# DELIVERABLE D5.8 PART 1

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**Sustainable development, global change & ecosystems**

**This deliverable has been quality checked and approved by QCITY Coordinator**
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# 0 EXECUTIVE SUMMARY

## 0.1 OBJECTIVE OF THE DELIVERABLE

The objective of this deliverable is to show how quiet zones can be established using traffic control combined with low noise vehicles and what their contribution would be to noise mitigation in a Stockholm case study.

## 0.2 STRATEGY USED AND/OR A DESCRIPTION OF THE METHODS (TECHNIQUES) USED WITH THE JUSTIFICATION THEREOF

Establishing a quiet zone implies constraints on car use. Such constraints will affect the behaviour of car drivers in many ways. Therefore it is necessary to apply a traffic forecasting model allowing a rich representation of possible adaptation effects, such as mode shift, destination shift and route shift. The Swedish national traffic forecasting system Sampers was selected for this purpose. The software allows for producing traffic flows for standard vehicles and low noise cars separately, which is then input in noise mapping software to provide noise effects. Traffic speeds are particularly important in this work package, as the effects of low driveline noise for electric hybrid cars are offset by tyre/road noise are reduced for higher speeds. Therefore, a sensitivity analysis was also undertaken with respect to the traffic simulation method.

## 0.3 BACKGROUND INFO AVAILABLE AND THE INNOVATIVE ELEMENTS WHICH WERE DEVELOPED

Effects on noise levels of combining traffic control and low noise vehicles by introducing a quiet zone in a small part of the Stockholm inner city have been shown.

## 0.4 PROBLEMS ENCOUNTERED

No particular problems have been encountered

## 0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

KTH has contributed with traffic forecasts and report writing, and ACL has contributed with noise calculations and writing of the sections on noise mapping software and tyre/road conditions.

## 0.6 CONCLUSIONS

Low noise vehicles, such as the Toyota Prius electric hybrid car, with reduced tyre/road noise provide about a 7 dB(A) noise reduction (25-40 km/h) as compared to standard cars (like the Volvo V70 petrol car).

The share of low noise cars in the total car fleet is currently very low, and even if it is likely that many car makers will introduce similar technologies in the future, it may take a substantial time before the low noise car share is large enough to bring about a significant general noise reduction in a mixed traffic flow of standard cars and low noise vehicles. The project idea is therefore to use traffic control to separate low noise vehicles from standard vehicles to provide quiet zones in limited town areas.

The separation can be done in different ways. One is to ban all standard cars and allow only low nose vehicles in a particular area. Such policies are now becoming more and more common when other types of disturbances are concerned, like NOx and particles. In many cities, it is now mandatory to have a permission to enter protected areas, a permission which is given conditioned on the type of vehicle and its emission levels.

Another way of separating low noise vehicles from standard vehicles is to impose a fee for entering and/or leaving the area in stead of a total ban. Such a policy is also used for other disturbances, for instance in Milan, where a charging system for entering the inner city is differentiated according to emission levels defined by the Euro emissions standard classification. The per day fees range from 0 - 10 Euros.

In this case study, we have studied the effects of banning all standard cars as well as imposing noise fees. The study has been carried out by using the regional model in the national Swedish forecasting system Sampers. The model reflects traveller behaviour by taking into account different substitution possibilities like route choice, mode choice and destination choice. The results of traveller behaviour in terms of car flows in different scenarios have been input in the CadnaA noise mapping software, resulting in noise maps and noise disturbance distributions of the residing population for these scenarios. The effects of theses policies are shown in the noise maps below, showing the original noise situation and the changes brought about by the different policies.

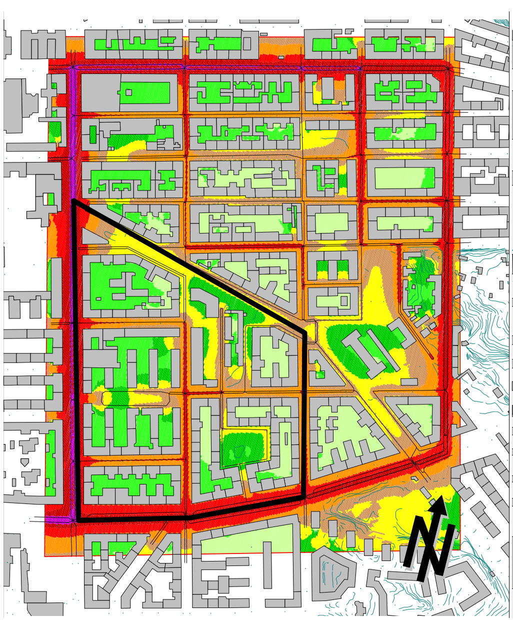



Figure E1 Current noise situation


Figure E2 Difference with standard vehicle ban

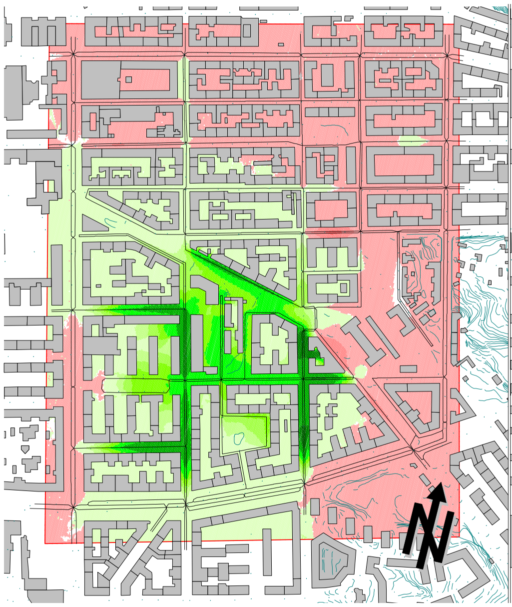


Figure E3 Difference with 1 Euro noise fee

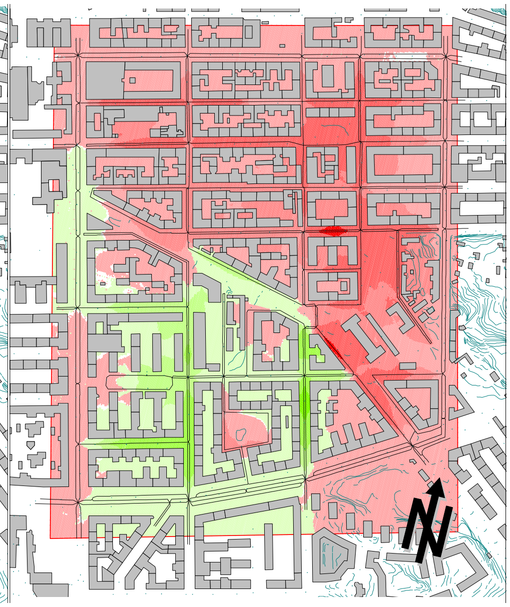
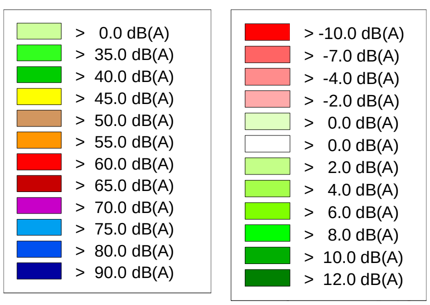


Figure E4 Difference with Half Euro noise fee




Legends for absolute noise levels (dB(A)), and differences in noise levels (dB(A))

A total ban of standard cars will provide a substantial noise reduction within the area. The main effect is a redistribution of moderately disturbed residents in the 50 -55 dB(A) segment to noise levels in the 35 - 45 dB(A) segments. Residents subject to more severe noise disturbance are likely to be living on the boundary streets and will not benefit from traffic reductions within the zone. The ban will also, to a minor extent, increase noise levels outside the area.

The 1 Euro noise fee scenario will give similar but smaller effects. After all, some drivers will, at least in some cases, choose to use their standard cars despite the fee. The main effect is a redistribution of moderately disturbed residents in the 50 -55 dB(A) segment to noise levels in the 35 - 50 dB(A) segments. The more severely disturbed residents are affected to almost the same extent as in the case of a total ban of standard cars in the zone. A sensitivity study with respect to traffic simulation methods showed that these effects may be somewhat overestimated but still significant.

The half Euro noise fee scenario gives different effects in that it brings about larger noise increases in the surrounding than the other scenarios. This is due to that the fee is not large enough to make people change mode or destination, but only to make some changing their routes (if not having their destination within the area) or to park outside the area and accept a longer walking distance to their destination. In this case, the reduction of car traffic in the surroundings caused by mode or destination changes will take place to a much lesser extent. There will still be noise reductions within the zone, although smaller than in previous scenarios, but there will also be noise level increases in the surrounding area. The extent is such that the share of residents in the 55+ dB(A) segment increases from about 35 percent in the previous scenarios to about 45 percent in the half Euro scenario.

The noise disturbance distribution for the different scenarios is summarized in figure E5 below.

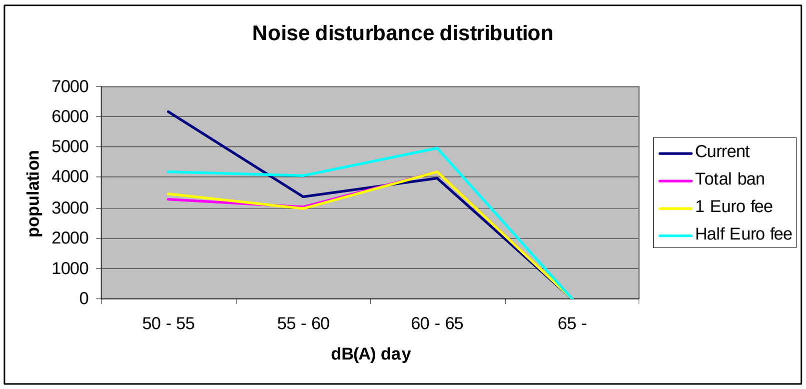



Figure E5 Noise disturbance distribution

We also studied effects of increased low noise vehicle ownership. As was discussed above, the 1 Euro scenario (Q2) effectively moved people in the 50 – 60 dB(A) range to lower levels. An increase of low noise car ownership inside the quiet zone to 100 percent would reduce this effect to some extent, mainly by a larger number of low noise vehicles entering the quiet zone. A further increase of low noise car ownership from 5 to 20 percent outside the zone would have a different effect, as it would reduce noise exposure also on the bordering streets which are more exposed to traffic noise. The effect of the further increase of low noise vehicles among resident outside the quiet zone is therefore that exposure in the 65 – 70 dB(A) range would be reduced. The result is also a further increase of low noise vehicles inside the quiet zone, moving exposure levels from the 40 – 50 dB(A) range to the 50 - 55 dB(A) interval.

Finally we studied effects of an increased zone size. An enlargement of the quiet zone, given the 1 Euro noise fee, did not improve noise exposure for noise levels over 45 dB(A). An important reason for this was that available parking facilities outside the zone were not assumed to exist. But, when low noise car ownership increases, improvements occur for noise levels over 50 dB(A).

The final conclusion for this case study would then be that even in the case of an already traffic zoned situation, substantial noise reductions can be brought about by banning standard cars or by imposing noise fees. It is however important to impose fees high enough to make drivers change mode and destination and not only change route or parking behaviour. It is time to consider bans and charging systems not only for air pollution but also for noise emissions.

## 0.7 RELATION WITH THE OTHER DELIVERABLES (INPUT/OUTPUT/TIMING)

This deliverable (D5.8) is closely related to Deliverable D5.13 "City areas with quiet vehicles - road surface", produced in WP 5.13. We think that it is beneficial to the reader to concentrate on the establishment of quiet zones in Deliverable 5.8, and to concentrate on road surface tests in D5.13. This deliverable also provides input to deliverable D6.6 "Technical consolidation report on all validation results".

# 1 OBJECTIVE OF THE DELIVERABLE

## 1.1 OBJECTIVES

The objective of this deliverable is to show how quiet zones can be established and what their contribution would be to noise mitigation in a Stockholm case study.

This deliverable "Stockholm - Quiet vehicles (with reduced tyre/road and drive line noise) combined with traffic control)", produced in WP 5.8, is closely related to Deliverable 5.13 "City areas with quiet vehicles - road surface", produced in WP 5.13. We think that it is beneficial to the reader to concentrate on the establishment of quiet zones in Deliverable 5.8, and to concentrate on road surface tests in Deliverable 5.13.

## 1.2 RELATION WITH PREVIOUS DELIVERABLES

This deliverable is related to deliverable D2.11 where an analysis on a generalised schematic quiet zone site was undertaken, showing that considerable effects could be achieved inside the quiet zone at a relatively small drawback in terms of increased noise on boundary streets and noise leakage into the quiet zone.

## 1.3 LAYOUT PRESENTATION

Following the background description, a short presentation on the methodology used comes next. Then the site selection and definition of the current situation is presented. Next follows definitions of different quiet zone scenarios in terms of assumed shares of low noise vehicles and conditions for entering the quiet zone. In the subsequent section, noise effects of the different scenarios are presented. After this, other effects and implementation issues are discussed. Finally conclusions are presented. A sensitivity analysis of the traffic calculation is presented in appendix 1, and measurements on a hybrid vehicle are presented in appendix 2. The deliverable is divided in two parts, where the second part contains appendix 2.

# 2 METHODOLOGY

The methodology used in this work package is the same as was used in Deliverable 2.11 "Small Prototypes for Traffic Control Measures for Vehicles". Here, only the main characteristics will be described and the reader is referred to D2.11 for further details. As a sensitivity test, a micro simulation exercise was undertaken and is described in Appendix 1.

