

## IMPLEMENTING PREDICTION STANDARDS IN CALCULATION SOFTWARE - THE VARIOUS SOURCES OF UNCERTAINTY

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Uncertainty in noise prediction is usually thought of being related to the accuracy of the input data and the accuracy of the prediction method. This paper addresses another important source of uncertainty that is related to the (un)clearness of the prediction method and the choices software engineers have to make while implementing ambiguous prediction algorithms. This paper also makes recommendations to avoid these uncertainties

There are 2 important steps needed for a calculation:

- 1 - Converting multi purpose digital data into calculation data
- 2 - Calculation of the noise level according to a prediction standard

Until digital data became available, paper maps were used. As most prediction standards only describe infinite thin screens the acoustic expert decided what the locations of these screens were. Nowadays GIS-data is available and most software can read GIS-data. This saves considerable time in the modeling process and avoids the uncertainty due to manual inaccuracy and subjective interpretations. However the conversion of multi-purpose GIS-data to noise prediction data is not standardized, and therefore is a source of uncertainty.

Tests done in the 90's prove that different cooks (developers) cook (program) differently with the same recipe (standard). Similar experiences were made more recently in commercial application where several products had been used on the same project, leading to differing prognosis. Implementing regulations into software will always imply some interpretation. Due to this, prediction results of different software products might have a bias as well as random deviation.

### 1 Introduction

Uncertainty in noise prediction is usually thought of being related to reliability of the input data and accuracy of the prediction method. The main source of uncertainty is considered to be the input data. The text 'garbage in is garbage out' is well known and refers to the quality of the input data. This paper will not go into the input data as such but will focus on the implementation of the prediction method itself.

The prediction method has some expected accuracies due to:

- Scope of application (range, situation, purpose, resulting levels, model complexity, worst-case or average).
- Level of understanding of the physics of sources and propagation at time of development.
- Expected form of implementation of the method at time of development (hand-calculations, spreadsheet, single source-receiver combination, 3D multi-point model).

- Clarity of documentation (description, details, test cases).

During validation the accuracy of the prediction method is defined. However if the method is not described precisely enough and contains ambiguous algorithms it will be open for different interpretations. Another interpretation will give other results for the models used for the validation. The accuracy of the method is therefore also depending on the quality and clearness of the document describing the method.

For the implementation of a method the software engineer and the acoustic engineer team up together to make a correct interpretation of the method. In practice most prediction methods contain ambiguous algorithms. Examples will be given in the next chapters. Most often the acoustic engineer will decide how the algorithms should be interpreted. However sometimes it is not clear to the acoustic engineer either. In those cases a call upon the writers of the method must be made. This proves not to be an easy task. In practice there is very little support on prediction

methods provided by the authorities and most questions remain unanswered.

One striking example of an unclear definition can be found in the IL-HR-13-01 method regarding the calculation of the screening effect of multiple screens as shown in the figure below.

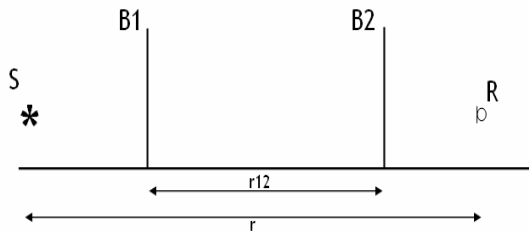


Figure 1: Unclear definition of screening effect of multiple screens ( $r_{12}/r \gg 0.1$ )

In the text it is written that “in case the distance between the barriers divided by the distance between source and receiver is much larger than 0.1 ( $r_{12}/r \gg 0.1$ ), method x should be used otherwise method y”. Without additional information it is obvious that this phrase will lead to many different implementations and different results.

Seen from a software point of view the problematic issues regarding the implementation of a prediction standard can be related to one of the following topics:

1. How to convert multi purpose digital data into calculation data
2. How to interpret ambiguous calculation algorithms of the prediction standard

Examples for both topics will be given in the following pages.

## 2 The various ways of converting digital data into calculation data

Until digital data became widely available the acoustic expert used paper maps. This introduced uncertainty due to manual inaccuracy and subjective interpretations. However the way the data was entered into the software matched very closely with the standard. For example, as most prediction standards only describe infinite thin screens the acoustic expert decided what the locations and dimensions of these thin screens were. Nowadays GIS data is more available and more standardized and most software can read GIS-data. The conversion to calculation input data is now done automatically by the software. This saves considerable time in the modelling process and avoids the uncertainty due to manual inaccuracy. However the conversion of multi-purpose GIS data to noise prediction data suited for the numerical algorithms is

not standardized yet, and therefore is still a source of uncertainty. In the following text some examples are given to show the challenges software engineers have to meet.

