Influence of Calculation Parameters on Time and Accuracy of City Road Noise Computations

Barbara Rudno-Rudzińska, Tomasz Habrat
Institute of Telecommunication and Acoustics Wrocław University of Technology, 50-370 Wrocław, ul. Wybrzeże Wyspiańskiego 27, Poland,
barbara.rudno-rudzinska@pwr.wroc.pl

According to the European Union noise policy and the European Noise Directive, relating to environmental noise assessment and management, currently the most important task is to compile acoustic maps for urban agglomerations. One of the main problems is the reliability and accuracy of such maps constructed with help of computational methods. Most programmes are based on the computational methods recommended by END, but the computer aided implementation of these methods is not always clear and for the same situations different results may be obtained, which has a major implication for the analysis and comparison of results and noise exposure levels for different agglomerations. The results of simulations of traffic noise in built-up areas with dispersed, high- and low-rise building developments are presented. The simulations were run for the same input data using programmes: IMMI and Cadna. The influence of input acoustical data and calculation procedures on the obtained results is examined. Different methods of comparing the results are suggested. The noise level at the first line of dwellings, the range of traffic noise levels, the total area, the number of inhabitants and the number of dwellings exposed to a constant noise level are considered. A comparative analysis of calculation results accuracy and computing time is carried out.

1 Introduction

The reliability of an acoustic map and results obtained by computing methods largely depends on the way in which the input data for acoustic computations are prepared and on the adopted computational model parameters. Studies have shown that even if the same computational models of noise are applied, one may obtain different results depending on the assumed model parameters and the input data. Calculation parameters, such as calculation grid resolution and the number of reflections, determine not only the result of the computations but also significantly affect the computation time. In the case of strategic acoustic maps constructed for large areas and many noise sources there is a tendency to neglect reflections in a low-resolution raster.

In this paper, calculation errors arising from the choice of basic computational model parameters and input data unreliability are analysed on the basis of simulations run for four different urban situations with developments typical for Polish cities. The computations were performed for road noise – the main noise exposure in large urban areas – using special software for making acoustic maps.

2 Research methodology

A series of simulations were carried out using programs CADNA by DataKustic and IMMI V5.1.5 by Woelfel. The noise computations were performed using the RLS90 and NMPB methods and differently configured PCs meeting the hardware requirements for the above programs: a) a 533 MHz Celeron processor and 256 MB RAM, b) a 2100 MHz Athlon processor and 512 RAM.

2.1 Investigated urban situations

Real residential areas with a varied development (characteristic of large cities in Poland), located along main roads with heavy traffic, were selected for the studies:

- US1. A single-family residential development with a building density of 11%, located by a national road carrying urban and transit traffic, with average traffic flow Q =2100 veh./h. The road has two roadways with a median, an asphalt surface and total width w = 17 m (Figure 1).
- US2. A mixed (single-family and semi-detached houses) residential development with a building density of 13 %, located by a national road with a predominant share of outgoing urban traffic, with traffic volume Q = 2000 veh./h. The 20 m wide road has two roadways with an asphalt surface.
- US3. A high-rise (11 storeys, h_z = 34 m) parallel residential development located by a local distributor road with a predominance of urban traffic. The road has width w = 16 m, two roadways with asphalt surface. The average traffic volume is

Q ≈ 1700…2000 veh./h. The first-line buildings are located at a distance of 10-30 m from the roadway.

- US4. A low-rise (2-3 storeys), alley-like, multi-family residential development with a varying spacing between houses along alleys: w = 39 m, 49 m and 59 m, with average building density B =10%, located by a regional road with traffic volume Q = 1300…1500 veh./h. The road has a single 10 m wide roadway and an asphalt surface.

2.2 Calculations

The studies included:

1. An analysis of the influence of model calculation parameters on computation time and results. The analysis focused on calculation grid resolution and the number of reflections influences. The other calculation parameters were assumed to be the same as in the standard settings of CADNA and IMMI. Also experiments aimed at investigating the effect of digital map simplification were carried out. It is more practical to import a digital map of an area from a town planning information system than to create it for the purpose of constructing an acoustic map. But because of too many details a map obtained in this way needs to be processed for acoustic computations.

2. An analysis of the influence of input data unreliability on road noise computation error. The effect of the façade sound absorption coefficient and that of the absorptive properties of the ground surface were investigated.

A work area and a computation area of identical size, located on one side of a road being the source of noise, were selected for the analysis of the influence of model calculation parameters on computation time and results for each urban situation. A 1200×500m work area, a 400×300 m computation area and a 1200 m long noise source were adopted. Computations were performed for raster resolutions: 100×100m, 50×50m, 20×20m, 10×10m, 5×5 m and 2×2 m for different numbers of reflections N = 0…3. A standard calculation grid height $h_o = 4$ m was assumed. The computations were performed for maps: 1) directly imported from the town planning information system, 2) automatically simplified using the available Cadna and IMMI functions which allow one to correct the shape of buildings and eliminate acoustically insignificant areas and 3) manually simplified by removing low-rise buildings, merging semi-detached buildings into single buildings and eliminating terraces, balconies, etc.

