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# Noise assessments using low-cost software: Possibilities and pitfalls

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This paper deals with the practical use of low-cost software in assessing and, in particular, mapping noise. The assessment process is divided into five main steps: 1) Evaluation of the noise situation; road traffic noise, noise from rail bound traffic, wind turbine noise, shooting range noise, etc. 2) Conditioning the input data using low-cost software. The emphasis will be on topography and buildings. 3) Using a corresponding software noise model. 4) Output data conditioning using low-cost software. 5) Noise maps and other graphical plots using low-cost cartography software. The main output data from the noise model is regular or non-regular arrays of computed dB-values. For noise contours these arrays must be interpolated / gridded in some way. Two different ways of such gridding are briefly discussed, showing typical variations and pitfalls. The process is similar to the corresponding process using off-the shelf software but the steps have to be done separately using stand-alone tools, yielding a less automated but in some instances a more flexible and cost-effective way to do the noise assessment tasks.

## 1 Justification

Typically, maps of environmental noise are made using costly software. For a small organisation (e.g. a small acoustics consultancy company) the software cost may prevent the organisation from undertaking such tasks, even though it has the required competence. This paper shows that e.g. noise mapping may be done using several low-cost softwares *used together*, each accomplishing a step in the overall process.

## 2 Noise assessment process

### 2.1 Applicable noise situations

The method outlined in this paper applies to assessing of all kinds of noise. It has been applied for a diversity of noise map areas, ranging from city blocks to medium-sized cities as well as large rural areas surrounding wind parks. The sole limitation of the software implementing the noise computation method itself is that it must include a means for exporting the numerical results in electronic file(s) of suitable format, e.g. ASCII or spreadsheet. The method may also be applied in small-scale mapping, e.g. mapping noise *within* industrial buildings, as well as mapping of measurement data.

## 2.2 Conditioning noise model input data

**Topography**

Nowadays, topographical information of the area of interest is available as digital terrain models / digital maps in GIS (Geographical information system) files. Typically this information is collected, kept and maintained by a local, regional or national authority. The topographical data may be supplied by the authority or by the customer requiring the noise map. Typical file formats are Shapefiles and DXF-files.

**Buildings**

Noise mapping requires information on the *location, outline and height* of any buildings within the area under assessment. This information should, for any practical size of a noise mapping area, be available as GIS files or CAD (Computer-aided design) files. Not all buildings are *noise-sensitive*. Thus, information *classifying the buildings* into dwellings, hospitals, public buildings, warehouses, office buildings, etc. is required. Noise mapping larger areas require such supplementary information to be available in GIS files, whereas a small area may be noise mapped using manually building classification based on knowledge of the area. Experience tells us that, at least as far as Norwegian data for building classification is concerned, the quality of the classification is highly variable. This uncertainty, of course, gives rise to an uncertainty in the number of noise affected inhabitants, etc. If possible, the building classification should be checked prior to use in noise mapping.

**Other crucial data**

3D information on noise source geometry (e.g. centre lines for roads & railways, wind turbine hub heights, buildings & point sources on industrial activity sites, point sources on construction sites, etc.) must be available, either in GIS / CAD files or by other means.

**Noise model input data**

The noise model may require one or several file format conversions or other conditioning prior to importing the input data mentioned above. Usually, these conversion tasks may be done in software readily at hand. For instance, conversion from the Norwegian digital map file format SOSI to Shapefiles is a simple and quick process.

## 2.3 The noise assessment model

*Any* software, computing tool or measurement giving the required noise indicator in *any* point in space may be used. The points may be in a grid (a rectangular array of values, regularly spaced), irregularly spaced points, in points of particular interest or a combination of these situations. Examples of software include spreadsheets or noise prediction tools. The software must, of course, implement the relevant and approved computation method for the noise assessment under consideration. The uncertainty of the method should be documented. In case of measurements, the measurement position in three dimensions must be known.

**Example: Noise model producing regularly spaced data (grid)**

Let us say a noise model produces regularly spaced data, as exemplified in Table 1.