## 2.1 TRAFFIC FORECASTING

Traffic is a result of people's choices. Where to travel, in what kind of mode, on which route and at what time, are all choices we make for a journey. These choices depend on the characteristics of different modes, routes, etc, and how the individuals value the characteristics. With traffic models we try to simulate these choices using people's values derived from actual behaviour in traffic. To evaluate effects of a change in the traffic system like a new road or introduction of tolls, traffic models are helpful tools. Consequently traffic forecasts are often used to support decision-makers when evaluating different solutions of current traffic problems or future scenarios.

Traffic models are based on two important components, traffic demand and traffic supply. The individuals that travel through the network in different modes constitute traffic demand whereas traffic supply is defined by the traffic network and the public transport system the travellers can use when making their trip.

Depending on the sort of traffic scenario to be studied different traffic simulation models to model supply are used. There are three main types of models, macroscopic, microscopic and mesoscopic. A macro simulation model describes the traffic at a high level of aggregation based on flows. It is a static model that takes a "snapshot" of traffic flows, and the network is simplified to a representation of links and nodes. Micro simulation models are dynamic models where each vehicle is simulated individually. The network is built in detail and traffic controls such as traffic signals and yield signs are modelled. Both macroscopic and microscopic models apply behavioural models to simulate how vehicles interact in the system, though micro simulation models model driver behaviour at a higher level of detail. Mesoscopic models typically model individual car movements along a road link less extensively.

### 2.1.1 The Sampers forecasting system

When studying traffic control measures in QCity we use the transportation modelling system Sampers (Beser and Algers 2002) which contains a multimodal travel demand model system and which is integrated with the network analysis package Emme/2 (Inro, Canada). Demand is calculated as a function of socioeconomic variables describing travellers, attraction variables describing destinations and traffic network variables describing the transport system. The demand is assigned to the traffic network by the network analysis package. The latter is a macroscopic model where a region to be analysed is described by zones, links and nodes. Zones are areas that generate or attract trips representing e.g. dwellings and working sites, whereas links and nodes make up the traffic network. The most detailed results are vehicle flows per category per link for different time periods, and transit loads per line for the same periods. Figure 6 illustrates the structure of the model, and the next two paragraphs give a more detailed description.

#### 2.1.1.1 Basic model structure

The Sampers system is built around a four-dimensional travel behaviour model, reflecting choices people make in the dimensions of trip generation, trip distribution, mode choice and route choice.

The three first dimensions are modelled simultaneously using discrete choice models of the nested logit type (Ben-Akiva, Lerman 1985). This implies that the probability to choose each possible combination of alternatives in the three dimensions (to travel or not, to what destination, by what mode) is calculated for each person in the area. The results are then aggregated to a level describing the total traffic demand between each origin and destination zone pair for each mode. For route choice, a network assignment procedure is used to be able to consider congestion effects of travellers' route choice.

Different variables are used to describe the alternatives in the different dimensions. The nested structure of the model allows factors affecting one dimension to also affect choices in other dimensions (a change in parking costs in one area will not only affect mode choice, but also destination choice and the choice to make a trip at all). The model parameters, reflecting the importance of the different variables, are estimated on the National Swedish Travel Survey 1994-2000, and calibrated for the year 2001.

In order to make it possible to consider peoples route choice with respect to congestion, a network assignment procedure is used that achieves consistency between route choice and network congestion. This is modelled in Emme/2 by the concept of network equilibrium (Ortúzar, Willumsen 1990). Each link is associated with a volume-delay function describing how travel time varies with traffic volumes based on the capacity of the link. Turning vehicles can also get so called turn penalties in the nodes (road junctions) to account for delays due to signals etc. An iterative algorithm is used to obtain an equilibrium situation. The final solution describes flows in accordance with Wardrop's user optimum principle where no traveller can decrease his or her travel time by changing route. For public transport, route choice of public transport submodes is modelled by the so-called Optimum Strategy approach (Spiess and Florian 1990). Here a passenger will pick the transit line or combination of transit lines that minimizes his or her travel time considering travel time in the vehicle, connection times and waiting times. For slow modes (walk and bike) people are modelled to use the shortest path.

Finally, in situations with congested networks, it is necessary to recalculate the travel demand and redo the network assignment in an iterative process. As the generalised cost of a link is based on the number of travellers travelling on the link the costs previous to and post to a network assignment may not be equal. Hence an iterative process between the demand model and the network assignment model results in a solution were there is consistency between choices in all dimensions and the level of congestion, reflected in travel times on the network. These iterations are often very time-consuming and therefore generally only a few iterations are made.

Figure 1 gives an overall picture of the structure of Sampers and its integration with Emme/2. Note that a traffic control policy applied on the network is input to Emme/2.

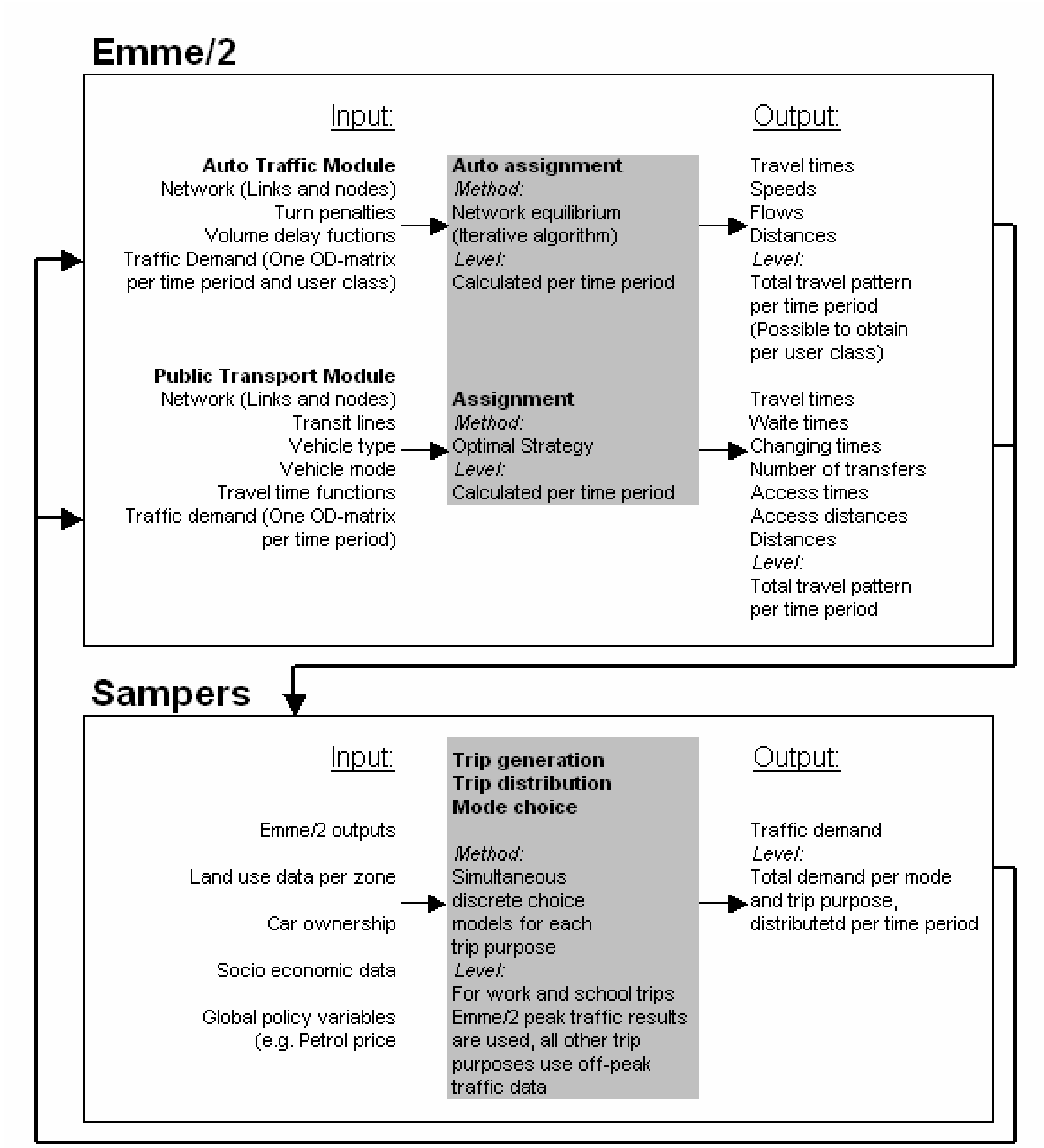



Figure 1: Structure of the transportation modelling system Sampers and its integration with Emme/2.

### 2.1.2.1 Features in Sampers used in this work package

Sampers contains submodels for all trips in Sweden including international trips, domestic long distance trips and regional and local trips. As local traffic control policies applied in the study areas may affect a whole region, we model regional and local trips of an area including all of Stockholm County using the submodel for regional and local trips. Long distance trips and heavy traffic are also included, but are fixed in terms of Origin and Destination zones (but can change routes).

In this application, the road and public transport network for year 2005 is used. The complete network consists of approximately 6 000 regular nodes and 1 500 traffic zones.

When evaluating different traffic control policies as restricting car traffic to specific links and restricting speed, the package is used to introduce these changes in the original model network. For example it is possible to restrict car traffic in an area by not allowing cars on the specific links, or reduce speed limits by changing volume delay functions. Note that all changes affect the whole travel pattern. If a strategy is to forbid car traffic on a link, this will force people who used to travel on that link to choose another route. However they may also change destination, mode or even cancel the trip, all depending on the change in accessibility due to the policy.

Sampers models six different trip purposes: work, business, school, social activities, recreation and other. In the network assignment procedure, the resulting demand is divided into several user classes with different values of time. This is necessary to reflect different route choice behaviour for different user classes when economic restrictions are imposed. The value of time parameter reflects the amount of money a traveller is willing to pay to decrease his or her travel time by one time unit. In Qcity, each user class (except the truck user class) has been subdivided into one user class for standard car drivers, and one user class for low noise car drivers. Different fees can then be imposed on different user classes, and the resulting differences in behaviour can then be modelled. The resulting flows for standard cars and low noise cars can then be used as input to noise mapping software.

The noise mapping software requires daily volumes as input. This means that the results from Sampers for different time periods need to be aggregated. A day is divided in three time periods, 7-9 a.m., 9 a.m.-16 p.m. and 16-18 p.m., reflecting the peak and off peak conditions. Traffic demand for each trip purpose and user group is distributed to these time periods in different shares. For example all work and school trips are set to take place in the peak hours (the first and the last period). The periods and distributions have been set to capture the dynamics of traffic during the day. An illustrative example is figure 2 showing the traffic distribution on a European highway south of Stockholm City (E4), with model periods marked in green (figure 2).

Simulation of travel demand for the first and the last period are assumed to give similar results (however with reversed direction). Thus by only simulating the first and second time period, representing peak and off-peak hour traffic, calculation time is saved. Nevertheless the simulation time for the base scenario used in QCity is approximately 12 hours.

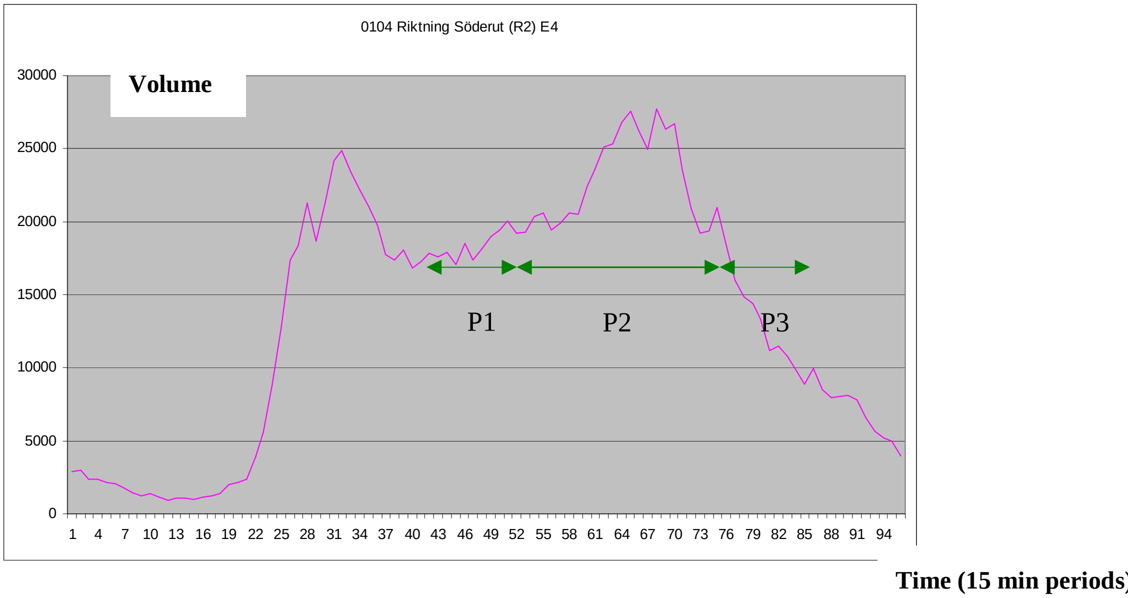



Figure 2: Traffic distribution during a day

### 2.1.2 Handling parking behaviour

The Sampers forecasting system does not handle choice of parking place in its standard version. For analysing traffic effects of imposing the quiet zone concept, it is however necessary to take into account the possibility to park the car outside the zone in stead of inside the zone, implying some extra walk time. If the extra walk time is small, this would be a better choice for many than using another mode or to go to another destination.