The computational model parameters describing propagation conditions for investigated urban situations SU1÷SU4 were adopted as alternative:

- building facade sound absorption coefficient – α= 0.1 and α= 0.2,
- for NMPB – ground surface G = 0.5…0.9 at a step of 0.1.

2.3 Analysis

Errors of sound level (L_A) distribution over the investigated area, including for the first-building-line noise level and the noise impact range, and errors of global noise evaluation indices such as: the number of population exposed to noise (NPEN) and the surface area exposed to noise (SAEN) were analysed. The number of population exposed to noise (NPEN) the level of which was higher than L_{AX} was determined by two methods: the conventional method based on an analysis of the determined noise impact ranges and the method (based on operations on rasters) used for constructing digital maps. In order to perform raster operations one must first acquire and process all the needed data into subject raster layers with uniformed resolution.

In method (1) the NPEN value was calculated proportionally to the number of staircases for multi-family housing or to the number of single-family houses manually inventoried within the impact range of noise $L_A > L_{AX}$. In method (2) CADNA's 'Object-Scan' function was used to determine NPEN and SAEN values.

The number of population exposed to noise level L_A at a given raster node was calculated proportionally to the living room of the buildings located within a window of specified size with the given raster point at its centre and to the average population density in the flats. The surface area of the area exposed to noise was determined proportionally to the number of grid nodes (n) at which noise level L_A is higher than the set value of L_{AX} and to surface area Δs^2 represented by the raster node.

3 Results

Noise distribution computation time largely depends on grid resolution and the number of reflections (N) as well as on the program used. CADNA is generally faster. At N = 1 computation time for CADNA was 5-7 times shorter than for IMMI. Computation time and its increase with the number of reflections (N) depend on the character and density of a development (Table 1). For processor Athlon 2100 and a 20 x 20 m raster as the number of reflections (N) increases relative to N=0 so do: N1 – 32 times, N2 – 269 times, N3 – 2289 times for US1 and N2 – 49 times and N3 – 202 times for US2.

Table 1: Calculations time, CADNA A, Athlon 2100

a) urban situation US1, number of buildings nb=481

grid	t [s]			
	N0	N1	N2	N3
100x100m	1	15	255	1847
50x50m	2	54	603	5062
20x20m	12	380	3229	27471

b) urban situation US3, number of buildings nb=97

gird	t [s]			
	N0	N1	N2	N3
100x100m	< 1	< 1	4	12
50x50m	< 1	2	10	41
20x20m	1	2	49	202

The ratio of the increase in computation time with an increase in raster resolution only to a slight degree depends on the number of reflections (N). The estimated average increase in computation time (tx) for grid resolution $X \times X$ relative to time (t100) for a 100×100 grid is:

Table 2: Increase in computation time tx/t100

grid	50×50	20×20	10×10	5×5	2×2
tx / t100	3±1	16±3	60±5	220±20	1200±200

The area map simplifications do not significantly affect determined sound levels L_A but differences < 1dB do affect computation time. The degree of computation time reduction is not significantly dependent on grid resolution. A computation time reduction of 2.5…3.6 times for US1 and 1.3…3.3 times for US3 was achieved.

The largest differences occur between sound levels L_A calculated for N=0 and N=1. Within an impact range of noise level L_A >50dB the differences amount to 2…8dB. The differences between results for N=2 and N=1 amount to 0…2dB and for N=3 and N=2 to 0…1dB.

Calculation grid resolution is not a critical parameter in computing the noise impact range and global noise indices by the conventional method. Interpolation and extrapolation methods allow one to determine the course of the same-sound-level line at a step of 5dB even when the differences between sound levels L_A for neighbouring points are several times larger than the step (Figure 2). For a grid with resolution below 20×20 the sound interval for the first building line may be incorrectly classified, e.g. 60-65dB instead of 65-70dB.

The method of determining global noise estimation indices on the basis of raster operations is highly sensitive to calculation grid resolution. The NPEN and SAEN estimation errors rapidly increase with calculation grid resolution. For US1 the NPEN estimation error for a 50×50m grid amounts to 50…100% and for a 100×100m grid to 300% relative to the values computed for a 10×10m grid. For US3 the errors are smaller amounting to respectively 20…50% and 65…135%. For grids with a resolution higher than 10×10 the errors are below 10%.

The noise level calculation error ($\delta L_{A,G}$) arising from the uncertainty of the value of parameter G, for distance d = 10…120m and calculation parameters: $\alpha = 0.2$, N=1, amounts to: a) h_o = 1.5…2m: G = 0.7±0.1 - $\delta L_{A,G}$ = -0.5 dB ÷ +0.4dB, G = 0.7±0.2 - $\delta L_{A,G}$ = -1,1 dB ÷ +1dB, b) h_o = 4…5.5m: G = 0.7±0.1 - $\delta L_{A,G}$ = -0.4dB ÷ +0.4dB, G = 0.7±0.2 - $\delta L_{A,G}$ = -0,9dB ÷ +0,6dB. For greater heights at d < 30 m the influence of parameter G on the calculation result is negligible.

