Assessing All Noise Sources In One Model Implementation Of INM And ECAC 3rd Edition in Noise Mapping Software

Fabian Probst, Antonio Notario

DataKustik GmbH, Gewerbering 5, 86926 Greifenberg, Germany
fabian.probst@datakustik.com, antonio.notario@datakustik.com

Legal circumstances, political motivations and technical reasons led in many countries to a separated approach for the calculation, assessment and handling of infrastructure noise caused by road and railway on the one side and the analysis of aircraft noise on the other side. Specific Research efforts analyzing the perception of noise led to guidelines like the German VDI 3722 (Effects of traffic noise/Characteristic quantities in case of multiple sources). Next to other approaches this guideline focuses especially on the annoyance of different noise types and derives a single number value, representing the overall perception of all noise sources, for each affected inhabitant. In order to enable an efficient overall evaluation of noise levels within urban areas, each infrastructural source must be handled within one noise model. The implementation of INM and ECAC 3rd Edition within Noise Mapping software opens various possibilities for an integrated approach to the noise assessment within cities.

INTRODUCTION

Thanks to the implementation of the European Directive about Environmental Noise 2002/49/EC, many countries implemented systems to control and manage the Noise Exposure caused by external noise sources. Noise indicators such as L_{DEN} and L_{Night} and their noise limiting values form the basis of such noise control systems.
But while noise indicators describe the exposure to noise, the relationship between them and the potential effects on health,- like annoyance, sleep disturbance or cognitive impairment- , is given by exposure – response curves which are derived from research into noise effects.
As annoyance is source dependent, the available dose – effect relations have been largely confirmed by later studies in the case of specific types of sources such road, railway and aircraft traffic separately. Unfortunately there is a lack of studies deriving exposure – response relations for the effect of multiple types of sources.
In addition, both calculation methods and limit values are set usually for each type of source separately. As an example, TNM (The US Federal Highway Administration's traffic noise model) and INM (US FAA's application for modeling noise around civilian airports) are different software solutions to calculate and manage road and aircraft noise separately.
However, parts of the population are exposed to more than one type of traffic simultaneously, and, although individual limit values may not be exceeded, the overall noise load may nevertheless be unacceptable because of the combined effects induced by the exposure to multiple noise sources. Therefore an integrated approach to the noise assessment is becoming an urgent need. Two challenges need to be addressed in order to achieve that integrated approach: first, the need of a single software platform to assess all types of noise sources, and secondly, the implementation of a procedure for the evaluation of influence of multiple types of noise sources on the inhabitants.

ASSESSING ALL NOISE SOURCES IN ONE MODEL

Use of different models versus an integrated software platform

As mentioned before, one of the main problems is that different software applications are developed and used to calculate and manage noise from different types of sources. This approach usually leads to several constraints, affecting both modelling workflow and analysis possibilities.

Assessing each type of noise source on different software implies building up as many separate projects as types of sources are present, although modelling tools and data import formats may be different on each program. Even if the same raw data is used to model all projects, certain software might need data simplifications due to size or calculation restrictions while others not. Finally, the user will need to set up as many different configurations of calculation as types of sources are present.

After calculation, resulting grids calculated by different software can be opened with any third party software and integrated afterwards by energetic summation. This is the case of TNM and INM software, which share the same NMPlot windows application for viewing and editing georeferenced grids. However, if the user carried out simplifications on the model in order to meet the individual software limitations, we can conclude that the resulting grids are not coming from the same situation. Also, the grid configuration should be taken into account. If the grid spacing has been set different (i.e. road noise map and aircraft noise map with different distance between receivers), the resulting grid will be inexact at certain positions due to extrapolation of values.

The ideal situation would be to integrate all relevant calculation methods in one professionally developed software platform. In such a way, further and continuous development of new software techniques wouldn´t be constrained, while acousticians can benefit from the wide range of possibilities to calculate and assess noise levels caused by all types of sources, individually or combined.