The option to park outside the zone has been modelled by providing walk links from existing parking locations into the quiet zone area. This means that the driver can choose to go by car all the way to the destination, or to go to a parking location and then walk to the final destination. As car speed is higher than walk speed, the option to park outside the zone is not used in the base scenario. When the entrance to the zone is banned, then the only option to arrive to the zone by car is to use the outside parking facilities. In the case of noise fees, there will be an additional option to pay the fee and go by car all the way. The tractability of this option will depend on the fee, the extra walk time and how the driver would trade off travel cost and walk time.

In the Emme/2 assignment procedure, there are 5 different classes with respect to value of time. The middle class has a value of 60 SEK (6 Euro) per hour. For this class, one hour of travel time is perceived as equivalent to a travel cost of 6 Euros, and 10 minutes of travel time is perceived as equal to 1 Euro travel cost. So, under these conditions, to be willing to pay one Euro extra, the gain in travel time has to exceed 10 minutes. 10 minutes of walking would take a person about 800 metres if walking speed is 5 km/h as assumed in the assignment procedure. So, outside parking would be used as long as the extra distance is shorter than 800 metres or the value of time is higher than 6 Euro/h. In reality, walk speed may be lower than 5 km/h, and the value of walk time relative to in vehicle car time may be higher.

## 2.2 THE NOISE MAPPING SOFTWARE CADNAA

### 2.2.1 General

The calculation program CadnaA, developed by Datakustik GmbH in Munich, has been used for the road noise calculations. CadnaA is a commercial software, continually developed, improved and updated with new calculation models.

The calculations are made according to the current Nordic calculation model for road noise, rev 1996.

The ground and the buildings are assumed to be totally noise reflecting, and one noise reflection is considered in the calculations.

The noise maps are calculated at 2 meters above ground level and the size of the receiver grid is 3 x 3 meters.

More information about CadnaA can be found on the webpage www.cadna.de.

### 2.2.2 Combining low noise and standard car noise levels

The noise emission from a Toyota Prius was measured with the aim of separating noise from tyres from noise from driveline. The driveline noise was assessed by the total noise emission at very low speeds, while the tyre/road noise was assessed by the noise emission at higher speeds.

Assuming that the tyre/road noise and the driveline noise both could be written in form

Lp = n 10log(v2/v1) a velocity exponent for tyre/road and driveline noise can be obtained. Those velocity exponents have been used in order to state the tyre/road and driveline noise separately as reported in chapter 3.5 in this deliverable

The results were implemented by calculating an average noise reduction (found to be 7 dB(A)-units) for Toyota Prius in the speed range from 25 - 50 km/h.

In the case where also normally noisy cars are allowed to enter the quiet zone with its surroundings (at a fee of 1 or 0,5 Euro) we first calculated the noise from the hybrid vehicles in the zone, with its surroundings, according to the Nordic Prediction Method. Then we also calculated the noise from normal passenger cars for the actual traffic in the restricted zone.

The total sound level in the area is achieved by logarithmically adding the sound level from ordinary vehicles and the hybrid vehicles. We also calculated the traffic noise before introducing the quiet zone based on the traffic flow data from the computer simulation. This enabled us to calculate difference plots displaying the noise reduction after introducing the quiet zone (relative the status before).

### 2.2.3 Adapting Traffic Forecasts to Noise Mapping Software

In order to use the outputs of Sampers as input to the noise mapping software CadnaA an interface is generally needed to assign network flows in Emme/2 to street objects in the Cadna data base. In this work package, the network coding in Emme/2 has been done to match the full detail of the existing physical network. A one-to-one classification has been made between the Emme2 network and the digital map used in Cadna.

# 3 SITE SELECTION AND DEFINITION

## 3.1 NETWORK

In Stockholm, traffic zoning has already been used to prevent through traffic in residential areas. In the inner city, there is still a considerable amount of traffic and hence traffic noise on many streets. This is due to the fact that no inner city area is purely residential, so activities related to business and recreation will still be accessed by non-residents.

In the short run, when low noise vehicles still are very rare, establishing a quiet zone means to drastically reduce the amount of traffic to and from the zone. This places some restrictions on the size of the zone, at least in the short run. The area which we have chosen for the case study is therefore rather small, but with important extension possibilities.

The site was selected with respect to the realism in imposing quiet zone restrictions and where an effect of introducing quiet road surfaces could be expected. This lead to the selection of an area in the inner city, as is shown on the map below (figure 3):

Figure 3 Map of Stockholm inner city (quiet zone in red)

The area is shown in larger scale in figure 4. The solid red line indicates the quiet zone, and the dashed red line indicates the area subject to noise mapping and more detailed traffic forecasting.

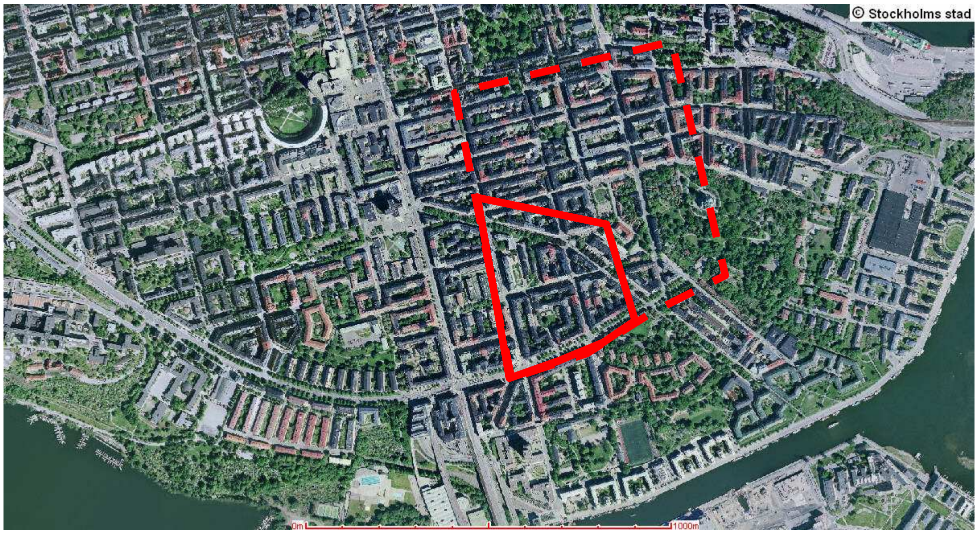



Figure 4 Map of Stockholm inner city (quiet zone in green)

The area subject to noise mapping contains about 20 000 residents, of which the quiet zone area contains about 5 000. The quiet zone also contains about 1500 workplaces.

## 3.2 CURRENT TRAFFIC

Traffic is intense on the southern and western borders of the area. Traffic volumes inside the areas are smaller, as can be seen from figure 5 below. The flow chart shows day traffic. The legend relates to half the total bandwidth for a link. The intended quiet zone area is marked with a red line.

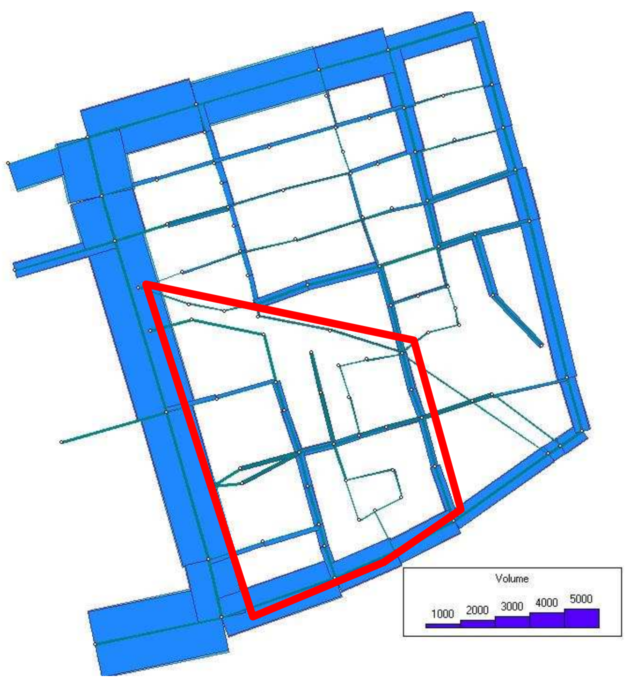



Figure 5 Day traffic flows

## 3.3 CURRENT NOISE LEVELS

The current situation is a moderately exposed area, as shown on the noise map below (figure 6).

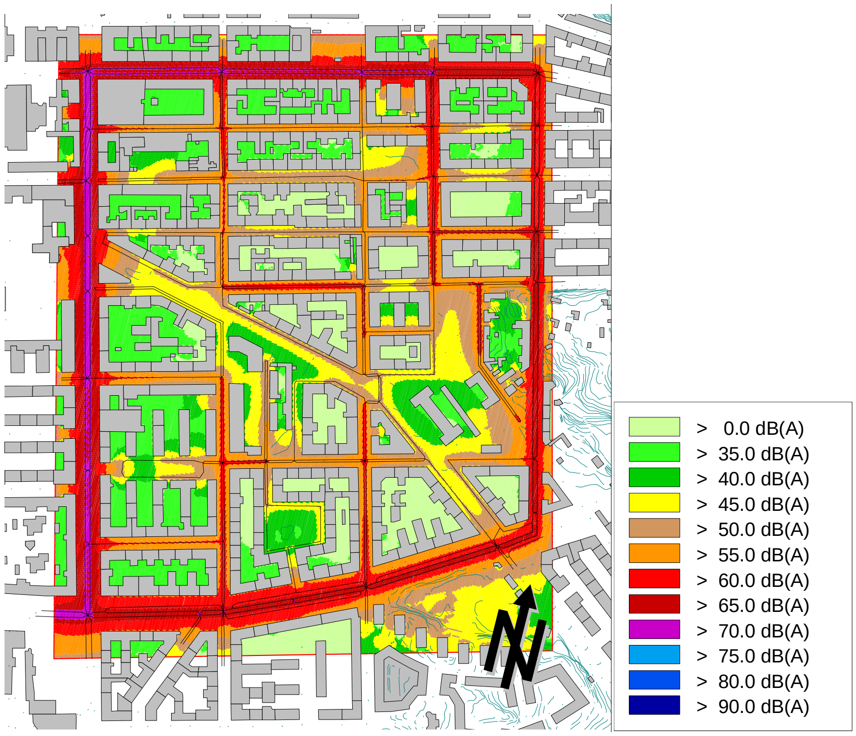



Figure 6 Noise map of current conditions (dB(A) day)

The distribution of noise exposure levels is presented in the graph below (figure 7), showing the number of residents subject to noise exposure in each of 8 5dB(A) classes:

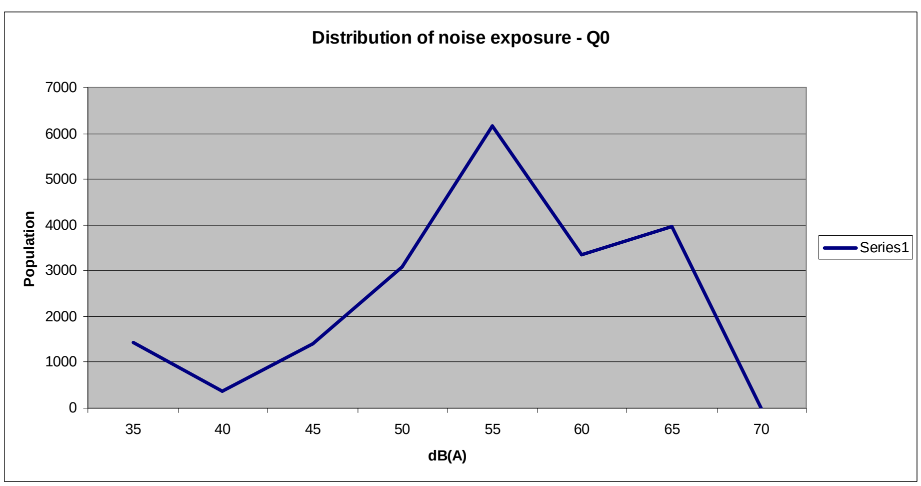



Figure 7 Noise exposure distribution, current conditions (dB(A) day)

The impact of the noise exposure in terms of noise disturbance can be described by the relationship shown in the figure below (Miedema 2007) and which is based on a meta study including a large number of noise annoyance studies in Europe:

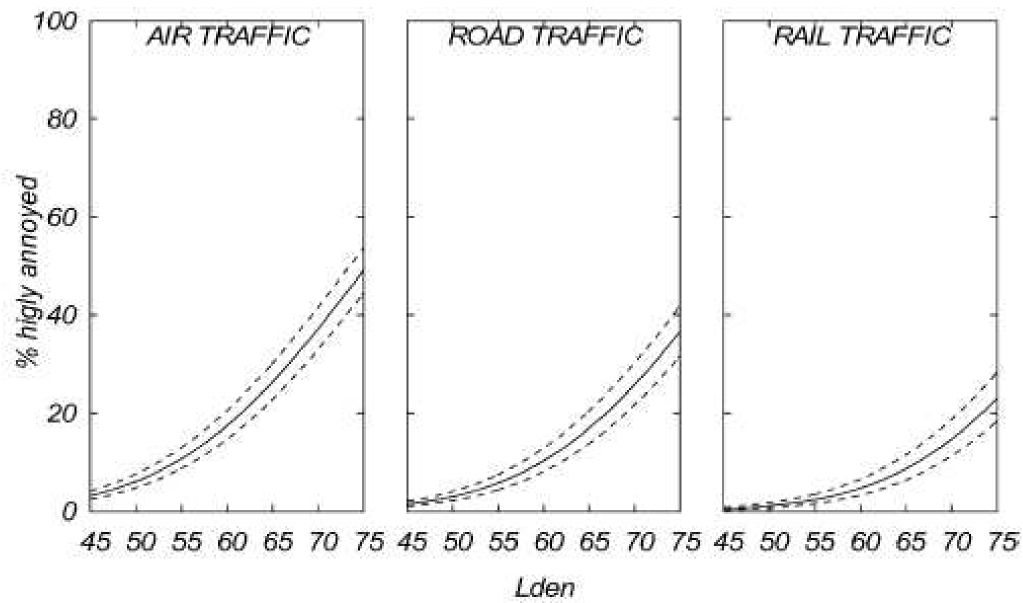



Figure 8 The percentage highly annoyed (%HA); solid lines) as a function of $L_{den}$, for air, road and rail traffic noise, and the confidence interval (broken lines).

