IMPLEMENTATION PROBLEMS OF IMAGINE NOISE SOURCE MODEL FOR POLISH PASSENGER TRAINS

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ABSTRACT

The aim of this study is to check to what extent the noise source model implemented in IMAGINE project is applicable to Polish railway conditions. The analysis performed is a part of the project devoted to the monitoring of the environmental noise. The main objectives of the realized study include the IMAGINE noise source prediction model implementation based on reference data of that model. The model implementation is compared with the measurement results and discrepancies between prediction and measurement results are determined. Modeling is performed for the same measured atmospheric conditions. Problems of reference data that are not fully applicable to the Polish railway structure are described in details. Moreover, the problem of a proper assignment of the distance between the noise meter location and the track centerline is also discussed.

1. INTRODUCTION

Issues of the environmental management are widely discussed nowadays. The main tool used to provide information about noise threat is noise maps, which are based on noise prediction methods. However, if all countries use their own models it will be not possible to compare results of noise prediction between particular countries. Simulations of the same situation would result in a different outcome. It is impossible to indicate country with the lowest or the highest equivalent noise level, because of different models used. The problem lies in the definition of the modeled noise level, and parameters required for performing such predictions. A solution of the above problems can be seen in HARMONOISE – IMAGINE (***I****mproved* ***M****ethods for the* ***A****ssessment for the* ***G****eneric* ***I****mpact of* ***N****oise in the* ***E****nvironment*) European projects. The main advantage of such an approach may be its flexibility which may result in using methods implemented in all EU member states [1]. It assumes using one prediction method for every country in Europe, which may serve as a comparison tool showing levels from the lowest equivalent noise to the highest one in European countries. For that reason it is necessary to find out whether exists a universal noise prediction model which is applicable to each European country. This paper focuses on the IMAGINE railway noise prediction model applicability to the Polish railway structure and conditions.

To accurately calculate noise level there is a need to acquire all necessary data. Theoretically all parameters required should be measured to perform these computations, but in the technical documentation of the IMAGINE project [] some sets of parameters, used in case when measurements cannot be carried out, are also to be found. Such parameters can also supplement data acquired from measurements. In this study, the measurements were carried out in the Gdansk area. For the given locations all parameters related to noise prediction were measured. Moreover, the IMAGINE model was implemented in C++ programming language and on this basis computations were preformed. The prediction model was used to calculate the total equivalent noise level using various parameters from the IMAGINE project reference data. The results of the measurement and simulations performed for the Polish railway conditions show that if one prediction model is obligatory for all European countries, it should provide unequivocal data on the basis of which it would be possible to calculate noise maps. Therefore, the documentation of the IMAGINE project should be more detailed and supplemented with the data gathered from all countries.

1.1. IMAGINE PROJECT FOUNDATIONS

In 2002 European Directive 2002/49/EC was established. The goal of this directive was to assure homogenous treatment of noise problems in EU providing the methods of reduction, prevention and understanding the adverse effect of the noise [2]. According to the requirements of the directive, the EU member states are obliged to provide access to information on noise pollution to the society of each country to be aware of the scale of the problem. 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 for prediction of the railway noise. In IMAGINE – HARMONOISE projects [3] four main national European models are contained: Schall 03 developed in Germany, Dutch SRM II, the Nordic model engineered in Scandinavia and French NMPB-FER model. On the basis of these models a common European methodology is formulated [1]. The main IMAGINE parts are related to source and the propagation models. The first one is divided into particular source groups: road, railway, air and industrial. Computations based on this part result in noise level in a place of its generation. The propagation part enables to calculate noise level for the chosen distance from the source. This model is necessary to generate noise maps for any area.

