PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Prediction of quiet side levels in noise map calculations – an initial suggestion of methodology

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ABSTRACT

Urban morphology, i.e. shape and position of buildings in relation to streets, affects the distribution of noise and air pollution and can thus, through urban planning and design, be used to improve urban areas. This is of interest in an ongoing project where both air quality and noise are in focus. The present paper concerns the prediction of noise levels at positions of non-direct noise exposure such as noise levels at inner yard facades and values of noise contour maps at inner yards. With increasing densification, housing is built closer to the roads and the directly exposed facades receive higher noise exposure levels. The balancing effect of access to a quiet side is often counted on, supported by regulation, whereas the noise levels predicted using commercially available software are often incorrectly low at those points. A suggested methodology is described for how to combine the previously developed Qside model with a commercial noise mapping software to improve the prediction for non-direct noise exposure situations like essentially enclosed inner yards. We present also initial noise level results as outcome of a model study of varying building morphologies.

Keywords: Noise mapping, Quiet side, Urban morphology

1. INTRODUCTION

There is increasing evidence for serious health effects due to long-term exposure of traffic noise at dwellings (1). Also air pollution, especially particles, has been shown in numerous studies to contribute to long-term illness and mortality from cardiovascular and respiratory diseases (e.g. (2)). Among environmental factors in Europe, air pollution and environmental noise constitute the top two in disease burden according to the World Health Organization (3–5). In urban street environment, road traffic is the largest contributor to both noise and air pollution (nitrogen oxide and particles as PM_{10}). Furthermore, the overall trend is negative (6). Future reductions at source are considered insufficient whereby additional measures are needed.

Until today, noise and air pollution has mostly been treated separately. This is ineffective with respect to production of new housing and may unnecessarily make the quality of life less good than it could be. Better solutions for a sustainable and efficient building process can be achieved by a more holistic approach to the problem of noise and air pollution considering urban morphology.

Concerning courtyard openings toward roads, they may reduce air pollution concentrations due to the created wind ventilation (7). Such openings may however prevent an effective reduction of the noise in the courtyard (e.g. (8)). At the same time, urban densification projects rely to a large extent on the *quiet side* concept, i.e. allowing higher noise levels toward the noisy street as long as a quiet (or damped) side to each apartment is guaranteed (9).

For investigating local effects of urban morphology on noise and air distribution, the Spacematrix method has been shown to be useful, as described in (10). Building types can be composed of specific combinations of specified density variables (floor space index, ground space index, building height, network density and open space ratio) enabling to quantify a building type and vary each variable separately.

Concerning the acoustic modelling of urban form on the local scale, most aspects can be considered

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using available noise mapping software. However, since these methods are not applicable to closed courtyards (11), an extension (12) is applied using results from the Qside project (13), as described below in detail. The multiple reflections in the street canyon and/or in the inner yard result in a higher noise level within the yard. In principle, these multiple reflections can be modelled using noise mapping software. However, the computational cost becomes overwhelming for all but very small cases. An extension like the Qside model is therefore preferable, which has previously been implemented and evaluated in comparison with noise mapping software and measurements for a few cases (12,14).

The present paper concerns a more generalised use of the Qside model, describing a methodology for predicting the non-direct noise exposure at inner yards, which is applicable for a large set of cases with multiple building blocks. The algorithmic procedure for the noise level prediction is described and model results are presented and discussed.

2. METHOD

2.1 Urban model case

For this study, six building types are investigated with respect to noise exposure. An urban mesoscale, i.e. between urban block and urban area (i.e. urban fabric), is chosen for the study, as exemplified in Figure 1, where the first six model cases are shown. These six cases are chosen to have the same floor space index (FSI), meaning that the estimated number of inhabitants is the same. The ground space index (GSI) is decreasing from the closed block (Case 1), via the U-block (Case 2), open corner block (Case 3), strip building (Case 4), and L-block (Case 5), to the point building (Case 6) whereas the number of floors is increasing. Case 1 has 5 floors whereas case 6 has 14 floors. (A following set of cases uses a constant number of floors where FSI decreases from case 1 to 6. Also other variations will be studied, including block size, not shown here.) The model cases are situated in an existing urban area (Heden, in Göteborg, Sweden), as exemplified for Case 1 in Figure 2. Concerning the traffic flows, each of the local roads has 1500 vehicles/24 h, consisting of 95 % light, 2.5 % medium heavy and 2.5 % heavy vehicles, driving 50 km/h. The traffic data for the surrounding roads are taken from the city database.

