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Determination of noise levels in railway station zones

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Determination of noise levels in railway station zones

Noise levels in the vicinity of railway stations are determined through noise model analysis, which is a highly demanding process as a great quantity of data on many relevant parameters must be collected. The model optimization procedure is described in the paper. Calculation results are validated by on-site measurements on two representative locations. Compared to field measurements, the results obtained during this procedure are reliable, which is significant for making decisions about implementation of noise protection measures.

Key words:
railway station, noise level, analysis model, road transport, railway transport

Izvorni znanstveni rad

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Određivanje stanja bučnosti u zonama željezničkih kolodvora

Određivanja stanja bučnosti u zonama željezničkih kolodvora svodi se na izradu modela proračuna što je zahtjevan postupak zbog potrebnog prikupljanja velikog broja podataka o brojnim utjecajnim parametrima. U radu je opisan postupak optimizacije izrade modela. Prikazana je verifikacija rezultata proračuna prema mjerenjima na terenu na dva reprezentativna primjera. Rezultati dobiveni primjenom opisanog postupka u odnosu na mjerenja na terenu su pouzdani što je nužno za donošenje odluke o provođenju mjera zaštite od buke.

Ključne riječi:
željeznički kolodvor, razina buke, model proračuna, cestovni promet, tračnički promet

Wissenschaftlicher Originalbeitrag

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Bestimmung des Lärmzustands in Gebieten der Eisenbahnhöfe

Die Bestimmung des Lärmzustands in Gebieten der Eisenbahnhöfe leitet sich auf die Herstellung eines Berechnungsmodells ab, was ein anspruchsvolles Verfahren ist wegen der nötigen Ansammlung einer grossen Zahl von Angaben über die beeinflussenden Parameter. Beschrieben ist ein Verfahren der Optimierung der Herstellung des Modells. Die Ergebnisse der Berechnung sind mit Terrainmessungen an zwei repräsentativen Beispielen verglichen. Die Ergebnisse gewonnen mit dem beschriebenen Verfahren in Beziehung zu den Terrainmessungen sind zuverlässig, was für die Entscheidung über die Verfahren des Lärmschutzes notwendig war.

Schlüsselwörter:
Eisenbahnhof, Lärmpegel, Berechnungsmodell, Optimierung, Terrainmessungen, Lärmschutz

1. Introduction

Forecasting, measuring and checking traffic noise levels in urban communities is inevitably gaining in significance due to rapid increase in the road and railway traffic, higher traffic speeds, greater number of people living in the immediate vicinity of road and railway facilities, lessening tolerance of local communities to traffic noise, and construction of new transport facilities. The analysis of traffic noise levels in such urban areas requires respect of a number of parameters that are not of significance when traffic noise in rural areas is analysed. For instance, in urban road and railway traffic corridors, traffic conditions and traffic flow rates are highly variable, and changes of vehicle moving speeds are quite frequent. Considering the time needed to make a noise model and conduct noise level calculations, and the quantity of data to be processed for that purpose, it can easily be concluded that the problem areas of highest concern are precisely railway stations and the zones around them. Noise emission and absorption conditions are quite complex because of: great number of various sources and factors influencing the occurrence and spreading of noise, different types of rail vehicles, a great number of rail systems and turnouts, different permanent way structures, dense construction in the surrounding areas, etc. [1]. In addition, railway stations are normally located in wider town centre areas where, besides rail traffic, intense road traffic is also present. The influence of road traffic on environmental noise levels is significant, and can not therefore be neglected during analysis of noise levels at railway stations. In order to clearly depict the issue of defining noise levels in railway station zones, the results of a greater study are presented, due to journals page restrictions, on two examples that are considered to be representative according to performance, number, and type of influence parameters. Procedures applicable to most examples that are likely to occur in practical situations are described.

2. Collecting input data for noise models

A uniform database for preparation of noise models and for analysis of noise emission has still not been developed in the Republic of Croatia, and this neither for railway nor for road traffic. For that reason, a great quantity of data obtained from various sources must be used before each analysis, in order to prepare a sufficiently accurate model of the area under study, and to define properties of the noise sources. The complexity and duration of the model preparation process can be further increased by the complexity of area for which noise analysis is conducted (density of built space, different space occupancies and various transport systems), by the quantity and accuracy of input data needed to apply interim noise computation methods [2, 3, 4, 5], and by the impossibility of presenting data (available in Croatia) in the form needed for the analysis. This greatly complicates the analysis of traffic noise levels, especially when noise analysis is conducted for urban areas where, in addition to data about the rolling stock, driving surfaces, etc., a complex noise propagation model must also be prepared, with data about the terrain and obstacles to noise propagation. In general, possible sources of necessary data can be classified into:

- primary sources: our own field measurements, and
- secondary sources: data from national, regional and local road administrations, town planning offices at town councils, and railway authorities [6].

