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THE INFLUENCE OF TYPICAL SOURCES OF TRAFFIC NOISE MODELLING METHOD ON THE ACCURACY OF CALCULATIONS OF ACOUSTICS EMISSION

2.1 INTRODUCTION

The evaluation of acoustic influence of road noise sources within strategic acoustic maps or other expert studies is connected with the necessity to model the noise source properly and to calculate its acoustic emission in accordance with the assumed computational model. However, acoustic emission modelling is quite a complex issue due to the possibility of various road geometry modelling (number of roadways, number of lanes, etc.) as well as due to the possibility to apply different computational methods. These factors exert a significant influence on the obtained results' accuracy.

This article presents results of a research experiment the purpose of which was to analyze the influence of different methods of road noise sources modelling as well as the influence of the applied computational method on accuracy of the acoustic emission calculations.

2.2 RESEARCH PROBLEM IDENTIFICATION

In accordance with the Polish legislation, while preparing road models for the purposes of strategic acoustic maps' creation, one uses the road networks layer available from the city's geodetic resources (SIT/SIP) and represented in the form of road axes. It shall be one axis in case of a single carriageway road and two axes in case of dual carriageway road. Therefore, the way of road modelling regardless of the number of lanes in each direction is here clearly imposed by the existing GIS model (GIS – Geographic Information System). For example, figure 2.1 presents various ways of a modelling of a road having one roadway and 4 lanes. In the city's GIS model the road is described by one axis (a) of traffic volume accumulated to 1 axis. However, this road may be modelled in a much more precise way, e.g. as a system of two directions i.e. two axes (b) and a system corresponding to reality where each lane is represented by a separate line source (axis) and specified by the traffic volume resulting from vehicles which actually move along this lane (c).

Thanks to our experience we know that the method of road modelling shall influence the calculations result. Yet, we do not know how big the influence will be. The conducted research experiment attempts to answer this question.

The experiment also focused on analysis of the results obtained while using the same method of road modelling but obtained with the use of various computational methods. The following five most popular computational methods were analyzed:

- French NMPB,
- German RLS-90,
- British CRTN,
- Scandinavian Statens Planverk 48
- Swiss STL-86.

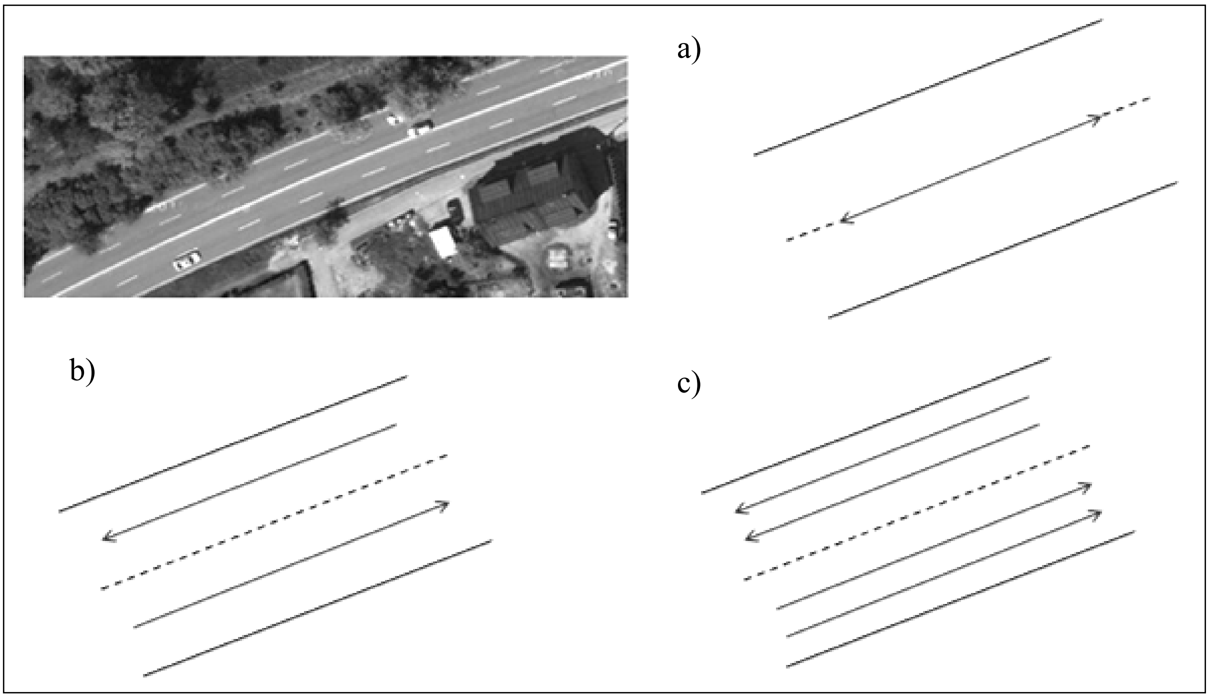


Fig. 2.1 Various models of one type of road:
a) one roadway as the total of all lanes, b) each direction modelled separately,
c) all lanes modelled separately