### 2.1 Location and dimensions of barriers

In the ISO 9613 method it is written that an object that has a closed surface without any large gaps and with horizontal dimensions larger than the wave length shall be represented by a barrier with vertical edges giving single diffraction. Lacking however is the exact definition of ‘object’, ‘barrier’, ‘large gaps’ and the location of the resulting barrier. Therefore it is also not clear if 2 houses that are separated by a narrow passage should be seen as 1 object or 2 objects. As a consequence different interpretations can lead up to many dB’s difference in results.

### 2.2 Location and dimensions of reflecting obstacles

In the ISO 9613-2 method it is written that reflections are from outdoor ceilings and more or less vertical surfaces, such as facades of buildings. These reflections shall be calculated in obstacles that meet certain requirements. One of the requirements is that the surface is large enough compared to the wavelength. Although the numerical equation belonging to this requirement is well defined, the exact definition of the dimensions and location of a surface of an obstacle is missing. If a building has extensions or if a row of buildings are not situated in a straight line the ISO is open for interpretation. As a consequence different interpretations can lead up to many dB’s difference in results.

### 2.3 Ground reflection

According to formula (11) of ISO9613 influence of the ground reflection is defined by the distance between source and receiver as well as the height of each of them above terrain.

For large rooftops or podium constructions it will be a matter of interpretation within the software as well as the decision of the engineer of how to describe his model.

### 2.4 Flat terrain issues

Quite often wording and descriptive graphics of the regulation will only consider flat terrain.

The software will then have to adapt the suggested logic to complex terrain. This may effect practical

issues such as the reflective behaviour of a reflector standing on a slope, has the lower edge to be recognized or will there be reflection beneath the terrain level?

## 2.5 2D or 3D method of projection

The method of projection is indicated in several regulations as a means to segment line sources. Seen in the perspective of the receiver, barriers are projected onto the source line. Though this is always described by 2-d examples it should be handled as a 3-d problem in the software. For road that are on a climb this can e.g. lead to distinguishing road sections with free propagation, single diffraction and multiple diffraction. The software should best apply barrier projection in 3-d, even distinguishing single and multiple screening.

## 2.6 Location of ground-reflected beams

In NMPB a strategy is shown that will help to define to locate the position where the two potential ground-reflected beams hit the terrain surface. Applying this in a situation with high rising buildings and steep hills, such as in Hong Kong, will lead to a position that is placed even behind the building and not within the terrain between receiver and source.

## 3 The various interpretations of ambiguous and unsteady algorithms

### 3.1 Segmentation of line sources

Some regulations avoid the segmentation of source lines by working with slant distance and aperture angle. In RLS 90, NMPB and others however we are requested to segment a line source. There are 3 principle strategies commonly used:

1. Segmenting at constant length with source representation in the centre of each segment. (Not discussed further, as it combines the risk of unsteady results and high calculation effort for larger noise mapping projects).
2. Method of projection  
Here, seen from the receiver, all obstacles are projected on the line source. In case there are no obstacles to project, segmentation will only have to obey the regulation's rule, such as e.g. "no segment should be larger than  $0.5 * \text{distance}$  between receiver and segment centre point". In that case, at the programmer's choice, the software can now start splitting the source at either end or at

the slant position. Each approach will already lead to slight differences in results.

3. Ray tracing at constant increment of angle  
Segmentation will depend on the orientation of the source and this will influence results.

All three methods can be used within the limits of the regulation but will give different results. Let us just consider a plane terrain and no obstacles between source and receiver.

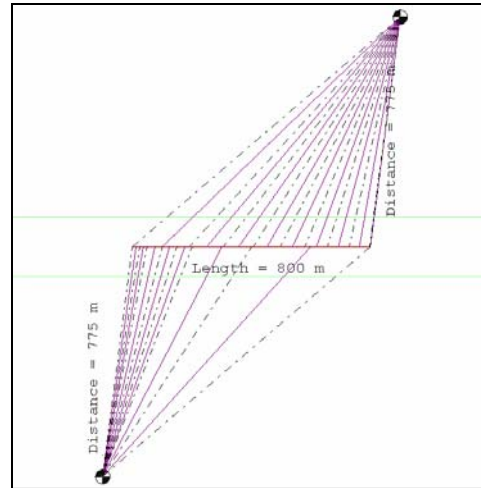


Figure 2: Segmentation of a plane terrain without obstacles

In the example shown above, Receptor A has been calculated using the  $0.5 * \text{distance}$  criteria and for B a constant increment of 5 degree was used. Differences in result seem almost insignificant, i.e. 0.05 dB. Next grid results were compared for a 3000 x 3000 (m) area, using a 10 m grid increment giving 90601 grid points. In this very clear case the 2 methods, each working within the limits of the regulation, showed differences in mean value of 0.14 dB standard deviation of 0.57 dB.

