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Urban noise mapping - an approach to the establishment of standard making procedure

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The Directive 2002/49 relating to the assessment and management of environmental noise and the Croatian legislative derived from it define the basic rules to carry out strategic noise mapping. However, in real life situations, each mapping project implies a different approach, depending on various case related distinctions e.g. availability and quality of input data, extent of noise annoyance, the form and the volume of output data to be presented etc. Based on the experience from various urban noise mapping projects, this work is an approach to defining key steps in urban noise map production and establishing standard step-by step procedure, and an attempt to define the procedure for each step. The examples that are given for each step are based on the case studies from our previous urban noise mapping projects.

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1 Introduction

In the past four years Brodarski institut has produced fifteen noise maps (road traffic noise, railway traffic noise and industrial noise) of seven different cities in Croatia, ranging from 11 000 to 65 000 inhabitants. The basic rules for the urban noise mapping are defined by END and Croatian legislative derived from it, but with various projects, increased knowledge and experience, it became clear that the standardization of the noise map production procedure should be attempted. The procedure was governed by various software used (software for noise mapping, GIS software, databases etc.), availability and usual form of input data needed, output data to be presented and so on. Also, as more people got involved in the team, the approaches to solving small problems, dilemmas and the methods of reaching certain steps begun to differ.

2 Calculation model build-up

2.1 Environmental model

The basic model of the environment for noise level calculations consists of four layers: 3D terrain model, obstacles (houses, embankments, bridges etc.), road (rail) axis and ground absorption, as illustrated in Fig. 1.

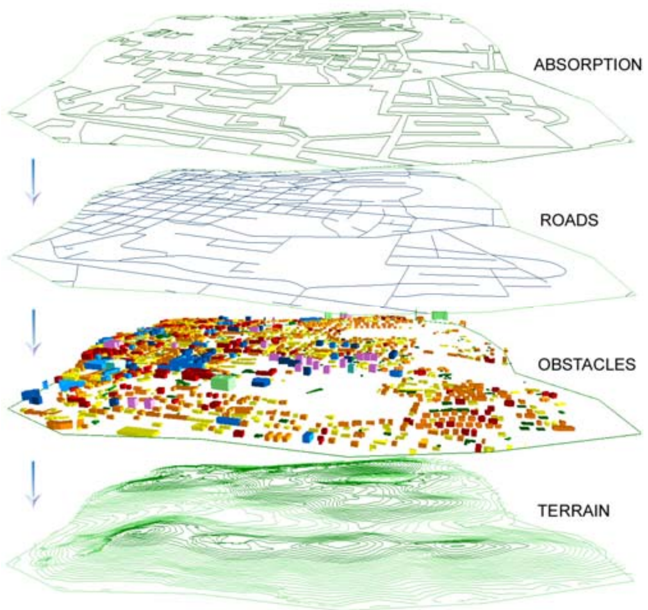


Figure 1: Layers of the basic model

The terrain model is generally not available from the customer, so the data are obtained from Croatian geodetic authority and then processed and converted to the format required by the noise mapping software that is used. The contour lines resolution is typically 1 m. The other layers are usually copied in digital form from the planning documentation of the client cities. The position accuracy of the dwellings and other building objects (including industrial objects) and the road and rail axis are checked with the orthophotograph (aerial photograph). Some additional digitalization is done manually if necessary. The main problem encountered so far in the model build up, is the lack of the buildings height information. The height of the buildings and the other obstacles is estimated from the orthophotograph and from direct in-situ storey counting. The heights determined that way are than manually inputted in the model for each building. This is tedious and time consuming process and various ways to automate it are under consideration. After the input of the data has been finished, the model is completed. Example of a complete model is shown below in Fig. 2.

