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Uncertainty of noise mapping software

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Noise map is a tool to come to noise policy and especially to an action plan. The most important question connected with noise mapping realized by computational methods is about reliability of results. It is closely connected with quality of input data and calculation algorithms and their parameters. An influence of elements location, buildings height and number of vehicles accuracy on calculated results was considered in first stage. Before implementation of Harmonoise/Imagine P2P algorithms there are differences between various software. The paper presents first results from investigations with two commercial prediction programs. The absolute accuracy (uncertainty) of predicted by software sound levels is very difficult to quantify because an uncertainty in the measurements. The main result of investigations is a table of differences in sound level calculations related to variation of input data (geometry of objects and acoustic parameters) and calculation algorithm.

1 Introduction

In the first round of action plans results only from calculation software are used so the question about accuracy of results is the most important question. Because economic impact of plans is very significant there will be probably many reservations or objections regarding noise control decisions.

2 END accuracy guidelines

END requires results which are sufficiently accurate that dividing them into discrete 5dB(A) wide sets is appropriate process. It means that absolute accuracy should be within 2dB(A) of the actual value [1].

For the Harmonoise/Imagine reference model, an overall accuracy was defined for the full L_{DEN} assessment, which is half the accuracy as for the engineering model. For the reference model the following accuracy, expressed in terms of the expected standard deviation in the predicted noise levels should be reached [2]:

- ± 1 dB for free field and distances up to 100 meters,
- ± 2 dB for flat terrain and distances up to 2000 meters,
- ± 5 dB for mountaineous terrain and built up urban areas.

Such numbers “not seem to be very ambitious values, it is felt that this already a big improvement compared to the existing models” [2].

The most important question connected with noise mapping realized by computational methods is about reliability of results. It is closely connected with quality of input data and calculation algorithms and their parameters. It is shown in Table 1 that only expensive methods of data collection can realize END accuracy guidelines:

Toolkit No	Possible accuracy		
	Inexp.	Med.	Exp.
2: Road traffic flow	4 dB	2 dB	0,5 dB
5: Road surface type	3 dB	1 dB	0,5 dB
13: Ground surface type	3 dB	2 dB	1 dB
14: Barrier heights	2 dB	1 dB	0,5 dB
15: Building heights	3 dB	1 dB	0,5 dB

Table 1 Possible accuracy depending on costs [3]

Process of collecting input data for noise mapping is not only expensive but also difficult and time-consuming. But some kind of data is more important than another, so one can accelerate such process and reduce costs by classify data acquisition from the most to least important. Difficulty is connected with fact that importance depend on arrangement of elements and is different e.g. for open space and urban areas.

3 Sources of uncertainty

Within any modeling system designed to reproduce a real word environment, such as software for noise mapping, there are four sources of uncertainty to be considered [3]:

1. **input uncertainties** – estimation of uncertainty in model inputs and parameters (involve a study of each of the various types of data required to construct a noise map);

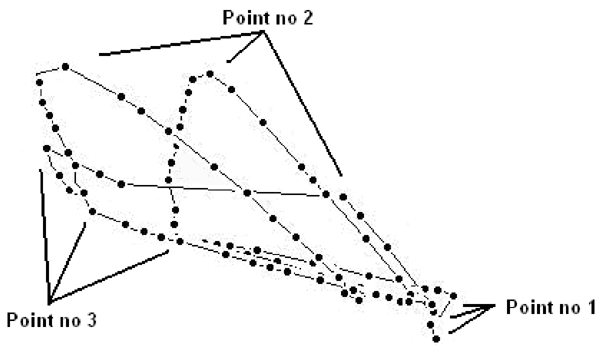
2. **uncertainty propagation** – estimation of the uncertainty in model outputs resulting from the uncertainty in model inputs and model parameters;

3. **model uncertainty** - uncertainty associated with different model structures and model formulation;

4. **uncertainty in model predictions** resulting from uncertainty in the evaluation data.

In this paper uncertainties type 2 and 3 are considered.

