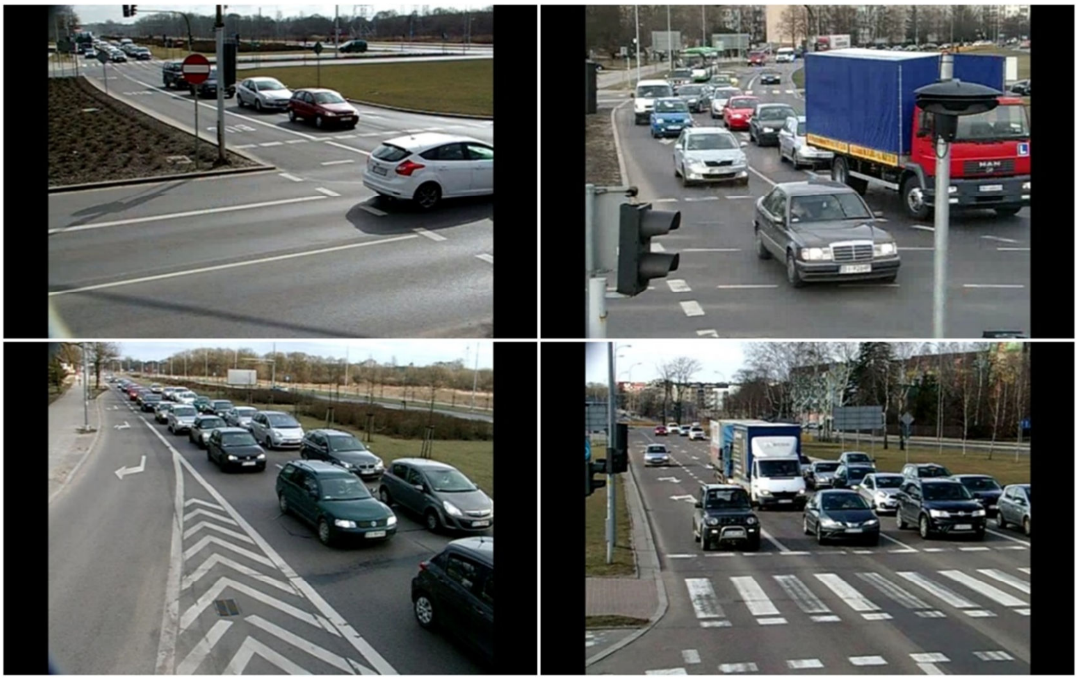
Traffic conditions at road junctions can be determined based on individual vehicle time losses, the number of stops, and the queues of vehicles at entrances. The practical determination of traffic conditions at intersections is a rather complex issue. This is due to the need to simultaneously determine traffic parameters such as intensity and type structure as well as quantitative and measurable measures of traffic conditions such as vehicle stops (including multiple stops) and queue lengths (maximum, remaining). An additional difficulty arises from the need to define the above-mentioned factors at multi-lane entrances and the variability of green signals or traffic light phase sequences, as well as the visibility of the end of queues often reaching several hundred meters. Therefore, measurements of traffic conditions are most often carried out with the use of many video cameras synchronized with each other, allowing for subsequent, detailed analysis of the registered traffic of vehicles at the intersection and its entrances. An example of such tests combined with noise tests are the measurements carried out in Białystok in March and April 2015 in the vicinity of two intersections with the central island marked W2 and W6 (after 8 hours of measurements: W2: 4 am–8 am and 4 pm–8 pm; W6: 10:30 am–2:30 pm, 3:00 pm–5:00 pm, and 8:30 pm–10:30 pm). Measurements of traffic parameters and traffic condition meters were made using 22 or 30 cameras simultaneously recording vehicle traffic on all lanes and at all intersection entrances. Figure **1** shows the arrangement of cameras at one of these intersections, and Figure **2** shows examples of frames of images recorded by cameras.