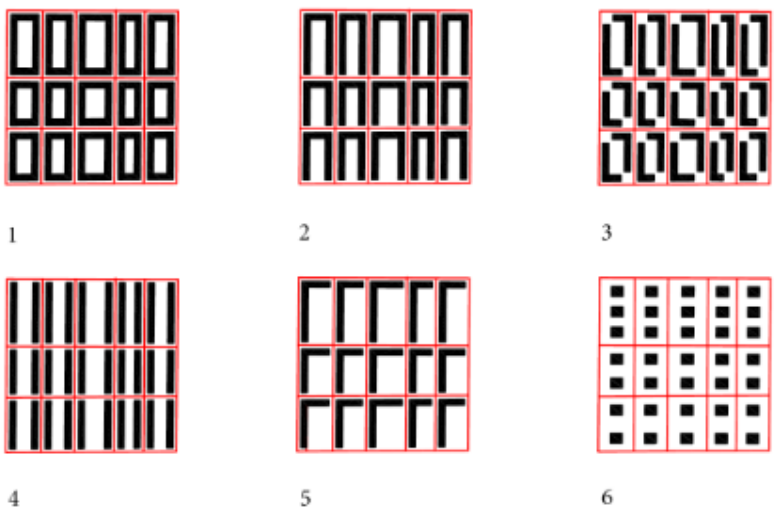

Figure 1 – Model cases 1–6 (top view; roads in red, houses in black).

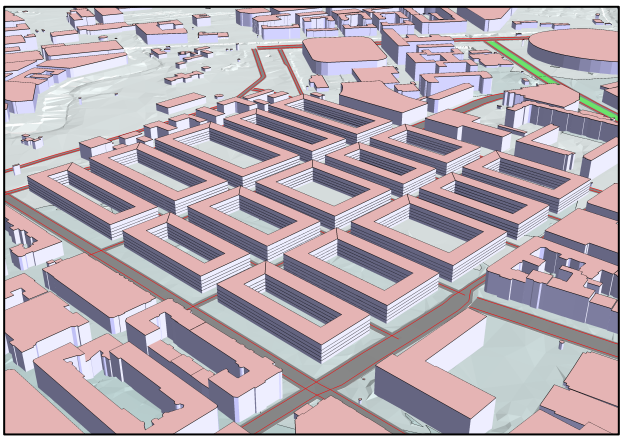

Figure 2 – Placement of the model cases in an existing urban area, exemplified for Case 1.

2.2 Calculation of non-direct noise exposure at inner yards

When the sound propagation from road vehicles to the nearest facade is unshielded, the noise level is usually dominated by this direct exposure. The non-direct noise exposure, on the other hand, typically takes place at shielded inner yards, where receiver positions do not have unobstructed paths from the sources. The noise level at such positions may be dominated by sound paths over the roofs, including multiple reflections in the street canyon and/or in the inner yard, as predicted by the Qside model.

The results from the Qside model are combined with those from a commercially available noise mapping software. Here, we have used SoundPLAN (version 8.0), following the *Nord2000 Road* prediction model, which considers 27 frequency components of the sound (third-octave bands from 25 Hz to 10 kHz). For the calculations made here, we have used five reflections and neutral weather conditions.

The steps of the non-direct noise prediction are described as follows. (The geometric parameters are found in Figure 3.) To simplify the input geometry of the buildings surrounding the model area, each block is made into a single building shape, as shown in Figures 4 and 5. Then all the road segments (traffic is constant within a road segment) are converted into a set of points using 10 m discretization along the road. The source height, h_s, is set to 0.05 m. For each inner yard of the model area, a single receiver is used, positioned in the centre of the yard, at height h_r=1.5 m.