The method recommended by the 2002/49/EC Directive for road noise calculation is the French method NMPB Routes 96 (SETRA-CERTU-LCPC-CSTB), specified in „Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, art. 6" and by French standard "XPS 31-133".

2.3 COURSE OF THE RESEARCH EXPERIMENT

The research experiment conducted consisted in selecting homogeneous, in respect of traffic volume, various types of roads and making very precise measurements of traffic volume and equivalent level of noise in a particular measurement point. While selecting measurement points special attention was paid to the necessity of ensuring low level of the background noise during measurements. Then the roads were subjected to acoustic modelling in CadnaA computational system, using various modelling techniques and various computational methods, and the obtained results were presented in the form of diagrams and tables.

2.3.1 Selection of road sections and measurement points

The determinant of selection of roads where measurement points were situated was the road type (highway, national road, local road), the number of roadways, the number of lanes, traffic homogeneity and lack of disturbance from other sources. Thanks to the variety of roads it was possible to make a more detailed analysis of modelling ways of road noise sources' acoustic emission. The measurement points were located near four different types of roads:

- **Point PP1** – A4 highway – two roadways with three lanes each, the section between Wspólna junction and Wirek junction,
- **Point PP2** – national road no. 88 – one roadway with two lanes in each direction, the section between Gliwice and Zabrze,
- **Point PP3** – district road – dual carriageway road with two lanes each way, Bytomska Street, Zabrze,
- **Point PP4** – district road – single carriageway road with one lane each way, Kujawska Street, Gliwice.

2.3.2 Field measurements of sound levels

Field measurements of the levels of sound emitted by motor vehicles were made in measurement points located near four types of roads. Each measurement point was located 20 metres away from the external edge of the road at the height of 4±0.1 metres above the ground level.

The measurements were made on working days from Monday to Friday, which was connected with lower traffic on weekends. The measurements were taken during good and stable weather conditions, i.e. when it was neither rainy nor windy.

In case of each type of read the measurements of sound levels as well as measurements of traffic volume were taken at the same time, i.e. between 3pm and 4pm, that is at the time when the traffic was relatively high, however, in each case the traffic was smooth (no traffic jams). Results of measurements regarding the equivalent level of noise in each of the measurement points have been presented in table 2.1.

Table 2.1 Results of traffic noise measurements

ID	Sound level, dB			
	L_{Amin}	L_{Amax}	L_{Aeq}	SEL
PP1	61.9	86.9	**76.1**	111.7
PP2	50.0	86.6	**67.9**	103.5
PP3	43.1	84.5	**64.0**	99.5
PP4	41.4	83.1	**63.8**	99.4

An acoustic parameter taken into consideration in further studies is obviously the equivalent noise level (L_{Aeq}). It is used for comparison of the results of acoustic calculations, made with the use of CadnaA software on the basis of analysis of particular models of road noise sources, with the results of acoustic measurements.

2.3.3 Traffic volume and traffic structure measurements

The results of traffic volume measurements constitute the basis for calculating the source's acoustic emission by means of computational methods implemented in CadnaA software produced by DataKustik. GmbH. That is why the main assumption of the research experiment was a very detailed analysis of the road traffic volume measurements and identification of the traffic structure. Traffic volume measurements were made exactly for the time when the measurement of road noise was made. Vehicles were counted for each lane separately dividing them into lightweight vehicles (passenger cars, delivery vans) and heavyweight vehicles (cars above 3.5 tons – trucks, buses, tractors and motorcycles). Figure 2.2 represents the road (measurement point) with marked measurement sections where traffic volume measurements were taken, whereas table 2.2 presents the results of traffic volume measurements for measurement point PP3.