## 3.4 VEHICLES

The quiet zone concept is about achieving a better noise environment by constraining the use of relatively noisy cars (normal petrol and diesel cars) but allowing low noise vehicles (such as electric hybrid cars in electric mode). We will term these two groups "standard vehicles" and "low noise vehicles". Vehicles must also be equipped with low noise tyres to qualify as a low noise vehicle, in order to preserve the lower driveline noise from the electrical hybrid in the relevant speed range.

## 3.5 TYRE/ROAD CONDITIONS

Noise effects are calculated under the following assumptions on tyre/road conditions:

Tyre/road noise for electric hybrid cars is assumed to be reduced by 5 dB(A)-units. The driveline noise emission for electric hybrid cars has, by measurements, been found to be reduced by 10 dB(A) units. In the speed range of 25-40 km/h a total noise reduction of 7 dB(A)-units will be obtained.

The total noise obtained with quiet vehicles is assumed in this study to be reduced by 7 dB-units compared to standard petrol cars at vehicle speeds below 25 km/h. However, according to a study on a hybrid electric vehicle performed by ACL within the QCITY project (presented in Appendix 2), this assumption of the total noise reduction may be slightly underestimated. A short summary of this study is presented in the section below.

### 3.5.1 Study of noise emission from a hybrid electric vehicle

It has been shown that hybrid electric cars, due to its low driveline noise, may be an efficient tool for creating quiet areas in city environments. Information on the noise reduction from hybrid vehicles in comparison to standard petrol powered passenger cars is required in order to establish a requirement on the noise emission level of tyre/road noise. Therefore, the driveline noise for a hybrid electric vehicle (Toyota Prius - manufactured in 2006) and a standard petrol car (Volvo V70) has been studied by ACL (Appendix 2). A hybrid electric car is propelled by a petrol engine and/or an electric motor. In this study the hybrid car was only propelled by the electric motor.

The basic concept used in this study is that driveline noise is dominating at lower speeds while tyre/road noise is dominating at higher speeds. With this in mind and further assuming a constant characteristic velocity exponent of each source type, it has been possible to separate the driveline noise and the tyre/road noise from the total emitted noise level.

The velocity exponent for tyre/road noise is higher than the velocity exponent for driveline noise, which means that there is a velocity limit over which the tyre/road noise is dominating. The results show that this velocity limit for the hybrid car is 13 km/h while the corresponding limit for the petrol car is about 30 km/h. The total emitted noise level for the hybrid car is reduced by 4-10 dB(A) in the speed range 10-60 km/h (typical urban driving conditions) compared to the petrol car. The tyre/road noise is reduced by 3.5 dB(A) while the driveline noise is reduced by 12 dB(A) in the whole speed range, see Figure 9 below.

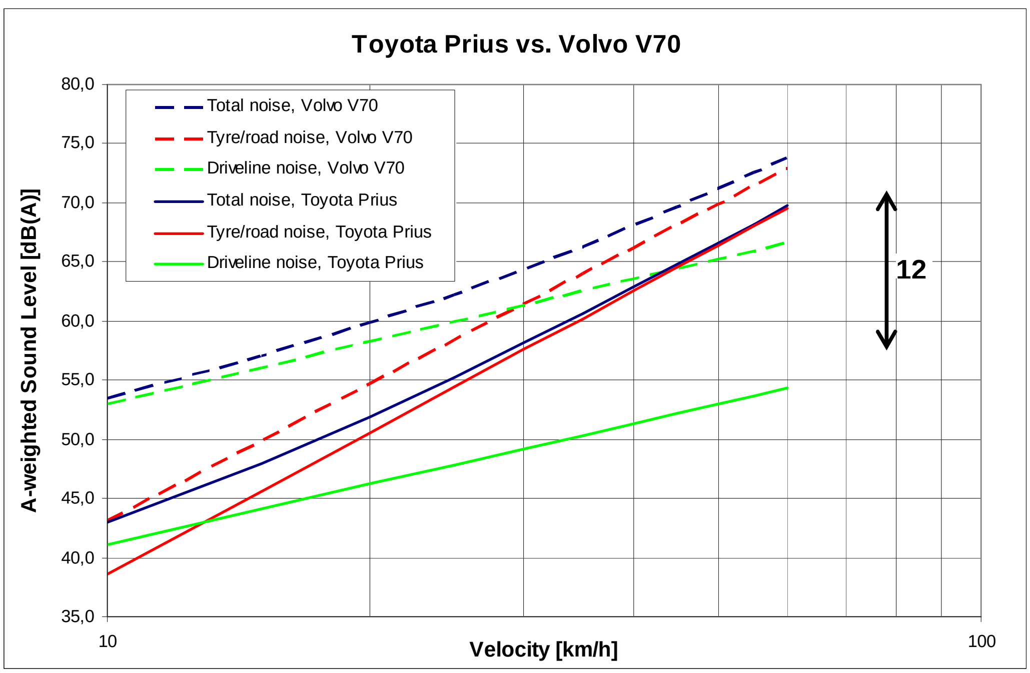



Figure 9. Comparison of noise emission levels for the hybrid and the petrol car.

Results above show that the tyre/road noise must be reduced in order to obtain a significant reduction of the total noise emission in the whole speed range.

Tyre/road noise is the noise emission from the interaction of the tyre and the road surface. Therefore, new type of quiet tyres and road surfaces must be developed in order to reduce the tyre/road noise significantly. The total noise reduction will depend on the level of the tyre/road noise reduction.

A new type of tyre called DualQ is developed by ACL within the QCITY project, see deliverable D5.11. Measurements show that DualQ reduces the tyre/road noise by 6-8 dB-units relative to a standard car tyre. Studies on quiet road surfaces are also performed within the QCITY project, c.f. deliverable D5.5 and D5.13.

The total noise level reduction due to different levels of tyre/road noise reductions is shown in Figure 10. The largest reductions of the total noise are obtained at higher velocities, while almost no reduction is obtained at lower velocities due to dominating driveline noise.

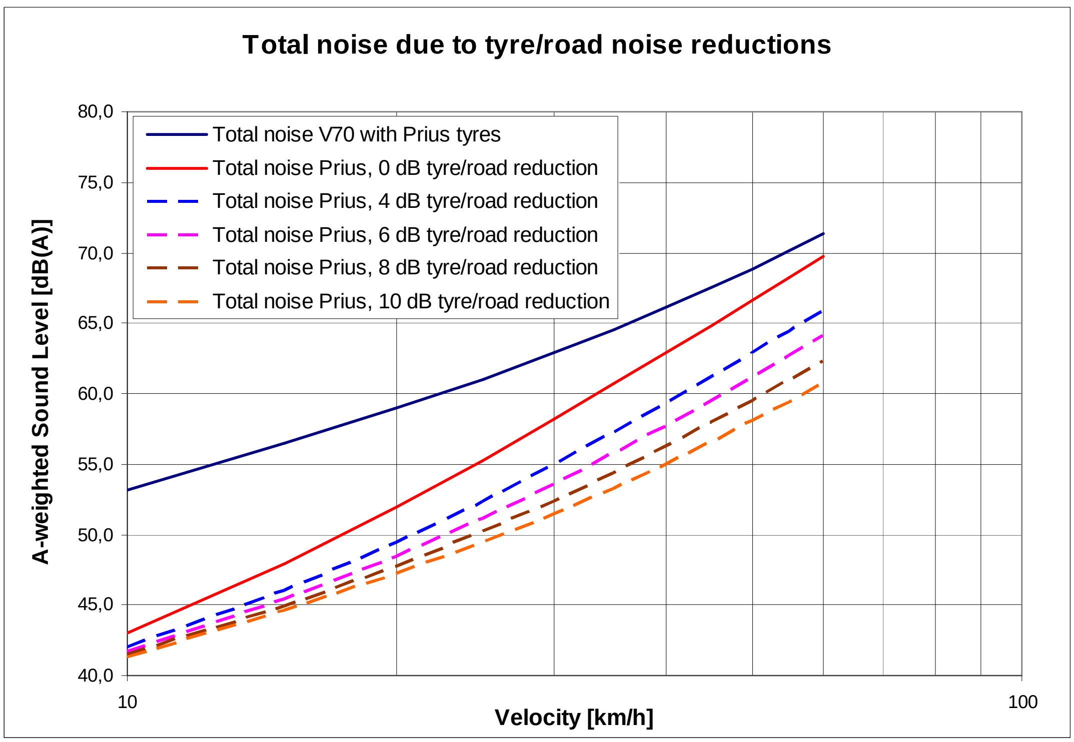



Figure 10. Total noise due to different levels of tyre/road noise reductions.

The total noise displayed for the V70 in Figure 10 is the V70 driveline noise in combination with the unchanged tyre/road noise taken from the Prius measurements. In other words, Prius and V70 in Figure 9 have the same type of tyres running on the same type of road surface, which means that it is only the driveline noise that differs.

The difference in total noise level relative to V70 due to different levels of tyre/road noise reductions is shown in Figure 11 below.

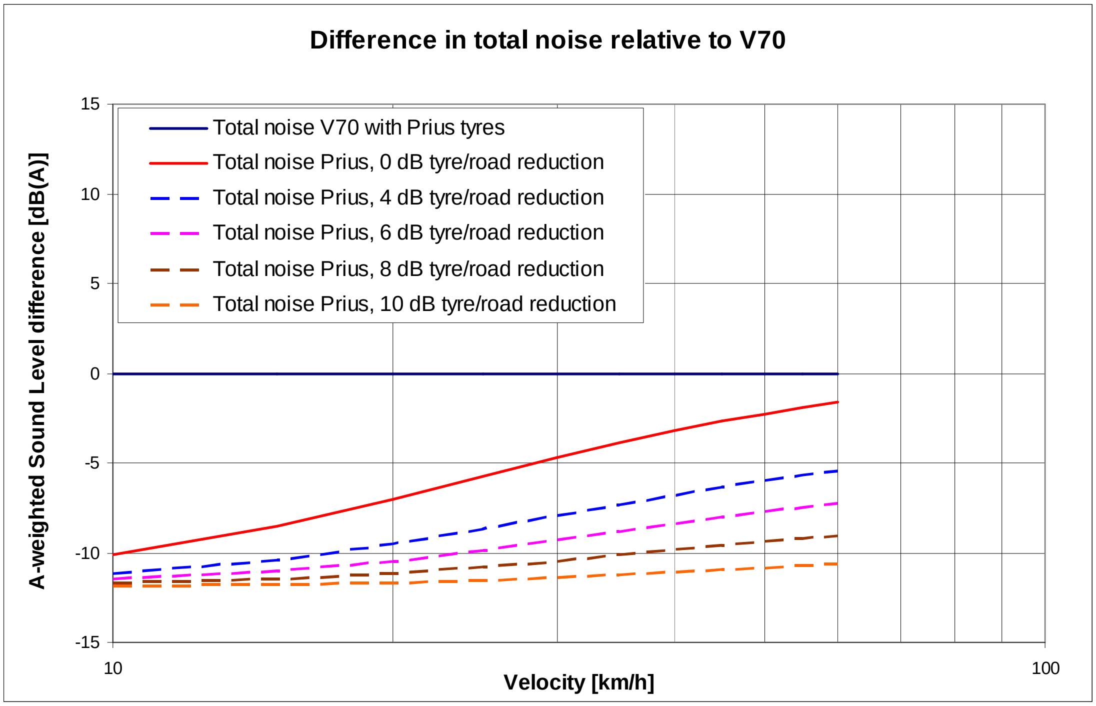



Figure 11. Total noise difference relative to V70 with Prius tyres at different levels of tyre/road noise reductions.

Note that a 10 dB(A) tyre/road noise reduction results in a total noise reduction of about 12 dB(A) in the whole investigated speed range. This means that a 10 dB(A) tyre/road noise reduction is required in order to obtain a 12 dB(A) reduction in total noise for a hybrid electric vehicle compared to a standard petrol powered car, with the assumption that they are supplied with the same type of tyres running on the same type of road surface.

The results in this study are based on rough estimations and may therefore serve primarily as guiding principles.

# 4 NOISE MITIGATION SCENARIOS - DEFINITIONS

## 4.1 DO NOTHING

The do nothing scenario Q0 is today's traffic situation, and provides the base for comparison. The traffic situation is shown figure 5 (day traffic). The share of low noise vehicles among residents in Stockholm is not known in geographical detail, so assumptions need to be made. In the base scenario it is assumed to be 5 percent, which is probably somewhat more than today, inside as well as outside the quiet zone.

