Development of Methodologies and Means for Noise Protection of Urban Areas—Project Results

Zlatan Šoškić, Milan Kolarević, Branko Radičević, Momir Praščević, and Vladan Grković

Abstract The paper presents the results of the Serbian national project "Development of methodologies and means for noise protection of urban areas" after eight years of work (2011–2018). Initially designed to last for four years; the project was extended and represented an important contribution to the development of technological basis for creation and implementation of noise protection policies in Serbia. The paper has presented the resources committed to the realization of the project, publications, registered technical achievements, as well as Ph.D. thesis and other results achieved in the course of the project duration. The project impact and a lack of an institutional response up to now are also discussed.

1 Introduction

In 2009, the Government of Republic of Serbia has passed the law on environmental noise protection [1] that addressed subjects in charge for environmental noise protection, means and conditions for environmental noise protection, measurements of environmental noise, access to information about noise surveillance and other topics of relevance for environmental and health protection. Further, directions were defined by respective regulations [2], guidelines [3–7] and standard [8] that are relevant to environmental noise protection and are in line with the Directive 2002/49/EC [9] of European Parliament and The Council of The European Union.

However, majority of the measures prescribed by the regulations were not supported by the existence of relevant accredited institutions, noise protection means available at market and adequate software support. Proposed as a response to a call of the Serbian Ministry for Science and Technology, the project "Development of

Z. Šoškić (✉) · M. Kolarević · B. Radičević · V. Grković
Faculty of Mechanical and Civil Engineering in Kraljevo,
University of Kragujevac, Kragujevac, Serbia
e-mail: soskic.z@mfkv.kg.ac.rs

M. Praščević
Faculty of Occupational Safety, University of Niš, Niš, Serbia

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Table 1 Project goals and objectives

Goal	Development of methodologies for estimation of degree of exposition to noise	Development of methods and materials for noise protection	Design of means for active and passive noise protection	Dissemination of the results
Objectives	Study on dominant noise sources in urban environment	Design and testing of reverberation chamber	Methodologies for application of active noise protection	Website of the project
	Database on urban noise sources	Accreditation of laboratory for urban noise measurements	Design of modular noise barriers	Launching of regional journal on noise protection
	Software support to strategic noise mapping	Investigation of acoustic properties of materials	Design of modular cabins for noise protection	Seminars on noise protection
	Methodology for drawing of action plans for noise protection of urban environment	Database on acoustic properties of materials	Implementation of the designed solutions	Monograph on noise protection of urban areas

methodologies and means for noise protection of urban environment" (acronym "urbaNoise") is aimed to facilitate the solution of these problems and deficiencies. The project was initially proposed to last for four years (2011–2014); but by the decision of the ministries responsible for science and technology development, it was later extended on annual basis, and it is still underway in 2019.

The goals and objectives of the project, and the project plan and the organization were described in a paper published at the start of the project [10]. The structure of the goals and objectives of the product is repeated here in Table 1.

This paper presents an overview of the project resources, activities and main results achieved in the period of 2011–2018. Its main goal is to assess the overall impact of the project. Besides, with reference to the paper it describes the project [10], and this paper should be a useful tool for planning further projects and actions.

2 Concept and Activities

According to the initial project plan, which was realized in the period 2011–2014, the project consisted of six work packages, presented in Fig. 1. The first work package "Theoretical and methodological project preparation" was of a preparatory character and managerial type. The activities of the work package comprised of state-of-the-art analysis, definition of the project aim and structure of the goals, the establishment

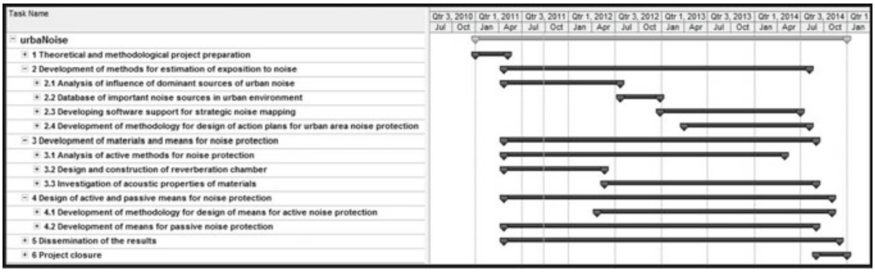


Fig. 1 Gannt chart of the project

of the team and organizational structure of the project, determining the work breakdown structure, resource requests analysis, cost–benefit analysis, determining of the expected results and risk analysis. The work package lasted for four months (January to April 2011), and the results of that activity were later presented in the paper [10].