Table 1: Predicted noise in 15 regularly spaced (50 m spacing) assessment immission points

| Assessment point | | | Noise |
|---|---|---|---|
| **Point ID** | **Easting [m]** | **Northing [m]** | **$L_{den}$ [dB]** |
| C1R1 | 327850 | 6617950 | 53,6 |
| C2R1 | 327900 | 6617950 | 51,9 |
| C3R1 | 327950 | 6617950 | 50,6 |
| C4R1 | 328000 | 6617950 | 50,3 |
| C5R1 | 328050 | 6617950 | 49,9 |
| C1R2 | 327850 | 6617900 | 63,6 |
| C2R2 | 327900 | 6617900 | 54,8 |
| C3R2 | 327950 | 6617900 | 54,0 |
| C4R2 | 328000 | 6617900 | 53,1 |
| C5R2 | 328050 | 6617900 | 52,5 |
| C1R3 | 327850 | 6617850 | 67,0 |
| C2R3 | 327900 | 6617850 | 65,1 |
| C3R3 | 327950 | 6617850 | 59,1 |
| C4R3 | 328000 | 6617850 | 57,2 |
| C5R3 | 328050 | 6617850 | 55,6 |

A noise contour map representing the predicted noise in the area may look like in Figure 1.

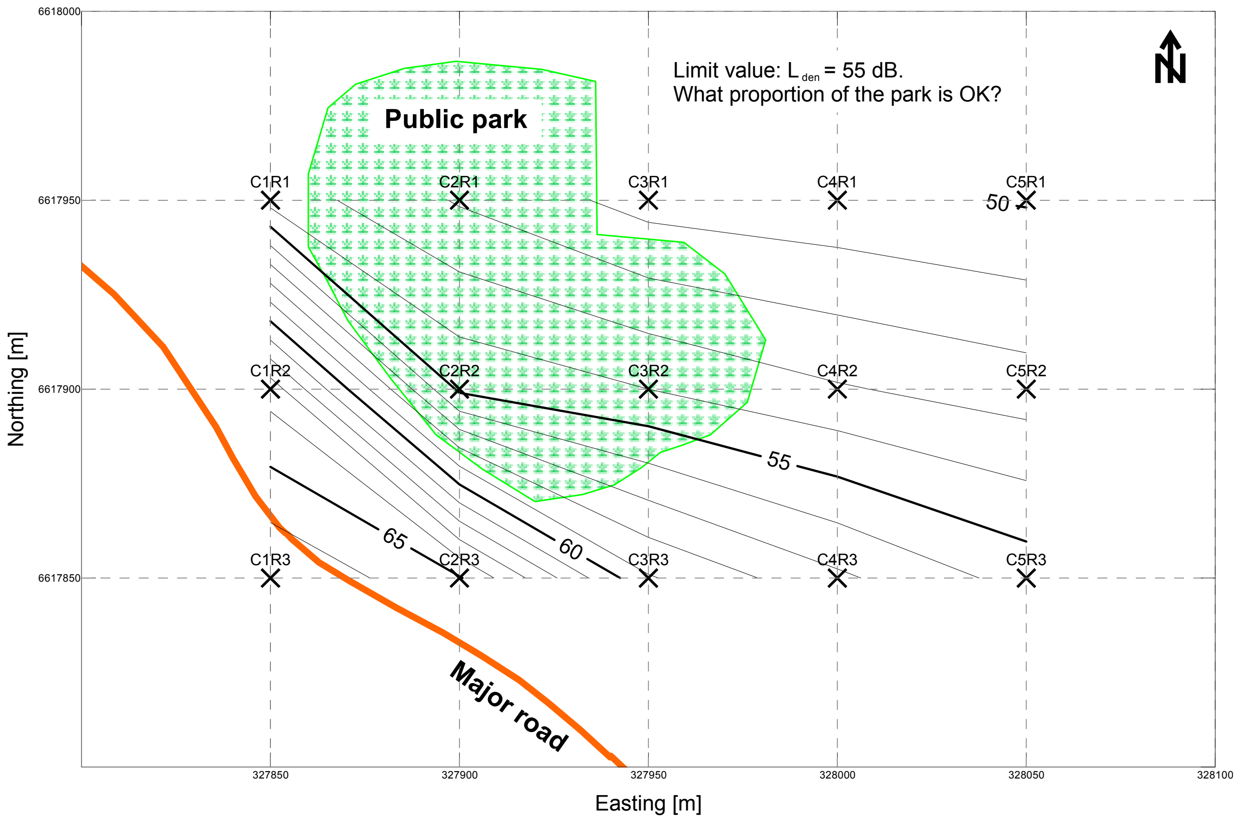


Figure 1: Noise contour map resulting from a (too) coarse computation grid. Calculation points spaced 50 m, no further interpolation. Noise contours of the noise indicator $L_{den}$ are shown in black. Calculation points are marked by crosses.

