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Safety Engineering & Management - Science, Industry, Education
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FACULTY OF OCCUPATIONAL SAFETY

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SAFETY ENGINEERING & MANAGEMENT –
SCIENCE, INDUSTRY, EDUCATION (SEM-SIE 2023)

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COMPARISON OF NOISE POLLUTION IN AGGLOMERATIONS VS SMALL URBAN AREAS

Abstract: *In the last few decades, noise pollution has had a growing impact on quality of life, as a result of inadequate, unplanned urbanization, traffic intensification, usage of obsolete motor vehicles, etc. A number of surveys and monitoring studies in recent decades have shown that noise pollution, as a part of air pollution, presents a real threat to people's health and quality of life. Therefore, a two-year monitoring of noise level in three urban areas, the cities of Skopje, Tetovo (as an agglomeration), and Štip (as a smaller urban area), was performed. The Municipality of Štip was chosen as a representative of a small urban area with dynamic development, whose noise dispersion model (NDM) can be applied to all other similar urban areas. Based on performed measurements, a noise dispersion model for the three urban areas using SoundPLAN Software was developed.*
The aim of this paper is to point out the fact that small urban areas, such as Štip, also have a problem with high noise levels. On the other hand, they have no legal obligation to develop strategic noise maps and action plans for solving noise pollution problems, or to assess health effects related to high noise levels and apply noise reduction measures. The paper attempts to answer if small urban areas are safe from noise pollution and if they should also develop noise reduction action plans.

Keywords: strategic noise maps, action plans, noise dispersion model, human health

INTRODUCTION

A number of surveys and monitoring studies in recent decades have shown that environmental noise pollution is a real threat to human health and quality of life (Ising et al., 2009). Noise level generally increases each subsequent year, so some authorities claim that the average noise level in cities has increased by 1 dB per year for the last 30 years (Lambert et al., 1994). In developing countries, the problem of increased noise levels is mainly due to inadequate urban planning and overcrowding of cities. These countries are striving to engage in modern technological and industrial development trends and their governments are ready to sacrifice the environment for intensifying development and industrialization that will allow these countries to be competitive on the world market, neglecting the health of the population exposed to high noise levels (Hadzi-Nikolova, 2013).

Noise pollution is considered today as one of the main environmental problems in cities, as cited by the World Health Organization (2011), as the second among a series of environmental stressors for its public health impact in a selection of European Countries.

In this regard, strategic noise maps present the main tool for assessing exposure of the population to environmental noise as outlined in the European Directive 2002/49/EC (Directive 2002/49/EC). Different strategies can be considered for noise mapping. One is the elaboration of noise maps through computerized methods, usually performed by different commercial software, whereas a second option is *in situ* measurements (Bunn et al., 2016; Fiedler et al., 2015; Sarantopoulos et al., 2014; Romeu et al., 2011; Hadzi-Nikolova et al., 2013; Hadzi-Nikolova et al., 2012).

In the Republic of North Macedonia, according to available literature data, no extensive research about environmental noise levels and its harmful health effects has been carried out. There is no established state network for continuous noise level monitoring and, consequently, strategic noise maps have not been prepared yet.

Accordingly, the main objective of this paper is to define and analyse noise levels in urban areas and to consider proposed measures for improving the situation with noise pollution. As representative urban areas, the cities of Skopje and Tetovo were taken as agglomerations that, according to the Regulation on agglomerations, main roads, main railways, main airports for which strategic noise maps should be prepared (2011), have an obligation to develop a strategic noise map, while the City of Štip, as a smaller urban area, does not belong to the agglomeration group and has no obligation to develop a strategic noise map.

METHODS AND MATERIALS

Noise level measurements at 30 measurement points in the City of Skopje and the Municipality of Tetovo, as well as at 20 measurement points in the Municipality of Štip during 2 years of monitoring were performed in the one-third frequency octave band according to ISO 1996 2:2017 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels (International Organisation for Standardisation, 2017), using a Sound Level Meter type CR:171C, an instrument Class 1 according to IEC 61762. Locations of all measurement points were selected near a busy intersections and commercial buildings as the main noise sources in urban areas.