The activities of the three following work packages, which were carried out simultaneously and independently were of scientific character. The simultaneous flow was possible due to the difference in the required expertise, which enabled avoiding of overlapping between the assignments of team members.

The work package "Development of methods for estimation of exposition to noise" comprised of four activities. The activity "Analysis of influence of dominant sources of urban noise", primarily scheduled for the period 2011–2012, raised a lot of attention of the project team and, after the completion of the initial project plan in 2014, was turned into a permanent activity in the period of 2015–2018. Within the activity were studied industrial noise sources met in practice of Serbian industry (impact hammers, junkyard presses, fans and other components of ventilation systems) [11–14], traffic noise sources (railway vehicles, buses and helicopters) [15–19] and noise sources of public service companies (construction machinery) [20–22]. The key source of the project results was the activities performed on systematic noise measurements of the road traffic in cities Niš and Kraljevo [23–25]. The obtained results were served as the basis for updating the present [26–28] and the development of new traffic noise models, based on application of the soft computing techniques [29, 30]. The activity "Database of important noise sources in urban environment" was completed in 2012 [31, 32], and the database was made publicly available; but the amount of data in the database is still very limited. The activity "Developing software support for strategic noise mapping" is passed through a change of the initial scope, as it was redirected to develop a software tool for the calculation of noise fields in urban areas. The reason for the change was the presence of complex commercial software packages for strategic noise mapping, which were, on the other hand, not suited for usual applications of development of local noise protection measures. The software package for the local noise mapping became available in 2013 [33, 34] and was later used for evaluating variants of noise protection systems by project team [35, 36]. The activity "Development of methodology for design of action plans for noise protection of urban areas" comprised two groups of actions: analysis and definition of the descriptors of the influence of the noise to environment [37–39], and the development of procedures for systematic assessment of the level of danger that noise poises to environment [40–44].

Activities of the work package “Development of materials and means for noise protection” were carried out in two directions: the first was the development of the means for characterization of materials for noise protection [45–47] and the second was the development of the materials for noise protection [48–50]. While the initial project plan considered just the construction of the reverberation chamber for the characterization of the noise protection materials, during the project it was found out that the other means for the characterization of noise protection materials are needed, and they were designed and manufactured almost until the end of the initial project lifetime in 2014. Conversely, the activities on the studies of the sound absorption materials were postponed for the project extension in the period of 2014–2018.

The activities of the work package “Design of active and passive means for noise protection” were focused to the application of the methodologies and means developed within the previous two work packages to the construction of the noise protection systems against the industrial [11–13, 51, 52] and traffic [35, 36, 52, 53] noise. Despite the practical aspect of the activity, certain conclusions of general character were drawn [54, 55], which suggest the directions of development and construction of modular components for noise protection.

The whole project was made permanent efforts within the work package “Dissemination of project results” and not only in the form of publication of scientific papers and participation in scientific conferences aimed for researchers, but also through the organization of seminars for noise protection aimed at professionals in environmental protection, as well as by participation in the technical fairs organized in Serbia, aimed at the widest range of general audience.

3 Results

The project results are published in 59 papers in international, as well as in 43 papers in national, peer-reviewed journals; they were also presented in 123 articles in international and 14 articles in national conferences. A list of the references of the selected publications is given in the literature, and a more complete overview may be found at the overview of project results at the website of the project, http://www.mfkv.kg.ac.rs/urbanoise/pages/ostvareni-rezultati.php. However, here it will be pointed out some important project results of practical importance that are not visible in the publications, or which are not presented in the publications in a systematic way.

Six project results are registered as original technical accomplishments at national level:

- The reverberation chamber constructed at the Faculty of Mechanical and Civil Engineering in Kraljevo (Fig. 2); the reverberation chamber, with the volume of 203 m^3, is the largest reverberation chamber in Serbia.