Here the noise consultant is asked to assess the road traffic noise in the public park from the major road running nearby. The consultant is, of course, not content with this coarse noise contour map. For the time being, let us assume that the noise contour map shown above is an excerpt from a larger noise map and that the *computing grid cannot be made denser*. However, the consultant is free to place *supplementary* immission points *wherever she wants*. A solution giving a better noise contour map is discussed in the next section.

## 2.4 Iterative conditioning of noise model output data yielding a required noise map

**Strengthening a weak computation grid by inserting supplementary points**

Let us say that the noise consultant wants to trace the limit value $L_{den}$ = 55 dB through the park. She therefore places new immission points randomly in the area where she suspects that the limit value noise contour goes, in order to "fill in the gaps" between the original immission points with too large spacing. The resulting noise contour map is shown in Figure 2.

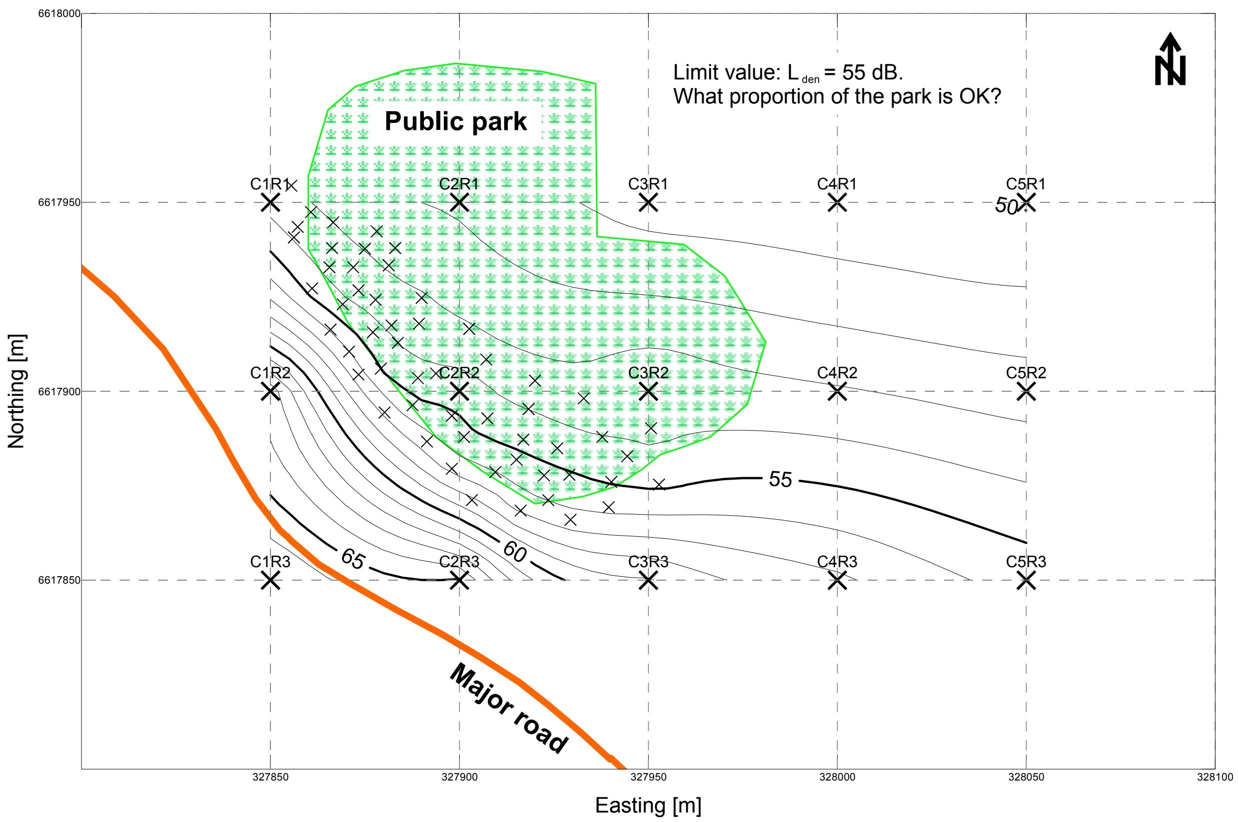


Figure 2: Noise contour map resulting from a *refined* computation grid. Calculation points spaced 50 m, interpolation to 5 m. Noise contours are shown in black. Original calculation points are marked by large crosses. Supplementary calculation points are marked by smaller crosses. The compound data sets have been interpolated and gridded to new grids with 5 m spacing.

