THE APPLICABILITY OF 3D MODEL IN CALCULATION OF ROAD TRAFFIC NOISE LEVEL

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Abstract

This paper describes the procedure of drafting 3D model of calculation of road traffic noise level on the basis of the data obtained by means of the detailed geodetic records of the existing situation made exactly for that purpose, as well as 3D model obtained on the basis of the existing digital maps and ortophoto records of the observed area with the data collected by the tour of the grounds. The paper presents the comparison of the results of these models and the results of field measurements on the example of Čavle settlement, situated on the section of Rijeka-Zagreb highway, as well as the commentary on the applicability of the described models in calculating road traffic noise levels.

Keywords: road traffic noise, 3D space model, noise calculation method

1 Introduction

Environmental noise, particularly road traffic noise, is one of the main factors which influence the quality of life and cause a serious ecological problem. Regulations in the Republic of Croatia, the Law [1] and the Regulation [2], prescribe the continuous monitoring of the environmental conditions regarding noise pollution, making noise maps and adopting action plans as well as the highest allowed noise levels in working and residential areas in order to improve the situation in the areas of high exposure to noise, together with the protection of quiet areas.
In order to protect residents from excessive levels of traffic noise, it is necessary to pay special attention to the estimation of the influence of roads on environmental traffic noise situation, not only in the process of planning and designing new roads, which today is customary in Croatia, but also with already existing roads which pass through residential areas. Defining critical areas, that is, locations where maximum permitted noise level prescribed by regulation is reached or noise levels have been exceeded, is carried out by means of noise maps. Noise maps allow monitoring of noise level changes that happen in time as well as determining the efficiency of different protection measures. Making noise maps by means of modern computer programmes (packages) is preceded by drafting a complete 3D model of the terrain of the area for which the calculation is done. The time needed for the calculation and the precision of the calculation mainly depend on the precision of the model itself. It is necessary to verify noise level calculation models comparing them to calculation results according to field measurements. Research presented in this paper has been carried out with this aim in mind.

2 Making 3D Model of Traffic Noise Level Calculation

Making 3D Model of Traffic Noise Level Calculation with existing roads can be more difficult compared to newly designed ones (updated data) mostly due to the old data regarding the traffic load and building density, i.e. population density of the areas along the road together with the incomplete data on the forming road elements. It is possible to solve the problem by registering the traffic and topography by the detailed 3D geodetic recording of the researched area. The second possibility is making 3D model applying specialized computer programmes and existing data: digital model of the relief, digital topographic and ortophoto maps (owned by State Geodetic Administration) as well as traffic data, facilities and road geometry collected during the tour of the grounds. The answer which procedure to take is not an easy one. In any case, the optimum solution is the one that, along with the satisfactory accuracy, is also quicker, simpler and financially more convenient.
Field measurement is the only accurate method of making noise maps. It can be applied to determine noise conditions in the areas along the existing roads, whereas in the case of the planned roads it is useless. When it comes to future roads it is, therefore, necessary for making noise protection projects to apply so called derivative methods (models) of calculation. In this process, within the various software packages for noise level calculation different calculation methods are applied, and two of them will be used in this paper: the German RLS 90 and the interim French NMPB. It should be mentioned that even in the case of the existing road it is optimum to apply a calculation model, since field measurements aimed at making noise maps require extensive preparations, precise and expensive equipment and they are expensive and long-lasting. When it comes to an existing road, it is useful to apply field measurement for calculation model calibration. In this case it is reduced in scope. Field measurement is an unavoidable and significant method for determining reliability of the derivative methods which is important for optimizing noise protection projects.
By comparison to field measurement results on the example of Čavle settlement situated along the Zagreb-Rijeka highway section, the assessment of the applicability of noise level calculations has been shown. It was carried out by means of calculation package LimA applying **model 1** – the detailed 3D space model (geodetic 3D recordings of the terrain) and **model 2**-3D space model obtained on the basis of the existing data from digital maps. Understanding of model 1 and model 2 applicability can facilitate the decision on the necessary detail of the base in designing noise protection, depending, of course, on the level of the project. It is not justifiable e.g. for studies or concepts where other road elements have been elaborated with minor detail of incoming data to insist on higher reliability, detail and accuracy of the noise protection project.

2.1 Field Measurements

Field measurements of noise (Table 1) and traffic were carried out in the area of Čavle settlement situated immediately by Rijeka – Zagreb highway (Figure 1). Traffic counting is performed by hourly registration of traffic load. The number of vehicles (personal and freight), the share of freight vehicles and the average speed for each individual group of vehicles has been determined.