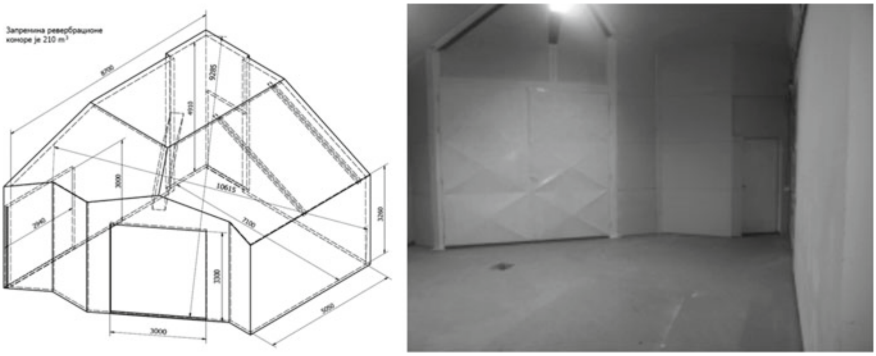


Fig. 2 Drawing and photograph of the reverberation chamber of the Faculty of Mechanical and Civil Engineering in Kraljevo

- The software package for drawing of local noise maps "BelCo" (Fig. 3); the software enables calculation of noise levels according to the ISO 9613-2 standard in a field represented by a 3D rectangular network of points.
- Noise protection system of the "SPIK Ivanjica Fantoni Group" plywood factory close to the residential area of a Serbian town (Ivanjica); the system, which comprises construction of two barriers with height of 6 m and total length of 108 m, as well as sound insulation of the selected noise sources within the factory (Fig. 4), reduced the maximal specific daily noise level in the surrounding settlement from 76 dB(A) to 62 dB(A), which is below the legally allowed 65 dB(A) 52.
- Database on noise sources that enables the description of noise sources by sound power, spectral content and spatial distribution of their noise emission; publicly available at the URL http://www.mfkv.kg.ac.rs/urbanoise/dbnoise/ the database

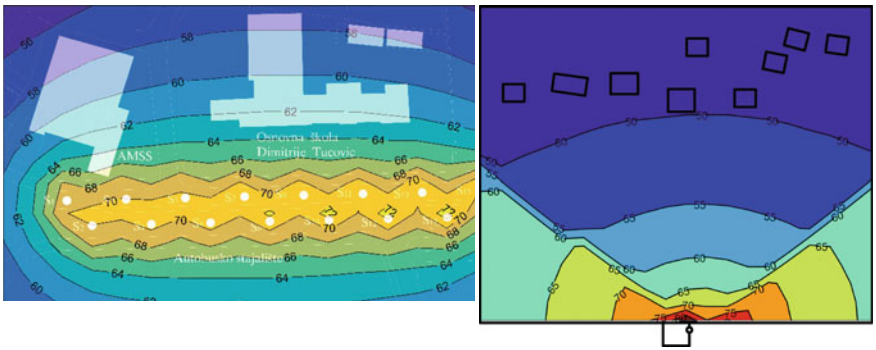


Fig. 3 Noise map of the area around an elementary school located between two crossroads in Kraljevo (left) and a neighbourhood of a car scrapyard (right), calculated by the "BelCo" software package

Fig. 4 Elements of the noise protection system in the "SPIK Ivanjica Fantoni Group" plywood factory

underwent recent reconstruction to be capable of storing various data that arose from measurements of noise emissions [31, 32].

- Acoustic zoning of City of Niš (Fig. 5), as the first and the most comprehensive endeavour of that type in Serbia, which comprised definition of the acoustic zones and limiting values of noise indicators, then calculation and measurement of the indicators, followed by the comparison of the two datasets which allowed the identification of the present level of danger and definition of action plans [41, 42].
- The NAISS model for calculation of the level of traffic noise in urban areas of Serbia; the model enables calculation of the equivalent noise level (L_{eq}) based on the number of the cars, buses and trucks within a period [26, 27].