Based on the recordings of vehicle traffic at the examined intersections, for each lane of the intersection entrances, the following traffic parameters and measures of vehicle traffic conditions, as well as traffic light operating parameters, were read for the 15-minute analysis period:

- intensity and generic structure of Q traffic,
- number of stopped vehicles (P_z - no multiple stops),
- number of stopped vehicles (N_z - including multiple stops) determined in sub-periods $\Delta t = 15$ s (i.e. 60 results for the analysis period of 15 minutes),
- total time of green signal transmission G_t



1. Location of 22 cameras at the W6 intersection covered by traffic conditions measurements



2. Example frames from the video recorded by the cameras during the measurement of traffic conditions

Based on the obtained measurement results concerning the number of stopped vehicles N_z and the total traffic volume at the entrance Q_{wl}, then the average time losses per vehicle at the entrance d_{wl} [s/P] were calculated, which were estimated by the so-called indirect method [1]:

$$d_{wl} = \frac{N_{z,wl} \cdot \Delta t}{Q_{wl}}$$

$$d_{sk} = \frac{\sum d_{wl} \cdot Q_{wl}}{\sum Q_{wl}}$$

where: d_{wl} / d_{sk} – average time loss at entry/junction [s/P]; $N_{z,wl}$ – number of vehicles stopped on the entry lanes in subsequent intervals Δt = 15 s of the period T = 15 min of the measurement (T = 60·Δt); Q_{wl} – traffic intensity at the inlet during the measurement.

An example of traffic parameters and traffic conditions meters read from the recordings for intersection No. W2, at 7:45-8:00 am shown in Table **1**.

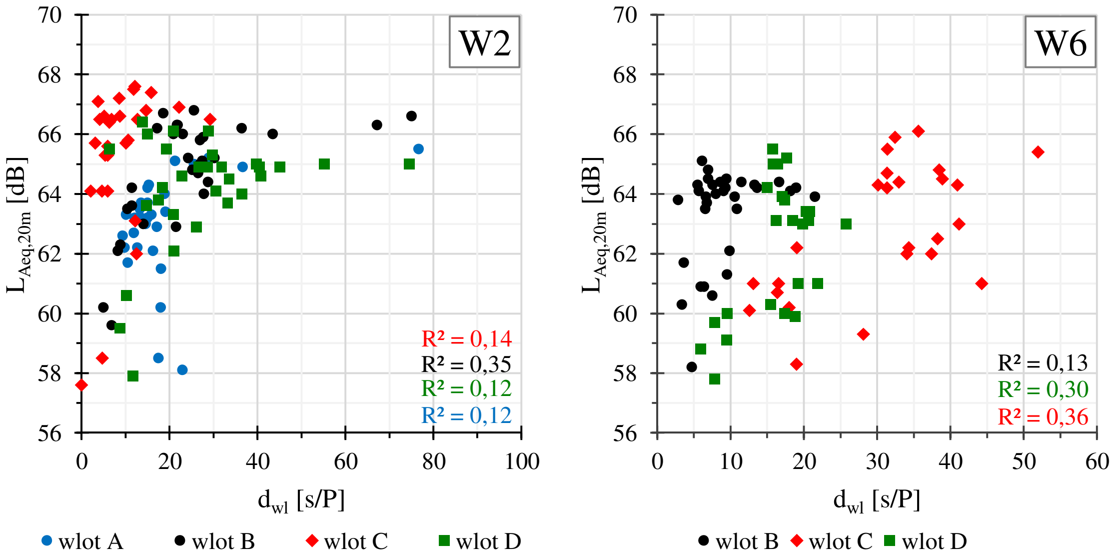
Tab. 1. An example of the results of measurements of traffic parameters and measures of traffic conditions obtained from recordings at the W2 intersection for the period of 7:45-8:00