Measurements were performed at 1.5 m height nearby main noise sources (frequency crossroad, commercial buildings) and on the most exposed facades of buildings at a 3.5 m distance from the buildings' walls and other reflective surfaces in accordance with the Regulation on locations of measuring stations and measuring points (2008). Frequency analysis provided additional information about the noise source as well as about the prevalence of certain frequencies and whether they are within the human hearing range. With measurements in the 1/3 frequency octave band, the following indicators were directly measured:

- L_d (Indicator for noise disturbance during the day) or daily noise level, which is A-equivalent long-term average sound level defined in ISO 1996-2:2017 (International Organisation for Standardisation, 2017);
- L_e (Indicator for noise disturbance during the evening) or evening noise level, which is A-equivalent long-term average sound level defined in ISO 1996-2:2017 (International Organisation for Standardisation, 2017);
- L_n (Indicator for noise disturbance during the night) or night noise level, which is A-equivalent long-term average sound level defined in ISO 1996-2:2017 (International Organisation for Standardisation, 2017);
- L_{eq} (Equivalent noise level) is an indicator of the noise calculated from the measured noise levels in an interval.

L_{den} (day-evening-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:2017 (International Organisation for Standardisation, 2017) was estimated based on 24-hour noise levels data for each measurement location using the formula below:

$$L_{den} = 10 log \left[\frac{12}{24} 10^{0.1 L_d} + \frac{4}{24} 10^{0.1(L_e+5)} + \frac{8}{24} 10^{0.1(L_n+10)} \right] \text{D}$$

ay-evening-night level is a descriptor of noise level based on energy equivalent noise level (Leq) over a whole day with a penalty of 10 dB for night-time noise (23.00-7.00) and an additional penalty of 5 dB for evening noise (19.00-23.00).

Noise level data (source specific profiles) were embedded within the digital ground model (DGM) for each intersection, using one of the most advanced noise and air pollution modelling software packages, SoundPLAN 7.2, produced by Braunstein + Berndt GmbH / SoundPLAN International LLC19. The software features easy to use tools for DGM development, noise sources approximation, and contour maps calculation.

Fig. 1 shows a general overview of model development and contents of noise maps using the SoundPLAN 7.2 noise and air pollution modelling software.

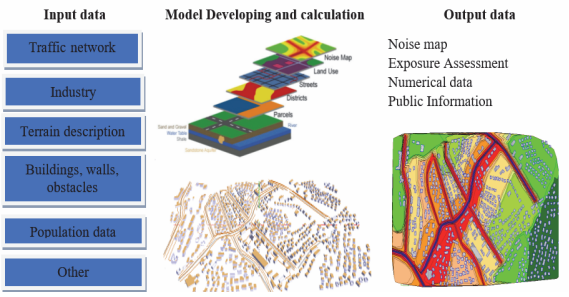

Figure 1. *General overview of model development and contents of noise maps (Hadzi-Nikolova, 2013)*

Noise maps present the existing and predicted noise emission level within the monitored area, determine the total noise exposure of the population caused by all human activities, giving directions on how to solve noise management issues and ensure efficient physical planning, planning of protection of existing spaces from noise sources, and 'acoustic space zoning' according to legally permissible noise levels.

RESULTS AND DISCUSSION

The results obtained during the 2-year monitoring for noise level indicators (L_d, L_e, L_n, $L_{eq,24h}$) in three urban areas, the City of Skopje, the Municipality of Tetovo, and the Municipality of Štip are presented in Table 1.

Table 1. *Measured noise levels in three urban areas*

Urban area	L_d (07.00-19.00)			
	Min dB(A)	Max dB(A)	$L_{eq,24h}$ dB(A)	Stan. dev.
Skopje	50.1	69.4	65.4	6.1
Tetovo	53.2	65.4	58.6	2.9
Štip	57.1	66.7	60.2	2.7
	L_e (19.00-23.00)			
	Min dB(A)	Max dB(A)	$L_{eq,24h}$ dB(A)	Stan. dev.
Skopje	56.5	69.8	62.8	6.1
Tetovo	51.2	62.4	56.1	3.3
Štip	56.3	65.1	58.6	1.9
	L_n (23.00-07.00)			
	Min dB(A)	Max dB(A)	$L_{eq,24h}$ dB(A)	Stan. dev.
Skopje	54.3	69.1	62.2	5.6
Tetovo	50.3	63.8	54.0	4.1
Štip	52.3	65.8	59.0	3.5

Table 2 compares the estimated day-evening-night level (L_{den}) and measured night noise level (L_n) values to the WHO (2018) recommended values.

Table 2. *Estimated day-evening-night level (L_{den})*

	L_{den} dB(A)	Max* dB(A)	L_n dB(A)	Max* dB(A)
Skopje	69.2	53	62.2	45
Tetovo	61.5	53	54.0	45
Štip	65.5	53	59.0	45

*WHO Guidelines strongly recommend reducing noise levels produced by road traffic below 53 dB during day-evening-night time (L_{den}) and below 45 dB during night-time (L_n).