Apart from that registered technical achievements were also constructed other noise protection systems:

- sound insulation of a small mechanical workshop with eccentric presses is located in a densely populated residential area of a Serbian City (Čačak); starting from the theoretical model of acoustic insulation power of a single solid partition, a complex partition and a multi-layer partition, the acoustic insulation power of the

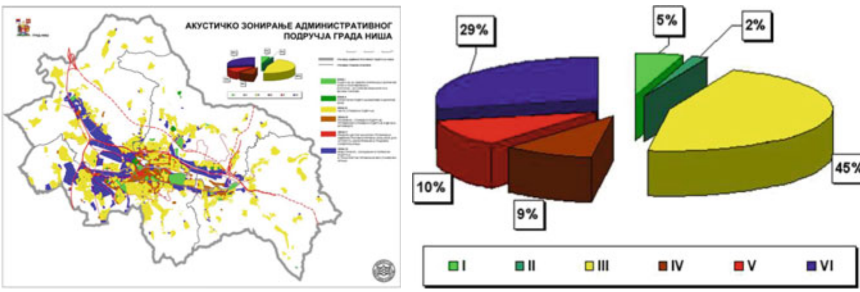


Fig. 5 Graphical representation of acoustic zones in the City of Niš and the distribution of surfaces of the acoustic zones

walls and the ceiling in the workshop were determined so that the noise level of 94 dB(A) in the machine room is reduced to 47 dB(A) in front of the building [12];

- noise protection curtain for a scrapyard with car crushers close to a suburban area of a Serbian City (Užice); application of the noise protection mean reduced the noise level in the control point on the border of the residential area from 53.1 to 51.2 dB(A) and the calculate noise map. Figure 3 shows that the level of the noise within the residential area is less than 50 dB [13];
- acoustic treatment of a mechanical workshop with seven machines that generated cumulative noise levels of 94.4 dB(A); by covering all of the open surfaces of the workshop (walls, floors and ceilings) with sound absorption materials, the noise level was reduced to 87.7 dB(A), which is sufficient to allow permanent exposition to noise in periods less than 6 h [51];

The project was also developed and three measurement systems for the characterization of materials by sound absorption, transmission or emission:

- Device for the measurement of airflow resistance according to the standard SRPS ISO 9053 (Fig. 6); the measurement cell of the device has the inner diameter of 100 mm and length of 300 mm; the air pump enables laminar airflow of 0,4 l/min through the measurement cell; the dynamic range of the pressure difference measurement is 1–200 Pa, and the measurement error of the airflow resistance is less than 7% in the range of 1.5–30 MPa s/m^3 [46];
- Laboratory prototype of a photoacoustic system for the characterization of porous materials and biological tissues (Fig. 7); the system employs an open-ended photoacoustic cell configuration and enables photoacoustic excitation by a LED or laser diode light modulated in the frequency range of 10 Hz–10 kHz [47];
- Laboratory prototype of a low-cost noise measurement monitoring station based on a MEMS microphone technology and a Raspberry Pi microcontroller (Fig. 7); after the construction, a communication protocol is developed and tested, and the further development comprises connection of temperature, wind speed and humidity sensors, as well as preparation for networking of similar devices [39];

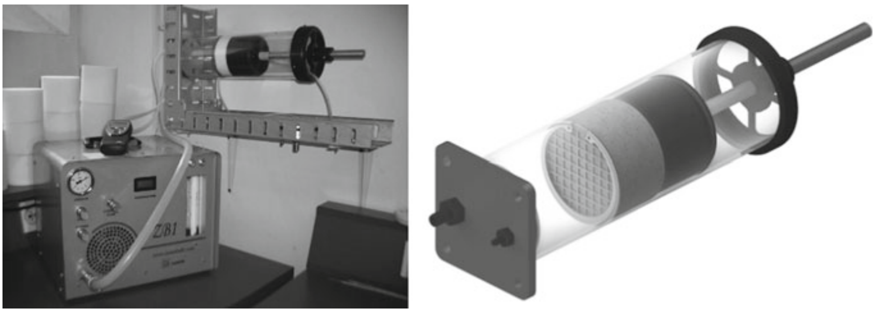


Fig. 6 Device for measurement of the airflow resistance (left) and a model of its cell (right)

