CESARE'17
COORDINATING ENGINEERING FOR SUSTAINABILITY AND RESILIENCE
Dead Sea, Amman, Jordan
3-8 May 2017
JORDAN UNIVERSITY OF SCIENCE & TECHNOLOGY
IRBID - JORDAN

SUSTAINABLE TRANSPORT DEVELOPMENT IN LITHUANIA: AIR POLLUTION AND NOISE REDUCTION IN CITIES, CONSTRUCTION OF BYPASS, IMPLEMENTATION OF ENVIRONMENTAL MEASURES

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Keywords: Sustainable transport, Noise, Air pollution, Road, Mitigation, Environmental Measures.

Abstract. *Noise generated by transport and air pollution has a significant direct impact on human health as well as quality of residential and recreational environment. The paper focuses on noise modelling program CADNA and air pollution modelling software ISC - AERMOD-View with regard to previous studies of relation between noise and air pollution and traffic along with its individual characteristics where impact of transport on the environment quality in the capital of Lithuania - Vilnius in terms of infrastructure development is evaluated. For that purpose, a less busy 2.7-kilometre-long street is selected where the traffic after the reconstruction by widening it would increase several times and the street would become one of the city's most important transport corridors and outside bypass of the city. The paper aims at assessing the direct relation between noise and air pollution and traffic density and mitigation measures without which today's urban development is hardly possible in terms of sustainable and conducive human habitation.*

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1 INTRODUCTION

1. Introduction

Rapidly increasing number of motor transport and expansion of cities determined the necessity of infrastructure development as well as the need to reduce or compensate the environmental impact, mostly by implementing environmental protection measures. The main factors that have an influence on the daily quality of life are the noise and air pollution, thus their management remains one of the most important tasks. Different countries employ different urban transport management techniques. During the past decades, especially after Lithuania's accession to the European Union, its economy has been rapidly growing and the number of transport in urban areas has increased significantly. The initiatives were taken to plan and design internal and external bypasses, however, higher building density results in higher number of people (potential sufferers from air pollution and noise), thus the negative impact is higher [2].

The main air pollutants emitted from vehicles and having a negative environmental impact are carbon dioxide – CO_2; carbon monoxide – CO; volatile organic compounds – VOC (HC); nitrogen oxides – NO_X; particulate matter – PM; sulphur dioxide – SO_2; nitrogen dioxide – NO_2. Air pollution depends on the traffic intensity, speed, heavy per light vehicle ratio, climatic conditions, the type of motor fuel (gasoline, diesel, hybrid cars). The air pollution is not felt directly, however, noise pollution is a significant form of environmental pollution which is constantly increasing. As the transport demand is growing, the number of vehicles is increasing as well, the traffic is denser and acoustic discomfort zones are expanding accordingly.

The main factors determining the level of noise generated by the traffic include the traffic density, traffic composition (heavy vehicles, %) and driving speed [15]. The lower number of heavy vehicles there are on the roads, the lower the noise [15]. The slower one drives, the lower noise is caused. For instance, when the driving speed change is between 50 and 40 km/h, the noise reduction in passenger cars is as much as 2.8 dB, but when driving very fast, the noise reduction is not such significant, for example, when car speed is lowered from 130 to 120 km/h, the noise is reduced by 1 dB [11].

The noise is generated by the engine, exhaust and transmission systems. It is the predominant noise when driving at low speed or low gear. The main factors affecting the noise level generated by traffic is the traffic density, traffic composition (heavy vehicles, %) and driving speed. If traffic density decreases by 10%, the noise level is reduced by 0.5 dB (A). If the traffic density is reduced by 50%, the noise level is reduced by 3 dB (A) respectively, and if even 75%, then the noise in surroundings is reduced as much as 6 dB (A) [11]. Noise distribution also depends on design of road longitudinal profile such as: a road is at the same level as the noise receivers, a road is on the embankment, a road is through the excavation or over the overpass [16].

Constant exposure to traffic noise affects people psychologically and physiologically. When experiencing noise irritation people are annoyed, their sleep is disturbed. This may lead to behavioral, communication problems, increased stress. Psychological issues have an impact on the fact that the human approach to noise source (as well as the source visibility) is associated with the response to the noise, i.e. the individual's frustration level [13], and in certain situations, people may accept narrow, acoustically ineffective protection zone as a positive measure.