Road administrations, town councils, and railway authorities, are normally responsible for gathering and entering traffic noise input data into widely accessible databases. However, in the RC, these bodies neither collect nor systemize most input data that are needed for preparation of computation models. That is why the model preparation procedure that can actually be applied in Croatia is highly specific. In order to prepare an appropriate model, some data must be gathered through field measurements and observations, while other are obtained using the so called replacement data, introduced in cases when real data needed for calculation do not exist. The source of replacement data is regulated in Croatia by the Byelaw [7]. According to this byelaw, the latest edition of the following Position Paper must be applied: European Commission's 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"*, [8]. This document presents a number of replacement data, together with information on the complexity and cost of implementation, and on the accuracy of computation results obtained using a specific replacement data. The accuracy of results is expressed through deviation in dB from the real noise level and, at that, the greatest deviation is higher than 5 dB, while the smallest one is lower than 0.5 dB, [8]. It should be noted that deviations from computation results, as defined in this document, are applicable only in cases when all but one input data are known. According to [8], a higher number of replacement data would cause a significant increase in the deviation of results. However, the value of such increase is not defined in the document.

The objective of the large-scale research that is partly presented in this paper is to study possible use of available input data for traffic noise computations in Croatia, analyse introduction of replacement data for the data that are not available in the existing data bases, and to study influence of introduction of several replacement data on the model preparation speed and on the reliability of computation results. The reliability of model-based computation results is checked by comparison with on-site measurements.

3. Analysis of noise levels in railway station zones

According to [9], 248 railway stations are currently in use in the territory of Croatia. Twelve (5%) of these stations are situated in the greatest four urban centres with more than 100,000 residents (Zagreb, Split, Rijeka, and Osijek). While selecting stations in which field measurements were to be made, it was decided to select those stations that cover, according to their spatial and traffic properties (size, location, infrastructure, type, and traffic volume), most parameters to be used in computation. Out of these twelve stations, two are presented in this paper: Zagreb West Railway Station (Figure 1), and Osijek Railway Station (Figure 2). A general layout of these two stations is given in Figures 1 and 2, and a more detailed presentation is given in Figures 3 and 4. The Zagreb West Railway Station and the Osijek Railway Station were selected for analysis because of the following properties:

- they are located along significant international Pan-European corridors (Corridor X – Zagreb West Railway Station, and Corridor Vc – Osijek Railway Station),
- they accommodate international and local passenger and cargo trains, with various speeds of travel (without and with stopping at stations), and train compositions,
- they are located in wider centres of urban agglomerations,
- they are bordered with densely developed areas, usually of mixed and residential occupancy [10, 11],
- Zagreb West Railway Station features traffic activities such as boarding, disembarking and transport of passengers, with intensive cargo (through) traffic and passenger traffic, while the station itself is bordered with heavily-trafficked streets,
- besides being characterized by sparse traffic, the Osijek Railway Station features some technological activities (warming up of diesel shunters, fuel supply to locomotives, connecting and disconnecting locomotives from train compositions, small-scale locomotive repairs, and manoeuvring by means of shunters), while a low density traffic is operated in adjoining streets,
- railway traffic with diesel and electric locomotives is operated on electrified tracks of the Zagreb West Railway Station, while non-electrified tracks at the Osijek Railway Station feature only a much louder diesel locomotive traffic.

Figure 3. Zagreb West Railway Station

Figure 4. Osijek Railway Station

Figure 1. Layout of Zagreb West Railway Station area under study

Figure 2. Layout of Osijek Railway Station area under study

Noise levels were calculated using the specialized software LimA and interim computation methods defined in the Byelaw [7]. The French interim method NMPB/XP S 31-133 was used for calculating the road traffic noise, while the Dutch method RMR 1997 was used for calculating noise generated by railway traffic.