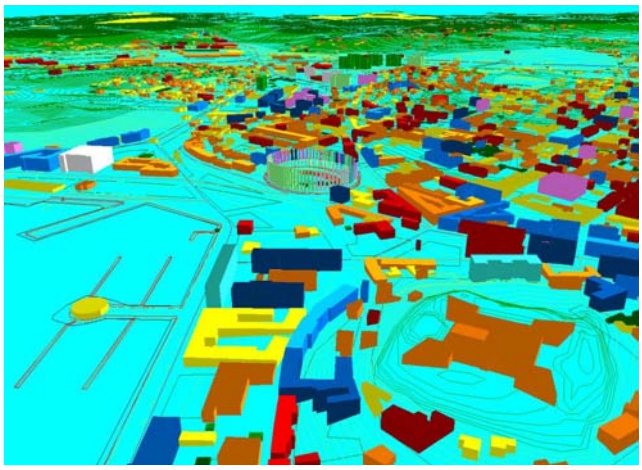


Figure 2: 3D view of a complete model

2.2 Source emission model

After the basic model of the environment has been built up, the sound power level of the noise sources emission are determined.

For the road traffic noise the roads and streets are defined as line noise sources with their sound power levels. The traffic data needed for that are usually insufficient and inconsistent

The usual approach used is to divide all roads and streets in three groups:

- Main roads and streets carrying the heaviest traffic including bypasses and fast city highways.

The exact traffic data on that category, including the total number of vehicles and percentage of heavy vehicles per hour, driving speed and traffic type (continuous, stop and go, uphill, downhill etc.) should be known. If the traffic data available are not sufficient, traffic counting has to be done. The duration of the measurements and the extent of the data gathered depend on the budget available. Sometimes traffic studies are well made and contain the amount of usable information but are out of date. In this case the increment of the registered vehicles that occurred between the traffic study creation and present, obtained from the traffic police administration, are used for an update. Even when the traffic data available are good and usable for the purpose of the noise mapping, they are only applicable to the daytime data (usually 6-22 hours). The nighttime data are generally not available as there are of no interest to traffic planning. Therefore, the nighttime data have to be obtained by combining the available daytime data, the night counts performed and Good Practice Guide [1]. The noise level measurements on the number of strategic places are also performed for the purpose of the model validation.

- Roads and streets connecting those from the first category and whose traffic data can be derived from the known data of the first category.

- Streets mainly in residential areas serving for residents living there

The traffic data from the Good Practice Guide are used for this category. When appropriate, this category is divided in two, using data for service roads and dead end roads. However, the experience has shown that the data from the Good Practice Guide have to be decreased in certain amount, to correspond to the intensity of traffic in Croatia.

All traffic data required by the software are organized in tabular form and inputted automatically in the model.

After that, the grid calculation, resulting in the noise levels on the grid points is performed. Standard grid for the calculation is 5 m. The validation of the model is done by separate receptor calculation in which the measurement noise levels are compared with the calculated levels at the same positions (receptors) and using the same traffic data as in the time of measurement. If the differences are significant (typically more than 3 dB), the part of the model where the difference occurs is scrutinized and revised if necessary.

For the railway noise the rails are defined as line noise sources with their sound power levels. As there is only one railway transportation provider in Croatia which is government owned (Croatian railways), all data on railroad traffic needed for the modeling (number of trains, driving speed, train length, the type of rail construction etc.) are easily obtained, regularly updated and accurate. No validation of the railway noise model was done so far.

For the industrial noise, plants are defined as area sources with their sound power levels. Generally there are no data on sound power levels, nor any data on sound pressure levels that can be used for the determination of sound power levels of each industrial plant. For all noise maps produced so far (four of them), the sound pressure level measurements of each industrial plant according to ISO 8297:1994 standard, had to be undertaken. For the determination of sound power levels of the industrial sources (plants) from the measured sound pressure level data, both, reverse engineering method and ISO standard were used.

The validation is equally important here in order to be sure that the model has been properly set up. It is done during the process of reverse engineering, where the differences between measured and calculated sound levels at the measurement positions are calculated and monitored. The sources are being re-modeled until these differences stop exceeding the value of 3 dB.

2.3 Calculation methods

The first road traffic and railroad traffic noise maps were made using methods NMPB-Routes 96 and RMR'96 respectively, as recommended in Annex II of END [2]. In January 2007, the Croatian Regulation on the development method and content of noise maps and action plans (OG 05/07) was adopted. As it required RLS-90 and Schall-03 calculation methods, these were used for the calculation of road and railroad traffic noise respectively ever since. For industrial noise calculations ISO 9613-2 method is used.