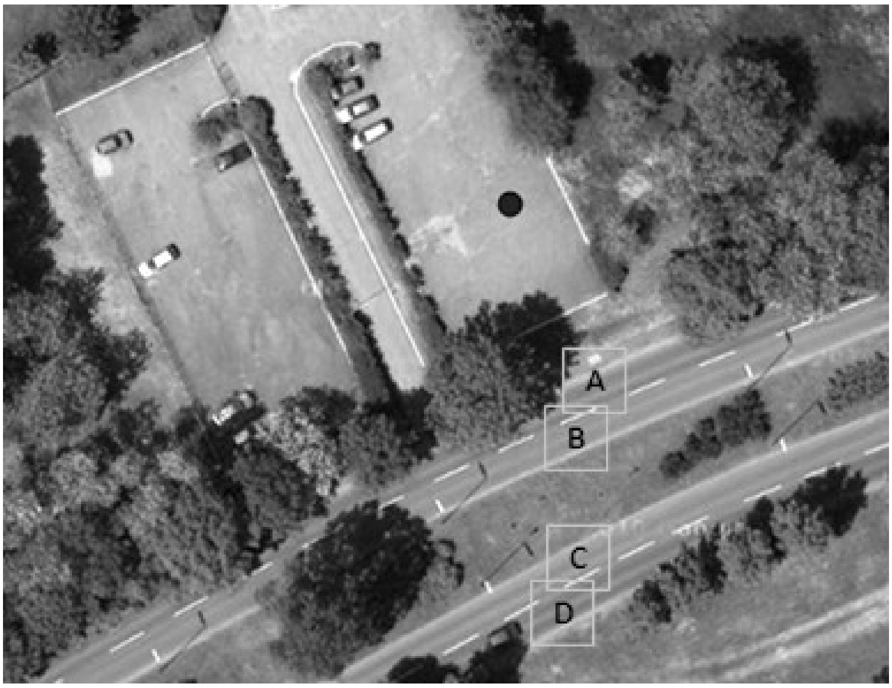


Fig. 2.2 PP3 measurement point together with the marked measurement sections

Table 2.2 The results of traffic volume measurements – point PP3

Section	Number of lightweight vehicles	Number of heavyweight vehicles	Total	Heavyweight vehicles share [%]
A	396	10	406	2.5
B	70	1	71	1.4
C	73	0	73	0.0
D	315	9	324	2.8

2.3.4 The method of road noise sources modelling

CadnaA software was used for the preparation of geometric and computational models of the examined sources of road noise. It was assumed that each of the road would first be modelled in a simplified manner thus it would be represented by one linear source (axis) and described by the total traffic volume on the road. Subsequent models would take more and more details into account, consequently, they would be more and more accurate. An example of the models created for a dual carriageway road (Bytomska Street in Zabrze- point PP3) has been presented in figure 2.3.

Models similar to the ones presented in figure 2.3 were prepared for the remaining roads analysed in the research experiment.