intersection. W2			intensity and type structure of traffic				traffic conditions			
22.04.2015 7:45 -8:00			Q_{PL} [P/15min]	Q_{PC} [P/15min]	Q_{PA} [P/15min]	**Σ Q [P/15min]**	P_z [P]	Σ N_z [P]	d [s/P]	G_t [s]
inlets	**A**	lane 1	142	1	6	**149**	225	965	97,1	298
		lane 2	121	10	2	**133**	198	678	76,5	
		lane 3	85	3	1	**89**	85	255	43,0	
		Σ	**348**	**14**	**9**	**371**	**508**	**1898**	**76,7**	
	B	lane 1	84	12	0	**96**	52	49	7,7	373
		lane 2	146	2	6	**154**	136	307	29,9	
		lane 3	112	1	0	**113**	93	169	22,4	
		Σ	**342**	**15**	**6**	**363**	**281**	**525**	**21,7**	
	C	lane 1	48	0	1	**49**	26	43	13,2	253
		lane 2	93	2	0	**95**	88	204	32,2	
		lane 3	105	0	1	**106**	88	240	34,0	
		Σ	**246**	**2**	**2**	**250**	**202**	**487**	**29,2**	
	D	lane 1	72	0	6	**78**	19	43	8,3	374
		lane 2	87	1	2	**90**	41	98	16,3	
		lane 3	39	0	1	**40**	16	51	19,1	
		Σ	**198**	**1**	**9**	**208**	**76**	**192**	**13,8**	
bays at the extension of the inlet	**A**	lane 1	161	1	4	**166**	41	78	7,0	414
		lane 2	155	9	1	**165**	47	82	7,5	
		lane 3	79	3	1	**83**	11	20	3,6	
		Σ	**395**	**13**	**6**	**414**	**99**	**180**	**6,5**	
	B	lane 1	0	0	6	**6**	0	0	0,0	497
		lane 2	184	2	2	**188**	38	61	4,9	
		lane 3	114	1	0	**115**	12	24	3,1	
		Σ	**298**	**3**	**8**	**309**	**50**	**85**	**4,1**	
	C	lane 1	28	0	3	**31**	19	52	25,2	410
		lane 2	104	2	0	**106**	21	33	4,7	
		lane 3	110	0	1	**111**	8	21	2,8	
		Σ	**242**	**2**	**4**	**248**	**48**	**106**	**6,4**	
	D	pas 1	52	9	6	**67**	15	13	2,9	536
		pas 2	126	2	2	**130**	31	31	3,6	
		pas 3	84	0	2	**86**	35	35	6,1	
		Σ	**262**	**11**	**10**	**283**	**81**	**79**	**4,2**	

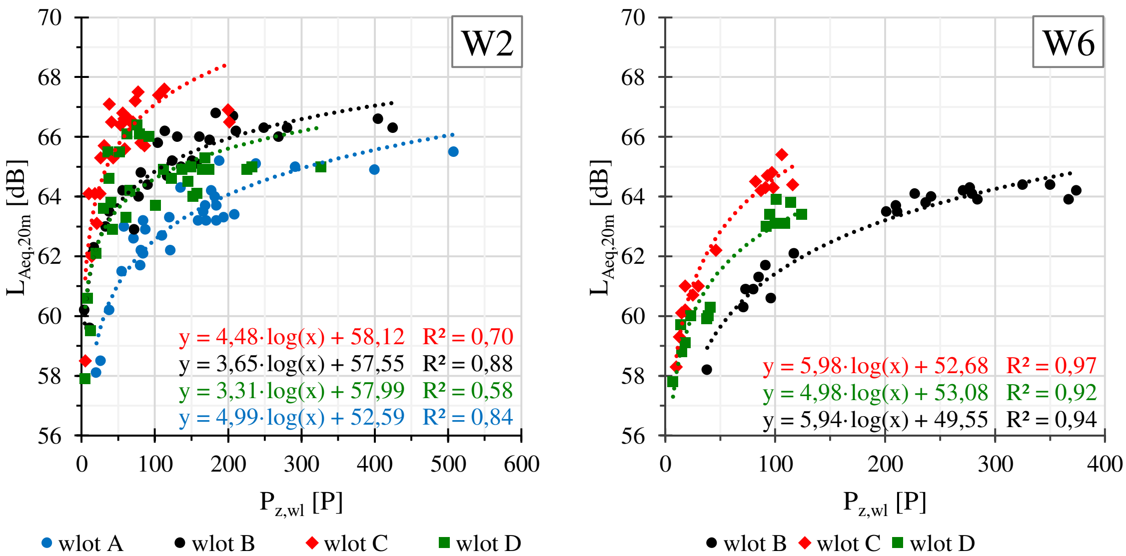
Q - traffic intensity of light vehicles (PL), trucks (PC), and buses (PA),
P_z - the number of stopped vehicles (excluding multiple stops),
N_z - number of stopped vehicles measured in sub-periods of 15 sec. (includes multiple stops),
d - average time loss,
G_t - the total length of the green signal transmitted by the signaling at the inlet.

Based on the obtained values of the average time losses d_{wl} at the entrances and the entire intersection, it was found that with the traffic load of intersections lower than 5000 P/h, the length of the signaling cycle T = 120 s and the confirmed traffic distribution, good or excellent traffic conditions occurred at the tested intersections PSR I÷II. At the entrances of intersections, the level of freedom of movement PSR I or PSR II was also found (average time losses were lower than 45 s/P), and only in a few cases was the level of freedom of movement PSR III established.