## 4.2 LOW NOISE VEHICLES ONLY

In the second scenario (Q1), all standard vehicles are banned. This provides the other extreme, which measures what the maximum noise reduction would be. The assumption on shares of low noise vehicles remains the same as in the base scenario.

## 4.3 NOISE FEES

In the third and fourth scenarios, noise charges are introduced in stead of a ban. In the third scenario (Q2) the noise fee is 10 SEK (1 Euro) per entry or exit, and in the fourth scenario (Q3) the noise fee is 5 SEK (half a Euro) per entry or exit. The assumption on shares of low noise vehicles remains the same as in the base scenario.

## 4.4 INCREASED LOW NOISE VEHICLE SHARES IN CAR FLEET

In the fifth and sixth scenarios, we combine the noise fee scenario with assumptions of increased shares of low noise cars. The noise fee is 10 SEK (1 Euro) in both scenarios. In the fifth scenario (Q4), the share of low noise vehicles is assumed to be 100 percent among residents in the quiet zone, and remains 5 percent among residents outside the zone. In the sixth scenario (Q5), the share of low noise vehicles increases to 20 percent outside the zone while keeping 100 percent in the zone.

The assumptions on the shares of low noise vehicles among residents inside and outside the quiet zone are of course important. Current levels of low noise vehicle ownership iare not known at a geographically detailed level, but the average level in Sweden is only around 1 percent. Forecasts have been made in context with the Swedish national transport investment planning process. in the base scenario, involving a number of measures to promote CO2 efficient cars, about 50 percent of the new car sales are estimated to be electrical hybrid cars in the year 2020,. Due to the inertia inherent in the vehicle fleet transformation process, the share of such vehicles in the total vehicle fleet is estimated to be about 10 percent in the year 2020. The share of electrical hybrids will probably be higher in highly urbanised areas such as Stockholm. For people residing in the quiet zone or regularly visiting the zone, the ban or noise fee scenarios provides additional incentives to acquire low noise vehicles, making the assumed shares reasonable even earlier than in the year 2020.

## 4.5 ZONE SIZE

In the seventh scenario (Q6), we combine the noise fee scenario with an increased size of the quiet zone. The noise fee is 10 SEK (1 Euro), and the assumption on shares of low noise vehicles remains the same as in the base scenario. The size of the quiet zone has been increased to contain the area shown in figure 12. In the eighth (Q7) and ninth (Q8) scenarios, effects on increased shares of low noise vehicles are assumed for the extended zone.

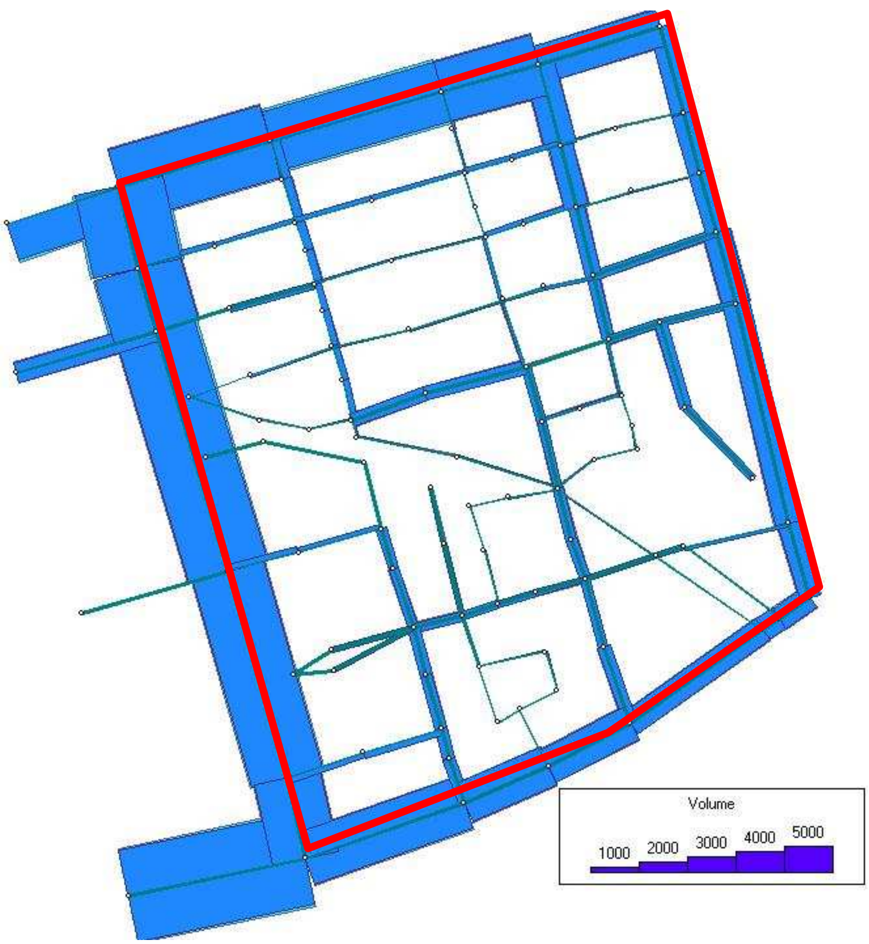



Figure 12 Extended quiet zone (base scenario day traffic volumes)

# 5 NOISE MITIGATION SCENARIOS – EFFECTS

## 5.1 GENERAL

The scenarios imply restrictions on standard car use. This will affect travel behaviour in different ways. Car users with a destination inside the zone need to consider the following main options:

- Pay the fee
- Use the car and park outside the zone
- Use another mode
- Change destination
- Not make the trip
- Acquire a low noise vehicle

It is assumed that there is available parking space at existing parking facilities at the same prices as inside the zone.

Car user that previously travelled trough the zone area will have to consider the following main options:

- Pay the fee
- Change route to avoid the area
- Use another mode
- Change destination
- Not make the trip
- Acquire a low noise vehicle

These different ways of adapting to the new situation is modelled in the Sampers model, except for the acquisition of vehicles which has to be modelled separately.

## 5.2 LOW NOISE VEHICLES ONLY – Q1

### 5.2.1 Traffic effects

The area has already been subject to traffic zoning, which implies that there is very little through traffic. The main effect will therefore be outside parking, mode shift and destination shift. In figure 13, differences with respect to the base scenarios are shown, using green colour for decreased volumes and red colour for increased volumes.

As can be seen from figure 13, traffic volumes are reduced inside the quiet zone but have increased on the main streets. The main effect is on parking behaviour. Changing destination or mode occurs to a much lesser extent.

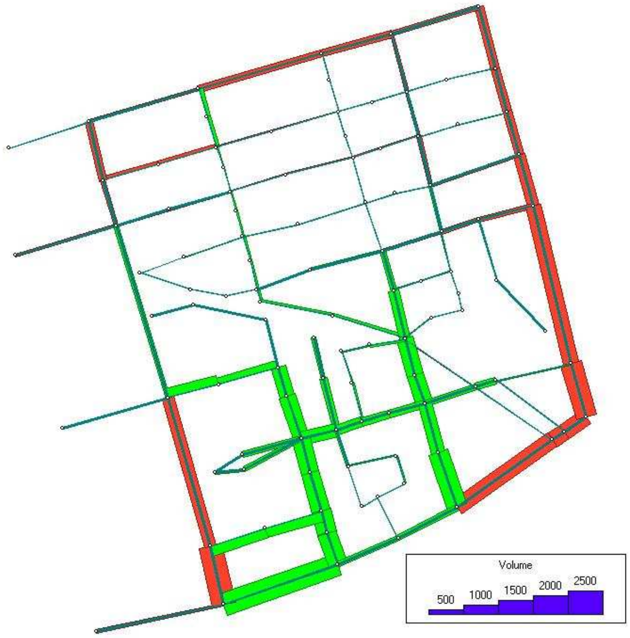



Figure 13 Day traffic volume difference between scenario Q1 and Q0

### 5.2.2 Noise effects

The new noise situation is depictured in the noise map below (figure 14).

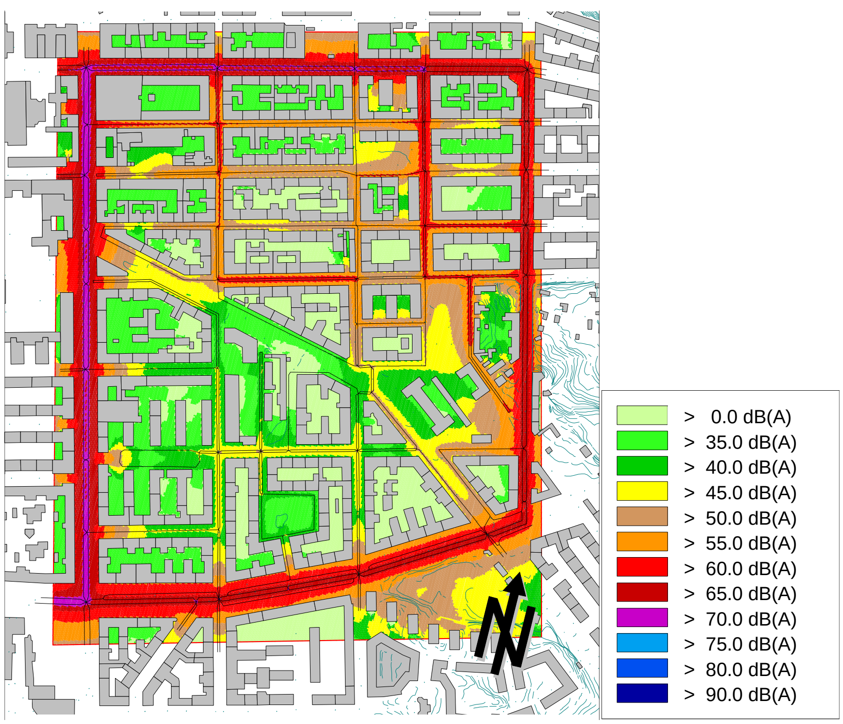



Figure 14 Noise map when standard vehicles are banned (dB(A) day)

Noise levels inside the quiet zone are low, in most of the zone less than 50 dB(A). In the map below, the difference with respect to the base scenario is shown on the noise difference map below (figure 15)

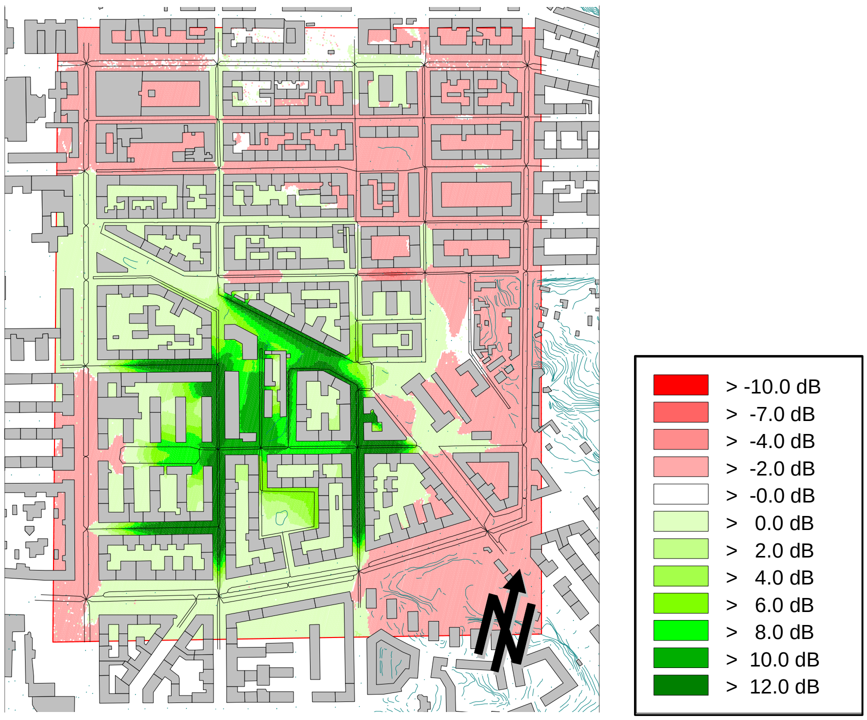



Figure 15 Noise difference compared to base scenario (dB(A) day)

The scenario has a large impact in the central parts of the zone. Minor increases in the surrounding area can also be identified. These are mainly due to traffic having to drive around the banned area, and going to neighbouring areas to find parking.

The effects in terms of a redistribution of noise disturbances are shown in the table below (table 1):

Table 1 Noise exposure distribution of residents

| From dB(A) | to dB(A) | Base (Q0) | % of total population | Banned standard cars | % of total population | Difference Q1 - Q0 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1424 | 7,2% | 1717 | 8,7% | 293 | 1,5% |
| 35 | 40 | 370 | 1,9% | 1875 | 9,5% | 1505 | 7,6% |
| 40 | 45 | 1404 | 7,1% | 2423 | 12,3% | 1019 | 5,2% |
| 45 | 50 | 3086 | 15,6% | 3256 | 16,5% | 170 | 0,9% |
| 50 | 55 | 6158 | 31,1% | 3281 | 16,6% | -2877 | -14,5% |
| 55 | 60 | 3360 | 17,0% | 3030 | 15,3% | -330 | -1,7% |
| 60 | 65 | 3969 | 20,1% | 4189 | 21,2% | 220 | 1,1% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

The table shows the noise exposure distribution for the entire population in the mapped zone, about 20 000 persons. The main effect is a redistribution of persons in the 50 – 55 dB(A) interval to the 35 – 45 dB(A) interval. Outside the zone, including its boundaries, there is a small increase in the order of 2 dB(A) over the entire area, also making 220 additional persons exposed to the 60-65 dB(A) noise level.

