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# STRATEGIC NOISE MAPS FOR MAJOR ROADS – THE FIRST RESULTS IN SERBIA

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**Abstract**. *The Republic of Serbia through the Law on environmental noise protection (2009), and related by-laws (2010) started implementing the Directive 2002/49/EC and set the deadline for the first round of strategic noise mapping to June 30, 2015. Strategic noise maps for four sections of major roads in Serbia have been produced in the first half of 2014 and have included 45.4 km of roads with the average annual traffic flow higher than 6,000,000 vehicles. This paper shows the experiences in production of the strategic noise maps, description of the used methodology, identification of the problems that have appeared and presentation of the results.*

**Key words**: *noise, strategic noise map, noise mapping process*

## 1. INTRODUCTION

In 2002, the European Parliament adopted the Directive 2002/49/EC [1] as a principal document for assessment and management of environmental noise. The purpose of the Directive was to define a common approach intended to avoid, prevent or reduce, on a prioritized basis, the harmful effects including annoyance, due to the exposure to environmental noise. Serbia started implementing the Directive attitudes towards adopting the Law on Environmental Noise Protection in 2009 [2] and the by-laws in 2010 [3-6].

Environmental noise regulation in the field of strategic noise mapping in Serbia includes the following documents:

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- Law on environmental noise protection, “Official Gazette RS”, No. 36/2009 and 88/2010 [2];
- Regulation on noise indicators, limit values, assessment methods for indicators of noise, disturbance and harmful effects of noise in the environment, “Official Gazette RS”, No. 75/2010 [3];
- Rulebook on the methods of development and contents of the strategic noise maps and the manner of presentation of the strategic noise maps to the public, “Official Gazette RS”, No. 80/2010 [4];
- Rulebook on the methodology for action plans development, "Official Gazette of RS", No. 72/2010 [5];
- Rulebook on Methodology of Acoustic Zoning, “Official Gazette RS”, No. 72, 2010 [6].

The Directive and the noise legislation of the Republic of Serbia have prescribed reporting obligation about the state and the impact of noise on population through the strategic noise maps. Reporting will provide the information about noise exposure at local, national and international level and development of action plans in order to manage and reduce the negative impact of the noise. All information from strategic noise maps shall be communicated to the public in the most understandable and accessible way using the appropriate information technologies.

EU member states have done two rounds of strategic noise mapping for major roads. The first round was done in 2007 and covered 63,902 km of main roads, while the second round was done in 2012 and covered 151,676 km of main roads [7]. According to the Directive, member states oblige to complete the third round of mapping by the end of June 2017.

In accordance with the legal obligation, the procurement of strategic noise mapping for major roads was announced in early 2014. The subject of public procurement was divided into four parties, namely:

- Lot 1: The strategic noise maps for major road I-A class (A3), section: Dobanovci – airport “Nikola Tesla“ (L = 5.3 km);
- Lot 2: The strategic noise maps for major road I-A class (A1), section: Vrčin – Mali Požarevac (L = 14.3 km);
- Lot 3: The strategic noise maps for major road I-A class (A1), section: Mali Požarevac – Umčari – Vodanj – Kolari (L = 12.4 km), and
- Lot 4: The strategic noise maps for major road I-A class (A1), section: Kolari – Ralja (Smederevo) – Ralja (Požarevac) (L = 13.4 km).

The strategic noise maps were completed in early July 2014. This paper will present the basic definitions of strategic noise mapping with a methodological approach to their production, as well as an identification of problems which have appeared during the production of noise maps. The results of the strategic noise mapping for section Vrčin – Mali Požarevac are shown as an illustrative example.

## 2. STRATEGIC NOISE APS

Basic notions about strategic noise mapping are defined by the Law [2]:

- Strategic noise map is a map representing data about the level of noise in certain area and it serves for the assessment of total noise exposure of certain area to different noise sources, or prediction of total noise in certain area;
- Development of strategic noise maps is a presentation of data on existing or assessed noise levels, including exceeding of prescribed limit values, number of people exposed to noise in certain area or number of households exposed to certain values of noise indicators in certain area.
- Strategic maps shall be mandatory for agglomerations with more than 100,000 inhabitants, for major roads with average annual traffic flow higher than 3,000,000 vehicles, for major railroads with average annual traffic flow higher than 30,000 trains, for major airports, as well for plants and activities for which and integrated permit has been issued.