Compared to the In-house software development, where developers usually implement a calculation method and design an interface so users can manage it, professional software development efforts are faced to a common User Interface, where the calculation methods are implemented as modules through it. This way, the user can access all the modelling tools and import data formats available from a single work bench, and build one general model where all types of sources will be present.

Implementation of INM and ECAC Doc. 29 3rd Edition Noise Standards into a common software platform

From a technical point of view, the calculation of aircraft noise requires extremely good precision, so different experts performing any calculation at the same scenario must get the same result. In the case of INM, developers must integrate the methodology correctly into the software in order to get precise results. In addition, the software should seamlessly integrate all input parameter dialogs into the user interface, so when the user switches between calculation methods, the user interface adapts to his choice.

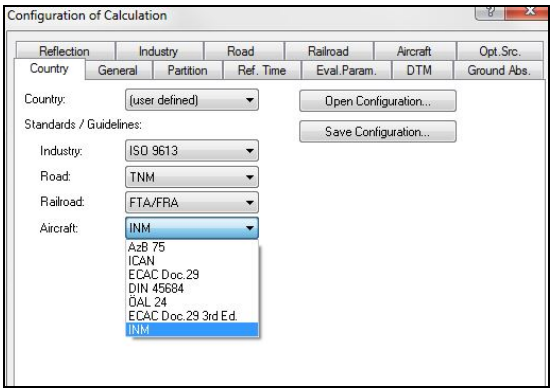

Figure 1a: Selection of the calculation standards from a common user interface

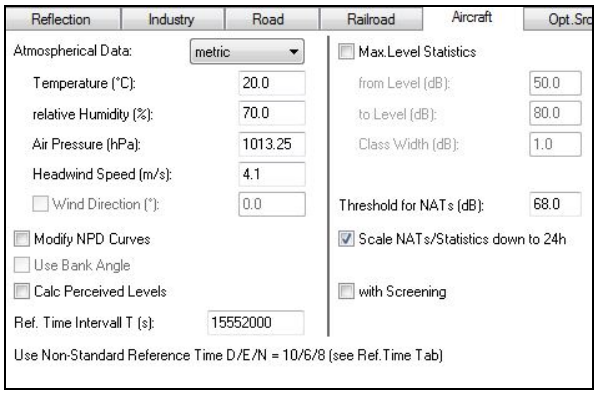

Figure 2b: Parameter input dialog adapted to the INM method

The software platform must allow the direct import of source data and even complete projects from INM software. Relevant data are the airport reference coordinates as well as the air routes.

Source data is directly imported from the Aircraft Noise and Performance (ANP) Database, an international data resource for aircraft noise modeling. The ANP database contains data about the aircraft groups, Noise – Power - Distance (NPD) relationships, spectra and performance data. All these data are used to calculate the final emission A-weighted level which will be applied in the calculation of propagation.