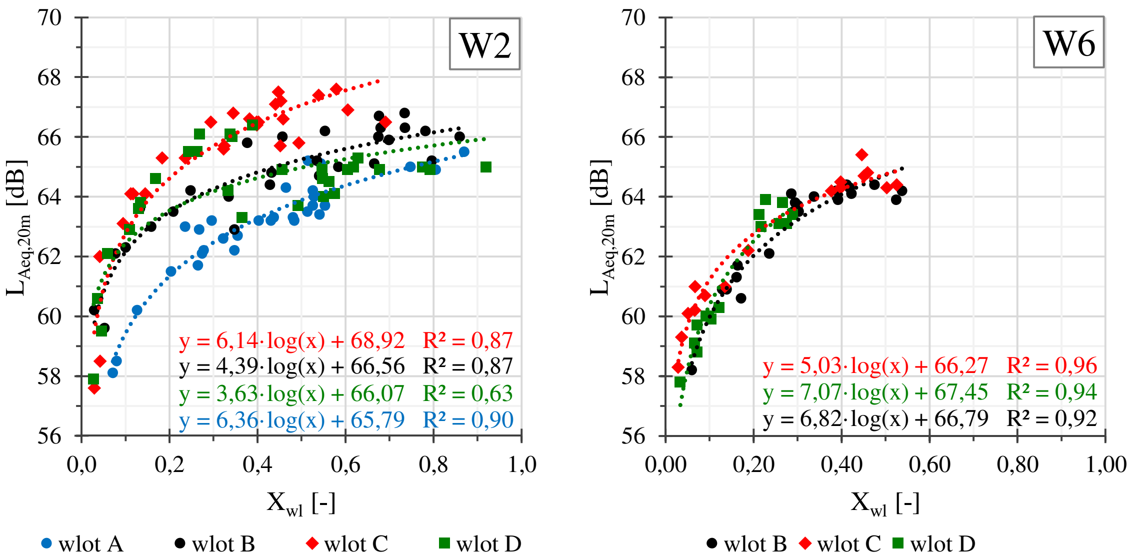
The analysis of the relationship between the obtained average time losses and the measured values of the equivalent sound level (L_{Aeq}) showed no linear relationship (Fig. **3**). This is due to the fact that the tests were carried out mainly with very good and good traffic conditions occurring at the intersection load $Q \leq 5000$ P/h, where low values of average time losses are not related to noise levels. Similar relationships with regard to field tests and good traffic conditions were shown in [4], however, indicating the situation of bad traffic conditions where time losses start to be related to noise levels. Significant relationships were obtained between the number of vehicles stopped at the entry $P_{z,wl}$, and the equivalent sound level L_{Aeq} (Fig. **4**). Differences in noise levels between individual inlets confirm the influence of other factors on the acoustic climate of the intersection's surroundings. Based on the results of the measurements of the duration of the green signal transmission time at the inlets G_t, the influence of the inlet load X_{wl} on the noise level was also determined, obtaining significant dependencies (Fig. **5**).



3. Relationship between L_{Aeq} at a distance of 20 m from the edge of the carriageway and average time losses per vehicle at the inlet d_{wl}



4. Relationship between L_{Aeq} at a distance of 20 m from the road edge and the number of vehicles stopped at the inlet $P_{z,wl}$



5. Relationship between L_{Aeq} at a distance of 20 m from the edge of the carriageway and the degree of loading of the intersection inlet X_{wl}

The studies conducted on the impact of traffic conditions on the noise level in the vicinity of intersections with the central island showed the existence of a relationship between the equivalent sound level and the number of vehicles stopped at the inlet and the degree of load on this inlet. It was also found that the average time losses incurred by vehicles when crossing the intersection had no significant impact on noise levels, but this may be due to the narrow range of analyzed cases, which covered only good traffic conditions. The established relationships may therefore change in the event of deteriorating traffic conditions. A measurable effect of the conducted measurements is also an indication of the possibilities and methodology of researching the impact of traffic conditions on road noise.