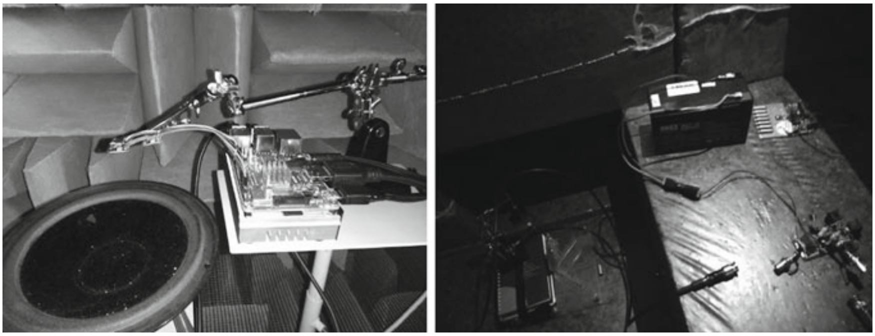


Fig. 7 Laboratory prototypes tests of the low-cost monitoring system (left) and photoacoustic measurements system (right) in an anechoic chamber

Under the auspices of the project were organized four seminars and one lecture for noise protection professionals, mainly the inspectors of the environmental protection departments of local governments. Besides, the project team supported through participation in program committees and organizing committees, organization of eight international conferences (four in Serbia and four in Romania) that dealt with noise and vibration protection.

Finally, the project team members have defended seven Ph.D. theses within the project duration. While three of them had an interdisciplinary character, four had topics directly connected to the subject of project [56–59].

4 Analysis

Since the ultimate goal of the paper is to serve as a tool for planning of future projects, the results should be considered from the aspect of the resources committed to the project.

The research organizations that participated in the projects were three faculties form three major Serbian universities: (1) The Faculty of Mechanical and Civil Engineering in Kraljevo of University of Kragujevac; (2) The Faculty of Occupation Hazard from University of Niš; and (3) The Faculty of Transport and Traffic Engineering of University of Belgrade. The supporting organizations were representative end-users of the project results, two Serbian local governments (City of Niš and City of Kraljevo) and two Serbian companies ("Korali" from Kraljevo and "ABS Minel" from Mladenovac).

The team consisted both from experienced researchers (full professors, associate professors, assistant professors and research associates) and Ph.D. students (teaching assistants and research assistants). The composition of the project team varied through years from the points of view of the number of project team members, the level of their competences and their work engagement, as shown in Fig. 8. After

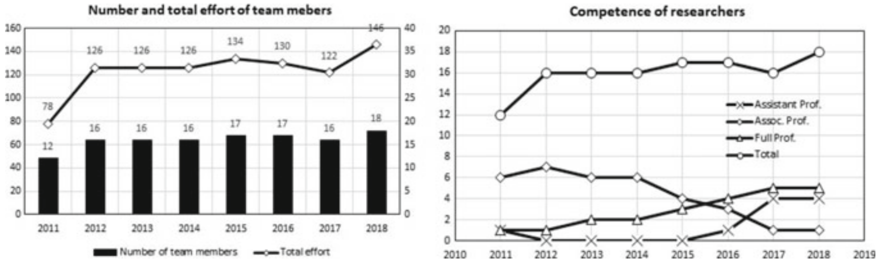


Fig. 8 Number and total effort of team members (left) and competence of the team members (right) in the period of 2011–2018

the start-up phase of the project, the overall research effort and research competence of the project team was kept constant by the replacement of the retired (hence most experienced) researchers by Ph.D. students without previous research experience.

The calculated direct project costs for the period 2011–2018 are close to 585,000 EUR with major part (close to 76%) being the personnel costs (Fig. 9), with the remaining costs being the equipment costs (around 18%), material, travel costs and overheads (in total 6%). However, the project funding may be separated into two distinct phases, the first during the initial project period (2011–2014) and the second in the extended period (2015–2018). While the first phase was characterized by a coherent long-term plan, the extensions of the project were granted as temporary measures, on annual basis. As a consequence, the annual project costs decreased in the extended period (Fig. 9), and, what could be even more important, the structure of the direct costs profoundly differed in the two periods (Fig. 10). The ratio between the personnel costs and equipment costs increased from 2.5 during the initial project period to 11 during the extension of the project lifetime.