Next we add two rows of buildings at 50 m distance to the road. Each building is 30 m long and 12 m wide and there is a 50 m gap between the buildings as shown in the figure below.

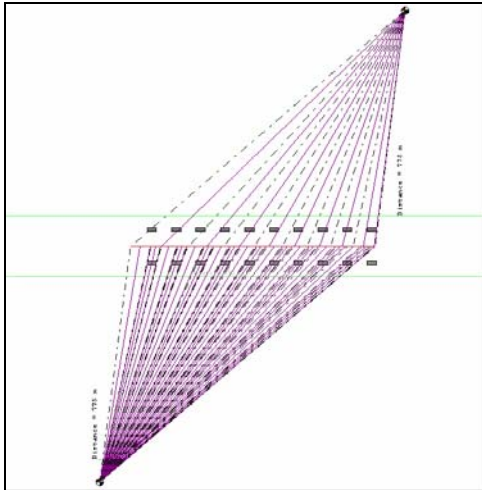


Figure 3: segmentation of a plane terrain with obstacles

Just by chance method 3 (constant angle increment) hits a number of buildings and the gap emission is underestimated. In method 2 (projection) all gaps are properly recognised. For the two symmetric receptor points this leads to a difference of 38.0 dB against 40.0 dB. As the regulation RLS 90 does not demand any splitting of the source according the obstacles that are found between source and receiver, both results need to be seen as valid and it is difficult to see how a reference value could be defined.

Again a 10 m grid calculation was performed and method 3 was compared against method 2 giving a mean value of -0.26 and a standard deviation of 2.32.

The effects that have been demonstrated could be avoided with the help of a few more definitions in regulations. The way a line source is segmented, especially in the presence of barriers, will also influence the standard deviation that is calculated for variations in receptor positions.

Propagation formulas widely refer to a point to point logic. It will lead to more steady results when the software introduces the point presentation of sources as late as possible in the process of geometric analysis.

### 3.2 Area Source representation

If a regulation only demands the software to split up area source into representative points, being points that represent an area with the maximum diameter less than 1/2 the distance from receiver to the centre of the area, this will open up a wider range of conform results as well.

Alternatively the software might use a line source representation for the areas in combination with the method of projection.

Further to this the software might keep the representative geometry constant, taking the risk of an increased calculation effort, or it will reshape and reduce the representative geometry when the receiver is at a larger distance. The later technique will potentially imply jumps in the barrier effect for neighbouring receptor positions.

As expected the line presentation of the area does produce more steady results and both procedures are acceptable according to regulation. For both approaches an automatic variation of receptor positions was performed. For 299 randomly chosen positions inside the calculation area the grid receptor position was varied by +/- 1 m in X as well as Y direction.

In both cases the average met the value of the centre position, but in the case of the point source presentation the average gradient was more than twice as high. Also the standard deviation was 0.43 dB instead of 0.23 dB for the line representation of the area.