The influence of building facade absorption coefficient α for points located beyond the first building line is: a) US1 and US2 - N = 1: on average – 0.35dB, max – 0.5 dB, N = 2 – on average – 0.5dB, max –0.8dB, b) US4 - N = 1…3: on average – 0.2…0.3dB, max – 0.3…0.6dB for sections A, B and E and on average – 0.4…0.9dB, max – 0.5…1,1dB for C. The differences are less than 0.2dB for the first building line.

4 Conclusion

Since computational model parameters have a significant influence on forecasted noise indices and computation time their proper selection in the process of creating digital acoustic maps of large and medium-sized towns is of critical importance. Parameters for acoustic map computations should be selected as a compromise between accuracy and computation time. The investigations have shown that a 10×10 grid resolution and taking into account the first reverberation (N=1) seems to be a reasonable compromise when making strategic acoustic maps.

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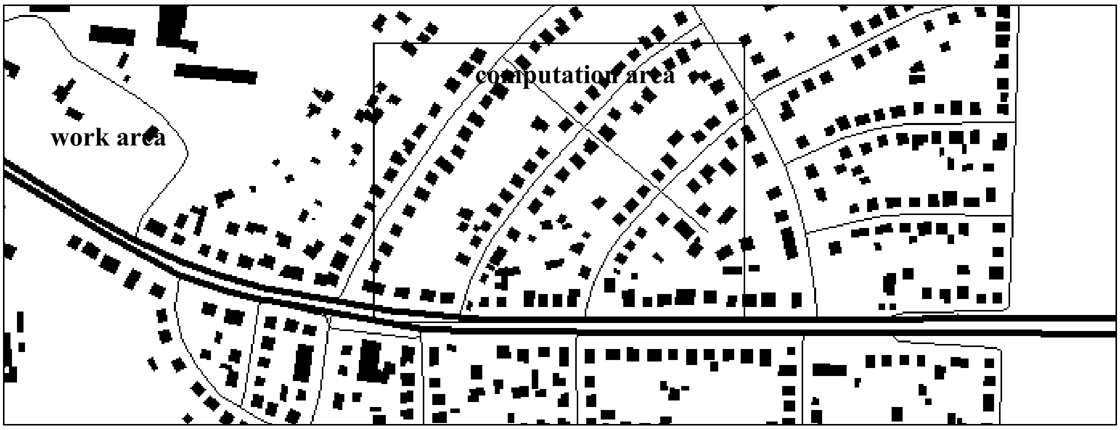

Figure 1: Map of urban situation US1

a) grid 100x100m, N=0

b) grid 50x50m, N=0

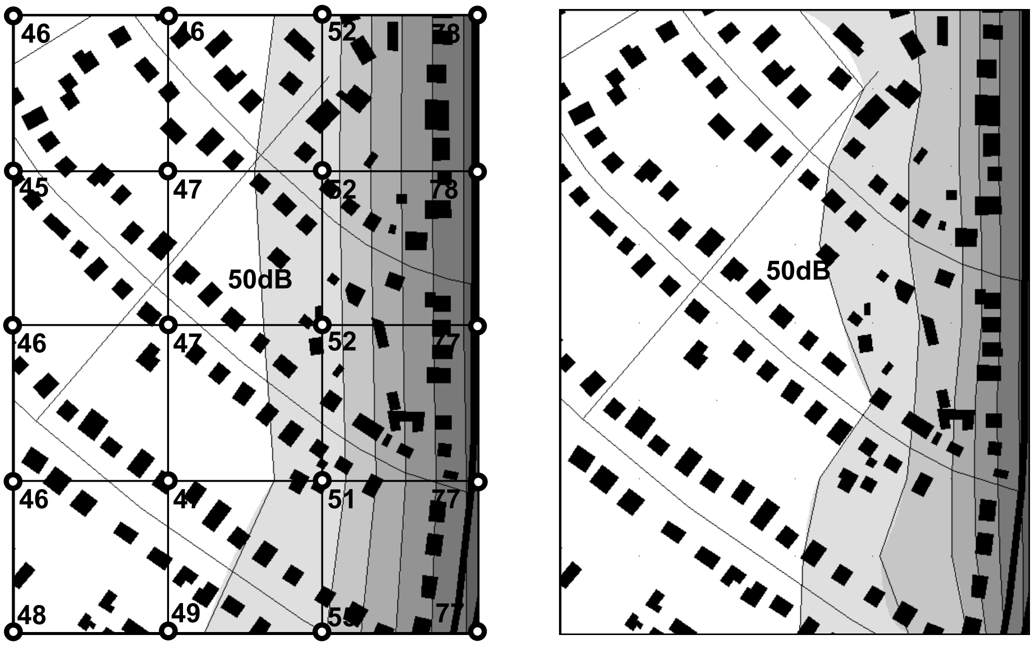

Figure 2: Influence of grid resolution on calculated traffic noise range - urban situation US1