## 5.3 Noise fee 1 Euro – Q2

### 5.3.1 Traffic effects

Traffic effects are quite similar to the ban scenario (Q1). The difference between the 1 Euro scenario and the base scenario is shown below (figure 16):

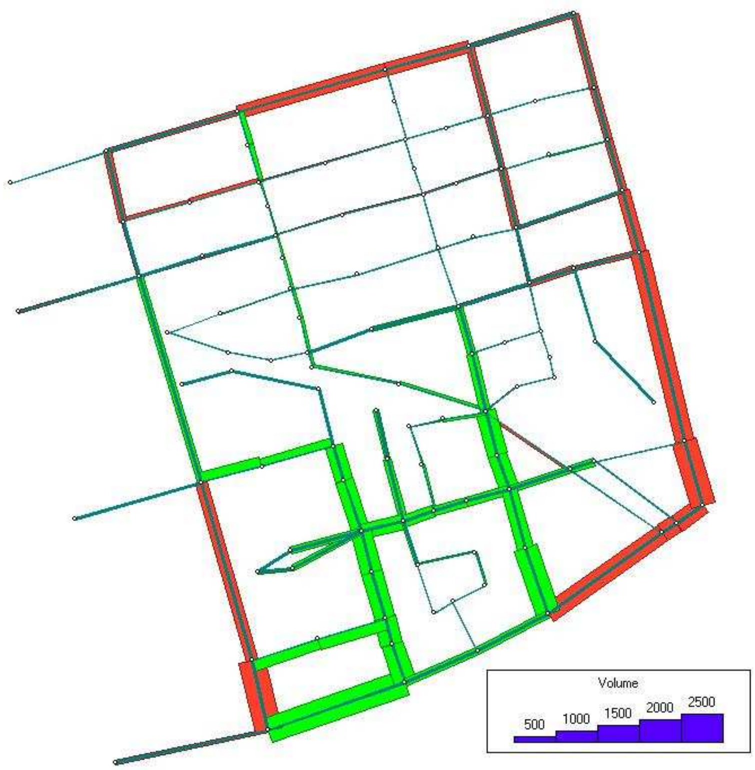



Figure 16 Day traffic volume difference between scenario Q2 and Q0

For many travellers it is not worth paying one Euro to gain a few hundred meters of walking, and consequently the main effect also in this scenario is to use outside parking (assuming that there is a choice). In practise, this would mean that there is demand in excess of current parking capacity at equal parking prices inside and outside the quiet zone.

### 5.3.2 Noise effects

In the 1 Euro noise fee scenario, not all standard vehicles will disappear from the quiet zone. Noise disturbance effects will be less, but on the other hand it will be possible for standard car drivers to access the area for various reasons. The noise situation is shown below (figure 17):

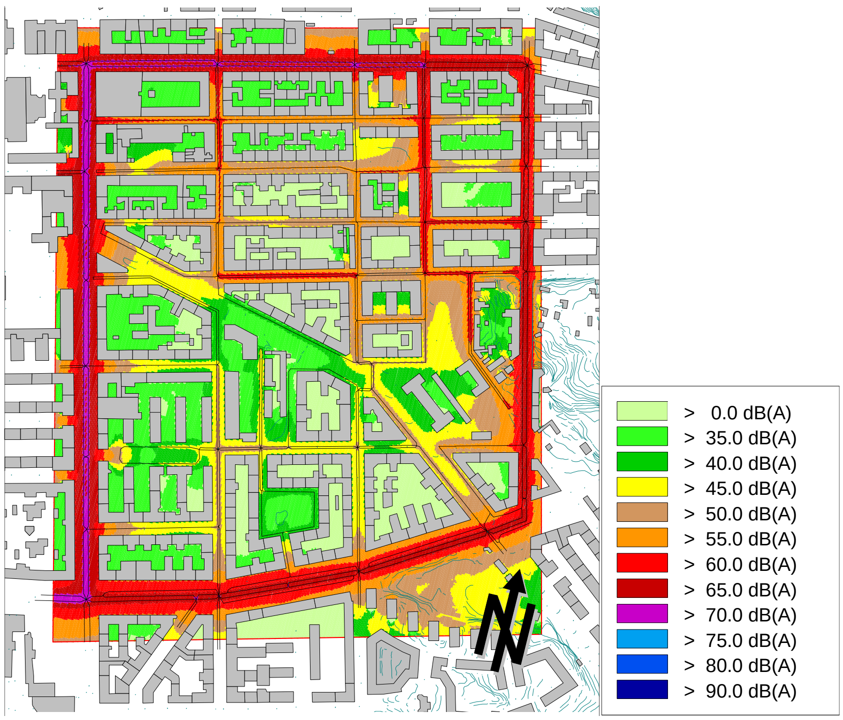



Figure 17 Noise map with 1 Euro noise fee (dB(A) day)

A comparison with the base scenario is presented below (figure 18):

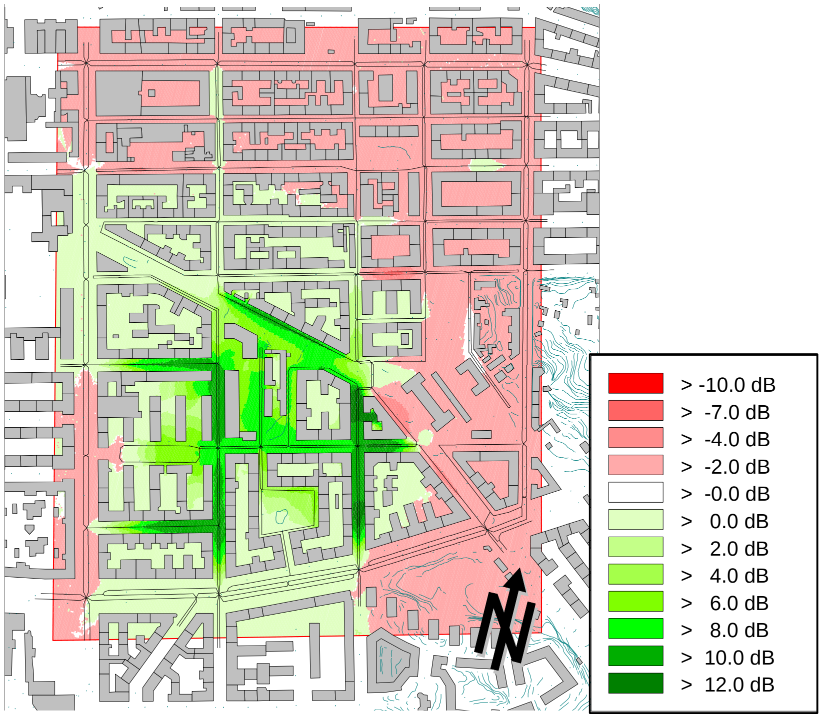



Figure 18 Noise difference compared to base scenario (dB(A) day)

The pattern is the same as for the previous scenario, but the magnitude is somewhat weaker as can be expected from the smaller traffic reduction.

The noise exposure redistribution effects are presented in table 2:

Table 2 Noise exposure distribution of residents

| From dB(A) | to dB(A) | Base (Q0) | % of total population | 1 Euro noise fee | % of total population | Difference Q2 - Q0 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1424 | 7,2% | 1505 | 7,6% | 81 | 0,4% |
| 35 | 40 | 370 | 1,9% | 1157 | 5,9% | 787 | 4,0% |
| 40 | 45 | 1404 | 7,1% | 2950 | 14,9% | 1546 | 7,8% |
| 45 | 50 | 3086 | 15,6% | 3535 | 17,9% | 449 | 2,3% |
| 50 | 55 | 6158 | 31,1% | 3453 | 17,5% | -2705 | -13,7% |
| 55 | 60 | 3360 | 17,0% | 2982 | 15,1% | -378 | -1,9% |
| 60 | 65 | 3969 | 20,1% | 4189 | 21,2% | 220 | 1,1% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

In this case the main effect is a redistribution from the 50 – 55 dB(A) interval to the 35 – 45 level, but less pronounced.

For this scenario, a sensitivity analysis with respect to the traffic simulation method used was undertaken (see Appendix 1). The analysis suggests the effects may be somewhat overestimated, concerning reductions inside the quiet zone as well as increases outside the zone. The sensitivity analysis also suggests that the noise exposure in the base scenario may be somewhat underestimated, implying that even though noise level reductions (and increases) may be less, they will emerge from higher noise levels.

## 5.4 HALF EURO NOISE FEE – Q3

### 5.4.1 Traffic effects

As the noise fee is lower, traffic effects are also lower. We are now in the range where more car drivers will find it worthwhile to pay the fee to avoid walking time. We therefore will find more traffic in the centre of the quiet zone. This will also add to traffic in the surroundings of the quiet zone.

### 5.4.2 Noise effects

This scenario represents a less burdensome economic constraint on the use of standard vehicles in the quiet zone. Interestingly, noise effects differ from the previous patterns in that it worsens the surrounding area more than it improves the area within. The noise situation is presented in the map below (figure 19):

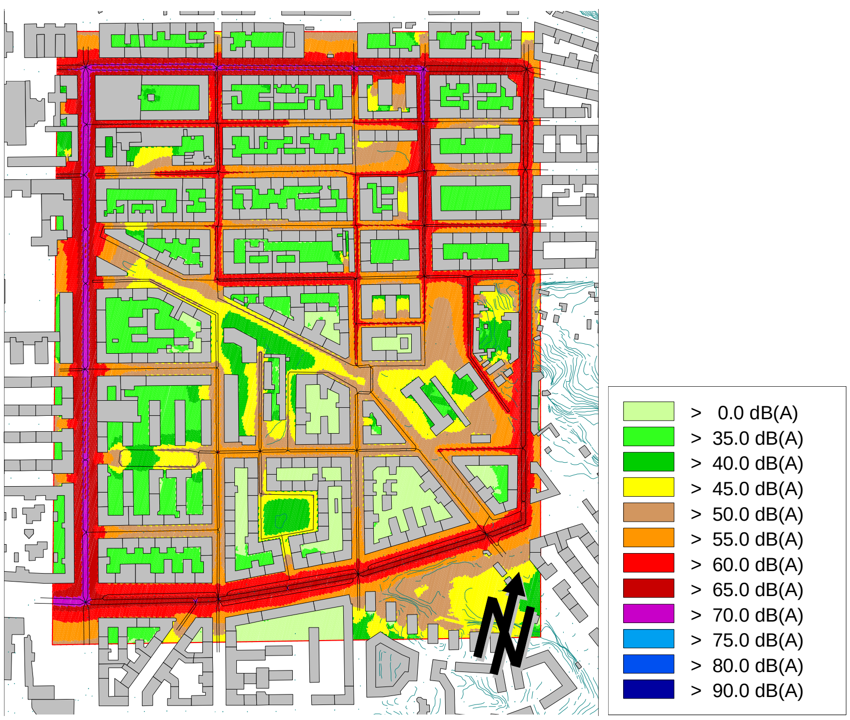



Figure 19 Noise map with half a Euro noise fee (dB(A) day)

The effects can be seen more clearly on the difference plot below (figure 20).

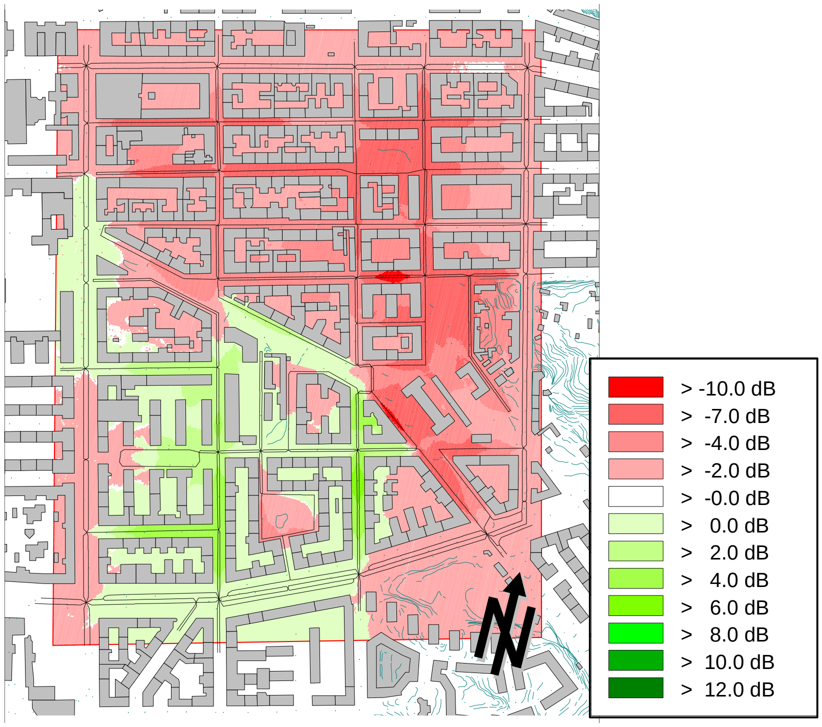



Figure 20 Noise difference when compared to base scenario (dB(A) day)

Noise decreases are in the range of 2-4 dB(A), as are the increases. However, increases are to a large extent located where noise level are already higher. That means that the noise disturbance redistributions are often from a lower level to a higher, as is shown in table 3.