Table 1 Measured noise levels for the day and night period in the field

	Measured noise levels LAeq [dB(A)]					
Measurement spot	M-06	M-07	M-08	M-09	M-10	M-11
Period day	60.1	59.2	73.6	63.7	64.4	71.5
Period night	57.0	58.2	69.6	60.3	58.1	63.2

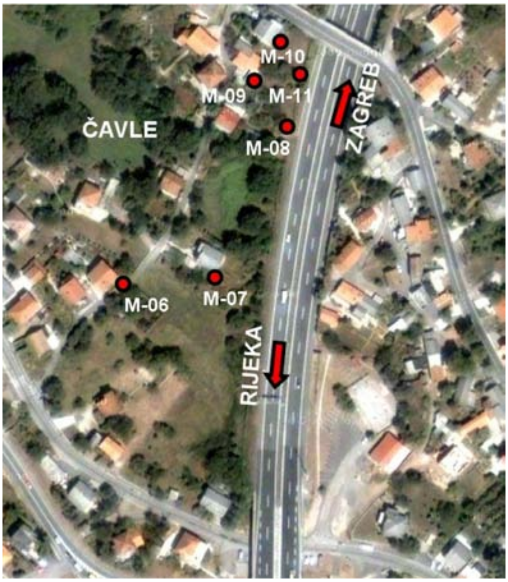

Figure 1 Tested area and locations of measurement spots

2.2 The Detailed 3D Space Model

The detailed 3D space model made by the geodetic 3D field recording contains many more data than necessary for the noise level calculation using calculation models. Each computer program and each individual calculation method contain simplifications due to the increased working speed and simplicity.

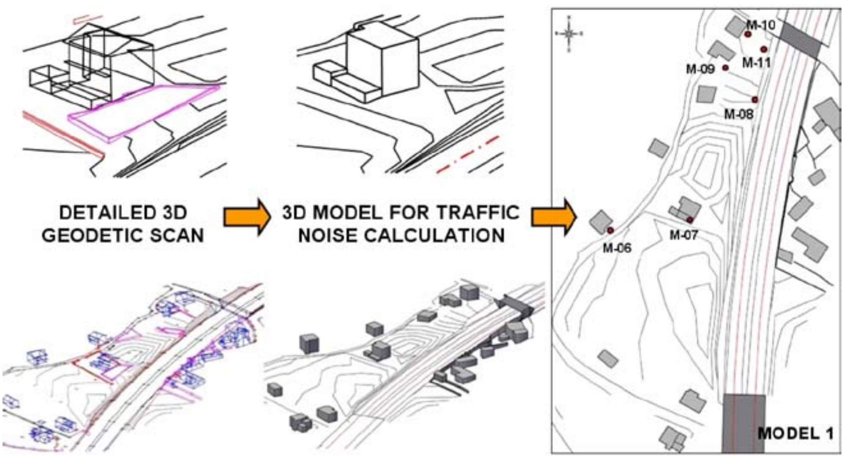

Figure 2 Detailed 3D geodetic space model and the model modified for the calculation purposes (model 1)

In order to be applicable to noise level calculation by computer programme, the detailed 3D model should be additionally "arranged". Incoming data necessary for road traffic noise level calculation by means of software package LimA (.dxf format) are: contour lines and breaking lines, the position of the objects on the road (viaducts, bridges), ground-plan position of

noise propagation barriers (buildings and walls with the average height above the ground higher than 1m) as well as the position of the source of noise. Figure 2 shows the detailed 3D model before and after the adjustment for the calculation needs on one object and on the tested area.
The adjustment was performed in such a way that all noise propagation barriers lower than 1m were omitted from the detailed 3D model (e.g. fences, low walls and columns) while objects with slanting surfaces (housing facilities with balconies and slanting roofs, viaducts) were approximated by upright prisms.
The need for the additional, often long-lasting adjustment process of the detailed 3D space model is the main drawback during their application in road traffic noise level calculations using special computer programmes.

2.3 3D Model Obtained by Using Existing Digital Maps

In the Republic of Croatia State Geodetic Administration [3] is in charge of systematic collection, processing and presentation of spatial data in the form of maps and digital database. In making 3D models for the road traffic noise level calculation it is possible to apply digital models of reliefs (DMR) and digital ortophoto maps (DOF) of the tested area which are available for almost the whole territory of Croatia. Spatial model for the needs of noise level calculation is specific [4] so the existing DMR should be completed, that is, a digital model of the terrain (DMT) should be made. DMT is a continuing model where each point in the sense of position can have one or more corresponding heights [4], and it is made by joining DMR and the digital model of the objects (in this case, buildings and roads). The basic disadvantage in the application of such models in road traffic noise level calculations is insufficient up-to-date data: the missing source of noise (new road section built), newly constructed facilities which represent barriers to noise propagation, as well as housing facilities which should be protected from excessive noise levels.