The objective of the IMAGINE railway noise prediction was to provide a database system enabling the controlled acquisition, storage and extraction of disaggregated rail noise source information [4]. Moreover “the database was to be delivered with an initial measured dataset representative of the range of railway vehicles operating across Europe. In addition, default data, based on the combination of measurement and theory, was to be provided to assist the modeler in situations where appropriate measured data were not available” [4]. Within this framework such parameters as roughness of wheel and rail, and contact filter or parametric excitation were also added to definitions of noise as it was found that they are important factors of noise generation.

2. MEASUREMENT TESTS

The measurements were performed during the spring season. In Tab. 1 specification of measurement locations along with the results are presented. Each measurement corresponds to the single train passage. Temperature was approx. 8°C and air humidity 80 %. In performed tests the analyzer was set up at around 7 m distance and about 1.2 m height accordingly to the project assumptions. All parameters were written down during measurements. Some of them were estimated, for example train velocity was calculated from the pass-by time interval measured utilizing stopwatch. The outcome was the A-weighted equivalent noise level for a single pass-by.

Table 1 Specification of measurement points

No.	Train type	Length [m]	Pass-by interval [s]	Sleepers type	Velocity [m/s]	Measured noise level [dBA]
1	Electric, local	91	10	Concrete	9	71.46
2	Electric, local	61	6.5	Concrete	9.42	76.69
3	Passenger	61	6	Concrete	10.2	79.9
4	Fast train	163	10	Concrete	16.3	84.9
5	Electric, local	61	5	Wood	12.24	78.12
6	Electric, local	91	9	Concrete	10.11	83.03
7	Passenger	91	6	Concrete	15.16	80.6
8	Passenger	61	4	Concrete	15.3	81.06
9	Electric, local	91	8	Concrete	11.37	77.87

Another series of tests consist in continuous measurements. Tests were carried out for regular trains in two approaches. The results were A-weighted equivalent noise level. During the first period 20 trains were passing-by within 40 minute interval, and in the second one, there were nine trains. The level meter was set up at 20 meters distance from the track centerline. In addition, the measurement point was located 1.6 m above the ground surface. The measurements conditions for the continuous tests are shown in Tab. 2.

Table 2 Atmospheric conditions for both measurement series

Series – (Springtime)	1	2
Temperature	12 ^{o}C	10 ^{o}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	-

3. RESULTS OF SOURCE MODELING USING IMAGINE-HARMONOISE METHODOLOGY

As mentioned before, the IMAGINE model for the noise prediction was implemented in C++ by the authors of this paper. This was a basis of the computation for the trains passed by during the measurements. However it is a very problematic issue to compare measured values with the ones computed using the HARMONOISE model. Tab. 3 contains equivalent noise levels related to the railway: the first one is the measured value, the second one corresponds to the computed rolling noise level and the last one signifies the computed noise level including rolling, traction and aerodynamic noise. All values were obtained at the distance of 7.5 m from the railway.

Table 3 Comparison of computed and measured equivalent railway noise levels

No.	Train type	Equivalent noise level [dBA]		
		Measured	Computed rolling	Computed summary
1	Electric	71.5	82.8	92.05
2	Electric	76.7	84.6	93.79
3	Passenger	79.9	84.6	93.79
4	Fast train	84.9	83.9	87.19
5	Electric	78.1	85.2	93.88
6	Electric	83.0	83.5	92.05
7	Passenger	80.6	86.4	89.07
8	Passenger	81.1	88.9	91.44
9	Electric	77.9	83.5	92.05

As can be observed, discrepancies between measurement and computed noise levels are very high and ranged up to 20 dB for the total noise level (while including rolling, traction and aerodynamic noise). Some problems with the interpretation of these differences can be seen while taking into account that measurement tests were executed in various distances from the track centerline on which train was passing for each train (passing-by tests). In Gdansk, where the measurements were preformed, four rails belong to one track line in Gdansk. The analyzer was placed about 7.5 meters from the outer track line. Because of this it is essential to consider the difference between the real and the required distance. The estimation of the equivalent noise level L_{eq} for the first of measurement is described in a detail in another study by the authors [5].