It is a prescribed obligation in the Republic of Serbia that the first round of strategic noise map shall be done no later than June 30, 2015 and must include the agglomerations with more than 250,000 inhabitants, major roads with average annual traffic flow of more than 6,000,000 vehicles, main railway lines with the average annual traffic flow of more than 60,000 trains and major airports with more than 50,000 operations (take-off and landing operations) annually.

The second round of strategic noise maps shall be done no later than December 31, 2020 and must include the agglomerations with more than 100,000 inhabitants, major roads with average annual traffic flow of more than 3,000,000 vehicles, main railway lines with the average annual flow traffic of more than 30,000 trains and the airports that were not included in the first round of mapping.

## 3. STRATEGIC NOISE MAPPING PROCESS

The process of producing strategic noise map for major roads is very similar to the methodologies used within noise modeling for environmental impact assessments for road development and reconstruction. The key difference is in covered area which is significantly greater for strategic noise mapping.

Strategic noise mapping process may be divided into seven stages. Each stage of the process is defined by preceding stages such that requirements and specifications are captured ahead of the datasets. Strategic noise mapping process can be defined through the following stages [8]:

- Stage 1 - Defining areas to be mapped
- Stage 2 - Defining noise calculation methods
- Stage 3 - Developing dataset specification
- Stage 4 - Producing dataset
- Stage 5 - Developing noise model dataset
- Stage 6 - Noise level calculation
- Stage 7 - Post processing and analysis

Prior to the adoption of the strategic noise mapping process and their producing, an analysis of literature in this area has been done. In this way it was attempted to look at what was good and what was bad in their production in Europe in the last two rounds. It was one of the ways not to repeat the perceived mistakes, to optimize some methods or to omit unnecessary things. Of particular importance were papers [9] and [10] which describe the sensitivity of strategic noise maps to the change of input data and uncertainties that may occur during their producing. The report [11] summarized the European experience in the strategic noise mapping for major roads.

### 3.1. Defining areas to be mapped

Strategic noise maps produced for major roads must cover all areas exposed to noise levels greater than 45 dB(A) for noise indicator $L_{night}$ and greater than 55 dB(A) for noise indicator $L_{den}$.

The area which should be included in strategic noise mapping of major road was determined on the basis of the preliminary calculation in open condition (i.e. without ground terrain, objects, etc.). The estimated calculation boundaries are increased by safety factor of 1.5.

### 3.2. Defining noise calculation methods

Road noise indicators were calculated using French method NMPB-Routes-96 (Bruit des Infrastructures Routiers Methode de calcul incluant les effets météorologiques) [12] and French standard "XPS 31-133" [13] in accordance with the recommendations of Directive [1] and Law [2]. For input data with respect to emissions, these documents refer to "Guide du bruit des transports terrestres, fascicule prévision des niveaux sonores, CETUR 1980".

### 3.3. Developing dataset specification

Dataset specification development for the road noise calculation was performed on the basis of the noise indicator calculation method specification, noise mapping process, as well as area on which the strategic noise mapping is carried out. Systematized overview of basic data required for strategic noise mapping of main roads is shown below:

- 3D Model Environment:
  - DTM – 3D surface model
  - DEM – 3D building heights
- Road as noise source:
  - Carriageway centerline
  - Technical and technological characteristics of road
  - Traffic flow
  - Traffic speed
  - Percentage of heavy vehicles
- Meteorological parameters:
  - Speed and wind frequency
  - Average air temperature

- Average humidity
- Average atmospheric pressure

- Demographics data:
  - Number of people in the strategic noise mapping area
  - Distribution of population in the strategic noise mapping area

If actual data required for strategic noise mapping is missing, a source of data for replacements that can be used is the last edition of the European Commission Working Group Assessment of Exposure to Noise - Position Paper - Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure [14].

Procuring entity of strategic noise maps must be informed and must agree with the data from this document. Used data must be clearly indicated.

### 3.4. Producing dataset

For strategic noise mapping, it is necessary to use data from the year proceeding the year of their production. In the case of strategic noise maps for main roads, those should be the data from 2013. Also, it is necessary to use the data from authorized organizations only.

It was not possible to provide all relevant data from 2013. The 2012 data were used for the calculation instead. Demographic data were taken from the last census in the Republic of Serbia which was held in 2011. Part of the topographic maps that have been used as the basis for the creation of 3D terrain models were developed between 1959 to 1972.