2.4 Meteorology

Depending on the computation method used, long term meteorological data are taken into consideration. The data for temperature, humidity and the distribution of wind direction and speed (wind rose) are used. The data are obtained from the Croatian meteorological and hydrological service as 25 year average for the specific location.

3 Annoyance model build-up

For the purpose of annoyance analysis three additional layers should be inputted in the model: the number of the inhabitants included in the analysis, dwellings and noise limit levels.

In order to obtain a more accurate annoyance analysis, the whole area to be mapped is split to smaller entities, usually following the boundaries of local self-government (mjesni odbor or gradski kotar in Croatian) or statistical entities. The boundaries with corresponding number of inhabitants for each entity are entered in the model.

The dwellings are separated from non residential buildings in the existing obstacle layer by using data from the planning documentation of the client cities where dwellings are specially marked.

As there are no noise limit levels for noise indicators as defined by END in Croatia for the time being, the noise limit levels from the Regulation of the highest allowed noise levels in working and living environment (OG. 145/04) [3] are used. This imposes the problem as there are no limit levels for L_{den} and L_{evening} , while the limit levels for day and night periods are expressed in L_{Aeq} without the definition of duration. Also, all limits are not source dependent, i.e. that the same limit levels apply to all kinds of sources. Although the limit levels used are technically not the ones required by END, the annoyance analysis and later conflict noise maps calculated with its usage are useful as they clearly reveal the extent and the location of the noise problem in the city. According to the Regulation of the highest allowed noise levels in working and living environment (OG. 145/04), the limit levels are dependent on specific acoustic zones in question. These again, are dependent on the planned land usage, from the planning documentation of the client cities. According to that, the boundaries of the acoustic zones derived from the planned land usage are inputted in the model, along with their corresponding limit levels.

After that, the annoyance calculation is performed.

4 Results and output data

The minimum data to be presented to the client are determined by Directive and Croatian Regulation on the development method and content of noise maps and action plans (OG 05/07) [4]. Lot of discussion was held, about what additional information would improve client's understanding of the overall noise problem in its community. As the topic of assessment and management of environmental noise with its instrument noise map is rather new in Croatia, the client's responsible professional staff is not educated enough. So there is a possibility that too much information could, in this initial phase, blur the most important issues considering the noise problem in client's community. The following data were found to be useful and are contained in the report submitted to the client:

- Graphical presentation of noise indicators L_{den}, L_{night} and L_{day} separately for road noise, railway noise, and industrial noise, showing noise contours in 5 dB bands of values in the range of <35 to > 80 dB. The scale of the graphics is 1:5000 to match with the planning documentation of the client cities. The graphics are also delivered in various digital formats (most commonly .dwg or .shp) to match with client's GIS software

The example of graphical presentation of noise levels within a part of a city, as presented to the customer, is given in Fig. 3.

Figure 3: Graphical presentation of noise levels within a part of a city

- The number of people in each city entity, living in dwellings that are exposed to the values of L_{den} in the range of <55 to > 75 dB in 5 dB bands of values, separately for road noise, railway noise and industrial noise. This information is also presented for the city as a whole.
- The number of people in each city entity, living in dwellings that are exposed to the values of L_{night} in the range of <45 to > 70 dB in 5 dB bands of values, separately for road noise, railway noise and industrial noise. This information is also presented for the city as a whole.
- The number and percentage of the people in each city entity exposed to the levels of L_{den} and L_{nigh} that exceed the limit levels for the day and night period set by Regulation of the highest allowed noise levels in working and living environment (OG 145/04), separately for road noise, railway noise and industrial noise. This information is also presented for the city as a whole.
- LKZ index for the day period for each city entity and for the city as a whole, separately for road noise, railway noise and industrial noise.
- LKZ index for the night period for each city entity and for the city as a whole, separately for road noise, railway noise and industrial noise.

Examples of the tabular and graphical data on noise exposure and annoyance analysis, as presented to the customer, are given in Fig. 4, and Fig 5.