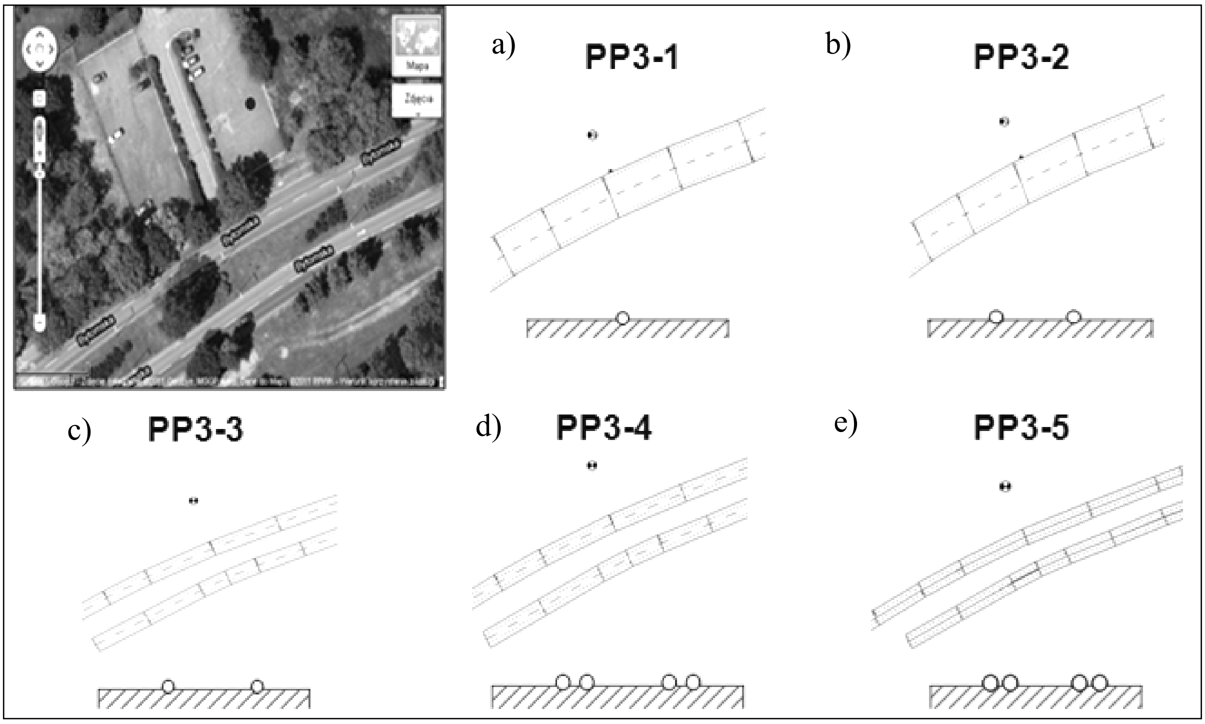


Fig. 2.3 Exemplary models of the noise source for a dual carriageway road (point PP3): a) model of one roadway as the total of all lanes, b) model of one roadway with the "*Calculate both external lanes separately*" function on, c) each of the roadways (traffic directions) modelled separately, d) as above with the "*Calculate both external lanes separately*" function on, e) each of the lanes modelled separately

2.3.5 Computational determination of selected roads' acoustic emission by means of various modelling ways

In order to determine the sound level in measurement points by means of computational methods, each of the created geometric models of roads had to be supplemented with detailed data connected with traffic parameters, road parameters, etc. Input data for the use of computational methods from CadnaA software were as follows:

– traffic volume with the percentage share of heavyweight vehicles

Depending on the method of a selected type of road's modelling, the volume of traffic was specified for each lane separately or was accumulated for each of the roadways. Moreover, most of the computational methods used includes the "*Calculate both external lanes separately*" option. In case when this option is on, the program divides the total traffic volume of one roadway equally for two lanes.

– admissible speed limits for lightweight and heavyweight vehicles

Different speed limits are admissible for lightweight and heavyweight vehicles in case

of the various types of roads analysed. Article 20 of the Traffic Code contains information regarding admissible speed of vehicles on various road types. Admissible speed limits of vehicles on the analysed roads are as follows:
PP1 – A4 highway – admissible speed: 140 km/h; for heavyweight vehicles: 80 km/h**,**
PP2 – national road no. 88 – admissible speed: 100 km/h, for heavyweight vehicles: 80 km/h,
PP3 – reduced speed limits on the basis of vertical signs – 70 km/h,
PP4 – built-up area from 5am until 11pm – admissible speed limit 50 km/h.

– <u>type of surface of the analyzed road type</u>

Computational methods used for the calculation of the level of noise emitted from various types of roads include the option of selecting road surface. The surface of all the analyzed types of roads is made of smooth asphalt and their condition is good. Figure 2.4 presents an example of a dialogue box "Roads" of the CadnaA software which allows to enter the data specified above.

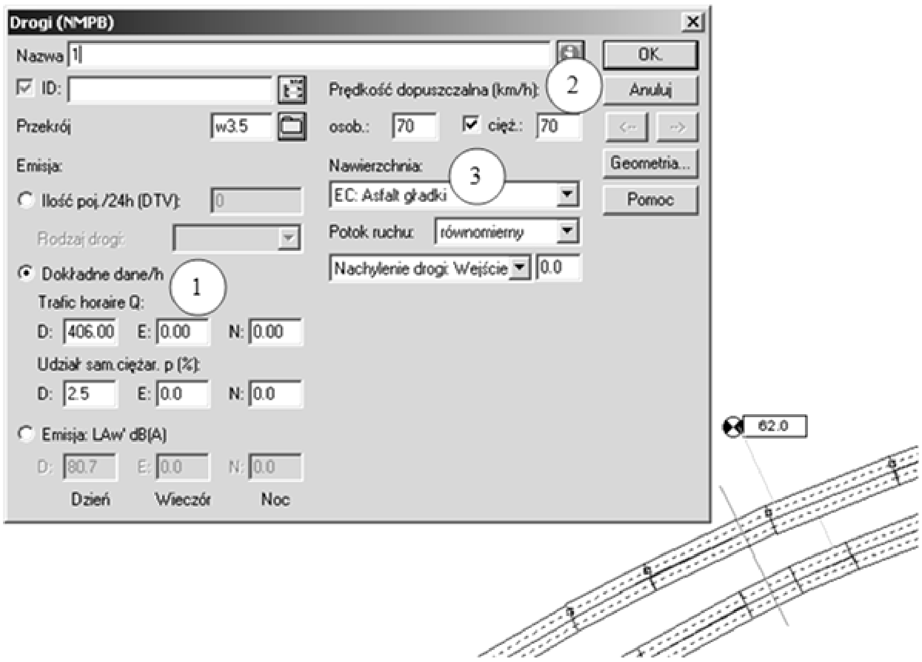


Fig. 2.4 "Roads" dialogue box with data entered regarding:
1) traffic volume, 2) admissible speed limits, 3) type of surface