All the maps to the scale of 1:25,000 meet the required accuracy of the topographic surface defined by the relative relationship of height points which cannot be less than 1.5 meters. However, this large-scale maps are not detailed enough to produce precise strategic noise maps. This issue should be further defined in terms that maximum scale of topographic maps should be set. Otherwise, the details of generated 3D terrain model, which affects the results of the noise indicators calculations, can vary significantly depending on the topographic map used.

Population data were available at the level of the settlement or census units. Their allocation to individual residential buildings for the calculation and assessment of noise annoyance was left to the knowledge and experience of each individual maker of strategic noise maps.

### 3.5. Developing noise model dataset

All collected data were analyzed and customized in accordance with the requirements for their use in the software package for the noise indicators calculation and analysis of population exposure.

All spatial data were georeferenced according to the new geodetic reference system of the Republic of Serbia, which is consistent with ETRS89 (European Terrestrial Reference System 1989).

### 3.6. Noise level calculation

Software package which is used for the noise indicators calculation must be in accordance with the requirements of Nordtest Method "Framework for the Verification of

Environmental Noise Calculation Software", ACOU 107 (Nordtest, Finland, 2001) and DIN 45687 "Acoustics - Software products for the calculation of the sound propagation outdoors - Quality requirements and test conditions", Beuth Verlag GmbH (Germany, 2006).

The first round of strategic noise mapping for major roads has been done using the software packages Predictor-Lima, SoundPLAN and CadnA.

### 3.7. Post processing and analysis

Post processing and analysis of the strategic noise mapping results for each individual section was performed by using already prepared templates for displaying numerical data to the public [15-17]. All necessary templates are given by the Regulations [4]. The number of noise-affected people and the degree of their affection was determined using the LarmKennZiffer - LKZ Method (Noise-Evaluation-Index-Method).

The Serbian noise legislation requires the calculation of noise indicators at 4 meters height above the ground. Accordingly, only the population living in residential buildings that are taller than 4 meters were taken into consideration during the annoyance analyses. In the settlements along the section of major roads, for which strategic maps were done, almost half of residential buildings are lower than 4 meters, or attics and roofs are at this height.

During the noise exposure calculation there were several input parameters whose sizes are not specified, since it was left to each individual strategic noise map maker to determine their values. This primarily refers to the distance of measuring points with respect to the façade, the mutual spacing between the measurement points and minimal length of the façade which will be taken into the consideration. The value of these input parameters should be in certain ranges, which may lead to some discrepancies in the final results. Graphical representation of strategic noise maps for the night period ($L_{night}$) and the period of the day-evening-night ($L_{den}$) have been prepared in accordance with the Regulations [4] which define the colors for each noise level bands. In order to correctly display color on the screen and print properly, it was necessary to calibrate monitor and printer. In practice, this means that regardless of the care taken at the stage of prepress, if the same strategic noise map are printed on printers that do not properly calibrate, the differences in colors will appear.

As part of the strategic noise maps, it is necessary to analyze the impact of noise to kindergartens, schools, hospitals and other facilities sensitive to noise. If we literally implement the legislation which provides that the strategic noise map are made for periods of "day-evening-night" and "night", the result would be unusable in the post processing and analysis. Analyzing noise exposure of kindergarten, school, or community-health center using $L_{den}$ and $L_{night}$, we cannot get any real conclusions. On one hand, the Serbian legislation does not recognize the noise indicator $L_{den}$ and cannot be compared with threshold limit values. On the other hand, these institutions do not work at night, so in that sense, the noise exposure indicator $L_{night}$ is of no significance.

## 4. RESULTS

As an illustrative example of the strategic noise mapping for major roads, the results for the section Vrčin - Mali Požarevac are presented in this paper [15].

Section length is 14.2 km, and the calculation boundaries were set at 1000 m on the left and right from the axis of the highway. Total covered area for analysis was 29.1 $km^2$.

The mapping area partially or fully encompasses a range of seven settlements whose demographic data are shown in table 1.