Environmental measures both for reduction of air pollution and noise in the city may improve the situation or compensate for the deterioration in the quality of life. Environmental measures may be either street parameter customization for lower impact or target ones, i.e. landscaping, noise barriers, such as noise barriers or particularly installed embankments. For instance, 50-100 m wide natural greenery can reduce the noise level by 3 dB(A), but ~ 60 m wide, dense natural greenery opaque median-strip can reduce the noise by ~ 10 dB(A) (feels like – twice). By planting the greenery purposely, it is possible to reduce the noise level. Greenery (trees and shrubs) strip of 6-7 m wide planted especially along the road or street can reduce noise by 4-8 dB (A) [16]. One of the measures applied in Lithuania and other countries is thr replacement of existing windows by increased noise insulation windows. For the windows to stop > 15 dB (A), they should be closed, but from the psychological point of view, the majority of the city's population finds it difficult to adapt to such a limitation of their normal behavior. The noise measurement study in Europe showed that from April to November only ~ 25% of nights the population sleeps with the windows closed in bedrooms [14]. If the road embankment is installed as a measure, in order for this measure to be effective, the embankment must be> 2.5 m in height [16].

2 CONTROL OF TRANSPORT NOISE IN CITY STREETS

2.1 Noise Control on the basis of Lithuanian Law

In Lithuania Law on the Management of Noise on 26 October 2004 No. IX–2499, (Official Gazette, 2004, No. 164–5971) is valid. It specifies that the noise threshold – average Lday, Levening Lnight noise indicator beyond which the noise source controller must take measures to remove and (or) reduce noise emissions. Lithuanian Hygiene Standard HN 33:2011 "Noise limit values in residential and public buildings and in their environment" approved by the Lithuanian Ministry of Health on 13 June 2011 by the order No. V-604 determined the noise source noise limit values in residential and public buildings and in their environment and is applied for assessing the noise impact on public health. Noise limit values specified in the standard are shown in Table 1.

Table 1. Maximum permissible noise limit values in residential and public buildings and in their surroundings in Lithuania (HN 33:2011) [9].

Measurement sites	Time of day, h	Equivalent sound pressure level (LAeqT), dB(A)	Maximum sound pressure level (LAFmax), dB(A)
Dwellings in residential buildings (houses), bedrooms in public buildings, wards in inpatient health care institutions	6–18	45	55
	18–22	40	50
	22–6	35	45
In environment of residential buildings (houses) and public buildings (except the catering facilities and culture centers) affected by transport noise	6–18	65	70
	18–22	60	65
	22–6	55	60

1.1. Noise Modelling Method

Noise modelling is conducted by a computer program CADNA A 4.0. Using the French national calculation methodology and standard "XPS 31–133" (NMPB–Routes–96 (SETRA–CERTU–LCPC–CSTB), referred to in the document "Arrėtė du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Offieciel du 10 mai 1995, Article 6" and the French standard "XPS 31–133") [10]. Equivalent noise levels are calculated as follows: Lday (12 h); Levening (4 h); Lnight (8 h) and Lday indicators at the noisiest walls of buildings and their surroundings in 2 meters height. The height of buildings, terrain noise absorption properties, noise data sources – roads, traffic density, composition, driving speed are estimated. The current noise situation without the project and projected noise situation with the project are evaluated.

At the moment, due to the poor road surface condition the annual average daily traffic density (AADT) is 1380 vehicles per day and traffic of heavy vehicles on the street is prohibited by warning signs. Having implemented the economic activity, it is planned that in 2025 AADT Mykolo-Lietuvio street will be overpassed by 23 100 vehicles per day and heavy vehicles that include public transport will be 0.5%, all other vehicles weighing > 3.5 tons will be prohibited by warning signs. The planned speed is 50 km / h.

When performing assessment by noise modelling method, as background noise sources nearby streets, which will have the greatest impact because of the planned activities, are included.

1.2. Results of Noise Modelling

The research has revealed that the implementation of project will adversely affect the health of the population: exceedances in the living environment (in Lithuania it is considered to be 40 m from a residential house) during the day rose to 16 dB(A) during the evening to 15.9 dB(A) and at night to 15 dB(A) and will exceed hygiene norms applied in Lithuania. For these reasons, the introduction of environmental measures is mandatory regardless the installation costs. For the current noise situation see Fig. 1 (b), for the projected one see Fig. 2.