Table 3 Noise exposure distribution of residents

| **From dB(A)** | **to dB(A)** | **Base (Q0)** | **% of total population** | **Half Euro noise fee** | **% of total population** | **Difference Q3 - Q0** | **% difference of total population** |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1424 | 7,2% | 1435 | 7,3% | 11 | 0,1% |
| 35 | 40 | 370 | 1,9% | 217 | 1,1% | -153 | -0,8% |
| 40 | 45 | 1404 | 7,1% | 961 | 4,9% | -443 | -2,2% |
| 45 | 50 | 3086 | 15,6% | 3908 | 19,8% | 822 | 4,2% |
| 50 | 55 | 6158 | 31,1% | 4195 | 21,2% | -1963 | -9,9% |
| 55 | 60 | 3360 | 17,0% | 4073 | 20,6% | 713 | 3,6% |
| 60 | 65 | 3969 | 20,1% | 4982 | 25,2% | 1013 | 5,1% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

In this scenario, the main effect is a redistribution from the 50 – 55 dB(A) range to higher levels.

To make the difference between the two fee levels clearer, a difference plot has been made to compare the two scenarios directly (figure 21). Green colour means that the 1 Euro scenario Q2 provides lower noise levels than the half Euro scenario (Q3).

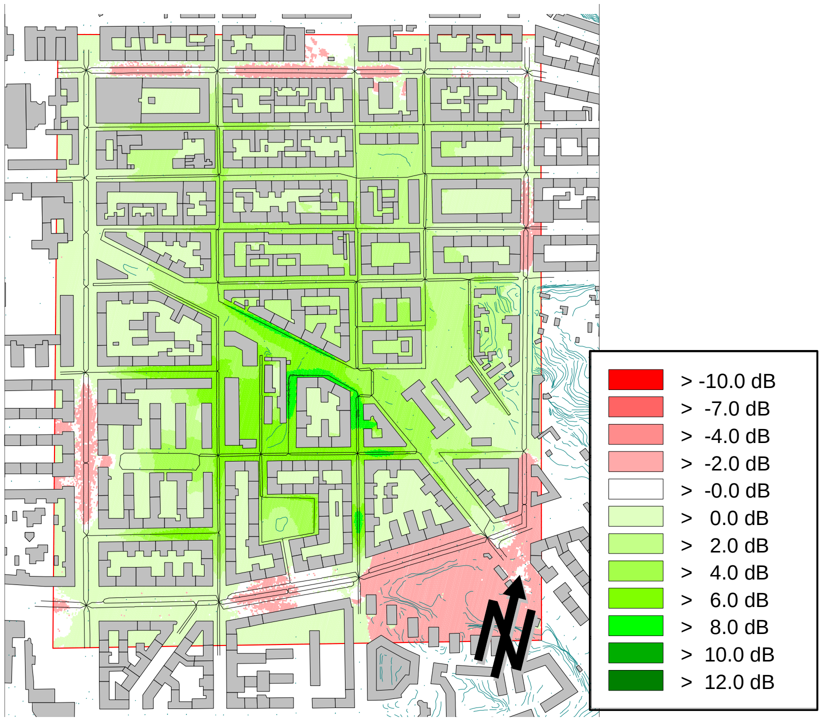



Figure 21 Noise difference between half a Euro noise fee and one Euro noise fee (dB(A) day)

From the map it is clearly seen that the higher noise fee in scenario Q2 reduces noise levels not only in the quiet zone, but also in the surrounding area.

## 5.5 INCREASED LOW NOISE VEHICLE OWNERSHIP IN THE QUIET ZONE – Q4

It can be expected that residents in the quiet zone have a higher incentive to acquire low noise vehicles than other residents. In scenario Q4, the assumptions has been made that residents own low noise vehicles only. In other words, the 5 percent low noise vehicles ownership is assumed to be 100 percent, the total number of vehicles owned by the quiet zone residents being the same. It is also assumed that there is a 1 Euro noise fee (as in scenario Q2).

### 5.5.1 Traffic effects

Now more cars can enter and exit the quiet zone without paying the noise fee (1 Euro). The volumes increase inside the quiet zone compared to scenario Q2, which is the same scenario as Q4 except for the share of low noise vehicle owners, which is 5 percent in scenario Q2. The differences in total flow can be seen from figure 22 (red and green indicates higher and lower volumes in scenario Q4 compared to scenario Q2) :

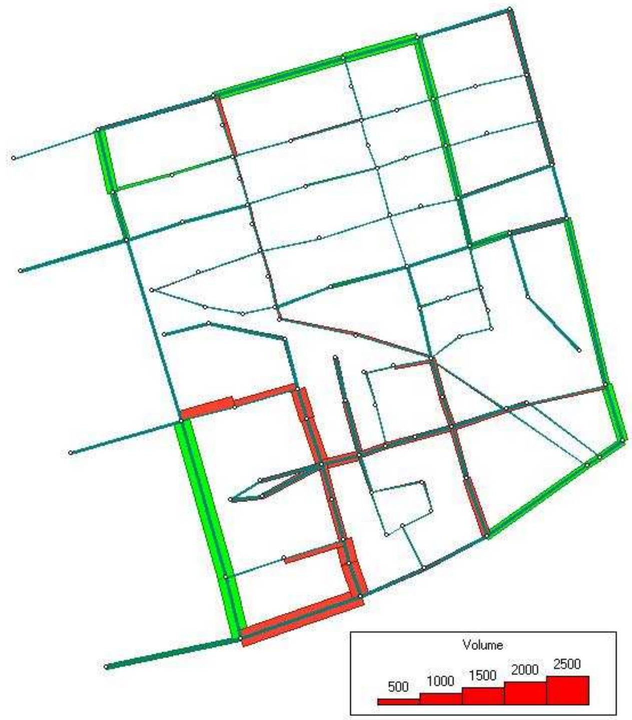



Figure 22 Day traffic volume difference between scenario Q4 and Q2

### 5.5.2 Noise effects

Although low noise cars are less noisy than standard cars, they still add to noise levels. The noise situation resulting from an increase of low noise car ownership to 100 percent inside the quiet zone would then correspond to the following noise map (figure 23):

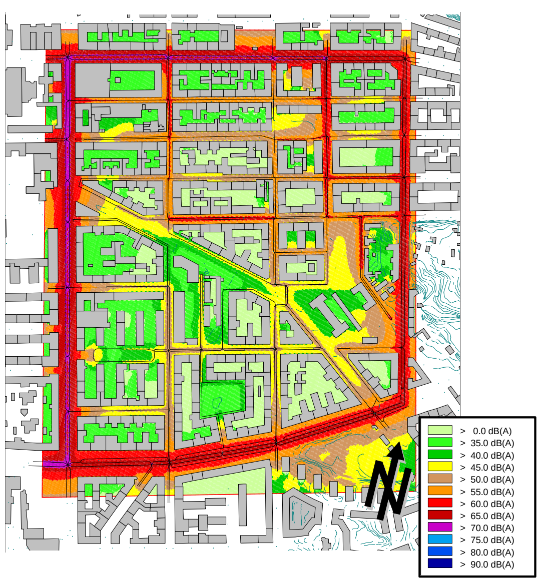



Figure 23 Noise map for scenario Q4 (dB(A) day)

The difference from the base case is more clearly seen from the difference plot below (figure 24):

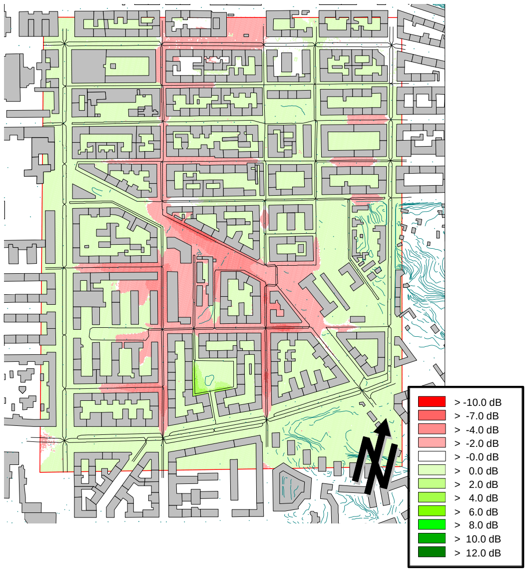



Figure 24 Noise difference between scenarios Q4 and Q2 (dB(A) day)

The effect on noise disturbance is less with respect to the scenario with 5 percent low noise vehicles, because now more of the residents will use cars as they are not subject to noise fees. Although these cars are low noise vehicles, they are not entirely silent, and consequently add to noise disturbance. On border streets, traffic is somewhat reduced, and partly replaced by less noisy vehicles, leading to noise exposure reductions there. In table 4, noise exposure distribution effects are compared to the 1 Euro scenario (Q2):

Table 4 Noise exposure distribution of residents

| From dB(A) | to dB(A) | Base (Q2) | % of total population | Banned standard cars | % of total population | Difference Q4 – Q2 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1505 | 7,6% | 1550 | 7,8% | 45 | 0,2% |
| 35 | 40 | 1157 | 5,9% | 770 | 3,9% | -387 | -2,0% |
| 40 | 45 | 2950 | 14,9% | 2672 | 13,5% | -278 | -1,4% |
| 45 | 50 | 3535 | 17,9% | 4155 | 21,0% | 620 | 3,1% |
| 50 | 55 | 3453 | 17,5% | 3453 | 17,5% | 0 | 0,0% |
| 55 | 60 | 2982 | 15,1% | 3035 | 15,3% | 53 | 0,3% |
| 60 | 65 | 4189 | 21,2% | 4136 | 20,9% | -53 | -0,3% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

As was discussed above, the 1 Euro scenario (Q2) effectively moved people in the 50 – 60 dB(A) range to lower levels. An increase of low noise car ownership inside the quiet zone to 100 percent would reduce this effect to some extent

## 5.6 INCREASED LOW NOISE VEHICLE OWNERSHIP INSIDE AND OUTSIDE THE QUIET ZONE – Q5

In scenario Q4, ownership of low noise vehicles is assumed to increase to 100 percent. In addition to this, low noise vehicle ownership for residents outside the quiet zone is In this scenario (Q5) assumed to increase from 5 percent to 20 percent, the total number of vehicles being constant. Other assumptions are kept the same as in Q4 and Q2.

### 5.6.1 Traffic effects

Now a larger number of residents outside the quiet zone can enter and exit the quiet zone by car without paying the noise fee. Volumes show a further increase in the quiet zone. The effects are small however, depending on the fact that the low noise car ownership is assumed to rise only from 5 to 20 percent, and on the fact that the traffic is mainly generated by the quiet zone residents. In figure 25 below, the flows of low noise and standard cars can be seen (low noise cars in red, standard cars in blue).

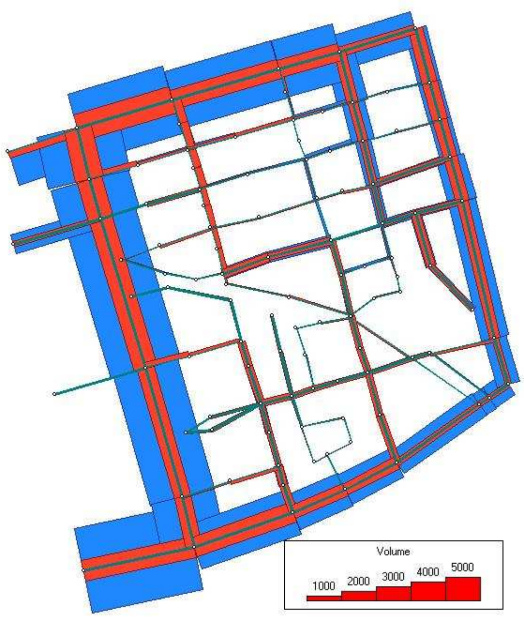



Figure 25 Day traffic volume low noise (red) and standard cars (blue) Q5

The additional effects of the increased share of low noise vehicle owners outside the quiet zone, can be expressed as the difference with respect to the previous scenario (Q4) as in figure 26. Volumes increase mainly in the eastern part of the zone, and are reduced on the border streets, indicating that through traffic increases.