With the above geometry data given, the sound paths from all source points to a receiver can be identified. Among the facades that cut the direct source–receiver line (R), the facade closest to the source defines the height of the source canyon (H_s) and the facade closest to the receiver defines the height of the receiver canyon (H_r). For simplicity, both sides of the source canyon are assumed to have the same height (i.e. H_s=H_{i1}), and similarly for the receiver canyon (i.e. H_s=H_{i1}). Further, the width of the source canyon is taken as twice the source–facade distance (i.e. W_s=2d_{si}), and similarly for the receiver canyon (i.e. W_r=2d_{ri}). In addition, the buildings are assumed to have flat roofs. For each source position along a road segment, the geometric parameters are updated following the vertical plane through source and receiver (see bottom drawings of Figure 3), completing the set of needed geometrical input data to the Qside model.

Using the Qside model, each point source contribution at each receiver is calculated relative to free field (in the same third-octave bands as in the noise mapping software). The absolute level at each receiver is given by adding the relative level from the Qside calculation to the output result from applying the noise mapping software to a simplified digital map with acoustically hard and flat ground in the absence of buildings, reduced by 6 dB to compensate for the pressure doubling due to the hard ground. Finally, a grid noise map from the noise mapping software (in dBA) is combined with the Qside result at each yard (in dBA) such that the level of the grid noise map within each yard is limited to not be lower than the corresponding Qside result (i.e. the maximum of the two is used as the final result).

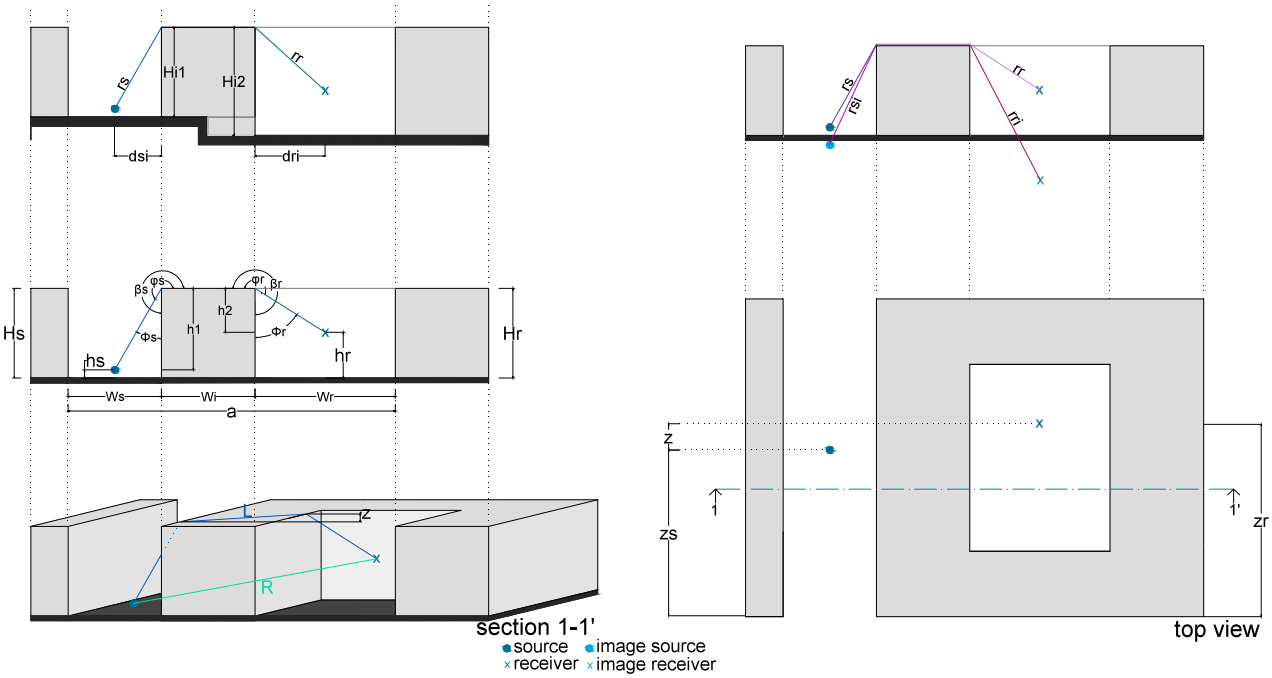

Figure 3 – Geometric parameters of the Qside model.