Due to the significant noise increase only set of measures, such as plantations, noise barrier only in one short section of road and quieter road surface can induce the noise reduction. According to the regulatory document applicable in Lithuania "Guidelines for design, installation and maintenance of environmental measures. Traffic noise reduction" [8], the gravelled road surface is 4-6 dB(A) noisier than normal asphalt pavement. Taking into account the significant noise exceedances and the fact that there are many driveways next to residential buildings, installation of noise barriers along the entire street for environment protection would be difficult, in some places impossible to implement, for this reason, as an alternative during the reconstruction instead of asphalt pavement to use silent pavement (SMA 5 S, S SMA8S or any other) with the acoustic efficiency of 4 dB(A).

Pavement noise is assessed in accordance with Order No. V-33 by the Director of the Lithuanian Road Administration under the Ministry of Transport on 30 January 2013 approving the methodological instructions MN APO 13 for the surface property optimization of the asphalt upper layer, indicating that with the importance increase in the noise reduction properties, recently asphalt top pavement have been tested allowing to reduce noise emissions and having a lower void content they are more durable than porous asphalt pavements. Modified stone matrix asphalt mixtures SMA 8 S and S SMA 5 are used where the air void content in laid and compacted layer comprises from 10% to 15%. The measurement results showed that the initial noise reduction effect can be approximately 4 dB. In the foreign references it is indicated that the pavement durability runs for 8-10 years [12].

Only the introduction of such innovative measures it is ensured that the noise on this street will not exceed the limit values hazardous to the local residents' health (see Fig. 2).

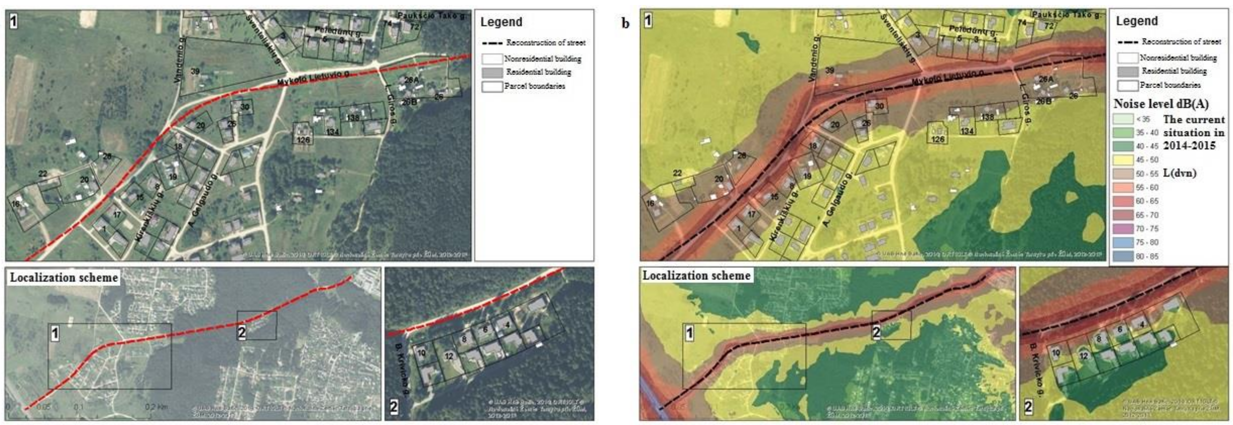

Fig. 1. (a) Current map; (b) Current map of noise spread L(den).