3.1. Sources of input data defined through computation methods

An overview of possible sources of data for model preparation and traffic noise computation, based on EC recommendations [2, 3, 4, 5], is given in Tables 1 to 4. These possible sources of data can be applied in case noise levels on existing transport facilities are analyzed, while design documents are used as the basic source of data in case noise levels are analysed for planned transport facilities.

Due to lack of systematic registration of data needed for calculating noise generated by road and railway traffic in Croatia, i.e. due to inexistence of good quality and widely available bases of secondary sources of data, and in order to simplify data collection by field measurements and observations, it was established that an optimum solution for noise calculation at

Table 1. Overview of input data for calculating road traffic noise emissions based on an interim method

Data needed for preparing the emission model based on "Guide du Bruit des Transports Terrestres – Prévision des niveaux sonores", 1980.		Possible sources of data
Pavement surface	Type of pavement surface: ▫ porous surface ▫ smooth asphalt ▫ concrete pavement and grooved asphalt ▫ smooth stone paving ▫ rough stone paving	field observations (visual inspection)*
		databases prepared by road administrations
Longitudinal grade	Type of section depending on longitudinal grade: ▫ horizontal: longitudinal grade < 2 % ▫ rise/fall: longitudinal grade > 2 %	topographic surveying
		topographic maps*
Number of vehicles by category	Vehicle category: ▫ light (Gross Vehicle Mass < 3,5 t) ▫ heavy (Gross Vehicle Mass ≥ 3,5 t)	field observations*
		statistical data: ADT + type of facility
Speed	average speed V50 (speed exceeded by 50 % of vehicles, 20 – 130 km/h)	measurement
	speed defined by speed limitation	field observations*
Section length of individual types of traffic flow	Type of traffic flow: ▫ continuous (fluid) ▫ continuous – pulsing ▫ pulsing - accelerating ▫ pulsing – decelerating	field observations: flow monitoring
		field observations: limitation of speed*
Position of source (road)	▫ height: 0,5 m; ▫ horizontal position: in the axis of each driving lane;	ortophoto*
		urban master plan (GUP)*
		cadastre
		topographic maps
		topographic survey

Table 2. Overview of input data for calculating propagation of road traffic noise based on an interim method

Data needed for preparing a noise model according to NMPB/XP 31-133		Possible sources of data
Noise indicator	time periods: day, evening and night; L_{den} and L_{night}	Noise Protection Act (NN 30/2009)*
Atmospheric absorption	range of temperatures according to ISO 9613-2	field observations *
Digital model of terrain (DMT)	DMT contains information about: ▫ relief (intercepting lines and altitudes) ▫ type of ground surface ▫ position and height of barriers near the transport facility ▫ position and height of buildings	noise map producers [7]
		existing digital maps* [12]
		field observations * [12]
Meteorological correction	frequency of conditions favourable for noise propagation: day 50 %, evening 75 %, night 100 %.	as recommended in method* [2]

Table 3. Overview of input data for calculating rail traffic noise emission using an interim method

Data needed to prepare emission model according to "Point 3 – De emissiegetallen per octaafband"		Possible sources of data
Vehicle categories	Categories from 1 to 10 depending on: ▫ type of traction ▫ braking system; travel speed ▫ type of load (passenger or cargo trains)	comparison of emission data
		field observations*
		databases prepared by railway authorities
Vehicle intensity	number of trains/hour for each vehicle category	field observations*
		timetable*
Percentage of braking vehicles	defined for each vehicle category	comparison of emission data
		field observations*
Speed	average speed (V_{mean})	measurements
		limitation of speed*
Track sections with homogeneous properties	correction according to track type: from 1 to 9, depending on: permanent way structure;	field observations (visual inspection)*
		databases prepared by railway authorities
		measurements
	correction according to rail system density: from 1 to 4, depending on: ▫ number of rail systems ▫ number of turnouts ▫ number of crossings	field observations (visual inspection)*
		topographic maps
		GIS
Position of source	▫ height: up to 5 sources at the height from 0 to 5 m (depending on train category); ▫ horizontal position: track axis;	ortophoto*
		urban master plan (GUP)*
		cadastre
		topographic maps
		topographic surveys

Table 4. Overview of input data for calculating propagation of rail traffic noise based on a interim method

Data needed for preparing noise propagation model according to RMR 1996		Possible sources of data
Noise indicators	time periods: day, evening and night: L_{den} and L_{night}	Noise Protection Act (NN 30/2009)*
Atmospheric absorption	temperature range according to ISO 9613-2	field observations*
Digital model of terrain (DMT)	DMT contains information about: ▫ relief (intercepting lines and altitudes) ▫ type of ground surface ▫ position and height of barriers near the transport facility	noise map producers [7]
		existing digital maps* [12]
		field observations * [12]
Meteorological correction	C0 = 3.5 dB (for frequency of favourable noise propagation conditions: 45 %)	as recommended in method* [2]

railway stations would be to use one of possible sources of data that are marked in tables by asterisk (*). The sources applied are at the same time the sources of "replacement data", the use of which is defined in the document [8].