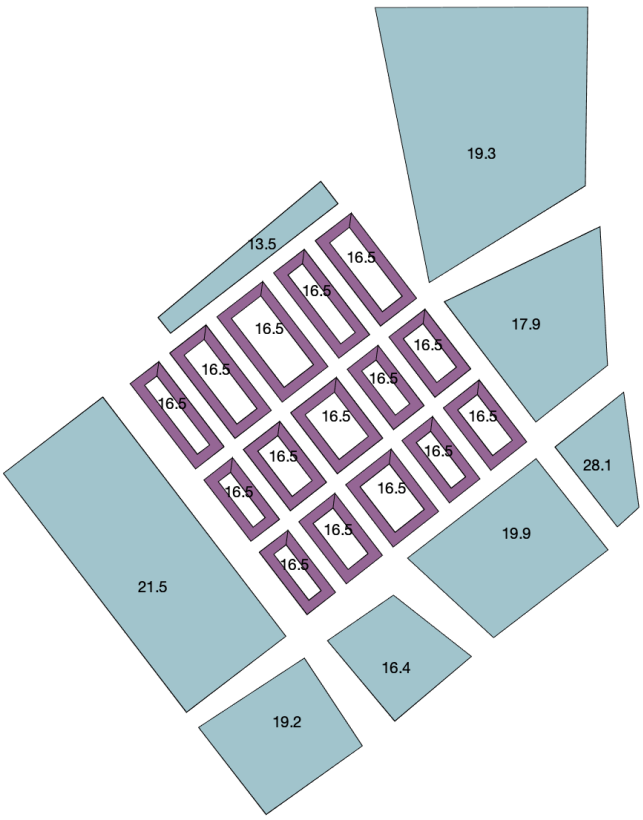

Figure 4 – Imported buildings as 2D elements for the non-direct noise prediction. The model buildings are displayed in purple and the surrounding building blocks are displayed in blue. Building height, also displayed (in m), is given as an attribute for each object.

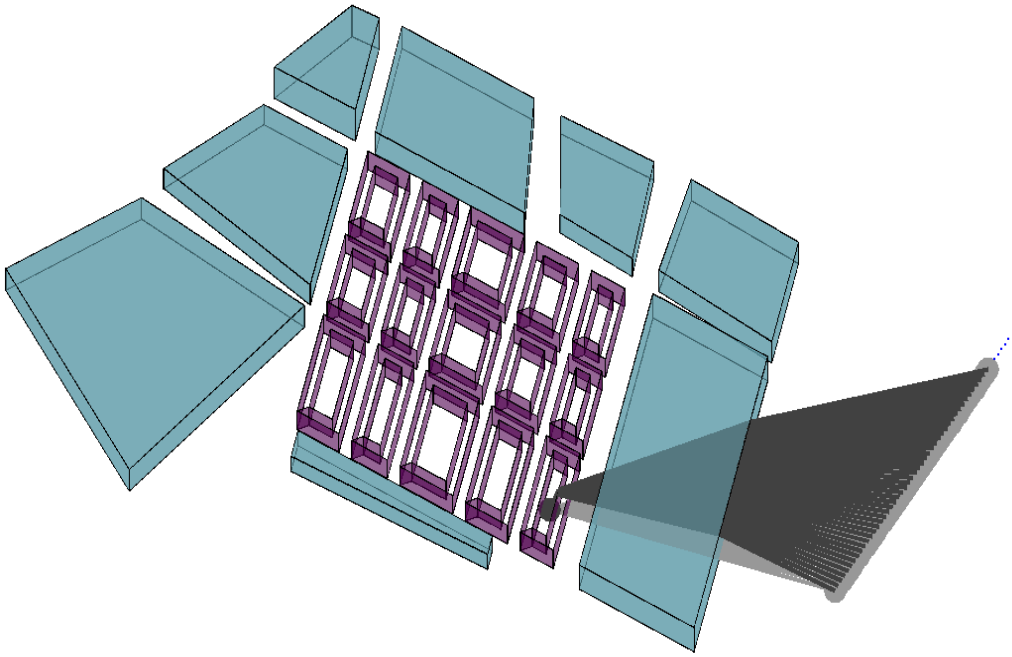

Figure 5 – An example set of sound paths (in dark grey) illustrated for the non-direct noise prediction for a few source positions and a receiver located in one of the inner yards. The model buildings are here displayed without roof (in purple) and the surrounding building blocks are displayed as 3D volumes (in blue).