Additionally, computations based on continuous measurements were performed. Because created software calculates noise level for a single passage, all noise levels computed for particular trains were energetically added[1]. In this case the assumption of the environmental noise level is required. In the above situations this value was measured and it was equal to 53 dB. Computation and measurement time intervals are the same and equal 40 minutes. Achieved results can be used just as an indication of the difference between the measurement test and computation results for a given period, they are presented in Tab. 4.

Table 4 Comparison of measurements and the L_{eq} computed

No.	Computed L_{eq}(r)	Measurement results [dBA]
1	75.91	68.57
2	68.03	65.74

For the second test the difference between results of modeling and measurement is lower than in the first case. This may be due to the accumulation of singular inaccuracies, however, the largest problem remains, namely utilizing the default data for model parameters. Real Polish railway conditions are different than the prediction model employed. This mainly concerns track and vehicle transfer functions and total effective roughness with the built-in contact filter for the particular wheel and the rail pair. However, there is no database with the reference data representative for Polish conditions, thus in Poland the IMAGINE reference data is often used, which causes discrepancies between reference and measured (acquired) data. For example for the train classification a set of predefined values from the Imagine database is used, i.e. the wheel diameter can be classified as: small (<500 mm), medium (500 – 800 mm) and large (> 800 mm) [4]. The last class contains diameters of 840 and 1200 mm. Following this, the diameter descriptor for both of the values mentioned belongs to one vehicle transfer function for this class. Such a problem exists also for the train length. Different settings belonging to the same prediction class result in differences between computation and measurement values. Such problems indicate a need to check how these parameters influence the equivalent noise level.

4. THE INFLUENCE OF REFERENCE DATA ON EQUIVALENT NOISE LEVEL

To check differences in the total noise level calculation caused by choosing not adequate wheel diameter, the equivalent noise levels for all eight train types (to be found in the IMAGINE []) was computed. Disparity between 1200 and 920 mm and 920 and 840 mm are shown in Figs. 1 – 6. These data were calculated for 90 meters train long, 15 m/s speed for EMU train type, wood sleepers and two rail joints per 100 m track. As can be observed, while using diameters of 1200 mm and 920 mm the maximum difference is about 0.25 dB, but for the conditions when diameters were of 920 mm – 840 mm, the difference was more than 2 dB. In addition, the gap between maximum and minimum noise level differences for brake types was calculated. For the braking system these differences were approx. 8.5 dB for each train type of 640 mm diameter, 7.75 of 840 mm diameter, 9.5 dB of 920 mm and 9.3 dB of 1200 mm for each train type. An example of calculations for 1200 mm diameter and NS6400 Dloco train is presented in Tab. 5.

Table 5 Differences in equivalent noise level for each ride type and brake type for 1200 mm diameter and NS6400 Dloco train

	CI	CI-Kblock	Kblock	Disc-Kblock	Disc
constant speed	92.53705	0.257	92.28004	0.001	92.28123
idling	92.38118	0.267	92.11448	0.001	92.11572
acceleration	92.80725	0.241	92.56618	0.001	92.5673
braking	101.37	9.289	92.08098	0.001	92.08222
curving	92.34968	0.267	92.08222	0	92.08222
Maximum – minimum (without braking)		0.026	-	0.001	-

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[1] Energy summing = $10\log(10^{x1/10}+10^{x2/10}...)$

where:

CI – cast-iron block-braked vehicles
Kblock – K-block braked vehicles
Disc – disc-braked vehicles
Yellow color refers to the difference between equivalent noise level for cast-iron block-braked vehicles and K-block braked vehicles for braking is marked yellow. This value is not taken into account in calculating the gap between maximum and minimum noise levels for CI and K-block braked vehicles differences.
Grey color – modeled equivalent noise level
Blue color – gap between the maximum and minimum differences between the equivalent noise level for cast-iron block-braked vehicles and K-block braked vehicles for braking

In following figures train types are marked as:

