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Comparing railway noise prediction results for passenger trains using various models

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Railway noise modeling is a requirement for all European countries. Under the European Directive on the Assessment and Management of Environmental Noise, 2002/49/EC all member states were obliged to create strategic noise maps of the major railways by June 30th, 2007. Some of the participating states have their own national schemes dedicated to noise prediction. For those not having their own noise prediction model, the recommendation is to use the Dutch SRM II Model. The most important assessment criterion is an inaccuracy value, which is defined as a difference between the results calculated based on a model and the actual measurements under the same atmospheric conditions simulated. Therefore, it is essential to check out which of the main calculation schemes produces most accurate results. Therefore, all above models were implemented numerically and calculations of the noise maps were performed with the use of: Schall 03 developed in Germany, Dutch SRM II and the Nordic model engineered in Scandinavia. Those models were tested employing sample passenger trains data exploited in Gdansk, Poland. Noise maps were drawn in Cadna A software and then were compared to field noise measurement test results.

1 Introduction

Noise pollution constitutes a general threat to health and wellness. It is estimated that one third of Poles are exposed to the noise level which exceeds the level of acceptability. In 2002 there were 1.1 million people who were exposed to railway noise in Poland. [3]. Furthermore, most people are unaware of the threat. For these reasons noise pollution should be perceives as an important issue by environmental protection organizations. On February 1st, 1993 European Commission recognized noise as an essential problem of urban environment. In 1996 the Future noise policy, also known as a “green paper”, was elaborated. The European Directive on the Assessment and Management of Environmental Noise, 2002/49/EC of June 25th, 2002 was based on this paper. Its goal was to provide/assure homogenous treatment of noise problems in EU, understanding that the methods of reduction, prevention and avoidance adverse effect of the noise [5]. According to the requirements of the directive, the member states are obliged to provide access to information on noise pollution, and the society of each country should be aware of the scale of the problem. Under the European Directive 2002/49/EC all member states were obliged to create strategic noise maps of the major railways by June 30th, 2007 [5, 6]. Some of the participating states have their own national schemes dedicated to the noise prediction. For those countries which do not have their own noise prediction model, the Dutch SRM II Model is recommended to be used. In IMAGINE – HARMONOISE projects [1] four main national European models are indicated: Schall 03 developed in Germany, Dutch SRM II, the Nordic model engineered in Scandinavia and French NMPB-FER model. Because of the accuracy and precision problems it is essential to evaluate which of these models produces most accurate results. Comparison of the simulation effects can be performed on numerical data, noise maps or temporal noise charts for a passing-by train. The simulation was performed for two areas in Gdansk, Poland. Noise maps for railway noise were drawn in Cadna A software and then compared.

2 Chosen European noise prediction models

The partners of the European-founded HARMONOISE project dedicated themselves to the realization of a common European noise model. The first step of this project was, however, to find and evaluate existing noise prediction models which could constitute a basis of a new method. It was assessed that there are four national methods which are well defined and can be used in this project. In the paper they are shortly reviewed.

2.1 German model – Schall 03

Modeling with Schall 03 begins with a fixed value of 51 dB for all noise events. The next step is to add some corrections describing acoustical event of a passing-by train. Some parts of these corrections are related to train type, train speed and brake types. Next few modifications are connected with the track properties and track support structures. The last part of corrections is connected with the mechanism of sound propagation and parameters such as sound pressure level, the angle between direction of the train and sound propagation. Additionally, corrections are used for bridges, level-crossings and curves [1].

In the Schall 03 model neither the frequency dependence on railway noise nor atmospheric conditions were taken into consideration. Therefore even if the source directivity is included in the prediction model, physical mechanisms that affect sound propagation are not taken into account [2]. On the other hand, this model has a very clear construction, and it is easily implementable. Contrarily, it takes into account only a few of important parameters. More details can be found in the description of this model [1].