3. PRELIMINARY RESULTS

Results calculated with the non-direct noise method, as described above, are calculated for the model Cases 1–6 (see Figure 1). The resulting grid noise maps for the model area are displayed in Figures 6–11. (It can be noted that the calculations were made of LAEq24h levels and the presented levels in Lden are given by adding 3.5 dBA, from estimated 24-hour traffic composition.) As effect of the non-direct noise method, the lowest levels predicted by the noise mapping software in the yards are exchanged by those predicted by the Qside model, e.g. corresponding to a correction of more than 10 dB for Case 1. Among the cases, the inner yard levels of Case 1 are the lowest and the more open cases have higher levels, as expected. However, Cases 2 & 3 might be promising in terms of providing partial shielding at the same time as having some openings that may help to improve air quality.

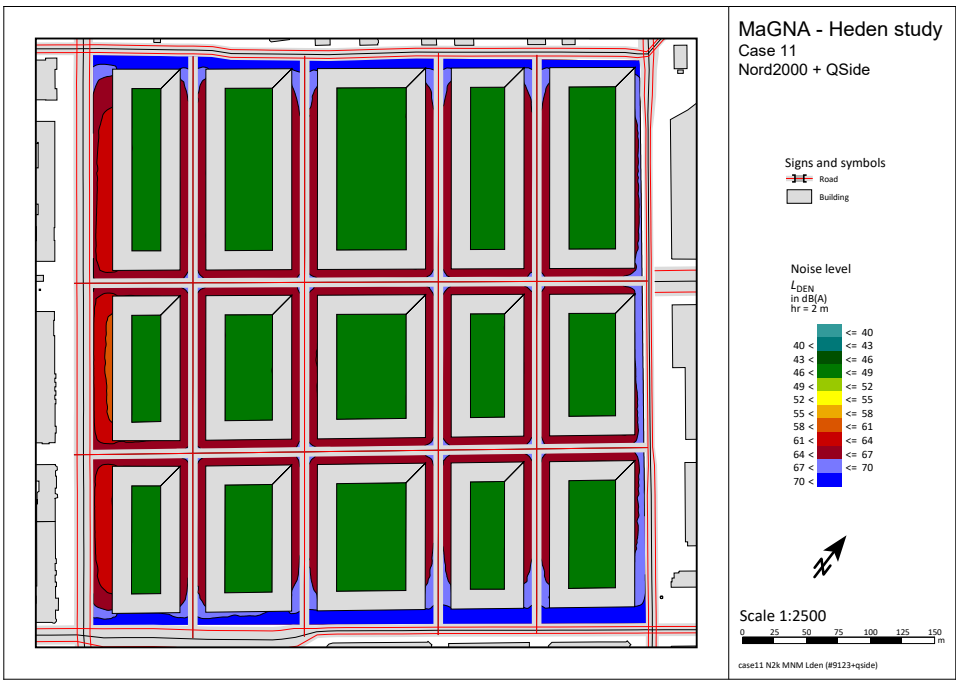

Figure 6 – Result for Case 1.

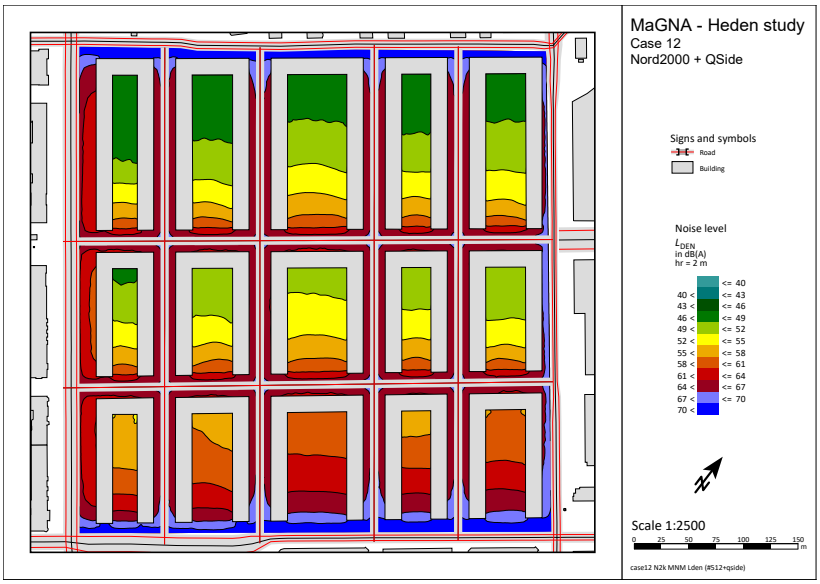

Figure 7 – Result for Case 2.