A – NS Mat64 EMU
B – NS 1700 Eloco
C – SNCF BB66400
D – SNCF CC72000
E – RENFE Dloco
F – NS6400 Dloco
G – TKOJ JT 42CWR
H – DM90 DMU

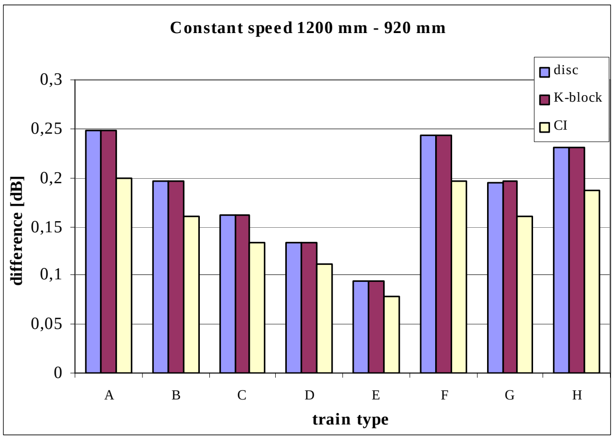

Figure 1. *Difference in the equivalent noise level for 1200 mm and 920 mm wheel diameters for constant speed*

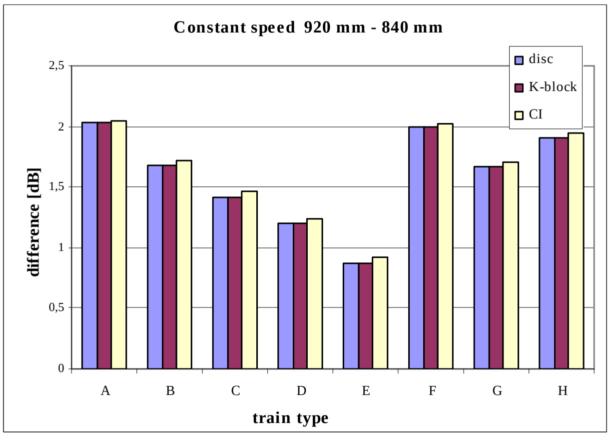

Figure 2. *Difference in the equivalent noise level for 920 mm and 840 mm wheel diameters for constant speed*

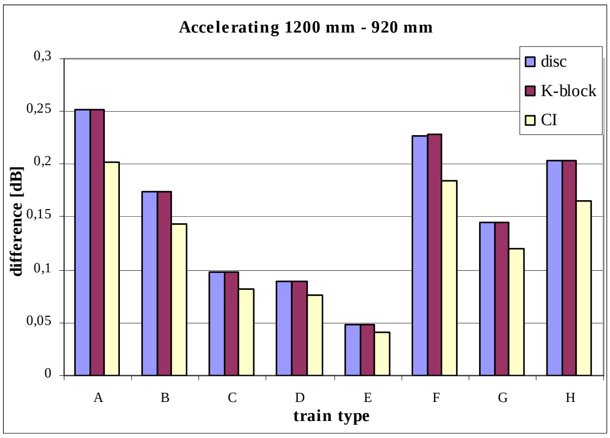

Figure 3. *Difference in the equivalent noise level for 1200 mm and 920 mm wheel diameters for accelerating*

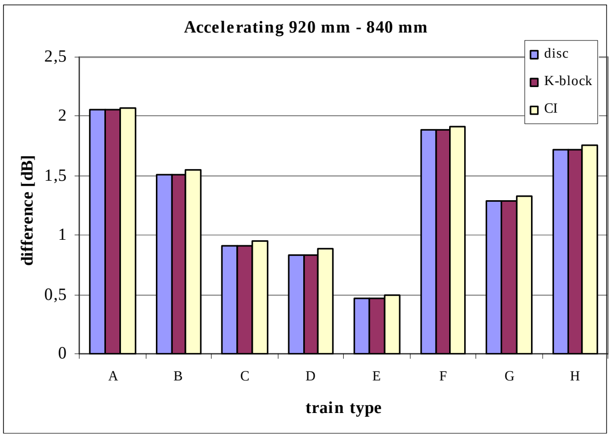

Figure 4. *Difference in the equivalent noise level for 920 mm and 840 mm wheel diameters for accelerating*