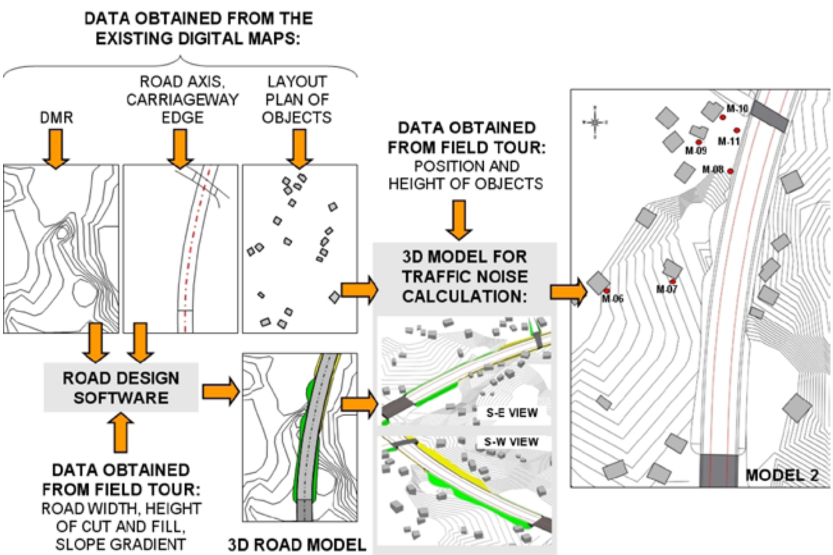

Figure 3 The procedure of making 3D model for road traffic noise level calculation from the existing documents (model 2)

When it comes to a new road, the road model is made by special computer programmes for designing roads. For an existing road it can also be made by special computer programmes

for designing roads by using available data regarding the terrain and the road itself obtained from digital maps, as well as data obtained during touring the grounds (tested area). The position of road axis can be determined from DOF, while the height data for the terrain - contour lines are taken from DMR. For the needs of making the model of the existing road, e.g. the one where the detailed data and project documents are missing or there have been some non-recorded alterations, the data such as height of cut and fill, slope gradient, road width, the number and width of lanes, longitudinal slope can be determined in two ways: by precise geodetic measurements or by visits to the grounds and collecting raw data on these parameters. If the model for an existing road is made by means of precise geodetic records, in that case the procedure, compared to making the detailed 3D spatial model described in the chapter 2.2, is not significantly simplified. It is necessary to add the data on facilities, which can be collected in the same way as the ones about the road, to 3D model obtained by "connecting" DMR and the model of the road.
The procedure of making 3D model from the existing documentation for the settlement Čavle area is shown in Figure 3. The model of the existing road is made by a specialized computer programme for road designing MXROAD V8i roads. The position of objects on the ground-plan as well as the ground-plan elements of the road were made by ortophoto maps of the area, and the data regarding the height of the objects and elements of road cross-section were obtained by the rounds of the terrain.
The biggest advantage of the 3D model for the road traffic noise level calculation made by means of existing digital maps and field measurement data on roads and facilities is its quick and simple making, while the basic disadvantage is its possible departure from the real conditions in the field. The departures occur due to the dated input data. It is, therefore, necessary, when making such models, to use the data obtained during the tours of the tested area in order to ensure the highest possible precision.

3 Calculation Results

The noise level calculation on model 1 and model 2 has been carried out by means of calculation package LimA using the German RLS 90 method and the recommended French NMPB method. The German RLS 90 method was a prescribed method of road traffic noise level calculation until the new Regulations [5], which prescribes the interim NMPB method, came into force. Table 2 shows the values of departures of the calculated noise levels compared to the results of field measurements (departure = calculated value – measured value).

Table 2 The departures of the calculated noise levels from the measured noise levels [dB(A)]

Measurement spot	RLS 90 method				Interim NMPB method			
	Model 1		Model 2		Model 1		Model 2	
	day	night	day	night	day	night	day	night
M-06	1.89	-0.49	2.74	0.26	5.79	3.99	5.79	3.99
M-07	7.08	2.82	7.21	2.95	10.28	6.59	10.28	6.60
M-08	-0.51	-1.40	0.30	-0.78	0.35	-0.07	0.35	-0.08
M-09	0.94	-1.26	0.58	-1.66	5.25	3.80	5.25	3.80
M-10	2.19	2.65	2.73	3.45	5.64	7.07	5.64	7.07
M-11	0.18	3.33	0.50	3.81	0.23	3.98	0.22	3.96

The departures of calculation results from measurement results using RLS 90 method, except for the measurement spot M-07, are satisfactory. Experts in this field consider the departures from the model and measurements up to 3 dB(A) satisfactory. The recommended interim NMPB method, compared to RLS 90 method, gives higher levels of noise by about 3 dB(A) which includes the additional safety since the calculated values, irrespectively of the model and the method, are mostly higher than the measured ones. Using RLS 90 method compared to the field measurement, departures from model 1 are smaller than 1 dB(A) compared to the departures of model 2. With the application of the recommended interim NMPB method there is not a significant difference in the application of models 1 and 2.

4 Conclusion

The application of 3D model obtained by specialized computer programmes on the basis of the existing documentation and the rounds of the terrain allows making the model of the satisfactory reliability for the estimation of road traffic noise level. It is applicable in making the project of protection against noise on the level of a study or a preliminary design of the road. It can be used in making the main project even more since noise level differences using the detailed 3D model and the space model obtained from the existing documentation applying RLS 90 calculation method are up to 1 dB(A) which corresponds to an error in field measurements. The differences are almost insignificant if the recommended interim NMPB method is applied. The example described in the paper shows that it is not always necessary to make a detailed spatial model since simplifications included in individual calculation methods cannot take into consideration all the details. Similarly, a less precise model gives satisfactory results especially for the project documentation of lower processing level (study and preliminary design) along with the increased speed and reduced costs.

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