2.2 Dutch model – SRM II

The Dutch model is different from the German one. First, the modeling is done in octave bands. Moreover, the heights of sources are taken into account to be able to predict the effect of noise barriers. Important parameters of this model are the number of trains during a day and night, also a type of the train category, track structure, i.e. type of sleepers, the number of rail segments, joints and crossings and the percentage of brake time of the whole time of train ride. A formula for obtaining the emission of noise is available in the documentation of the Harmonoise project [1, 6]. This model has some prefixed values for certain frequency band and the height of source. In general, that Dutch model may be easily customized for the railway conditions of any European country. It is because of its easy-to-use classification of trains based on train and braking system type. There exists a database entitled ASWIN [1, 7], in which information about particular track types and traffic parameters is contained, such as an average speed of passing-by trains and the average number of passages per hour, which depends on the track type and train category.

In Poland and other countries without their own prediction methods, SRM II is recommended to be adopted in noise calculations [4, 5]. There is no need to find technical parameters of a particular train. It is sufficient to know whether it is a passenger or freight train and find out the type of brakes and drive.

2.3 Nordic model

The Nordic method was elaborated as a result of cooperation between Scandinavian countries. The NMT 96 method is used to compute equivalent A-weighted noise level in octave bands and can be used to estimate maximum levels for any time period. The propagation module is similar to the Dutch propagation model. Atmospheric conditions are taken into account, but results can be computed for positive range of temperatures only. The NMT 96 considers the directivity of sound propagation against the wind. In the version of the Nordic method from 2000 (NORD 2000) meteorological parameters such as the speed of the wind, standard deviation of the wind speed, wind direction, temperature gradient and its standard deviation are considered. The NORD 2000 model is an extended version of NMT 96. Calculation give values in one thirds octave bands from 25 Hz to 10 kHz. Sources of railway noise are divided into 6 heights. Computing noise level requires some input parameters, such as for example category of a train and its operating condition. The latter may be determined by acceleration: a) if acceleration is less than zero it means braking, 2) if equal to zero – a constant speed or standing, and c) if greater than zero - increasing acceleration of the train. Basing on the above parameters the level of noise power per 1 meter of a passing-by train can be modeled. There are five categories of Scandinavian trains based on the speed and type of a train. More details about this model can be found in literature [1].

2.4 French model

The French model is called NMPB-FER (fr. N*ouvelle Méthode de Prévision de Bruit*). It mainly focuses on propagation. This scheme comprises two methods of computations. The first takes meteorological conditions favourable to sound propagation into account, and the second -- homogeneous atmospheric conditions [1]. After both calculations are performed, the equivalent noise level is computed weighted with percentage time of these two acoustic conditions. Trains are divided into four main categories with subcategories based on speed and type. The model has the possibility to choose the tram option. For track, no parameters are taken into consideration [1]. In this model, the height of noise sources depends on frequency. In this paper, the French model was omitted because of big differences between the Polish and French trains. Moreover, the NMPB-FER method is more based on propagation than source modeling. The NMPB model was chosen as most consistent with the EU 2000 framework for road noise, and was indicated as an interim calculation method for road noise. The railway noise method was based on that road model.

3 Measurement

Modeling in Cadna A with national methods was preceded by measurements in Gdansk, Poland. It was performed in two series for regular trains coursing. The outcome was equivalent A- weighted noise level. The first measurement encompassed twenty trains within 40 minutes measurement time slot, and the second one nine trains within the same time period. The measured background noise level was equal to 53 dB. The distance from the measurement location to the track line was 20 meters. The measurement microphone was mounted 1.6 meter above the ground surface. The measurements conditions are shown in Table 1 below.

Date	7 V 2007	18 V 2007
Temperature	12 °C	10 °C
Relative air humidity	80 %	91 %
Cloudiness	high	very high
Period	40 min	40 min
Number of trains	20	9
Equivalent noise level	68.6 dBA	65.7 dBA
Maximum noise level	89 dBA	88.9 dBA
Minimum noise level	43.6 dBA	-