3.2. Sources of replacement input data

The "replacement data" used for calculating noise levels at railway stations under study are presented in Table 5.

Table 5. Application of replacement input data: complexity and collection cost, and accuracy of computation results

Input data	Source of replacement data	Complexity	Cost	Accuracy
	EMISSION			
Pavement surface	Visual inspection	3	1	1 dB
Longitudinal slope of transport facility	calculated using a small number of spot heights	1	3	< 0.5 dB
Speed				
road traffic	limitation of speed	3	3	2 dB
rail traffic	limitation of speed on track	3	3	-
Traffic flow				
road traffic	defining position of signs and markings during field inspection	1	4	< 0.5 dB
rail traffic	defined during field inspection	1	4	< 0.5 dB
Position of source	defined by digital terrain model	-	-	-
Track sections	visual inspection	3	1	1 dB
	PROPAGATION			
DMT				
relief	defined by digital relief model	-	-	-
type of ground surface	use of defined values (according to planned use)	3	3	1 dB
height of barriers	visual inspection	3	3	1 dB
height of buildings	visual inspection (number of storeys × 3m)	1	3	1 dB
Absorption coefficient	use of defined values (according to material)	1	1	1 dB
Favourable conditions for propagation	use of defined values (50 % day; 75 % evening; 100 % night)	1	1	-
Relative humidity and temperature	use of measured values	3	1	-
	AVERAGE	**2.1**	**2.4**	**-**
	TOTAL	**-**	**-**	**10.9 dB**

Their complexity and cost of their introduction, and possible deviations from real noise levels due to use of replacement data, are presented [8]. The complexity and cost are defined using ratings that range from 1 to 6. At that, the rating "1" stands for "low", and the rating "6" for "high" complexity and cost. These sources have been selected for analysis of railway stations under study due to their simplicity (average complexity rating: 2.1), and low cost of data collection (average rating: 2.4) during field inspections. The document prepared by the European Commission [8] also offers a number of replacement data that do not require introduction of additional input parameters for noise analysis: this is not needed as their values have been defined based on long-term traffic noise analyses conducted in EU countries. Although these replacement data are characterized by the lowest level of complexity and cost, they also offer the lowest assumed accuracy (in excess of 5 dB for some replacement data).

As can be seen from Table 5, if only one replacement data is introduced, such as for instance the data about building height, the resulting error would be ± 1 dB. It can therefore be concluded that the introduction of a greater number of such replacement data could result in a considerable total increase of deviation from actual noise levels. The energetic summing of absolute deviation values given in Table 5 was conducted in order to define maximum possible deviation of computed noise values, due to introduction of these replacement data. It was established that the maximum deviation amounts to ± 10.9 dB. Regardless of selection of the most favourable possible sources of replacement data for calculating noise in railway stations under study, this deviation greatly exceeds the value of ± 3 dB. In fact, the profession has accepted the recommendation that a model can be considered sufficiently accurate if the deviation of results obtained by model using computation methods does not exceed ± 3 dB, when compared to field measurements. This is why noise levels measured in railway station zones have been compared with levels calculated based on models in which the above replacement data were used.

3.3. Collection of input data

At the Zagreb West Railway Station and the Osijek Railway Station, the traffic load was measured both within the station zone, and in their immediate vicinity, along adjacent roads. Road traffic measurements were conducted by hourly registration of traffic load. At that, road vehicles were divided into three categories: passenger cars, light trucks, and heavy trucks. According to the composition and condition of traffic flow at road junctions under study, these road segments are typical junctions without traffic lights, situated in the very centre of the town: according to data obtained by field measurements, passenger cars are dominantly represented in road traffic (97% in Zagreb, 75% in Osijek). In addition, it was established that the traffic flow at these roads is relatively stable. At that, the exceptions are the morning and afternoon "rush hours" in Zagreb, during which a long queue of vehicles is usually formed.