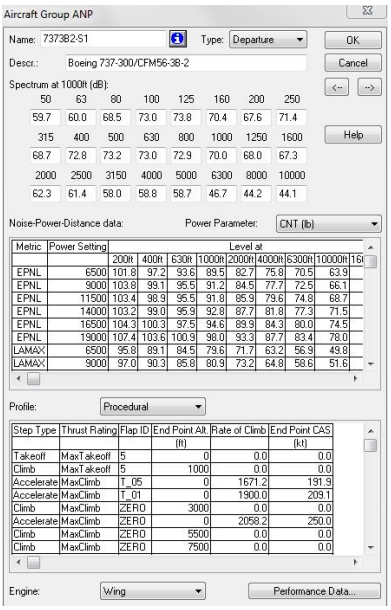

Figure 2a: Aircraft group selected from the imported ANP database

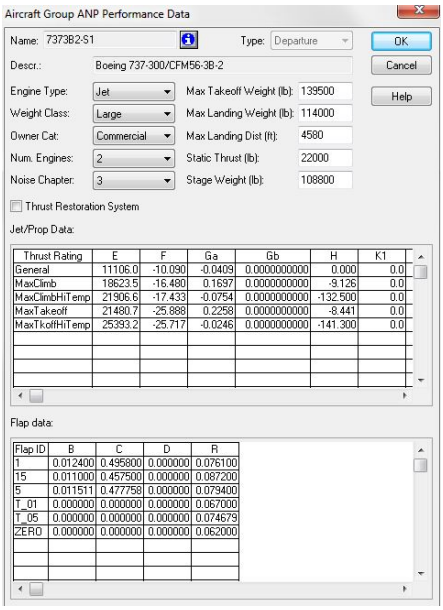

Figure 2b: Performance data parameters

Finally, operations – every aircraft taking off from, or landing into a certain track – need to be imported as well. Data is usually stored in a database (DBF format) but can also be imported from different RADAR systems.

Individual or combined assessment of noise sources in one model

During the execution of the calculation, all the present types of sources are simulated by following their respective calculation standards. After calculation, overall results are integrated and displayed in different ways: receiver points, grid contours, tables, etc. Overall results are important in order to investigate how much higher the effects of combined exposure to multiple traffic types are, compared to a scenario exposed to a single traffic noise source.

Noise Maps

Individual or combined noise maps can be delivered for the relevant evaluation parameters, without further post-processing by means of third party software.

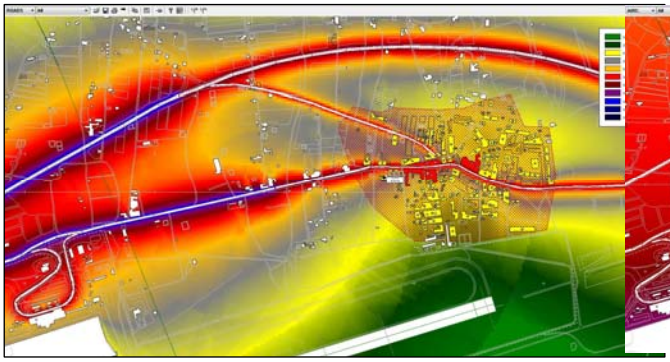

Figure 3a: Traffic Noise Map

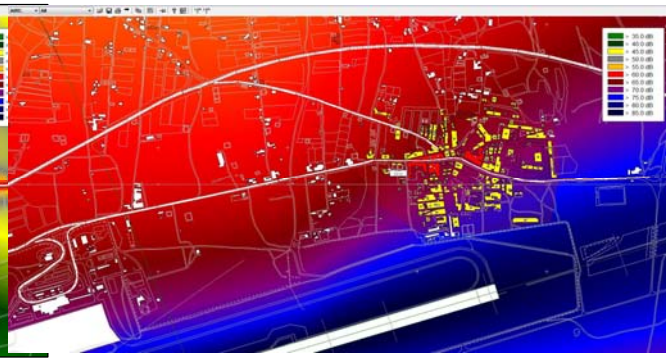

Figure 3b: Aircraft Noise Map

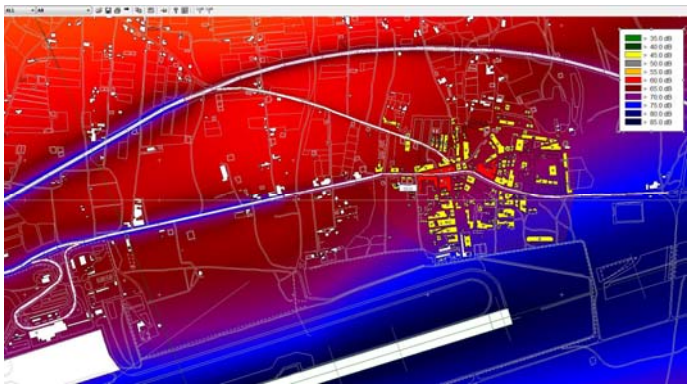

Figure 3c: Combined Noise Map (Aircraft + Road)