After one has entered all the data and made calculations using the "Calculate" command, the field next to the receptor displayed the value of noise level expressed in [dB] for the selected road model. Determination of the equivalent level of noise A in the assumed measurement points for the models created for each of the types of roads was carried out by means of five computational methods:

- french method – NMPB,
- german method – RLS 90,
- british method – CRTN,
- scandinavian method – Statens Planverk 48,
- swiss method – STL86.

2.3 COMPARISON OF THE MEASUREMENTS' RESULTS AND MODEL CALCULATIONS' RESULTS

The comparison of acoustic measurements' results and model calculations' results consisted in calculating the difference between the calculations' result, by means of particular computational method, and the result of the actual measurement of the sound level. Selection of the most accurate computational method and the most accurate modelling way for a particular type of road was based on finding the smallest difference between the calculations' result and the result of measurement for a particular model.

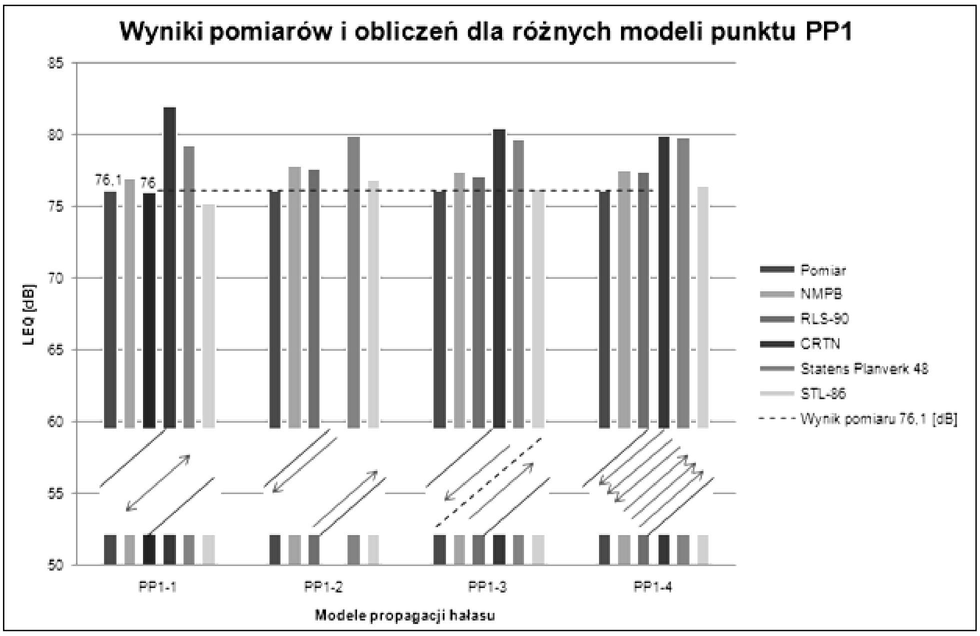


Fig. 2.5 Comparison of measurements' results and model calculations' results of noise emission from A4 highway (point PP1)