Based on noise level measurement data and the number of vehicles on specific streets in the City of Skopje, Noise Dispersion Models (NDMs) were developed for individual parts of these three urban areas. The NDM for Aerodrom district was developed using data about the daily flow of vehicles for the following streets: Kuzman Josifovski Boulevard, Jane Sandanski Boulevard, Nikola Karev, Belasica, Bojmija, Vladimir Komarov, Vasko Karangeleski, Franjo Kluz, and Gjuro Djonović.

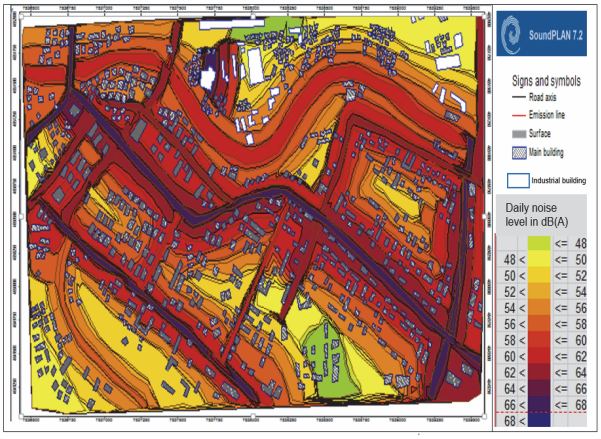

Figure 2. *Daily noise map for Aerodrom district – City of Skopje*

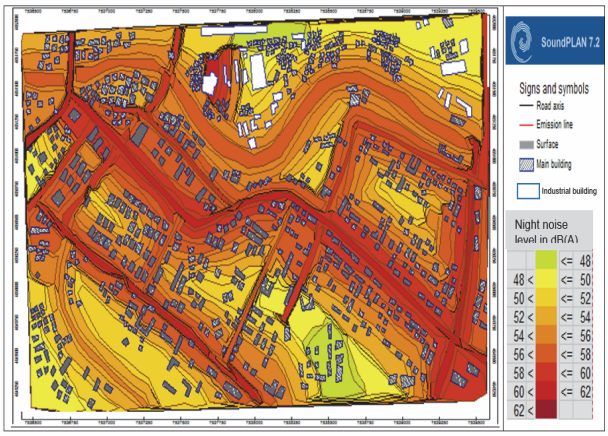

Figure 3. *Night noise map for Aerodrom district – City of Skopje*

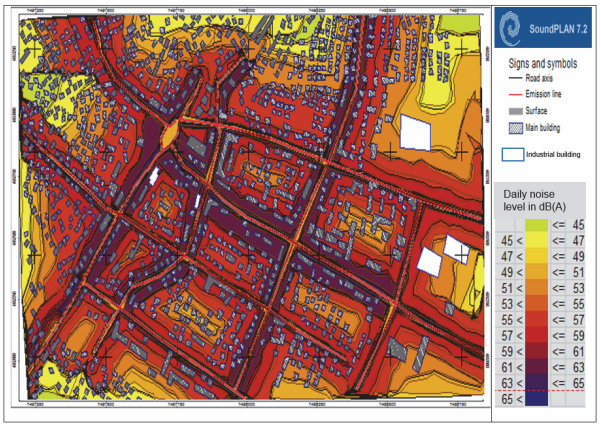

Figure 4. *Daily noise map for the central part of Tetovo*

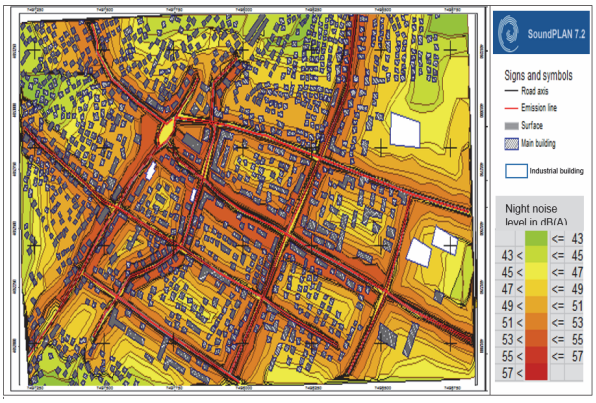

Figure 5. *Night noise map for the central part of Tetovo*

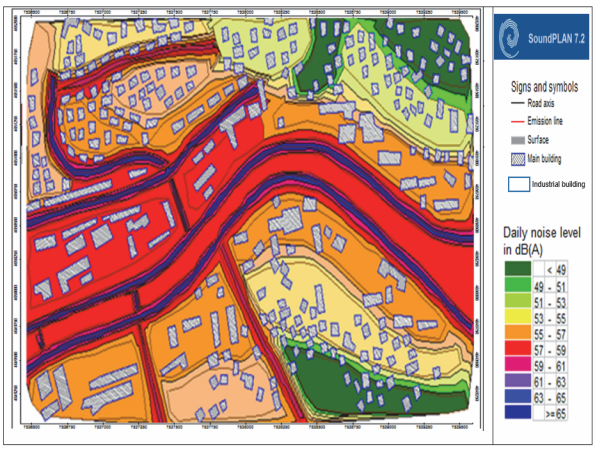

Figure 6. *Daily noise map for the central part of Štip*

The NDMs developed using the SoundPLAN 7.2 noise and air pollution modelling software clearly indicate excellent compliance between modelled and measured data for the three considered urban areas.

According to the Regulation on environmental noise level limit values (2008) regarding the permissible noise levels, the urban areas are divided into four groups, given in Table 3. All three urban areas, Aerodrom district (Skopje), the central part of Tetovo, and the central part of Štip are included in the third level area according to noise level protection.

Table 3. *Division of urban areas*

An area defined according to noise level protection	Noise level in dB		
	L_d	L_e	L_n
First level area	50	50	40
Second level area	55	55	45
Third level area	60	60	50
Fourth level area	70	70	60

Results from the 2-year monitoring of noise levels clearly indicate that the measured noise levels (daily, evening and night noise level) exceed the limit values for all three noise indicators, L_d, L_e, L_n, in accordance with the Regulation on environmental noise level limit values (2008). Exceedance of the permissible noise levels of indicators for daily and evening noise levels ranges from 5 to 7 dB for all measurement points. Significantly higher noise levels compared to the limit values were registered for the indicator of night noise, which exceeds the limit values by 7 to 13 dB. On the other hand, WHO Guidelines strongly recommend reducing noise levels produced by road traffic below 53 dB during day-evening-night time (L_{den}) and below 45 dB during night-time (L_n) (Table 2). If these recommended values according to the WHO Guidelines are exceeded, adverse health effects will occur frequently and a sizeable proportion of the population will become highly annoyed and sleep-disturbed. There is also evidence that the risk of cardiovascular disease will increase (WHO Regional Office for Europe, 2018).