Noise Analysis at receiver points

While noise maps are mostly used to present and explain the noise situation to the public, calculation results at receiver points are extremely important as a baseline for the analysis and improvement of the acoustical situation at critical positions. Thanks to the integrated approach, receivers are not only showing the overall Sound Pressure Level, but also partial levels coming from different types of sources. In Fig. 4, a single receiver point with the overall and partial levels due to road and aircraft noise is shown:

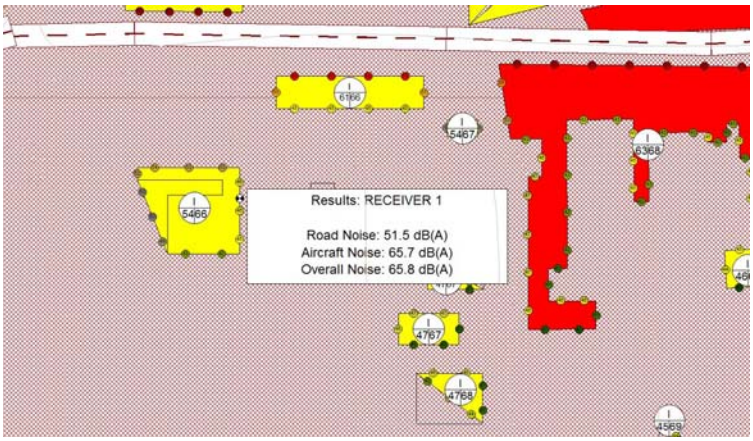

Figure 4: Calculation results at an individual receiver

Results at receivers can be comprised in dynamic tables which can be updated automatically after recalculations.

Result Table

Close | Edit... | Sync. Graphic | Copy... | Print... | Font... | Help

RECEIVERS	LAND USE	LIMITING VALUES			CALCULATED VALUES			EXCEEDING			ACTION REQUIRED?		
Name		Road - Day	Aircraft - Day	Overall - Day	Road - Day	Aircraft - Day	Overall - Day	Road - Day	Aircraft - Day	Overall - Day	FHWA	FAA	Joint Solution
		dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)			
RECEIVER 1	III	55	67	69	51.6	65.7	65.9	-	-	-	NO	NO	NO
RECEIVER 2	III	55	67	69	44.9	66.2	66.3	-	-	-	NO	NO	NO
RECEIVER 3	III	55	67	69	60.0	68.6	69.1	5.0	1.6	0.1	YES	YES	YES
RECEIVER 4	III	55	67	69	49.9	66.0	66.1	-	-	-	NO	NO	NO
RECEIVER 5	III	55	67	69	45.0	67.1	67.1	-	0.1	-	NO	YES	NO
RECEIVER 7	III	55	67	69	56.9	63.6	64.4	1.9	-	-	YES	NO	NO
RECEIVER 6	III	55	67	69	56.9	63.4	64.3	1.9	-	-	YES	NO	NO

Figure 5: Table of results at different positions

These tables give the most important information in order to know what type of noise source is exceeding the limits, how big the exceeding is and whether further actions are needed (including who should be in charge of). If new planning scenarios are included, the result table will show the predicted results accordingly after an updated calculation.
In conclusion, assessing all noise sources in one model by means of an integrated approach proves to give an extended range of analysis possibilities, while avoiding loss of important data, as for example, partial levels at receivers.

Assessment of the effect of multiple types of sources within urban areas

From a practical point of view, indicators should be easy to explain to the public so that they can be understood intuitively. National and International regulations and standards use as indicators A-weighted equivalent continuous sound pressure levels, which are related to day and night separately and represent the acoustical situation over a long time period. For all sources these Leq levels are compared with defined limiting values in order to check fulfilment of legal requirements.