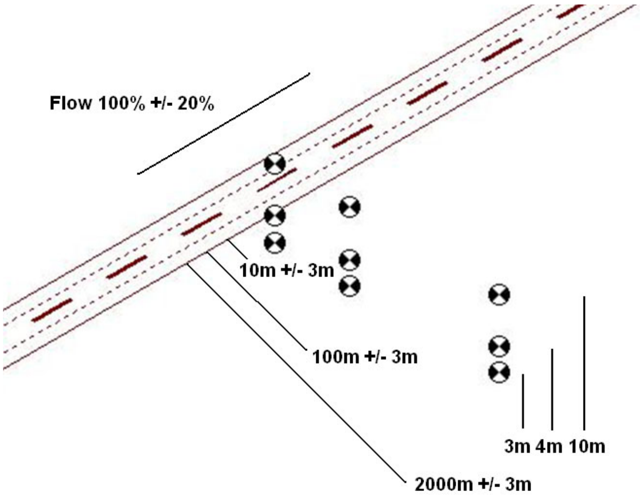
Receiver position indicated by GPS can be a good example of input uncertainty. Many tests with commercial GPS equipment took place and results are not completely repeatable. In Fig.1 the same path between three points in open space is presented – noticed differences are about 3-5m. In this paper arbitrarily selected 3m error is considered.



.Fig.1 Differences in GPS indicated positions.

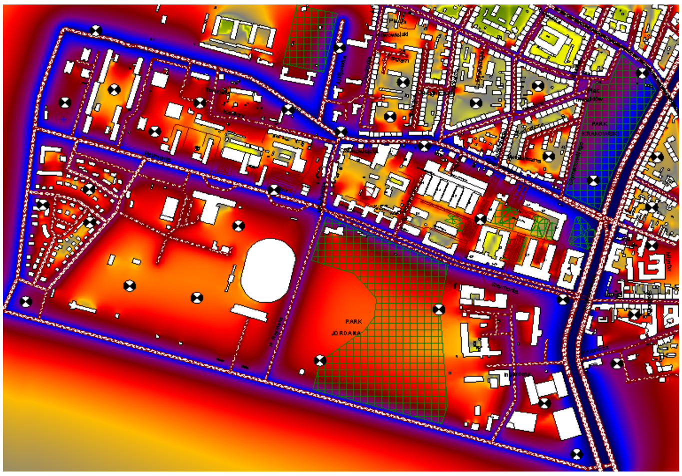
4 Experiment

All experiments are connected with estimation of type 2 and 3 uncertainties. Accuracy (uncertainties) in distances or vehicle flow are arbitrarily selected. For example one of the simplest test is presented in Fig.2:



.Fig.2 The simplest test of model multi-input uncertainty estimation (uncertainty propagation).

In was assumed that vehicle flow estimation is made with ±20% error and receiver position was specified with ±3m margin. Next calculations for all combinations of flow and receiver distances for 3 receiver heights were made using two commercial software. After several dozen simple configuration tests for real urban area presented in Fig.3 took place.



.Fig.3 Model of real urban area.

5 Results

Results are presented in table form for each experiment. For example in Table 2 maximum calculated differences are presented – it is clear that the biggest value is for distance change of the nearest receiver:

Receiver height	Car Flow	Distance from road with GPS accuracy 3m		
		10 m	100 m	2000 m
3 m	80%	**2,9 dB**	0,4 dB	0,1 dB
	100%	**2,9 dB**	0,3 dB	0 dB
	120%	**2,9 dB**	0,3 dB	0 dB
4 m	80%	2,7 dB	0,4 dB	0,1 dB
	100%	2,8 dB	0,4 dB	0 dB
	120%	2,7 dB	0,4 dB	0 dB
10 m	80%	1,5 dB	0,4 dB	0 dB
	100%	1,5 dB	0,5 dB	0 dB
	120%	1,5 dB	0,4 dB	0 dB

Table 2 Maximum differences between calculated values of L_{DEN} for one software