High noise levels in the considered areas resulted primarily from traffic noise, increased number of motor vehicles, malfunction of motor vehicles, damaged roads, inadequate urban planning, bars, and commercial-office buildings.

The developed noise maps can serve as a basis for the preparation of strategic noise maps, which, in accordance with the Regulation on closer contents of strategic noise maps and noise action plans (2010) should contain data about

- Existing, previous or predicted noise conditions expressed through noise indicators;
- Overcoming the permissible noise levels;
- Estimated number of apartments, schools, hospitals, and similar facilities in a given zone exposed to higher noise level indicators;
- Estimated number of people in the area exposed to higher noise levels.

CONCLUSION

The results of two-year noise monitoring clearly indicate that small urban areas, such as Štip, also have a problem with high noise levels, so they need to prepare action plans, including noise level reduction measures, although they have no legal obligation to develop strategic noise maps and action plans for solving noise pollution problems, or to assess health effects related to high noise levels and apply noise reduction measures.

High noise levels and the developed noise dispersion models in the three considered urban areas, Aerodrom district in the City of Skopje, and the central city areas of the Municipalities of Tetovo and Štip, as well as harmful health effects related to high noise levels, clearly point out the necessity of developing a state monitoring network for continuous noise level measurement. Continuous noise level monitoring is necessary for smooth data collection, systematization, processing, establishment of a database, possibility of its usage, determination of the so-called 'hot spots', and development of strategic noise maps for urban areas. Proper urban planning and sound insulation of residential buildings are of particular importance for solving the noise pollution problem.

Considering the harmful health effects of noise (Ising et al., 2004; Van Kamp et al., 2012; Babisch, 2011; Hadzi-Nikolova et al., 2013; ACOEM, 2003; Button et al., 2004; Dalton et al., 2007; Mathews, 2009), the overall goal of an urban noise management and control policy is to ensure that all activities in society are aligned with the residents' wish for a quiet society. The broad operational objectives include requirements for protection, promotion, and improvement of quality of life, i.e. the requirements for environmentally sustainable development, reduction of health risks, and prevention of environmental degradation. Such a policy seeks to promote ecological well-being by preventing and minimizing noise pollution.

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