However, the relation between Leq levels and the adverse effects on health is not straightforward, especially over the night. Firstly, the correlations between indicators like the Lnight and some long - term effects on health such as cardiovascular disorders can be established more easily. But effects such as the sleep disturbance are mainly instantaneous effects, and therefore are better related to maximum levels per event.

Secondly, each individual type of source has a different impact in the relationship between Lnight and health effects. For example, road traffic noise is characterized by a high number of events and low levels per event, while aircraft noise has fewer events but much higher levels per event. Due to a higher number of events, road traffic noise will lead to more awakenings per night, but smaller effects on health than aircraft noise. Finally, the effects of different types of sources appearing jointly have been rarely investigated. The main reason of that is the high number of possible combinations of types of sources, but also it is due to the fact that the effect of the same combination of types of sources could be different between day and night periods.

Based on exposure-response relations for particular types of sources the purpose of standards such as VDI 3722-2 is to provide procedures for the evaluation of influence of several of these types of sources on the inhabitants. These procedures comprise methods to estimate the total annoyance and sleep disturbance based on effect equivalent continuous sound pressure levels for the different types of sources.

Calculation of substitute levels for total impairment by multiple sources

The calculation procedure described in 1 and developed by Miedema is used to determine the total annoyance (%A), high annoyance (%HA), self – reported sleep disturbance (%SD) and high self – reported sleep disturbance (%HSD), from the energetic addition of the effect equivalent continuous sound pressure levels of the single types of sources. Here, road traffic is selected as reference quantity and therefore, a substitution method is used to convert the effect levels for different types of sources (air or rail traffic) to levels of road traffic noise for the same effect. The equivalence of effects is expressed by the percentage of impaired persons, (i.e %A). The method is illustrated in Fig. 6:

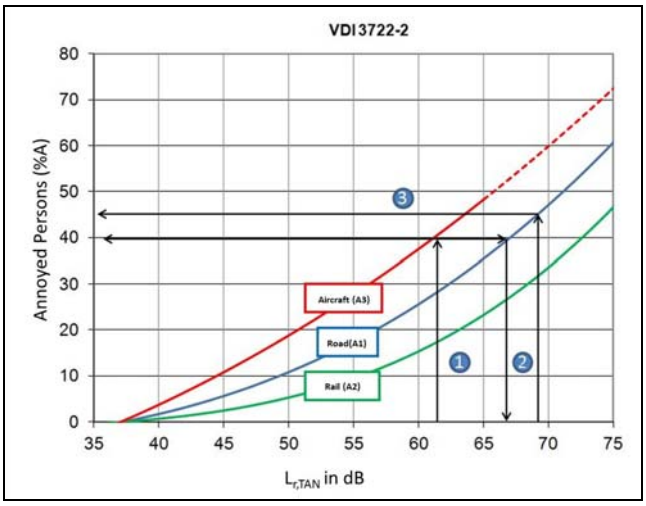

Figure 6: Determination of a renormalized substitute level for an aircraft noise level of 61 dB

In this case, for an aircraft noise level of 61 dB, the percentage of annoyed persons is 40%. Then, the substitute level (value of aircraft exposure resulting in reference to road traffic noise to the same value of annoyed persons) is 67 dB. Finally, substitute

levels are energetically added to calculate the Effect Related Substitute Level (LAES). Assuming a road traffic noise level of 65 dB, the Effect Related Substitute Level is 69 dB approximately. This value corresponds to an approximated percentage of annoyed persons of 45%.

Determination of characteristic quantities in case of multiple exposure

The method described in VDI 3722-2 has been implemented in 6, and therefore the characteristic quantities annoyance (%A), high annoyance (%HA), sleep disturbance (%SD) and highly sleep disturbance (%HSD) can be calculated in a simple way. To illustrate the procedure, a test case has been built including road, rail and aircraft sources as well as two buildings, where a number of residents are included as input data.