Table 1 Atmospheric conditions for both measurements

4 Results of modeling in Cadna A system

The modeling was performed for two areas. A map was computed for the track line from Gdansk Zabianka to Gdansk Glowny, a part of railway in Gdansk region, the second one was determined for a single location in Gdansk Oliwa. These maps were verified as to their prediction accuracy using measurement results. In order to achieve high-quality of modeling it was obligatory to classify all trains passing by the area. These data were the basis for computing acoustic maps using German, Dutch and Nordic methodology. In Table 2 the outcome of two measurement sessions are presented, compared against calculated ones for equivalent simulated atmospheric conditions. This table illustrates absolute inaccuracy of all three methods considered in this paper. The German and Nordic model have a similar inaccuracy, but it can be noticed that Schall 03 has lower inaccuracy for situation with lower number of trains, contrarily to the NMT 96 model. The largest discrepancy in predicted quantities in comparison to the measurement results can be noticed for the SRM II (Dutch) model. It resulted in 4 dB for the first and over 6 dB for the second measurement session. Of course every national model is supported by the databases of noise sources. Each country has its unique set of railway rolling stock. Because of various definitions of trains, the mentioned simulations differ from each other. A similar problem exists for a new European method called IMAGINE [8].

No.	**P** [dBA]	**L_{d_Ger}** [dBA]	**L_{d_Dutch}** [dBA]	**L_{d_Nord}** [dBA]	**$P-L_{d\_Ger}$** [dB]	**$P-L_{d\_Dutch}$** [dB]	**$P-L_{dNord}$** [dB]
1	68.6	67.1	64.2	68.2	1.5	4.4	0.4
2	65.7	65.2	59.7	67.1	0.5	6	1.4

Table 2 Comparison of measured and computed quantities for chosen models

where: **P** – measurement equivalent noise level, **L_{d_Ger}** – equivalent noise level calculated using German model Schall03, **L_{d_Dutch}** – equivalent noise level calculated using Dutch model SMR II, **L_{d_Nord}** – equivalent noise level calculated using Nordic model NMT96.

Figures 1 – 3 show noise maps for a part of the modeled area using various prediction methods. In order to show the difference between these maps it is essential to assign the same color range and scale for all models etc. It is worth mentioning that results of the implementation of the Dutch SRM II model differ from other models. Noise levels in the maps belong to the range from 45 dB to 85 dB for German and Nordic models, whereas the lowest defined level equals -99 dB and reaches the value of 70 dB for the Dutch model under the same atmospheric conditions. The maps presented show differences in propagation components in these models. It can be noticed that isophone curves were drawn differently near buildings which are present in the investigated area.