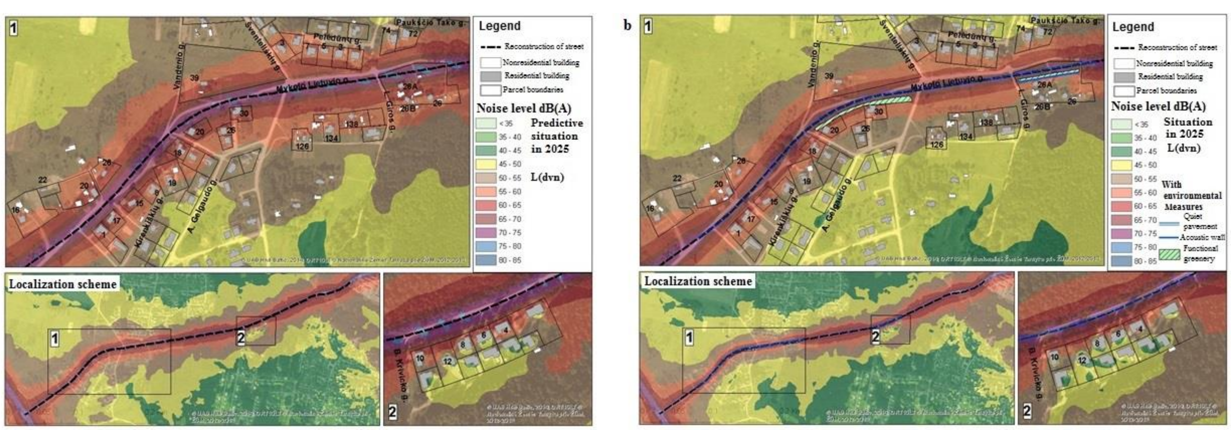

Fig. 2. (a) Map of the predicted noise spread without means L(den); (b) Map of the predicted noise spread with noise-reducing means (quieter road surface, noise barriers, functional greenery) L(den).

2. Control of Vehicle Air Pollution in City Streets

2.1. Legal Regulation of Air Pollutants in Lithuania

In 1999 the state adopted Ambient Air Protection Act regulating air quality management, mitigation and air pollution restrictive means. Air pollution modelling is regulated by the Order No. A-112 of the Director of Environmental Protection Agency on 10 July 2008 (as amended No. AV-14 on 26 January 2012) by which "Guidelines for background air pollution data use when assessing economic activity impact on ambient air" are approved [6], where assessment procedure of the meaning of PM_{10} and $PM_{2.5}$ in ambient air is defined and the Order No. AV – 200 the Director of Environmental Protection Agency on 9 December 2008 "On guidelines approval of air pollution dispersion calculation model selection when assessing economic activity impact on ambient air".

2.2. Modelling Method of Air Pollutants

Transport pollution is measured by pollutant dispersion modelling when results are being assimilated with pollutant limit values. The concentration of pollutants in the air is evaluated by software package ISC - AERMOD-View. AERMOD program is designed for calculation of pollutant dispersion from industrial and other types of sources (road, rail) or their complexes. Lithuanian Ministry of Environment identified AERMOD as one of the models that can be used for strategic and comprehensive environmental impact and health assessment.

Other parameters used for air pollution spread modelling are as follows:

- Averaging intervals of pollution dispersion results. Averaging time intervals applied for the pollutant dispersion modelling correspond to averaging intervals set in the requirements of each specific pollutant limit values.
- Variability factors of pollution sources. These factors indicate whether the pollutant is discharged continuously or periodically. Since the use of annual average daily vehicle traffic density data, it is assumed that emissions from transport are constant.
- Meteorological data.
- Receptor network. Receptor network is required to simulate the dispersion and calculate the concentration values in predefined areas at a certain height. Pollutant concentrations are calculated using the 177 receptor grid where the distance between the receptors is 100 m and the receptor height from ground is 1.7 m.
- Percentiles. In order to avoid statistically significant "excesses" of concentrations that can distort the overall view, the percentiles are used in the modelling. Percentiles to be used are present in procedure of ambient air emission mitigation description (according to criteria and standards of the European Union): the pollutant NO_2 1 hour averaging interval is 99.8 percentile; pollutant PM_{10} 24-hour averaging interval is 90.4 percentile.
- The background concentration.

2.3. Results of Air Pollutant Modelling

The pollutant dispersion modelling showed that the concentration of pollutants in the air arising from the street reconstruction impact (taking into account the background contamination in the analyzed area) will not exceed the limit values dangerous to health of people residing nearby and will not approach to them, but will increase slightly. The highest obtained values of pollutant concentrations are compared with the fixed limit values for the air pollution (see Table 2). Examples of modelling dispersion maps are presented in Fig.3.

Table 2. Air pollutant concentrations.