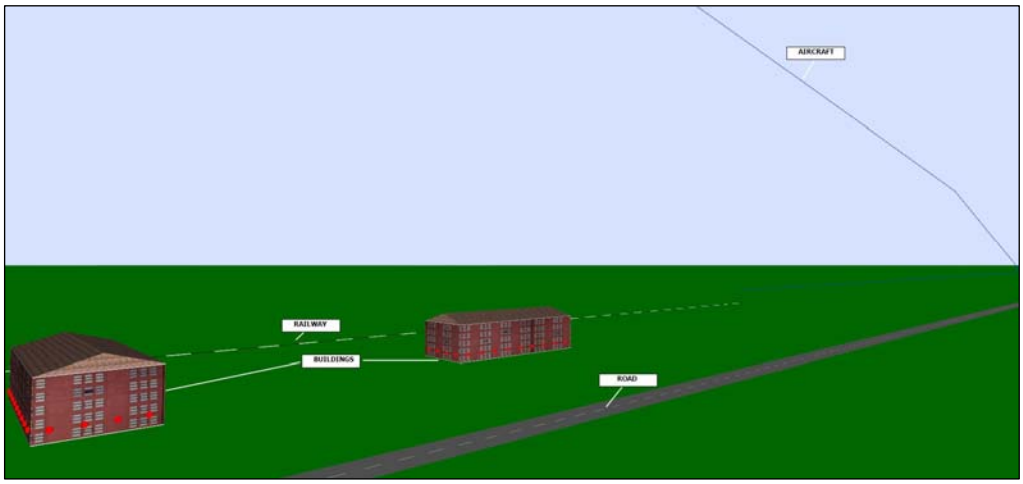

Figure 7: Test scenario

Each type of source is included into a different variant and the evaluation parameters Lden and LNight are then calculated for each type of source. After calculation, results are written on every building receiver. The next step is to calculate the characteristic quantities by opening the Multiple Source Effect dialog. This dialog enables the evaluation of different scenarios with respect to noise impact. The evaluation is based on the levels Lden and Lnight at facade points and on the number of inhabitant of the buildings.

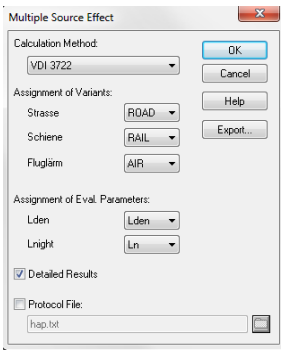

Figure 8: **Multiple Source Effect dialog**

When the present different types of source have been selected, and the OK button is pressed, the evaluation starts and generates the parameters Annoyed Persons (%AP), highly annoyed Persons (%HAP), Sleep disturbed (%SD) and highly sleep disturbed persons (%HSD), considering the noise impact of the selected source types. Results are written as attributes at each building and they can be shown and post processed in different ways. From the test case, a post processing example for the building Nr. 1 is shown in Fig. 9:

Building Nr. 1 (Number of Inhabitants : 45)