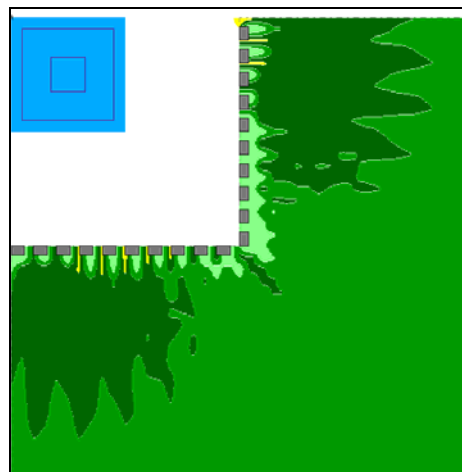


Figure 4: Line source presentation

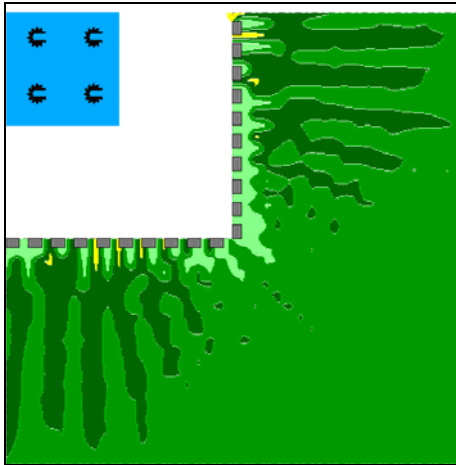


Figure 5: Point source presentation

### 3.3 Single or double diffraction

In the ISO 9613 method it is written that “double diffraction will occur in the case of thick barriers and/or well separated objects”. However the exact definition of ‘thick barriers’ and ‘well separated objects’ is not given. As the maximum barrier attenuation for double diffraction is 25 dB and for single diffraction 20 dB, different software implementations can lead up to 5 dB difference in results.

### 3.4 Side diffraction around vertical edges of barriers

Side diffraction is described by a graphical example, implying that the side detour shall be considered orthogonal to the vertical plane of propagation. Also the fact that the regulation only describes side detour for a simple screen, in the past led to the interpretation by one commercial software supplier that only situations need to be considered where there is just one single screen on the propagation path. Orthogonality is not mentioned in the text of ISO 9613. So we suggest a side diffraction should be recognized for the combined barrier situation of a larger small and a long but low barrier. In extreme cases the difference may be in the range on 20 dB.

### 3.5 Reflections

The way reflections against vertical surfaces are to be dealt with, is rarely well described. For most of the methods it is up to the software developers to decide whether reflected paths that have their reflection point above the reflecting surface, will have a contribution to

the total noise level. Whether ray curvature should be taken into account in most cases is not clear.

### 3.6 Barrier effect

In case of more than one diffracting edge within a propagation path, the barrier effect is to be taken into account only from the object that gives the highest screening effect in the absence of all other diffracting objects (RMR-SRM2). Since this may vary among the different octave bands, it should be specified whether this choice applies to each of the different mid band frequencies, or that it should be evaluated by the total contribution from this propagation path. Both methods will differ in result.

### 3.7 Height above terrain

In most methods the ground reflection is based on a formula that used the source and receiver height above terrain. A large roof or podium construction is a perfect substitute for the terrain, so shall the software relate the height above ground to the artificial object?

### 3.8 Ambiguous phrases

Phrases like “in case of parallel objects use this formula” or “in case the distance between the barriers is much larger then distance  $x$  use formula  $y$ ” (IL-HR-13-01) in the text of regulations are of no help unless a tolerance is defined as well.

### 3.9 Length related values

When regulations define a quality of a line or area as a length related value this will lead to different interpretation depending on the segmentation of the input data or any automated geometry analysis. Examples are:

“30% gaps along a road” as limit for a canyon situation (RLS 90)

“2 switches per 100 m” as description or rail quality (SRM2)

## 4 Conclusion and recommendations

### 4.1 Conclusion

Prediction standards should give reproducible results. However it proves out that implementing regulations into software implies considerable interpretation. The main causes are unclear and missing definitions. Although some text in a prediction standard might look logical from an acoustical point of view it quite often is

not clear and ambiguous seen from a software point of view. In many cases a call upon the writers of the method does not solve the problem. Most Prediction standards also lack appropriate information on how to convert 3D multi purpose digital data to calculation data. These aspects lead to uncertainty regarding the accuracy of a method. As a result prediction results of different software products will have a bias as well as random deviation.

## 4.2 Recommendations

- The making of a new calculation standard should be a cross discipline collaboration with a team across the following skills: Acousticians, GIS experts, software developers and mathematicians.
- The group developing the standard should
  - Provide the digital model data that is used for the validation.
  - Provide the source code of the software used for the validation of the method.
  - Provide 2 kind of test cases:
    - Idealized data matching the algorithms in the method. E.g. thin screens, exact location of sources etc.
    - Non idealized multi purpose GIS data
  - Provide support and helpdesk on the method for users and software engineers
  - Provide regular updates of the method
- A way of validating conformance with methods is required. This could be the Nordic self-declaration (reference) approach.

## 5 Bibliography

- [1] ISO 9613-2, *Attenuation of sound during propagation outdoors*, International standard, 1996
- [2] RLS 90, *Richtlinien für den Lärmschutz an Straßen*, German standard, 1990
- [3] IL-HR-13-01, *Handleiding meten en rekenen industrielawaai*, Dutch standard, 1981/1999
- [4] NMPB/XPS 31-133, *Calculation of road traffic noise*, French standard, 1995
- [5] RMR-SRM2, *Reken en meetvoorschrift railverkeerslawaai*, Dutch standard, 1996