As can be seen from Figure 2, the *refined* noise contour map is much more credible in the critical area along the limit value ($L_{den}$ = 55 dB) noise contour than the corresponding map based on the coarse grid values only. The compound data set has been gridded and interpolated to a new grid with 5 m spacing.

## Consequences of choosing different gridding methods

Noise contour maps typically require grids for their generation, whether in an off-the shelf noise assessment software or, like in this paper, in a general-purpose gridding and cartography software [1]. When *XYZ* data are supplied from e.g. a noise computation on regular intervals, you may produce a grid file that uses the noise values directly and there is no need to interpolate the noise values in the grid nodes. However, as have been shown in the example of refining an original coarse computation grid with supplementary points, the noise immission points may also be *irregularly spaced* in *XYZ*. The term irregularly spaced means that the points do not follow any particular pattern over the extent of the noise model / map, so there are many "holes" where data are missing. Gridding fills in these holes by extrapolating or interpolating noise immission values where no data exists. There is a lot of different gridding methods described in the literature, each having its pros and cons. Two common gridding methods are *kriging* and *local polynomial*. Kriging is a geostatistical gridding method that is useful and popular. Kriging tries to express trends in the data, so that, for example, points with high levels of noise are connected along a "noise contour ridge" rather than isolated by bull's-eye type contours. Local polynomial gridding assigns values to grid nodes using a weighted least squares fit with data within the vicinity of the grid nodes. Figure 3 illustrates the difference between kriging and local polynomial gridding for the familiar public park noise mapping example.