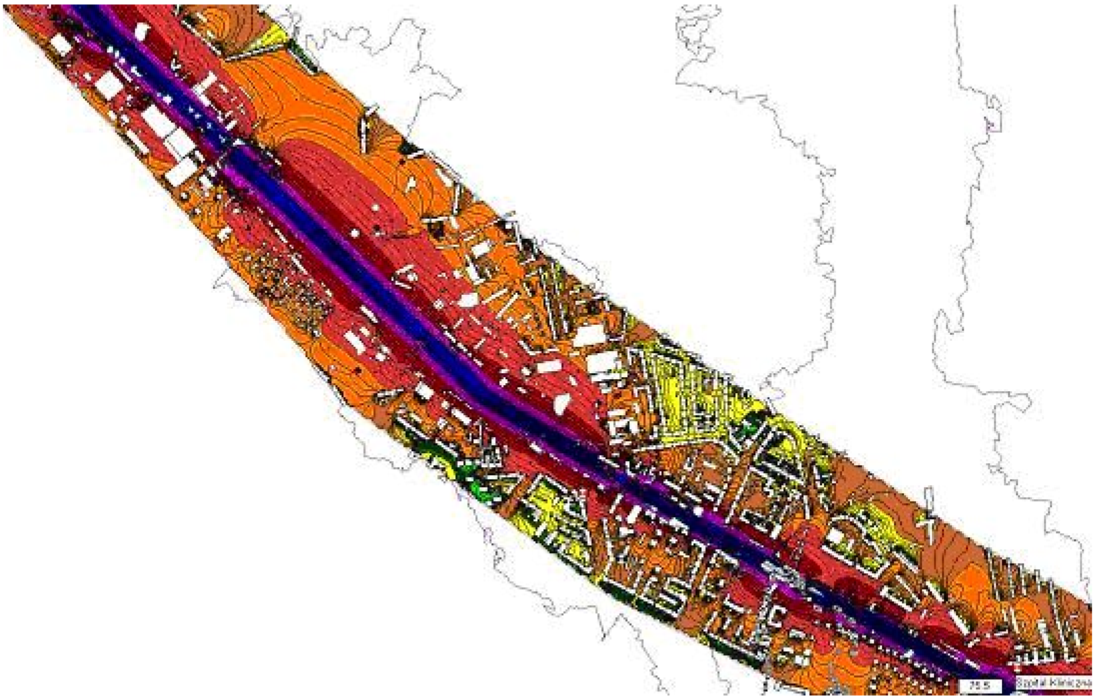

Fig. 1 Noise map L_{den} calculated for Gdansk Zaspa – Gdansk Wrzeszcz using Schall 03

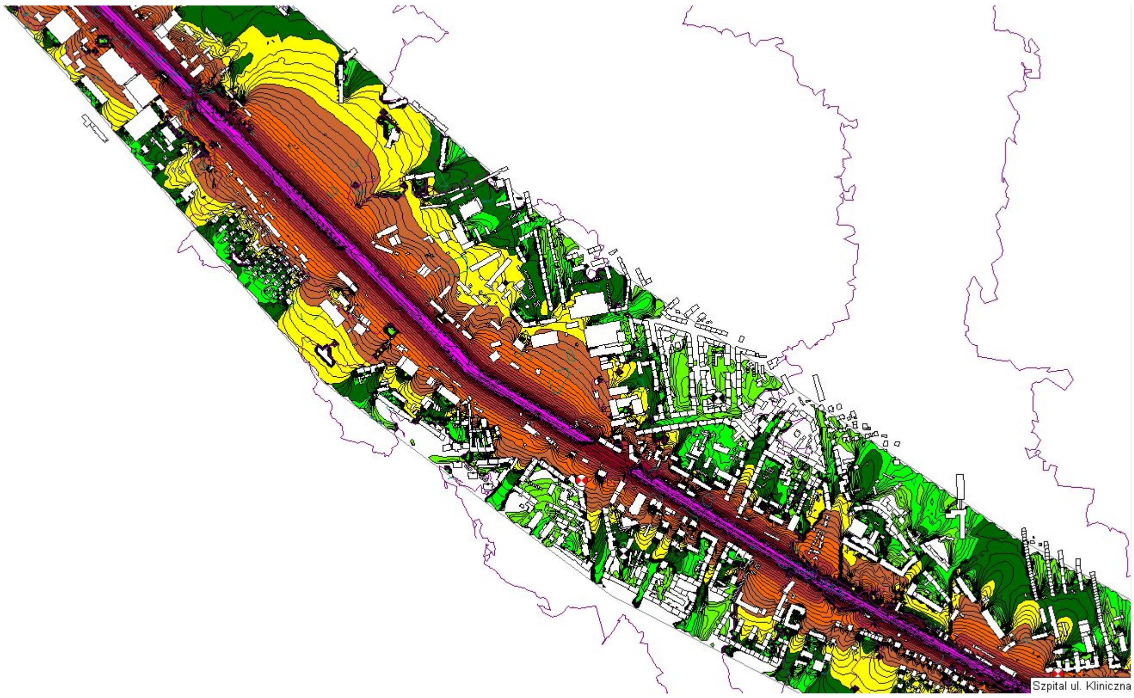

Fig. 2 Noise map L_{den} calculated for Gdansk Zaspa – Gdansk Wrzeszcz using SRM II