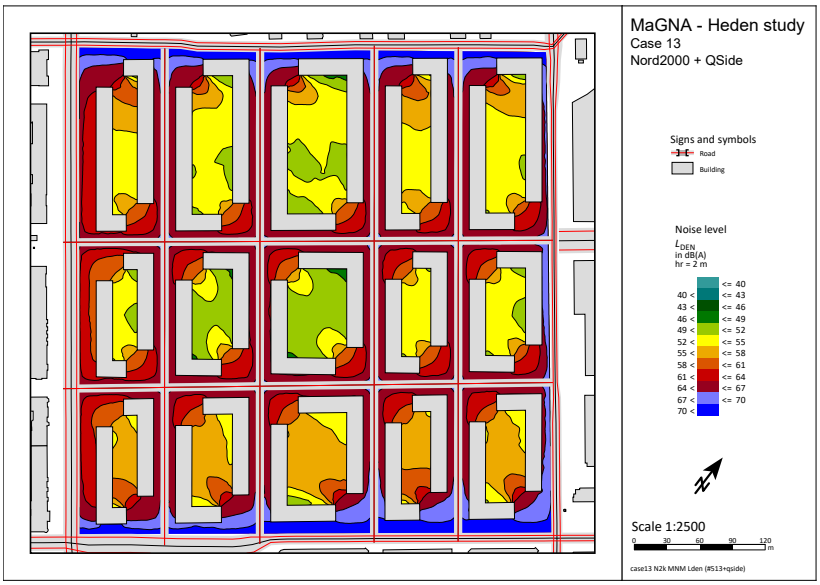

Figure 8 – Result for Case 3.

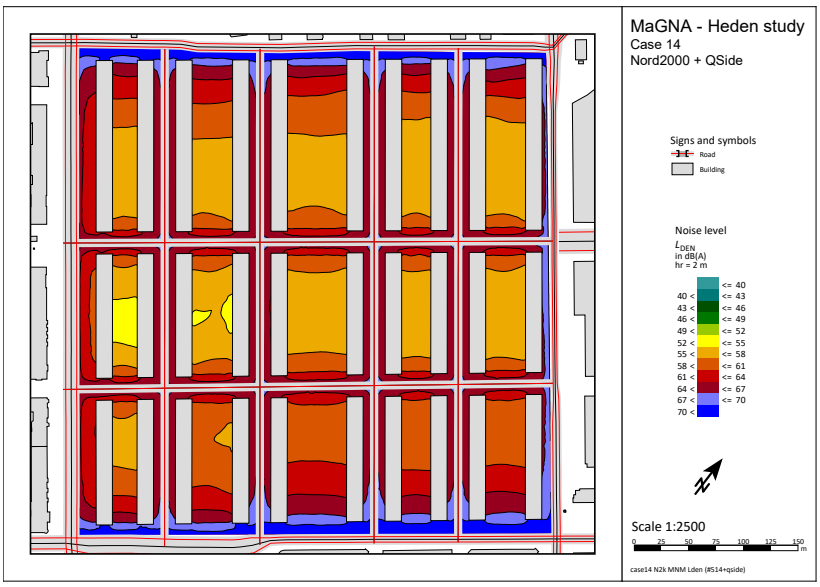

Figure 9 – Result for Case 4.