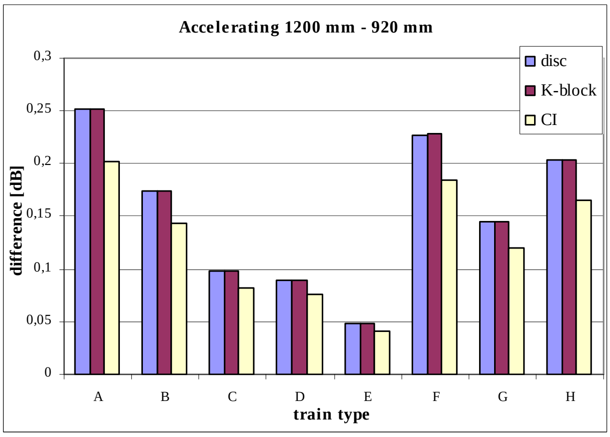

Figure 5. *Difference in the equivalent noise level for 1200 mm and 920 mm wheel diameters for accelerating*

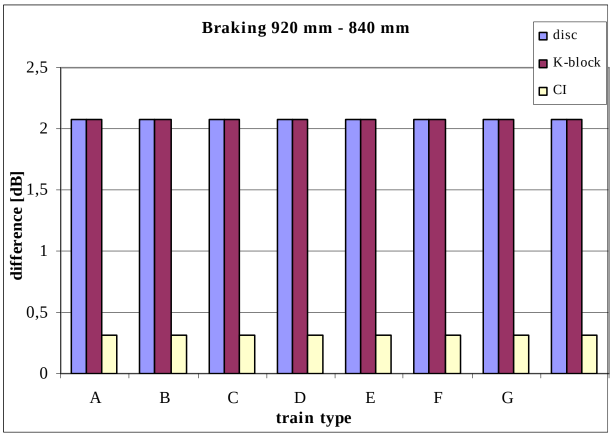

Figure 6. *Difference in the equivalent noise level for 1200 mm and 920 mm wheel diameters for accelerating*

As can be observed the discrepancy between levels for 1200 mm and 920 mm wheel diameters is quite small (approx. 0.3 dB), but differences for 920 and 840 mm are much larger. In this context the current wheel diameter classification which divides this parameter into three classes: small (<500 mm), medium (500 – 800 mm) and large (> 800 mm) seems to be inaccurate. In Figs. 7 and 8 the gap between maximum and minimum noise level differences for brake types of 920 mm and 1200 mm wheel diameter is shown. It is very important that differences between CI and K-block brakes are around 0.001 dB. On this basis it can be said, that it is important to classify brakes to either CI or to non CI classes for braking conditions. For other than braking conditions (i.e. constant driving or accelerating) the differences in the total noise level are very small, so there is no need to classify brake types into three categories: cast-iron, K-block and disc.