During rail traffic measurements, rail vehicles were divided according to traction, use, and track along which they move. Measured values were compared and complemented with applicable timetables of Hrvatske željeznice (Croatian Railways Co.) and Zagrebački električni tramvaj (Zagreb Tram Service).

The data on other noise emission parameters (pavement surface, longitudinal slope of pavement, speed of travel, traffic flow situation, track types, and rail composition density) were gathered during inspection of areas under study, and through consultation of available maps of the area (ortophoto, urban master plan (GUP)). The data on propagation parameters, which include information about the relief, type of surface, height of nearby barriers, and height of buildings, were entered into a digital three-dimensional terrain model which is based on existing digital models of relief. Additional data gathered during field inspection were also used [12]. An appropriate absorption coefficients and conditions favourable to propagation were introduced into the computation, using values set by the methods themselves, while data about relative humidity and temperature were registered in the course of field measurements.

3.4. Verification of computation model

Noise measurements needed to verify the computation model were carried out at appropriate measurement posts within the railway stations, and in their immediate vicinity, along the adjacent roads. Fifteen minute noise level measurements were conducted at such measurement posts using Brüel&Kjaer high-accuracy sound level metres 2270 and 2250, at 1.2 m above the ground level, during favourable meteorological conditions. The measurement was made simultaneously with traffic load measurements, and individual measurements were repeated four times at each measurement post.

Table 6. Verification of traffic noise computation model

Location	Measurement point	Summary levels	Measured levels	Difference
		L_{day} [dB(A)]	L_{Aeq} [dB(A)]	$L_{day} - L_{Aeq}$ [dB(A)]
Zagreb	MM1-ZG	61.71	59.80	1.91
	MM2-ZG	62.36	59.50	2.86
	MM3-ZG	68.80	67.50	1.30
	MM4-ZG	70.69	67.20	**3.49**
Osijek	MM1-OS	59.17	56.43	2.74
	MM3-OS	57.31	55.65	1.66
	MM4-OS	60.41	59.50	0.91
	MM5-OS	61.75	59.60	2.15

Noise levels for road and rail traffic were calculated separately from one another. Noise level computation results were then energetically summed ("superposed"). It can be seen from Table 6 that noise levels deviations determined in this way are mostly lower that 3 dB(A), when compared to actual field measurements. A greater deviation registered at the measurement point MM4-ZG (3.5 dB(A)) can be explained by high complexity of the noise propagation model in the immediate vicinity of that measurement post. Furthermore, all values obtained by computation are higher that the values measured at the corresponding measurement posts, which is favourable for local residents, i.e. for their protection during implementation of noise protection measures.

4. Conclusion

In the Republic of Croatia, traffic noise level computations are mostly based on the so called "primary" sources of data (data obtained by measurements and field observations) because the practice of systematic collection of data needed for calculation of traffic noise levels, and the grouping of such data into a widely accessible database, has still not been adopted on the national level. At that, a special problem related to environmental noise level determination are densely built urban agglomerations where a whole array of specific conditions, highly relevant for occurrence and propagation of traffic noise, is present in relatively small areas.

The study of noise levels in railway station zones in urban agglomerations shows that method described in this paper can be used to optimize the noise level determination procedure in railway station zones. In fact, the study is based on application of the described computation model and input data collection procedure, and involves the use of the mentioned replacement data compliant with our and European legislation, and an appropriate reliability checking procedure.

The procedure can also be applied for determining noise levels in railway station zones other than those described in this paper. It should be noted that verification of reliability of computation results based on the described procedure, through comparison with field measurements, has revealed that computation results are reliable, and this despite the fact that a number of replacement data, collected through relatively simple field measurements and observations, has been applied. This is especially significant for implementation in Croatia where, as already mentioned, noise level databases are incomplete, often unavailable, and incompatible with input data needed for application of prescribed computation methods.

It can be concluded with sufficient certainty that the combination of a large number of data obtained by field measurements and observations ("primary" sources of data) and, to a lesser extent, of data from databases ("secondary" sources of data), enables preparation of sufficiently accurate noise level computation models for use in urban areas. Nevertheless, an emphasis should be placed on the need to prepare, as soon as possible, a good quality database that would contain accurate input data, so that legally prescribed calculation methods can be applied. This would in turn contribute to simpler and faster preparation of noise maps, with a satisfactory reliability of computation results.

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