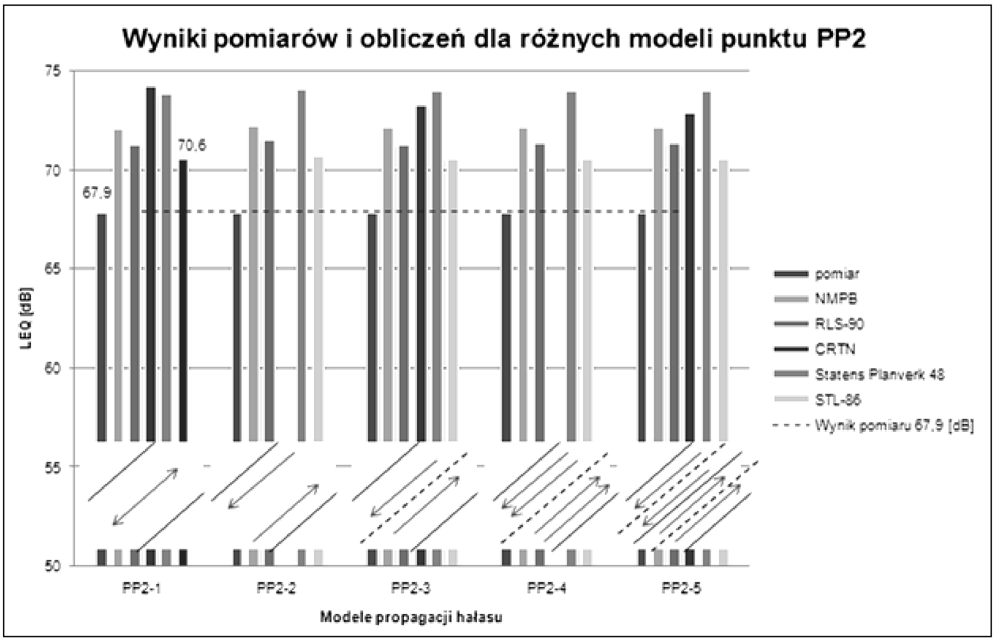


Fig. 2.6 Comparison of measurements' results and model calculations' results of noise emission from the national road no. 88 (point PP2)

Figures 2.5-2.8 present diagrams depicting the results of measurements and calculations made for various models of road noise sources and various models of noise propagation, for all types of the analyzed roads respectively. Red dashed line was used to represent the noise level corresponding to the measurement result. Red column in each of the diagrams represents the value of sound level for the most accurate computational method for a particular type of road.

Cumulative list of the recommended models as well as road noise computational methods for the four types of roads, which were the subject of the research experiment, have been presented in Table 2.3 on the basis of analysis of the results shown in figures 2.5-2.8.

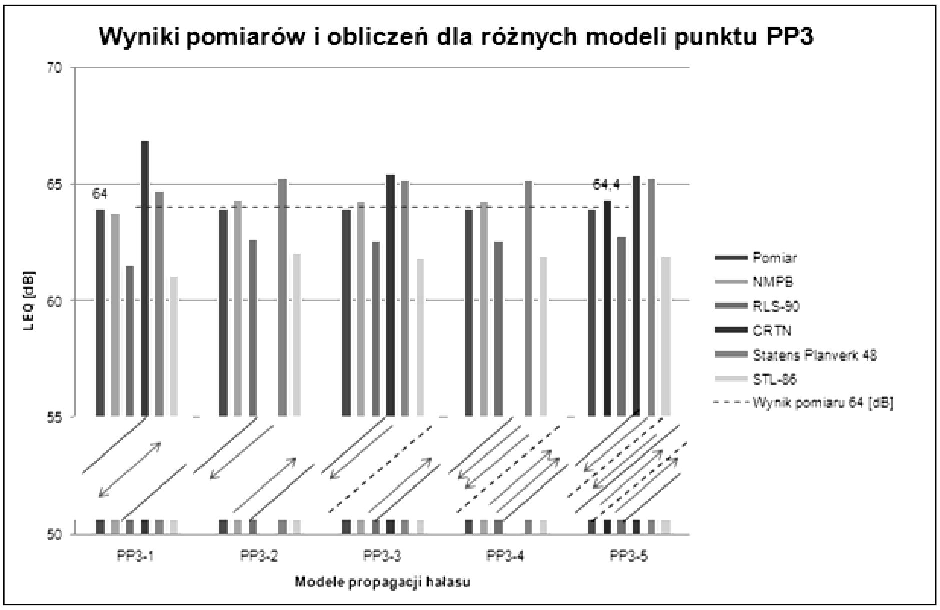


Fig. 2.7 Comparison of measurements' results and model calculations' results of noise emission from a district dual carriageway road (point PP3)