**Table 1** Settlements with demographic data

| Settlements | Population | Households | Average population per household |
|---|---|---|---|
| Vrčin | 9088 | 2397 | 3,8 |
| Zaklopača | 2297 | 709 | 3,2 |
| Grocka | 8441 | 2911 | 2,9 |
| Begaljica | 3029 | 942 | 3,2 |
| Mala Ivanča | 1769 | 642 | 2,8 |
| Mali Požarevac | 1391 | 441 | 3,2 |
| Senaja | 405 | 139 | 2,9 |

Data from noise exposure analyses, the number of inhabitants and dwellings as well as the area exposed ranges of noise indicators $L_{den}$ and $L_{night}$, are shown in Tables 2, 3, 4, 5, 6 and 7. The shown data are rounded to hundreds in accordance with the legislation, whereas the exact values are given in parentheses.

**Table 2** Population exposure analysis related to $L_{den}$

| Noise indicator $L_{den}$ [dB(A)] | Number of people |
|---|---|
| < 55 | 2700 (2736) |
| 55 - 59 | 800 (842) |
| 60 - 64 | 400 (433) |
| 65 - 69 | 200 (150) |
| 70 - 74 | 0 (40) |
| > 75 | 0 (7) |

**Table 3** Population exposure analysis related to $L_{night}$

| Noise indicator $L_{night}$ [dB(A)] | Number of people |
|---|---|
| < 45 | 2400 (2365) |
| 45 - 49 | 900 (896) |
| 50 - 54 | 600 (646) |
| 55 - 59 | 200 (222) |
| 60 - 64 | 100 (65) |
| 65 - 69 | 0 (14) |
| > 70 | 0 (1) |

**Table 4** Area exposure analysis related to $L_{den}$

| Noise indicator $L_{den}$ [dB(A)] | Exposed area [$km^2$] |
|---|---|
| < 55 | 9,5 |
| 55 - 64 | 13,2 |
| 65 - 74 | 4,9 |
| > 75 | 1,5 |

**Table 5** Dwellings exposure analysis related to $L_{den}$

| Noise indicator $L_{den}$ [dB(A)] | Estimated numbers of dwellings |
|---|---|
| < 55 | 900 (921) |
| 55 - 64 | 400 (434) |
| 65 - 74 | 100 (66) |
| > 75 | 0 (2) |

**Table 6** Population exposure analysis in dwellings with quiet facade related to $L_{den}$

| Noise indicator $L_{den}$ [dB(A)] | Number of people |
|---|---|
| < 55 | 0 (46) |
| 55 - 59 | 0 (16) |
| 60 - 64 | 0 (9) |
| 65 - 69 | 0 (5) |
| 70 - 74 | 0 (4) |
| > 75 | 0 (2) |

**Table 7** Population exposure analysis in dwellings with quiet facade related to $L_{night}$

| Noise indicator $L_{night}$ [dB(A)] | Number of people |
|---|---|
| < 45 | 0 (36) |
| 45 - 49 | 0 (23) |
| 50 - 54 | 0 (9) |
| 55 - 59 | 0 (6) |
| 60 - 64 | 0 (5) |
| 65 - 69 | 0 (3) |
| > 70 | 0 (0) |

There are no dwellings with special insulation against noise in the settlements which were included in the strategic noise mapping.

A part of the graphical presentation of strategic noise maps for the period day-evening-night (noise indicator $L_{den}$) for the settlements Mali Požarevac is shown in Figure 1.

## 5. CONCLUSION

Strategic noise mapping is a complex and demanding process which has to be done in several phases.

Strategic noise maps are accurate and precise as much as data upon which they are made are accurate and precise.