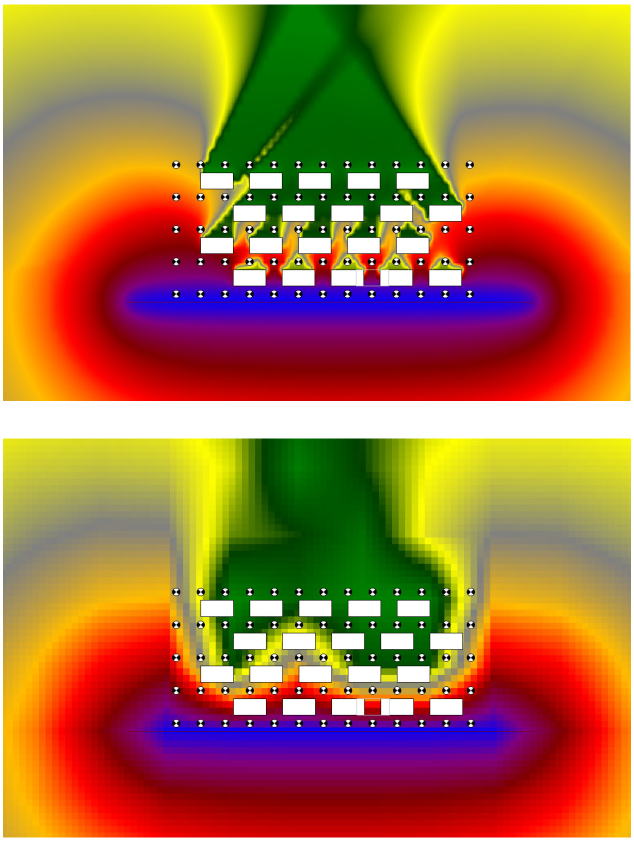
But results from next experiment show that there are differences between software:

Receiver Height	Car Flow	Distance from road with GPS accuracy 3m		
		10 m	100 m	2000 m
3 m	80%	0,3 dB	0,1 dB	**3,4 dB**
	100%	0,2dB	0,1 dB	3,3 dB
	120%	0,2 dB	0 dB	3,2 dB
4 m	80%	0,2 dB	0,1 dB	**3,4 dB**
	100%	0,2 dB	0,1 dB	3,3 dB
	120%	0,2 dB	0 dB	3,3 dB
10 m	80%	0,2 dB	0,2 dB	3,3 dB
	100%	0,1 dB	0,2 dB	3,2 dB
	120%	0,1 dB	0,2 dB	3,3 dB

Table 3 Maximum differences between calculated values of L_{DEN} for two software

They calculate near the same values for 10m and 100m distances but for 2000m difference is outside END limits.

During comparison of results special type of error has occurred - error in shape of equal L_{DEN} areas:



.Fig.4 Grid-dependent shapes of equal L_{DEN} areas.

A value of error is connected with grid size but concerns only graphical appearance, values calculated in points are correct.

6 Conclusions

After several dozen from hundreds of designed experiments already noticed that:

- results from various software are different – the maximum difference is even more than 10dB. Calculated results depend on experience of software user,
- calculation software should be improved especially in input data interface and calculation options (all input data should be tested e.g. buildings height – if one is much more higher than others or has 0m height – question to user about it, number of vehicles should be controlled – e.g. information about no car data on roads or car number addition from access roads, number of reflections should be selected by software, grid sizes should vary and should be optimized and selected automatically by software),
- the absolute accuracy (uncertainty) of predicted by software sound levels is very difficult to quantify because an uncertainty in the measurements,
- it is necessary to build comparable, good documented urban area in order to test various software.

An influence of input data inaccuracy on calculated values depends on acoustic elements configuration (open space, urban area etc.).

For example in some cases reliable data about road surface type are more important than buildings positions:

Parameter	Type	Possible error [dB]			Error
		<1	1-5	>5	ΔL[dB]
Sound sources position	geom.				11,7
Number of reflections	alg.				7,0
Buildings height	geom.				5,0
Road surface type	param.				4,5
Calculation standard	alg.				3,9
Buildings positions	geom.				3,4
Number of vehicles	param.				3,0
Road type	param.				2,6
Buildings cross-section sizes	geom.				2,4
Road width	geom.				0,2
Vegetation	param.				0
Residents numbert	alg.				0

Table 4 Table of differences in sound level calculations related to variation of input data - geometry of objects (geom.), acoustic parameters (param.) and calculation algorithm (alg.)

Such tables designed for typical configurations should shorten preparation time of input data.

It seems that in the first round of noise mapping calculation software should be used rather for calculation of differences in L_{DEN} after modifications (e.g. barriers height, vehicles flow) than accurate values of L_{DEN}. It seems also that monitoring system with long term L_{DEN} calculation should be obligatory part of noise mapping. Such solution is necessary not only for calibration of prediction software but especially for real-time noise mapping system.

References

[1] The Department for Environment, Food and Rural Affairs (Defra), Research project NAWR 93: "WG-AEN's Good Practice Guide And The Implications For Acoustic Accuracy." (2005)

[2] Imagine Project. Available from http://www.imagine-project.org/

[3] European Commision Workin Group Assessment of Exposure to Noise (WG-AEN) Position Paper "Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure Version 2." (2006)