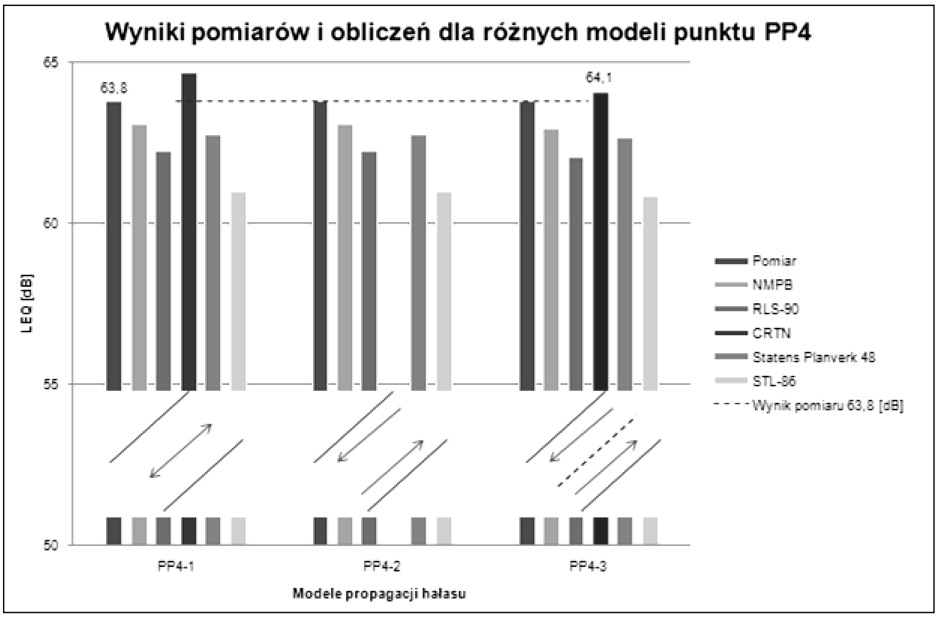
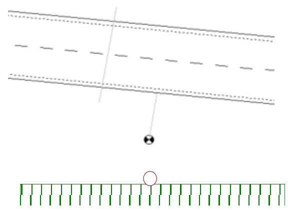
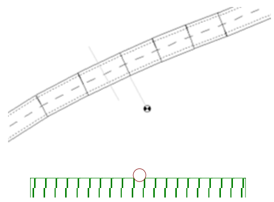
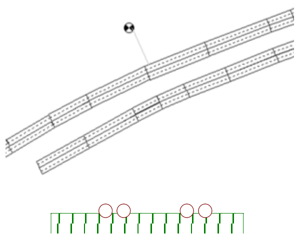
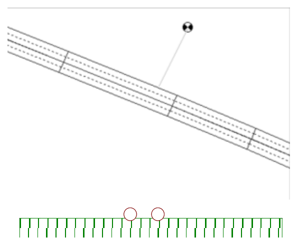


Fig. 2.8 Comparison of measurements' results and model calculations' results of noise emission from a district single carriageway road (point PP4)

Table 2.3 includes the most accurate geometric models of roads as well as computational methods for each of the analyzed types of roads. As it may be noticed, the results of calculations made in points PP1, PP3 and PP4 are slightly different from the results of measurements, whereas in case of point PP2 the difference is 2.7 dB.

Table 2.3 Cumulative list of the recommended geometric models and computational methods for various types of roads

ID	Recommended model		Recommended computational method	Measurement result [dB]	Calculations result [dB]	Difference [dB]
	Model number	Scheme				
PP1	PP1-1		RLS-90	76,1	76,0	-0,1
PP2	PP2-1		STL-86	67,9	70,6	2,7
PP3	PP3-5		NMPB	64,0	64,4	0,4
PP4	PP4-3		CRTN	63,8	64,1	0,3

CONCLUSIONS

The conducted research experiment as well as the analysis of the obtained results allowed to draw the following conclusions regarding the correct method of acoustic emission modelling of road noise sources:

- Computational determination of road noise emission in CadnaA program is based on data regarding the volume of traffic (including the percentage share of heavyweight vehicles), admissible speed limit and the type of the road surface. That is why, before the modelling commencement, great emphasis should be put on credibility of the data collected .

- In case of modelling, in CadnaA program, of roads of high traffic volume and a great number of lanes (e.g. highways), the program raises too high the results of noise emission calculations in comparison to the measurement result. Methods RLS-90 and STL-86 in the model which is theoretically the least accurate constitute an exception where the results of calculations are slightly lower than the measurement result.
- When modelling local roads having significantly lower traffic volume than in case of highways, CadnaA program results of noise emission calculations are lower in comparison to the measurement result.
- When considering roads of high traffic volume and a great number of lanes (in this case a highway and a national road), the most accurate modelling way turned out to be the modelling of one roadway as the total of all the lanes and introducing for this roadway an accumulated traffic of vehicles from all the lanes. In this case the source of noise emission is situated in the central part of the modelled roadway, i.e. on its axis.
- In case of local roads where the traffic volume is significantly lower than in case of highways, the most accurate model included the modelling of each of the roadways separately and introducing traffic volume for each of the roadways separately. In such a case there are a few sources of noise emission (depending on the number of lanes) located on the axis of each of the lanes.
- Methods RLS-90 and STL-86 are the recommended road noise computational methods for roads of high traffic volume and a great number of lanes. In case of RLS-90 method, for the recommended method of point PP1 modelling (highway) the difference between the measurement result and calculations result was only 0.1 dB. Whereas in case of STL-86 method this difference for point PP2 was 2.7 dB. However, it is worth mentioning that calculations' results obtained by means of STL-86 method changed slightly, withdrawing from the recommended modelling way. In case of RLS-90 method, the change of the modelling way from the recommended into a different one resulted in a increase of the difference between the measurement result and the calculations' result.
- In case of local roads of low traffic volume, NMPB and CRTN turned out to be the most accurate computational methods. As for the NMPB method, recommended by the EU Directive, the difference between the calculations' result and the measurement result for the recommended way of point PP3 modelling was 0.4 dB. It is worth noticing that that the CRTN method became more and more accurate proportionally to the decrease of traffic volume on the examined roads and proportionally to the increase of the model's theoretical accuracy (modelling each of the roadways separately). In case of PP4 point (local road of low traffic volume) the difference between the measurement result and the calculations' result was as low as 0.3 dB. One may also notice that the STL-86 computational method, which turned out to be the most accurate in case of roads of high traffic volume, was the least accurate for points PP3 and PP4 (local roads).
- The "*Calculate both external lanes separately*" option available in CadnaA software exerted a small influence on the calculations' results or increased the results in comparison to the measurement result. This option divides the total traffic volume of one