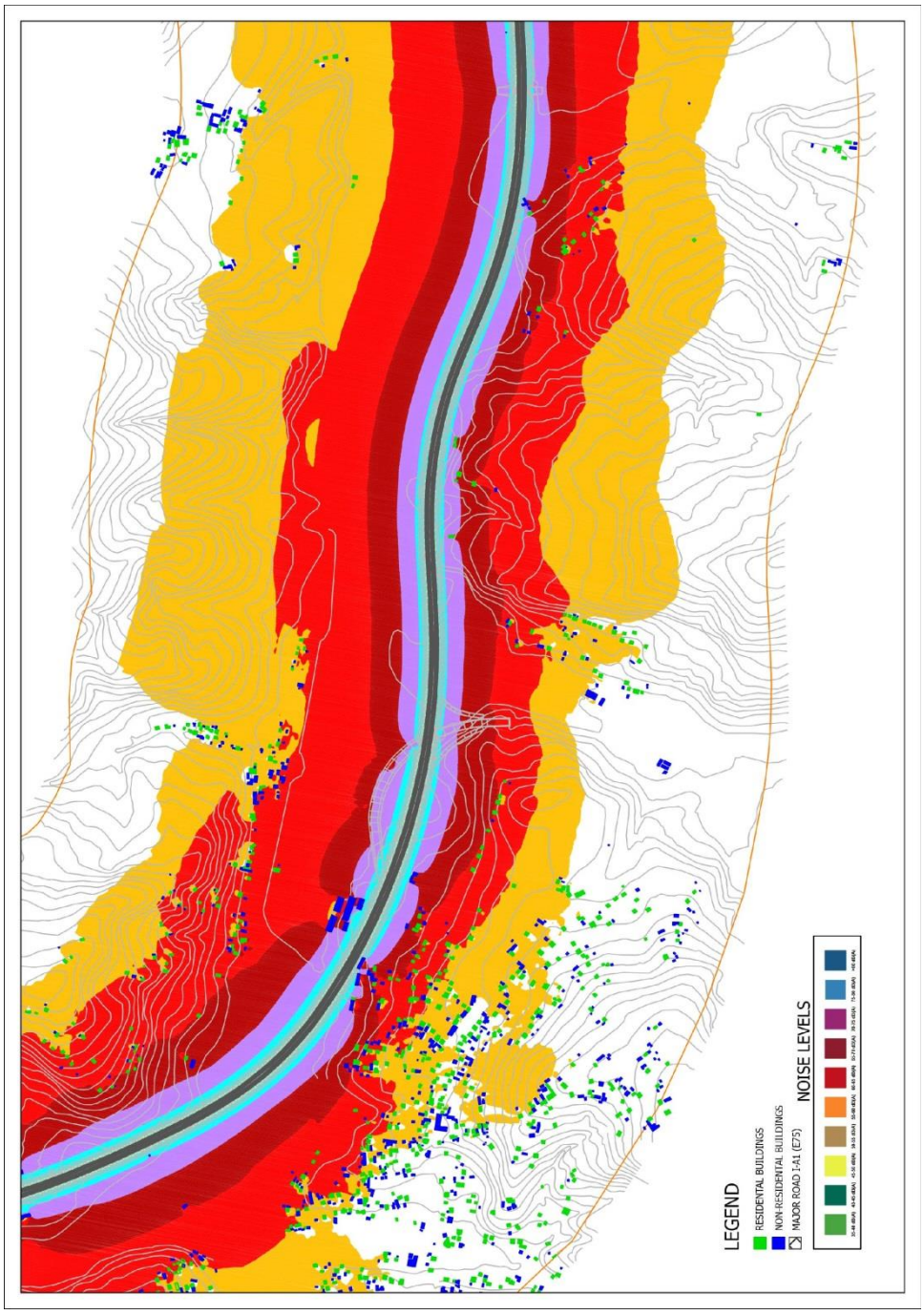


**Fig. 1** Detail of noise map for major road - Noise indicator $L_{den}$

Many parts of the strategic noise mapping process are not clearly and unambiguously defined, including the required quality of the input data. This may lead to different approaches which are all within the law, but we can get a lot of different outputs.

In order to avoid certain arbitrariness in the production of strategic noise maps, it is necessary to define the appropriate guidelines that will contain a methodology, as well as all other necessary information in order to get uniformly strategic noise maps.

Noise legislation of the Republic of Serbia does not prescribe the obligation and procedures for validation and verification of input data or strategic noise maps.

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# STRATEŠKE KARTE BUKE ZA GLAVNE PUTEVE – PRVA ISKUSTVA U SRBIJI

*Republika Srbija je usvajanjem Zakona o zaštiti od buke u životnoj sredini (2009) sa pratećim podzakonskim aktima (2010) počela sa implementacijom Direktive 2002/49/EZ i definisala da se prvi krug strateških karta buke mora završiti do 30. juna 2015. godine. Strateške karte buke za četiri deonice glavnih puteva u Srbiji završene su u prvoj polovini 2014. godine. Obuhvatile su 45,4 km puteva sa prosečnim godišnjim obimom saobraćaja većim od 6.000.000 vozila. U radu su data iskustva na izradi strateških karata buke, opis korišćene metodologije, identifikacija problema koji su se pojavljivali tokom njihove izrade i prikaz dobijenih rezultata.*

Ključne reči: *buka, strateška karta buke, proces izrade strateške karte buke*