Speed measurements on inter-junction sections and their impact on road noise

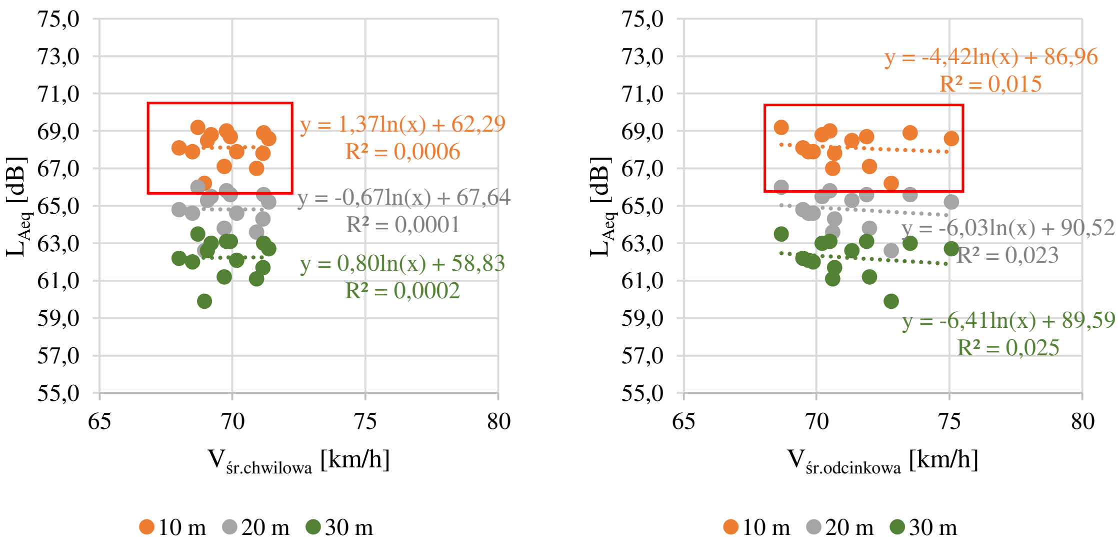
The level of road noise in the vicinity of inter-junction sections depends mainly on the traffic intensity, the share of heavy goods vehicles in the traffic, and the speed of the traffic flow. While the first two parameters are quite simple to determine, speed measurements require the use of more advanced equipment. In addition, there is the problem of determining the type of speed that will best reflect the impact of vehicle traffic on noise for a given road and traffic situation. In theory, it seems that the instantaneous speed of vehicles measured in the noise test cross-section will have the best relationship with the noise measurement results. In practice, however, it may turn out that the sectional speed of vehicles corresponding to the traffic conditions on the inter-junction section will better describe the impact of vehicle traffic on noise.

In connection with the above, it was decided to carry out a comparative study of the impact of the type of measured speed on sound levels in the vicinity of the interjunction section of the road. The measurements were carried out in November 2019 from 3 pm-6:30 pm on the section of ul. K. Ciołkowski in Białystok, characterized by a cross-section of 2/2 and the permissible speed of vehicles V_{dop} = 70 km/h. During the tests, the equivalent sound level LAeq and the movement of vehicles using video recording, as well as the instantaneous and average speed of vehicles, were recorded simultaneously. Before each measurement, all measuring devices were synchronized in real-time (in order to later accurately determine the relationship between noise levels and traffic parameters). The Sierzega SR4 apparatus (Fig. **6a**) was used to measure the instantaneous speed of vehicles (Fig. **6a**) - a radar device measuring the instantaneous speed of passing vehicles (in the noise measurement section), mounted on a low mast at an angle of 30º to the axis of the traffic lane. In turn, the average sectional speed was measured using two ANPR cameras (Fig. **6b**), which, based on the registration of the exact hour of the vehicle's travel time at the beginning and end of the measurement section and the recognized number of license plates (Automatic Number Plate Recognition), calculated the average sectional speed of registered vehicles. ANPR cameras were placed at the beginning and end of a road section of approx. 300 m. In the middle of this section, there was a section measuring noise, traffic intensity, and instantaneous speed with the Sierzega SR4 device. The collected measurement data were used to analyze the impact of the type of speed on noise levels. These data were analyzed in sub-periods of 15 min.

a)  b) 