roadway equally for two lanes and it constitutes some kind of a simplification (it is well known that more vehicles move on the external lanes). Nonetheless, as it has already been mentioned, this simplification did not have a significant influence on the calculations' results or raised them too high, that is why it is not recommended to use this option for modelling processes.

- Method NMPB recommended by the EU Directive for traffic noise calculation turned out to be the most accurate in case of modelling local roads having moderate or low traffic volume.
- The obtained results indicate to the necessity of conducting large-scale research in order to confirm the obtained results and conclusions.

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THE INFLUENCE OF TYPICAL SOURCES OF TRAFFIC NOISE MODELLING METHOD ON THE ACCURACY OF CALCULATIONS OF ACOUSTICS EMISSION

Abstract: *The implementation of the strategic acoustic maps or evaluation of traffic investments interactions entails the necessity of modelling the traffic noise sources and calculating the emission of acoustic source. The modelling of the traffic noise seems to be the complex matter owing to different methods of modelling the road geometry (e.g. the number of roads and lines) and the possibility of application different methods of calculation. Mentioned factors significantly affect the accuracy in received results. The article below presents the course and the results of the scientific experiment, which main aim was analyzing the impact of different ways of modelling the traffic noise sources and the influence of the applied method of calculation on the accuracy in calculations of road acoustic emission. With particular precision there were explored the results obtained with the use of French calculating method NMPB Routes 96 recommended by The Directive 2002/49/WE for traffic noise calculations*.

Key words: *strategic acoustics maps, traffic noise, modelling the traffic noise sources, accuracy of the acoustic calculation, French calculating method NMPB Routes 96*

WPŁYW SPOSOBU MODELOWANIA TYPOWYCH ŹRÓDEŁ HAŁASU DROGOWEGO NA DOKŁADNOŚĆ OBLICZEŃ EMISJI AKUSTYCZNEJ

Streszczenie: *Realizacja strategicznych map akustycznych miast lub ocen oddziaływania inwestycji drogowych na klimat akustyczny, wiąże się koniecznością modelowania źródeł hałasu drogowego oraz obliczaniem emisji akustycznej źródła. Modelowanie hałasu drogowego stanowi dość złożony problem, z uwagi na różne sposoby modelowania geometrii dróg (tj. liczby jezdni, liczby pasów ruchu, itp.) oraz możliwość zastosowania różnych metod obliczeniowych. Czynniki te wpływają w istotny sposób na dokładność uzyskiwanych wyników. W artykule przedstawiono przebieg i wyniki eksperymentu badawczego, którego celem było zbadanie wpływu różnego sposobu modelowania źródeł hałasu drogowego oraz wpływu zastosowanej metody obliczeniowej na dokładność obliczeń emisji akustycznej dróg. Szczególnie dokładnie przeanalizowano zbadano wyniki uzyskane przy zastosowaniu francuskiej metody obliczeniowej NMPB Routes 96 zalecanej do obliczeń hałasu drogowego przez Dyrektywę 2002/49/WE.*

Słowa kluczowe: *strategiczne mapy akustyczne, hałas drogowy, modelowanie źródeł hałasu drogowego, dokładność obliczeń akustycznych, francuska metoda obliczeniowa NMPB Routes 96*

dr inż. Arkadiusz BOCZKOWSKI, Grzegorz KOŹLIK
Silesian University of Technology, Faculty of Organization and Management
Institute of Production Engineering
ul. Roosevelta 26, 41-800 Zabrze
e-mail: Arkadiusz.Boczkowski@polsl.pl