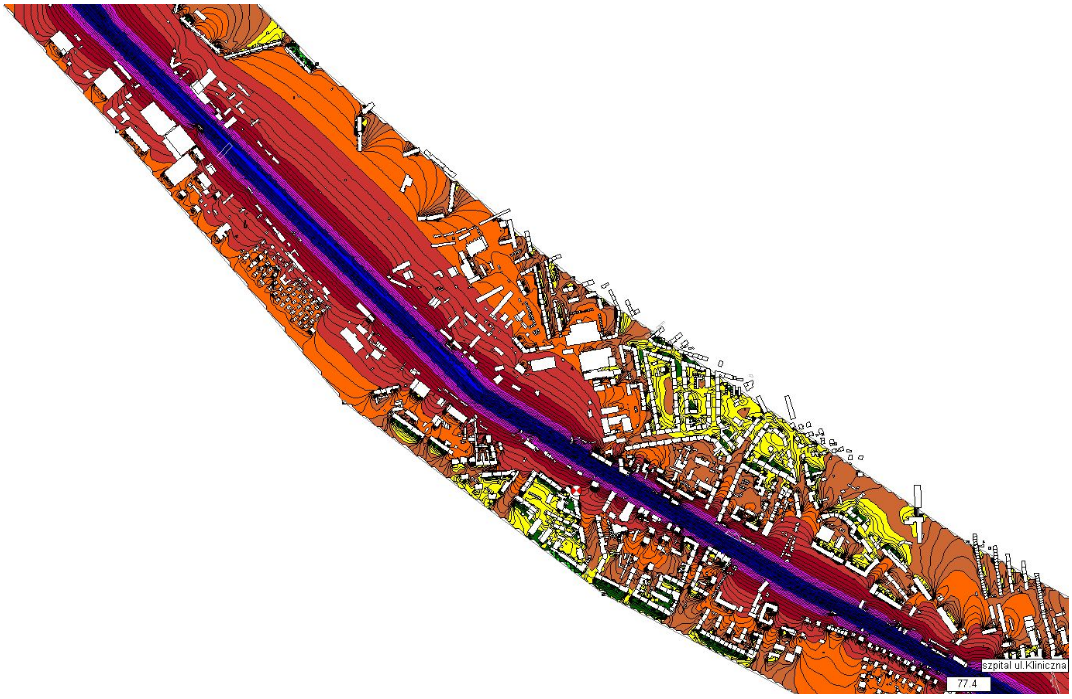

Fig. 3 Noise map L_{den} calculated for Gdansk Zaspa – Gdansk Wrzeszcz using NMT96

Another way to compare chosen methods of railway noise prediction is to match up maximum noise level (L_{max}) simulated for particular train pass-by in predefined receiving point. This can be achieved using "*Pass-By Level"* function of the Cadna A system. The comparison was used for three receiving points: Baltic Opera, hospital and Gdansk Oliwa. Table 3 shows the results of simulation for: 1) Intercity train, 310 meters long, 2) fast train, 163 meters long and 3) local, electric train, 60 meters long.

Receiver	**L_{max} [dBA] Level**								
	Intercity 310 m			**Fast train 163 m**			**Electric train 60 m**		
	Schall 03	SNR II	NMT	Schall 03	SNR II	NMT	Schall 03	SNR II	NMT
Oliwa houses	72.9	65.1	80.3	76.6	71.6	80.9	68.4	67.6	67.1
Hospital	81.6	64.1	90.8	86.7	78.4	91.9	82.8	77.9	79.4
Baltic Opera	75.4	61.9	82.9	79	67.1	83.4	72.4	64.7	69.6

Table 3 Maximum noise level from the passing-by train

The height of the measuring location was assigned at 4 meters. The main influences on the above results were the distance between the receiver and the track centerline and area specification. In all cases Dutch model has the lowest noise levels. Presented maximum noise levels were taken from simulation of temporary noise levels from pass-by of each train. Differences between noise levels values were related to the source noise. It is worth noticing that for various trains inaccuracies are similar for all described models. Simulated values for the Intercity train type are about 20 dB higher than the values obtained for the SRM II (Dutch model), and about 8 dB higher than values obtained for the German model. For the fast train deviation in both cases is lower, and for the electric train all deviations fit in 5-dB interval.