For the sake of the analyses, the project output is also very roughly structured on annual basis, providing the results presented in Fig. 11. The distinction between the publication output in two periods is striking: the average number of publications was rising during the initial project period, characterized by long-term planning and

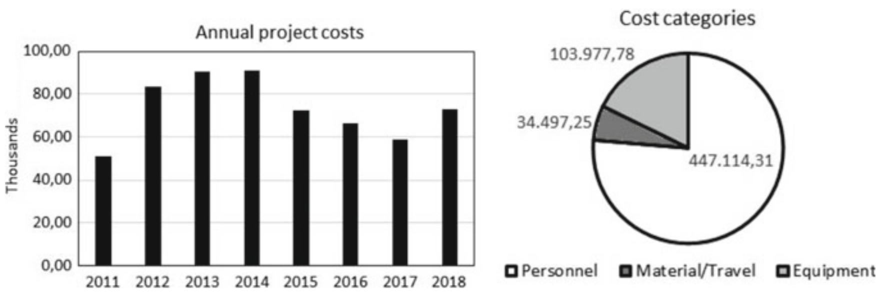
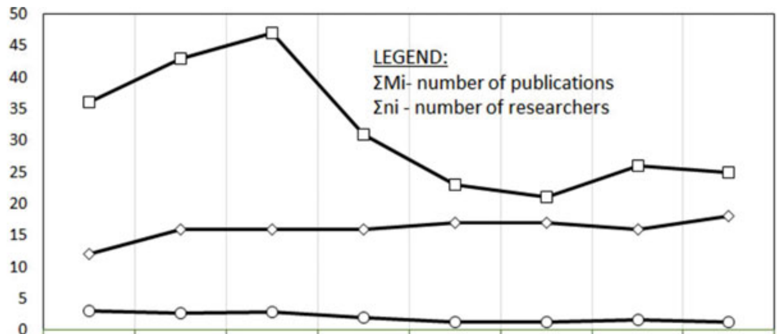


Fig. 9 Annual direct project costs (left) and direct cost distribution over categories (right)

Fig. 10 Distribution of the direct project costs (in EUR) within the initial (left) and the extended (right) project period



	2011	2012	2013	2014	2015	2016	2017	2018
ΣMi	36	43	47	31	23	21	26	25
Σni	12	16	16	16	17	17	16	18
Σmi/Σni	3,00	2,69	2,94	1,94	1,35	1,24	1,63	1,39

Fig. 11 Annual project output of the project

clear personal goals for each of the researchers and was suddenly halved after the project funding went to short-term arrangements.

Although the publications are not the only output of the project, the results presented in Fig. 11 are certainly worthy of consideration. It is the fact that during the periods of 2015–2018 were written and defended all the seven Ph.D. theses of researchers from project team, and that two more Ph.D. theses are being prepared for 2019; since both the candidates and mentors (who are also the members of the project team) were occupied with the activities during the process, a decline in the number of publications is expected. However, no original technical achievements or patents were registered in the meantime, and since the research effort stayed constant, the decrease of the project output in the period of 2015–2018 should be accepted as a fact.

5 Conclusions

The presented paper describes a national research project on noise protection, which was envisioned as a technical complement to the legislative measures made by the beginning of the decade. From the technical point of view, the project was successful, as it resulted in the establishment of hardware and software tools, procedures and methodologies that were devised to enable implementation of the legal framework. Further, it profoundly expanded the research basis for further studies of the noise abatement measures. Finally, it also established a basis for strengthening of the national education framework on noise and vibrations, as it is evident by the fact that majority of the project team members now participate also in the EU funded education project "Strengthening Educational Capacities by Building Competencies and Cooperation in the Field of Noise and Vibration Engineering—SENVIBE", which is carried out within the Erasmus Plus program.

However, the project team members believe that the project did not have the expected social impact because of the lack of true interest of the society at large. A very good and modern legal framework is not supported by a strong push towards its implementation. A full decade after the Law on Environmental Noise Protection is passed, no Serbian City really implements a consequent action plan for noise protection, and a majority of the local governments has a rather formal approach to the problem of environmental noise, as it was the case in 2011 [60].

The presented analysis led also to an unintended, but potentially very important conclusion. The research results of the project definitely thrived during the period when the project team carried out a coherent long-term plan. The same project team, under the same management, almost halved the research output during the period of short-term planning, which suggests that, despite frequent assertions that long-term projects do not suit the needs of industry, their beneficial influence to research may not be easily disputed.

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