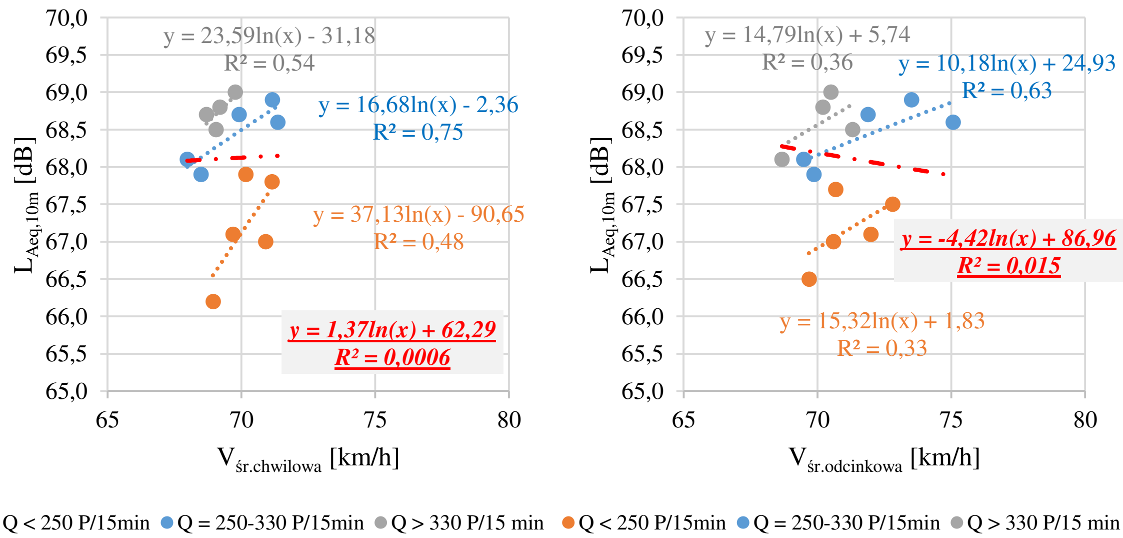
6. Apparatus for measuring the speed of vehicles: a) instantaneous - Sierzega SR4, b) segmental - ANPR camera (one of two on the section)

Figure **7** shows the established logarithmic relationships between the equivalent sound level L_{Aeq} and the average instantaneous speed $V_{śr.chwilowa}$ or segmental velocity $V_{śr.odcinkowa}$. Based on the obtained dependencies, it was found that the univariate analysis of the impact of speed on the noise level is incorrect because it does not take into account the impact of other significant factors responsible for the noise level, such as traffic volume and the share of noisy vehicles in the traffic. Hence, very weak relationships were obtained, and L_{Aeq} dependencies on velocity are even characterized by a negative slope, which is in contradiction to the generally known relationship: "higher speed = greater noise." It was noted, however, that the results of measuring the sectional speed with ANPR cameras show slightly better relationships with the L_{Aeq} values. The reason for this may be the fact that some vehicles slowed down near the middle of the measurement section where the instantaneous speed and noise measurement was carried out, seeing the measurement equipment by the road (speed differences at the beginning, middle, and end of the measurement section), which could have affected the established relationships.



7. Relationships between L_{Aeq} at 3 measurement distances from the road edge (10 m, 20 m, and 30 m) and vehicle speed: a) instantaneous, b) segmental

In connection with the problem described above, it was decided to analyze the impact of speed on the noise level as a function of traffic intensity ranges. The results of noise measurement at a distance of 10 m from the edge of the roadway were taken as an example. The results obtained from this analysis are shown in Figure **8**. "Separation of the point cloud" in Figure 7 (marked in red) by taking into account different ranges of traffic volumes revealed the relationship between noise levels and vehicle speeds. These dependencies have a logarithmic form and are characterized by good relationships (R^2 from approx. 0.33 to even 0.75). These relationships confirm that the noise level increases with increasing speed. The above shows that the univariate analysis of the impact of individual types of traffic parameters (intensity, percentage of noisy vehicles, speed) is burdened with a significant error. This applies in particular to single-factor analyses of the impact of the share of noisy vehicles and speed on the noise level because these factors are de facto derived from the volume of vehicle traffic; without vehicle traffic, there is no speed, and there is no contribution of noisy vehicles. Taking into account the influence of traffic conditions and density on the noise level, as well as other factors related to the propagation of the acoustic wave (landscape, sound absorption, reflection, atmospheric influences), the above confirms how complex the problem of assessing and forecasting road noise is.



8. Relationship between L_{Aeq} at a distance of 10 m from the road edge and vehicle speed: a) instantaneous, b) sectional, taking into account the ranges of vehicle traffic intensity

Summary

Based on the research and analyses carried out, a significant impact of road traffic parameters and measures of traffic conditions on the level of sound levels in the vicinity of roads and intersections was found. In particular, the impact of such factors as the type of vehicle speed (instantaneous or sectional); the average time loss at the intersection; the number of vehicle stops; and the degree of loading of the intersection inlet The obtained results of the analysis proved the significant impact of these factors on road noise, and the presented research showed the possibilities and methodology of measuring traffic parameters and measures of vehicle traffic conditions in road noise research.

Source materials

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