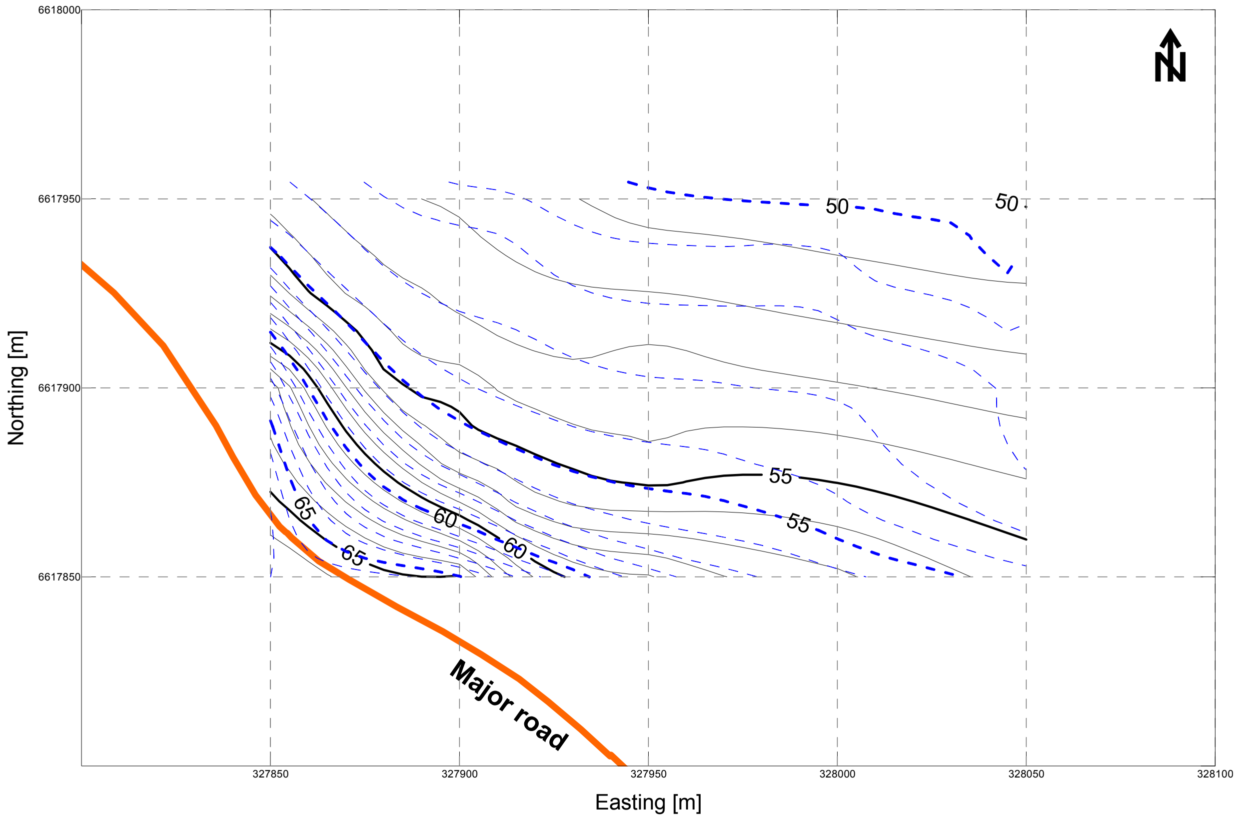


Figure 3: Noise contour lines resulting from gridding using kriging method (black noise contours) and from local polynomial gridding (blue, dotted, noise contours). Input data for both gridding methods: Original coarse 50 m grid *plus* supplementary points. The compound data sets have been gridded and interpolated to new grids with 5 m spacing. For clarity, calculation points and park border have been omitted.

It is clear from Figure 3 that, for this particular data set, the different gridding methods give rather different results, in particular towards the edges of the grid. Trying different gridding methods may be a way to getting to know your data and may rise your level of consciousness on the quality and other aspects of your data. A detailed derivation and discussion of the kriging gridding method may be found in [2]. Practical use of other gridding methods is described in e.g. [3].

**Other possible uses**

The method outlined in this paper may also be applied in testing and verification of new computation methods before they are implemented in off-the shelf software. Results from the new method may be mapped alongside results from already approved methods and visual comparisons between the different methods may be made.

# 3 Some possible pitfalls

**Gridding method**

As already mentioned, choosing a good gridding method may be critical.

**Uncertainty in the terrain model**

Typically, topographical maps in noise mapping have 1 m height contour intervals. Some noise mapping situations, e.g. noise mapping according to END (Directive 2002/49/EC of the European parliament) require a finer representation of the terrain in order to fulfil the END's specification of placing the noise assessment points $4.0 \pm 0.2$ m above the ground. If the terrain is regular, the height contours give enough information for a local, finer, height interpolation to be possible and all is fine. In cases of abrupt changes of local height, e.g. across cuttings and retaining walls, the terrain model needs information from *other height-associated objects* in the GIS file. If such supplementary objects are missing in the available GIS file, the resulting terrain model in your simple computer tools is not, strictly speaking, precise enough for use in noise mapping according to END. This may also be an issue with off-the shelf noise mapping software if that software does not interpolate height information in the correct manner.

**Calculation points / grid nodes within buildings**

Assuming your simple computer tools spreads out calculation points evenly across a populated area under noise assessment. Some calculation points may be within buildings' outlines. If your computer tool recognises the heights of the buildings, those calculation points will be behind "barriers" and will, accordingly, be associated with lower immission values than the "outdoor" calculation points. The "indoor" points should be corrected or possibly omitted from the data set prior to the gridding, otherwise the resulting noise contours in the populated area will have considerable errors near the houses.

# 4 Summary

Noise maps can be made using cheap software, with raw data supplied from the source of choice (e.g. noise prediction software, simple spreadsheets or even measurements) and gridded using well-known gridding methods. The grids may then be shown as e.g. noise contour maps using low-cost cartography software. Conditioning of input data and output data may require some file conversations (e.g. between different GIS / map file formats). However, such conversations may be done using simple and cheap softwares and may not pose any great obstacles to e.g. a consultant's efficiency.

It is important to evaluate different gridding methods and to search for method(s) that suits your noise assessment task. Documentation (e.g. manuals) of off-the shelf noise assessment software may document which method(s) is/are used in that particular software and thus give some hints to what method(s) to try.

# References

[1] Golden Software, Inc. *Surfer 8 Contouring and 3D Surface Mapping for Scientists and Engineers*.

[2] Cressie, N. A. C., The Origins of Kriging, *Mathematical Geology*, 1990, v. 22, p. 239-252.

[3] Golden Software, Inc. *Surfer 8 User's Guide*, Golden Software, Inc., Colorado, USA, 2002.