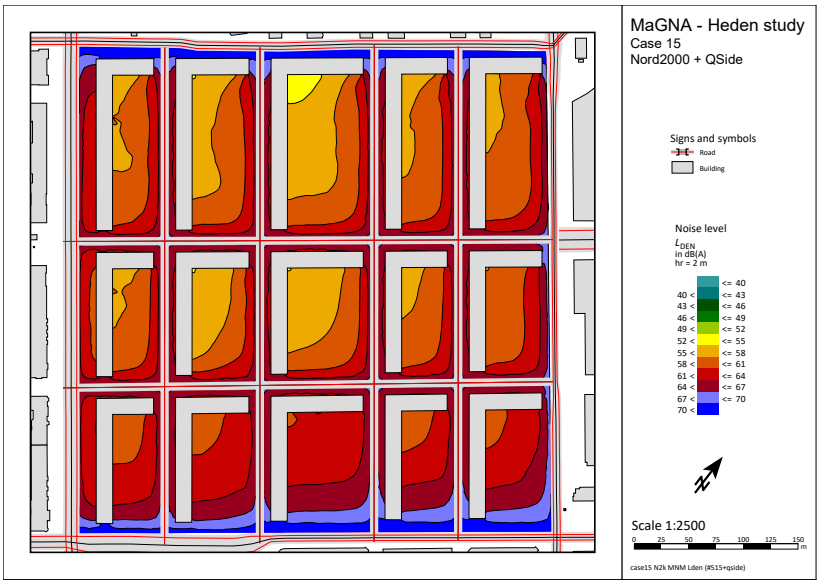

Figure 10 – Result for Case 5.

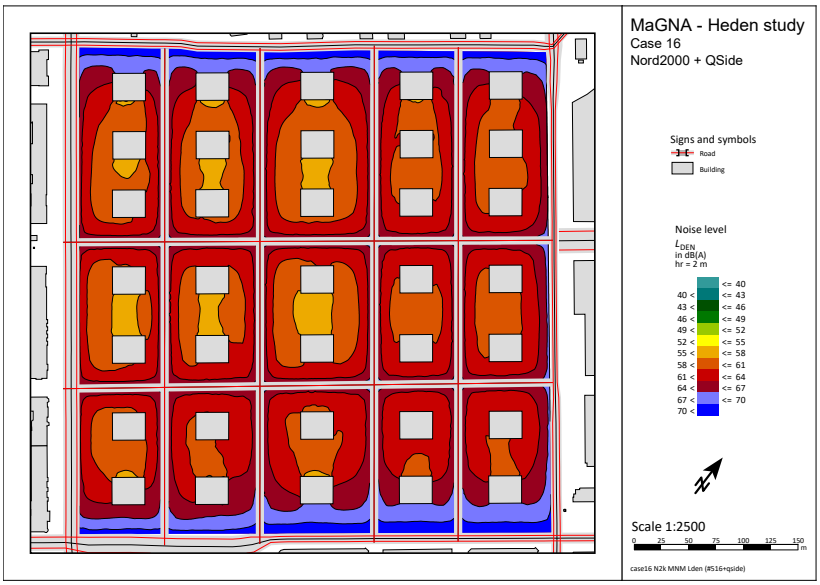

Figure 11 – Result for Case 6.

4. CONCLUSION

A suggested noise mapping approach for including the sound pressure levels at non-directly exposed inner yards is described. It uses a combination of a previously developed method (the Qside model) and a commercially available noise mapping software. (Here, SoundPLAN is used, whereas other noise mapping software could work equally well.) The noise mapping software is applied to the whole calculation domain of interest and the results at inner yard positions are exchanged by those obtained via the Qside model whenever they are larger. In the implementation of the Qside model used here, point-to-point prediction is made of the relative level at the inner yard receiver points due to sources along the road segments, for third-octave frequencies. The absolute levels at the inner yard receiver points are given by adding the relative levels to the output results from applying the noise mapping software to a simplified digital map with acoustically hard and flat ground in the absence of buildings.

The work shown here indicates that the suggested approach is functioning in terms of efficiently producing noise mapping results with levels corrected at inner yards.

Future work contains studying the effects of courtyard openings, vegetated and acoustically absorbing surfaces, as well as the combined aspects of noise and air quality, considering both morphology and greening, including the benefit of having access to a less noisy side.

ACKNOWLEDGEMENT

The project is funded by The Swedish Research Council Formas, nr 2017-00914, *Increasing cities' capacity to manage noise and air quality using urban morphology and urban greening* (MaGNA).

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