Name of matter	Limit value, µg/m^3		Maximum ground level concentration, µg/m^3	Maximum allowable discharge concentrations (amount of pollutants)
No background pollution				
Nitrogen dioxide (NO_2)	200	(an hour)	115,5	0,58
	40	(a year)	5,81	0,15
Particulate matter (PM_{10})	50	(24-hour)	0,54	0,01
	40	(a year)	0,24	0,01
Particulate matter ($PM_{2,5}$)	25	(a year)	0,12	0,00
Carbon monoxide (CO)	10000	(8 hours)	322,0	0,03
Benzene (C_6H_6)	5	(a year)	2,25	0,45
With background pollution				
Nitrogen dioxide (NO_2)	200	(an hour)	130,5	0,65
	40	(a your)	20,81	0,52
Particulate matter (PM_{10})	50	(24-hour)	17,44	0,35
	40	(a your)	17,14	0,43
Particulate matter ($PM_{2,5}$)	25	(a year)	8,57	0,34
Carbon monoxide (CO)	10000	(8 hours)	662,0	0,07
Benzene (C_6H_6)	5	(a your)	3,75	0,75

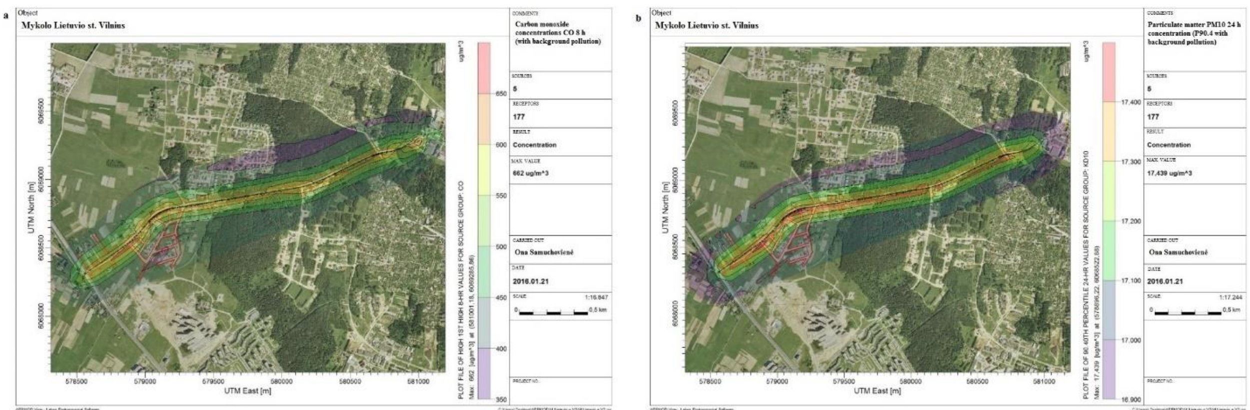

Fig. 3 (a) Concentration of carbon monoxide CO for 8 hours (with background pollution); (b) Concentration of particulate matter PM_{10} for 24-hour (P90.4; with background pollution).

4. Conclusion

The research conducted using noise modelling program CADNA and air pollution modelling software ISC - AERMOD-View and simulated situations where the intensive two-lane street in Vilnius city is planned to be reconstructed to four-lane one as an example (planned for city bypass) have proved a direct dependence of the ambient air quality and noise situation on motor traffic intensity and speed.

At daytime noise exceedances in residential environment (in Lithuania it is considered to be 40 m from a residential house) of Mykolo-Lietuvio street, where after the reconstruction the traffic density would increase nearly seventeen times (from 1 380 vehicles a day in 2015 with increase up to in 23100 vehicles a day in 2025), would increase of up to 16 dB(A), i.e. almost as much as increase in the traffic density is observed. During the evening an increase would be up to 15.9 dB(A), while at night up to 15 dB(A).

Predictive data without environmental measures would exceed the permissible norms in the Republic of Lithuania: during the day exceedances residential environment remain up to 5.5 dB(A), in the evening up to 8.9 dB(A) as well as at night up to 8.2 dB(A).

Implementation of this project without environmental protection measures would not be impossible, and the complex would consist of 4-10 m wide functional greenery, 1.8 m noise barrier and silent road pavement. Only such a way of project implementation would ensure high quality and sustainable urban infrastructure development.

With respect to air pollution, the modelling showed emission increase, but its amount shall not exceed the rate and in this case the noise situation remains more important as the modelling results confirmed the direct dependence of environmental measures introduction on the traffic density and health protection legislation and the fact that health and environmental protection is expensive but necessary attribute of every attractive city to live in.

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