Receiver	Inhabitants / receiver	L_{DEN} Road	L_{DEN} Rail	L_{DEN} Air	L^*_{DEN},rail	L^*_{DEN},air	LA_{ES}	%A,road	%A,rail	%A,air	%A,tot	A
1	1,70	60.9	44.5	57.5	40.8	63.6	65.5	27.2	2.3	32.6	36,60	0,62
2	1,70	60.9	44.6	57.6	40.9	63.7	65.5	27.3	2.4	32.7	36,60	0,62
3	1,70	60.9	44.8	57.6	40.9	63.7	65.5	27.3	2.4	32.7	36,60	0,62
4	1,70	60.9	44.9	57.6	41.0	63.7	65.5	27.3	2.5	32.8	36,70	0,62
5	1,70	60.9	45.1	57.6	41.2	63.7	65.5	27.3	2.6	32.8	36,70	0,62
6	1,70	60.9	45.2	57.6	41.2	63.7	65.5	27.3	2.6	32.8	36,70	0,62
7	1,70	60.9	45.3	57.7	41.3	63.8	65.6	27.4	2.7	32.9	36,80	0,63
8	1,70	60.9	45.4	57.7	41.4	63.8	65.6	27.4	2.7	32.9	36,80	0,63
9	1,70	60.9	45.6	57.7	41.5	63.8	65.6	27.4	2.8	32.9	36,80	0,63
10	1,70	57.8	60.4	57.7	53.9	63.8	65.1	21.8	16.0	33.0	35,70	0,61
11	1,70	57.3	60.8	57.8	54.3	63.9	65.1	21.1	16.6	33.1	35,70	0,61
12	1,70	56.9	61.2	57.8	54.7	63.9	65.1	20.5	17.1	33.1	35,70	0,61
13	1,70	56.6	61.7	57.8	55.3	63.9	65.2	19.9	17.9	33.2	35,70	0,61
14	1,70	32.7	64.9	57.8	58.5	63.9	65.0	0.0	23.1	33.2	35,50	0,60
15	1,70	32.6	64.9	57.8	58.5	63.9	65.0	0.0	23.1	33.2	35,50	0,60
16	1,70	32.6	64.9	57.8	58.5	63.9	65.0	0.0	23.1	33.1	35,50	0,60
17	1,70	32.6	64.9	57.8	58.5	63.9	65.0	0.0	23.1	33.1	35,40	0,60
18	1,70	32.6	64.9	57.7	58.5	63.8	64.9	0.0	23.1	33.1	35,40	0,60
19	1,70	32.6	64.9	57.7	58.5	63.8	64.9	0.0	23.1	33.0	35,40	0,60
20	1,70	32.6	64.9	57.7	58.5	63.8	64.9	0.0	23.1	33.0	35,30	0,60
21	1,70	32.6	64.8	57.7	58.5	63.8	64.9	0.0	23.1	32.9	35,30	0,60
22	1,70	32.7	64.8	57.7	58.5	63.8	64.9	0.0	23.1	32.9	35,30	0,60
23	1,70	56.1	61.6	57.6	55.2	63.7	64.9	19.2	17.8	32.8	35,30	0,60
24	1,70	56.6	61.1	57.6	54.6	63.7	64.9	19.9	16.9	32.8	35,30	0,60
25	1,70	57.1	60.6	57.6	54.2	63.7	64.9	20.7	16.3	32.7	35,30	0,60
26	1,70	57.6	60.2	57.5	53.7	63.6	64.9	21.6	15.7	32.6	35,40	0,60
												15,86

Figure 9: Percentage of annoyed persons (%A) – Building Nr. 1

From Fig. 9, the result of the building Nr.1 shows that approximately 16 residents out of 45 are annoyed by the effect of multiple sources. Annoyance by source type is also calculated. The lowest rates of annoyance caused by the different types of source are associated with residents near to the opposite facade to the sources. Therefore, inhabitants at receivers from 1 to 9 are less annoyed by rail traffic, while residents linked to receivers from 14 to 21 are not annoyed by road traffic noise.
As it is shown above, the assessment of all noise sources within one noise mapping software and the idea to express complex combined noise effects on health by a single number value, open a wide range of possibilities in the scope of city planning.

REFERENCES

VDI 3722-2:2003 Effects of traffic noise/Characteristic quantities in case of multiple sources, (2013)
European Environment Agency: Good practice guide on noise exposure and potential health effects. Copenhagen, (2010)
World Health Organization: Night noise guidelines for Europe. Copenhagen, (2009)
Probst W., Huber B., Vogelsang B. - ICAN – Instruction for the calculation of aircraft noise and for noise mapping around Airports, ICSV 2009, Krakow, Poland, July (2009)
Directive 2002/49//EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise, Official Journal of the European Communities, L 189/12 -25
CadnaA: “Computer Aided Noise Abatement”, software developed by DataKustik GmbH, www.datakustik.com