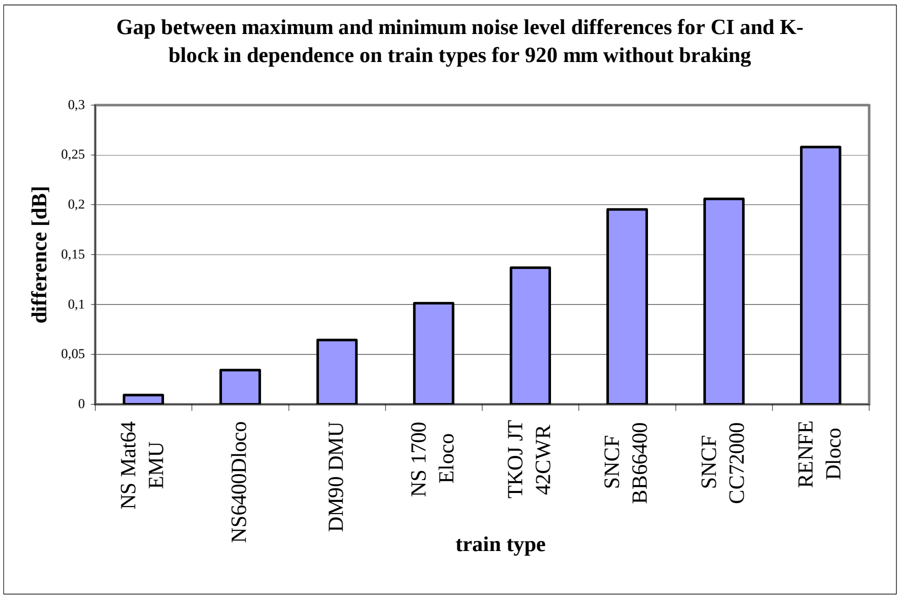

Figure 7. *The gap between maximum and minimum noise level differences for CI and K-block brakes of 920 mm wheel diameter (denotations as in Table 5)*

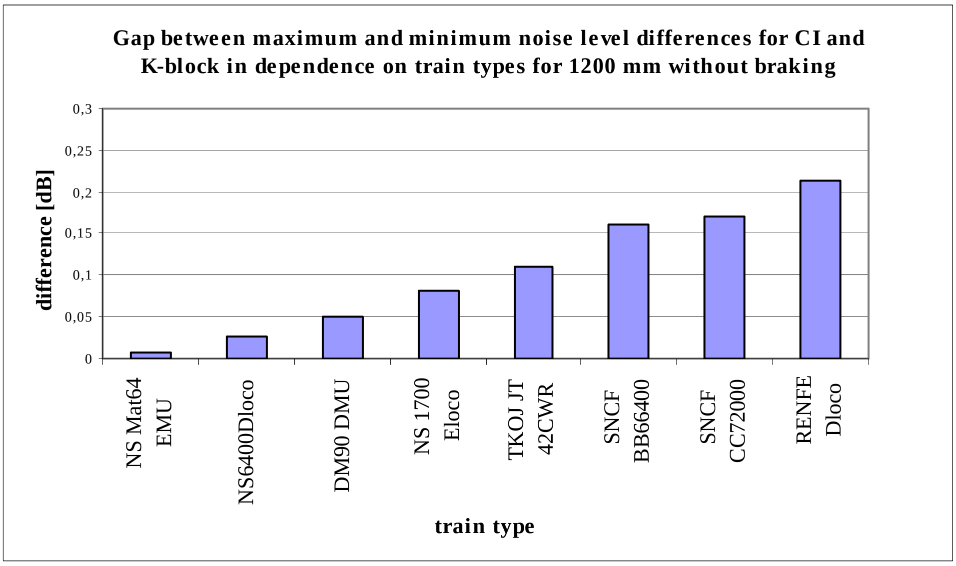

Figure 8. *The gap between maximum and minimum noise level differences for CI and K-block brakes of 920 mm wheel diameter (denotations as in Table 5)*

5. CONCLUSIONS

In this paper a discussion on problems related to applicability of noise source model contained in the IMAGINE project to Polish railway conditions was presented. In this study the IMAGINE project source model was compared with the measurement results performed for various train types and various track conditions in the Gdansk area. It should be pointed out that the modeling and simulation was performed for the same measuring atmospheric conditions. Then, differences between model prediction and measurement results were determined and probable causes for them were discussed. It was discovered that some of the problems are due to the assignment of the distance between the noise meter location and the track centerline, also railway features differs for the IMAGINE project and Polish railway conditions, thus they are not fully applicable to accurate describe railway structure in Poland.

6. ACKNOWLEDGMENTS

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