City entity	Number of inhabitants	$L_{r,avg}$/dB(A)	$L_{r,avg}$/dB(A)	Number of inhabitants included in the model	Number / precentage of inhabitants afflicted				LKZ noise index	
		den	night		den		night		den	night
STINJAN	1570	47.7	37.6	1569	419	27%	704	45%	1482	4101
VELI_VRH	3070	50.1	40.1	3046	790	26%	1433	47%	3108	8588
SIJANA	6834	51.9	41.9	6816	1058	16%	1907	28%	5860	12911
...	...	...	...	...	...	...	...	...	...	...
KASTANJER	5142	47.9	38.0	5116	868	17%	1424	28%	6721	12241
MONVIDAL	2201	46.3	36.3	2201	298	14%	487	22%	1900	3791
Total	**65062**			**64598**	**12171**	**19%**	**20429**	**32%**	**67414**	**145625**

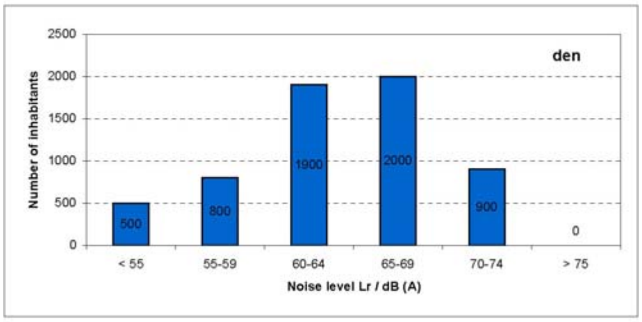
Figure 4: Example of noise exposure and annoyance analysis data

After all source dependent noise maps (road, railway, industry) are produced, the report with the same content as shown above for the total noise levels originating from all sources, is produced and delivered to the client.

The detailed description of all input data used and data sources are included in each report. That way the client gets not only the control over data used, but also an obligation to obtain better data for the next noise map update, if the data are considered to be of insufficient quality.

The report and the results are presented to the client's professional staff and after that on the city council. If possible, both presentations include the introduction in the problem of assessment and management of environmental noise, relevant legislation, and methodology of noise mapping in order to increase knowledge and noise awareness among the community decision makers

	Number / precentage of inhabitants afflicted				
Lr / dB(A)	den		Lr / dB(A)	night	
			< 45	400	7%
			45-49	500	8%
< 55	500	8%	50-54	1200	20%
55-59	800	13%	55-59	2400	39%
60-64	1900	31%	60-64	1600	26%
65-69	2000	33%	65-69	0	0%
70-74	900	15%	> 70	0	0%
> 75	0	0%			
Total	**6100**	**100%**	**total**	**6100**	**100%**



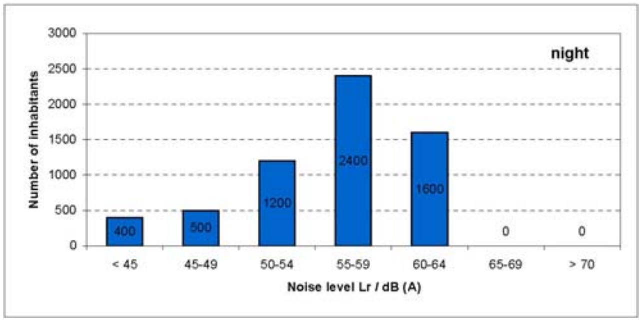


Figure 5: Example of noise exposure and annoyance analysis data

5 Conclusion

An attempt to standardize the procedure of noise map production seems like a fairly simple task. However, determining the universal procedure for deriving the right input data from raw material is not that easy after all, as this is in praxis case sensitive and can get quite complex. Very often it is a mixture of real components (such as numbers, figures, mathematical procedures, etc.), and more subjective components that can not be quantified (like the engineer's creativity, experience the ability of prediction, etc.). However, this work shows that it is possible to create an approach to defining key steps in urban noise map production. It is based on the experience from various urban noise mapping projects done in Croatia, and therefore it describes the usual procedures for reaching certain steps.

References

[1] Good Practice Guide for Strategic Noise Mapping and the Production of Associated data Data on Noise Exposure, EC WG Assessment of Exposure to Noise, Bruxelles, (2006)

[2] Directive 2002/49/EC of the European Parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise, Official Journal of the European Communities, EU, Bruxelles (2002)

[3] Regulation on the highest allowed noise levels in working and living environment, Official Gazette. No.145, Zagreb, (2004)

[4] Regulation on the development method and content of noise maps and action plans, Official Gazette. No.5, Zagreb, (2007)