Another problem is to find relationship between noise level and the type of passing-by train. For this purpose simulations for two different train types with the same length (90 meters) and velocity were performed. Simulation of the first of the trains included diversified of speed, whereas single velocity was selected for the second type of train. The chosen velocities of the trains were 110 and 140 km per hour which are maximum speeds of those trains. Results obtained are shown in Table 4. The table clearly shows that the class of the train is an essential parameter for the Nordic model. For the Schall 03 and SRM II differences are very small, approx. below 1 dB. For all of the presented methods velocity was a fundamental parameter. In generated simulation for German model the difference between 110 and 140 km/h speed is 2 dB for both receiver locations, for the Dutch model this difference is equal to 3 dB for both receiver locations. The variation of noise level for two receiver locations for the latter mentioned model is higher than for the Nordic and German methods. It can be noticed that for the location called Hospital the difference was equal to 4.5 dB and for the Baltic Opera receiver was equal to 2.6 dB.

Receiver	**L_{max} [dBA] Level**								
	Fast train 90 m (speed [km/h])						**Fast train 90 m** (speed [km/h])		
	Schall 03		SNR II		NMT 96		Schall 03	SNR II	NMT 96
	110	140	110	140	110	140	110	110	110
Hospital	83.5	85.6	75.5	78.4	85.7	90.2	83.2	75.2	78.7
Baltic Opera	75.2	77.3	65.6	68.6	79.8	82.4	74.2	64.8	69.6

Table 4 Results of pass-bys for 90-meter long trains of different classes

5 Conclusion

In this paper some chosen national European models are analyzed. All these methods aim to define the sound source of railway noise in a different way. The Schall 03 method does not include frequency characteristics of noise, as well as atmospheric conditions. Noise sources are categorized according to train classes. The Nordic model is more dependent on physical mechanism of sound propagation than the German one. The SRM II model defines equivalent noise level for predefined atmospheric conditions. Furthermore, the last mentioned method requires information on percentage of braking time in entire time of a train ride. The model has been highly rated in terms of classification of railway noise prediction models. That is why this model was recommended to be used by countries without their own national method including Poland. Because of modernization of the Polish railways there is a clear need to have a prediction model which can simulate noise levels with a low inaccuracy. It is also essential to acquire information about the threat caused by lengthy exposure to high noise levels. Noise prediction models can be used to see in which way the planned reform of the railways will govern the environmental noise pollution. In this context, however the inaccuracies of the Dutch model should be better managed. The decisions which will be made will have long-term consequences for the future. If for example the SRM II model returns values that underestimate sound levels, railway solutions which will be constructed can give higher than allowable noise level.

If all countries use their own models there will be no possibility to compare results of noise prediction between particular countries. Simulations of the same situation would result in a different outcome. Because of this, it is impossible to indicate country with the lowest equivalent noise level basing on different models. Moreover, it is very difficult to say which of the models presented is the most suitable for given conditions and for a particular country. A solution of the above problems can be seen in the HARMONOISE – IMAGINE projects. The main advantage of such an approach may be its flexibility which may result in using methods implemented in all EU member states.

Acknowledgments

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References

[1] A. van Beek, M. Beuving, M. Dittrich, Work Package 1.2 Rail Sources – State of the Art., HARMONOISE technical report no. HAR12TR-020118-SNCF10, 5 August 2002.

[2] M.G. Dittrich, IMAGINE railway noise source model, default source data and measurement protocol, IMAGINE report IMA6TR-050912-TNO01, TNO, Delft,12 September 2005.

[3] Z.W. Engel, W.M. Zawieska, Environmental noise protection, noise threat in the year of Poland joining EU, 13th International Conf. on Noise Control, Gdynia 6-9.06 2004 (*in Polish*).

[4] Commission recommendation of 6 August 2003 concerning the guidelines on the revised interim computation methods for industrial noise, aircraft noise, road traffic noise and railway noise, and related emission data, The commission of the European communities, Brussels.

[5] Directive on the Assessment and Management of Environmental Noise, 2002/49/EC from June 25th, 2002.

[6] Environmental Protection Act of 27 April 2001 (*in Polish*), 2001.

[7] Aswin, Rail source database of The Netherlands, AEA Technology.

[8] M.Reiter, B.Kostek, Results of Noise Source Modelling for Polish Passenger Trains, 1st International Conference on Information Technology, Gdansk, 18-21 May 2008