Figure 26 Day traffic volume difference between scenario Q5 and Q4

### 5.6.2 Noise effects

Although low noise cars are less noisy than standard cars, they still add to noise levels. The noise situation resulting from the additional increase of low noise car ownership from 5 percent to 20 percent outside the quiet zone would look as depictured by the following noise map (figure 27):


Figure 27 Noise map for scenario Q5  (dB(A) day)

The difference from the base case is more clearly seen from the difference plots below, also showing the effect of the 100 percent low noise car ownership in scenario Q4 (figure 28):


Figure 28 Noise difference between scenarios Q4 and Q5 with respect to Q2 (dB(A) day)

When the share of low noise vehicle ownership outside the quiet zone in addition is assumed to increase to 20 percent, then the noise effects are calculated to be as in table 5 (with respect to scenario Q2)

Table 5 Noise exposure distribution of residents

| From dB(A) | to dB(A) | (Q2) | % of total population | Scenario Q5 | % of total population | Difference Q5 - Q2 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1505 | 7,6% | 1652 | 8,4% | 147 | 0,7% |
| 35 | 40 | 1157 | 5,9% | 277 | 1,4% | -880 | -4,4% |
| 40 | 45 | 2950 | 14,9% | 2504 | 12,7% | -446 | -2,3% |
| 45 | 50 | 3535 | 17,9% | 3182 | 16,1% | -353 | -1,8% |
| 50 | 55 | 3453 | 17,5% | 6897 | 34,9% | 3444 | 17,4% |
| 55 | 60 | 2982 | 15,1% | 4106 | 20,8% | 1124 | 5,7% |
| 60 | 65 | 4189 | 21,2% | 1159 | 5,9% | -3030 | -15,3% |
| 65 | 70 | 6 | 0,0% | 0 | 0,0% | -6 | 0,0% |

The different scenarios can also be graphically compared (figure 29):

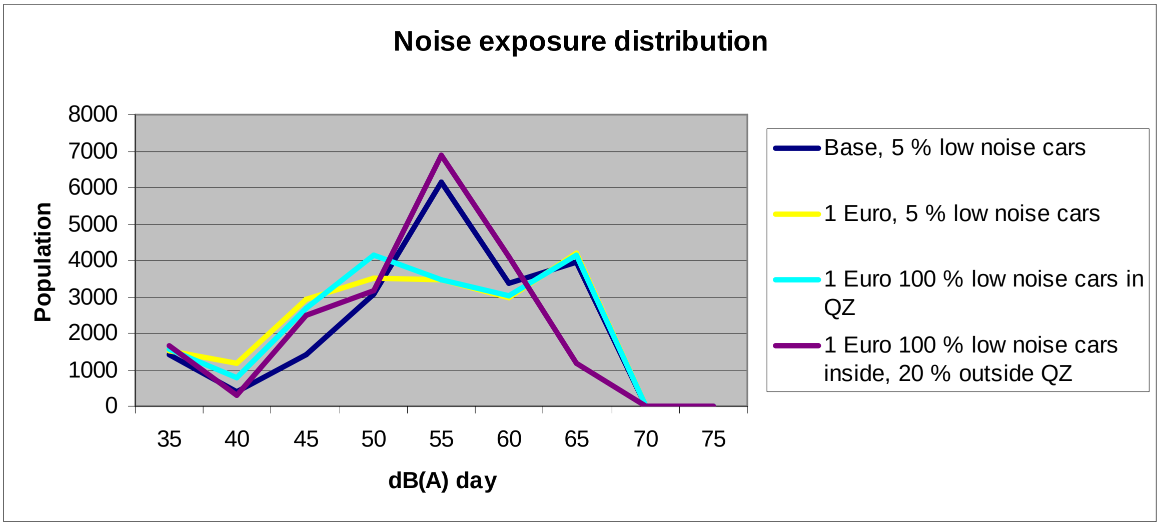



Figure 29 Noise exposure distribution of residents in scenarios Q0, Q2, Q4 and Q5

As was discussed above, the 1 Euro scenario (Q2) effectively moved people in the 50 – 60 dB(A) range to lower levels. An increase of low noise car ownership inside the quiet zone to 100 percent would reduce this effect to some extent, mainly by a larger number of low noise vehicles entering the quiet zone. A further increase of low noise car ownership from 5 to 20 percent outside the zone would have a different effect, as it would reduce noise exposure also on the bordering streets which are more exposed to traffic noise. The effect of the further increase of low noise vehicles among resident outside the quiet zone is therefore that exposure in the 65 – 70 dB(A) range is now reduced. The result is also a further increase of low noise vehicles inside the quiet zone, moving exposure levels from the 40 – 50 dB(A) range to the 50 - 55 dB(A) interval.

## 5.7 ZONE SIZE – Q6, Q7, Q8

As has we have seen from the previous scenarios, introducing a ban or a fee on standard vehicles increases noise levels outside the quiet zone. In scenario Q6, effects of expanding the quiet zone have been studied. In figure 30, an enlargement of the zone is shown (base scenario flows).

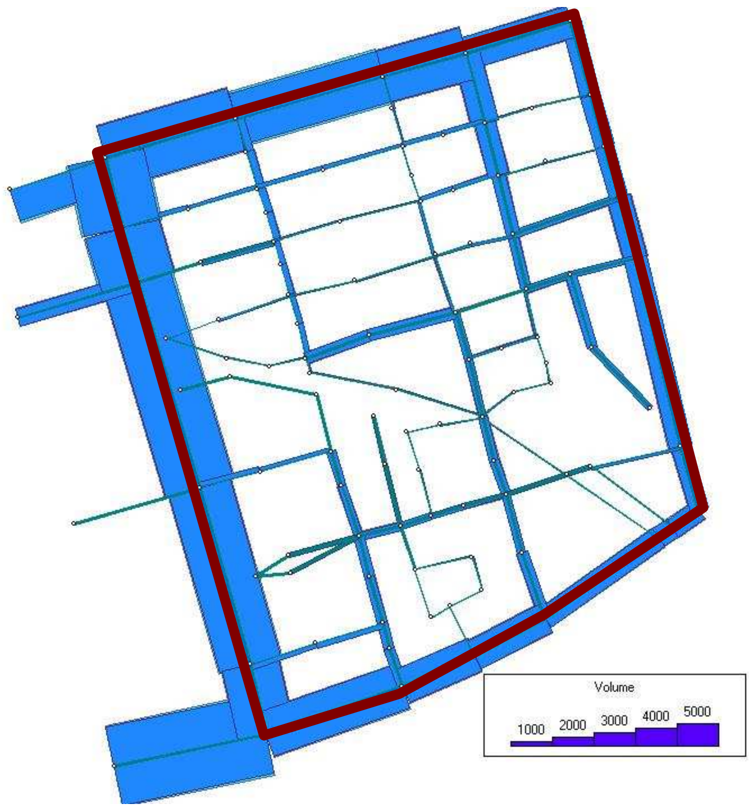



Figure 30 Enlarged quiet zone

The enlarged zone contains about twice as many residents and work places as the smaller zone. The main effect of introducing the smaller quiet zone was that people changed parking behaviour, by parking their car outside the zone. In practise, this would mean that extra capacity is needed to supply the forecast demand for parking space. If the zone is expanded, then even more parking space would be required in order to give drivers the option to park outside the quiet zone. This does not seem realistic, at least in a shorter perspective. Therefore it has been assumed that parking outside the zone is not available for persons driving to or from the enlarged part. This assumption will also serve to illustrate the effect of parking availability on noise levels. Other assumptions remain the same as in scenario Q2, including the 1 Euro noise fee. In scenarios Q7 and Q8, increased low noise car ownership corresponding to scenarios Q4 and Q5 is assumed.

### 5.7.1 Traffic effects

The traffic impact of increasing the zone size is not as outspoken as compared to the introduction of the smaller zone. This is largely due to the fact that external parking facilities are not supplied for the enlarged parts of the zone. The effect in the part of the quiet zone initially defined in scenarios Q1-Q5 is also reduced as some drivers, who now will pay to get into the zone, can reach their destination more directly by driving through the smaller zone area. The effects are shown on figure 31 below.

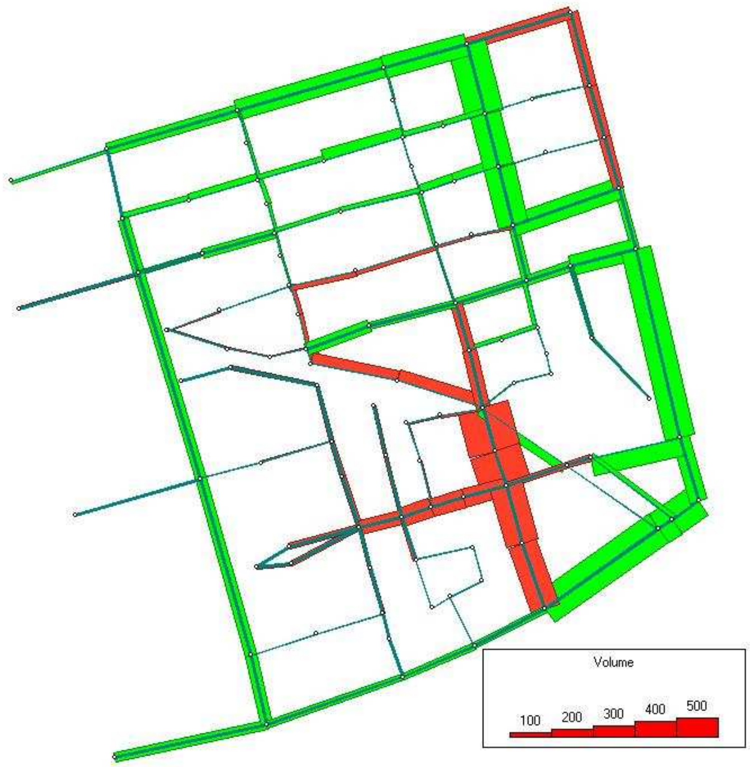



Figure 31 Traffic effects of quiet zone enlargement Q6

Effects of increased low noise car ownership have been studied also for the enlarged quiet zone (Q7, Q8). The traffic effects are similar to the smaller zone case. Traffic volumes for the case of 100 percent low noise vehicle ownership inside the (enlarged) zone and 20 percent outside the zone (scenario Q8) is shown in figure 32 (low noise vehicle flows in red and standard car flows in blue):

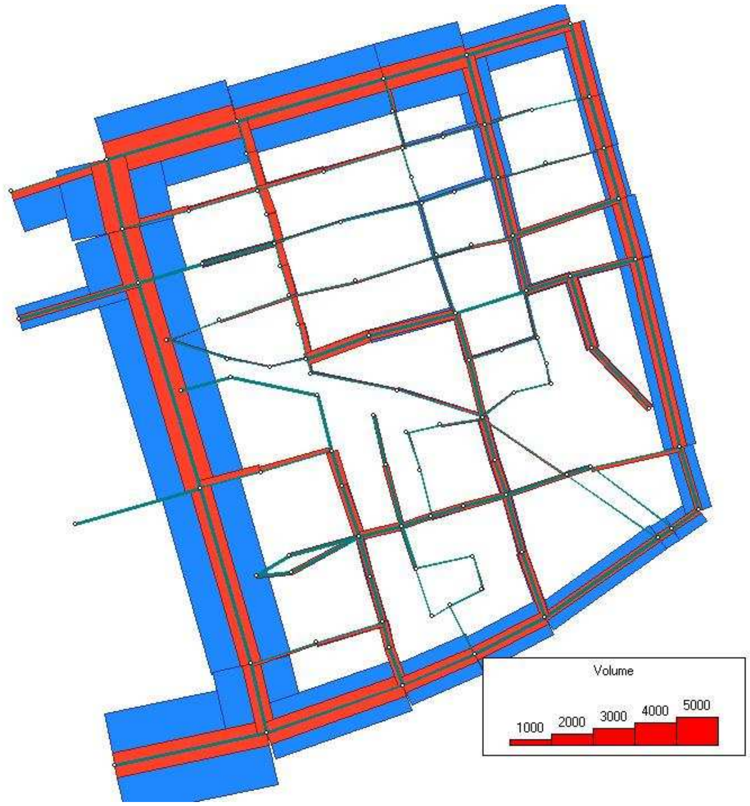



Figure 32 Day traffic volume low noise (red) and standard cars (blue) Q8

### 5.7.2 Noise effects

In figure 33, the noise map after imposing a 1 Euro noise fee on all standard cars is shown

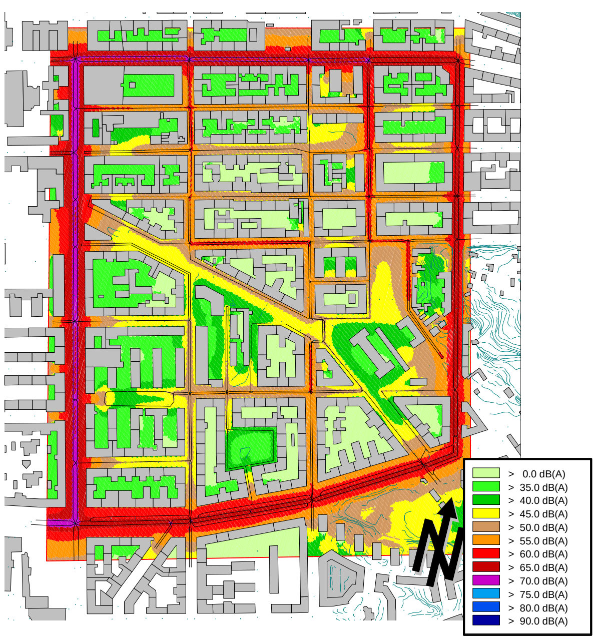



Figure 33 Noise map with enlarged zone (dB(A) day)

In figure 34, effects of a 1 Euro noise fee on the two zone sizes are shown (with respect to the base alternative).

Figure 34 Noise difference compared to base scenario (dB(A) day), small and large zone

The enlargement of the zone achieves some noise reduction in the enlarged area, but does not achieve as much reduction in the initial zone as before.

In table 6, the effects of the zone enlargement on the noise disturbance distribution can be seen. The main effect is that a larger share of the population is now subject to 45-55 dB(A) noise levels rather than 35 – 45 dB(A) levels. A small percentage (1 percent) of the population experiences a change from 55 – 60 dB(A) to lower levels.

Table 6 Noise exposure distribution of residents

| From dB(A) | to dB(A) | Q2 | % of total population | Half Euro noise fee | % of total population | Difference Q6 – Q2 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1505 | 7,6% | 1444 | 7,3% | -61 | -0,3% |
| 35 | 40 | 1157 | 5,9% | 629 | 3,2% | -528 | -2,7% |
| 40 | 45 | 2950 | 14,9% | 2319 | 11,7% | -631 | -3,2% |
| 45 | 50 | 3535 | 17,9% | 3927 | 19,9% | 392 | 2,0% |
| 50 | 55 | 3453 | 17,5% | 4495 | 22,7% | 1042 | 5,3% |
| 55 | 60 | 2982 | 15,1% | 2768 | 14,0% | -214 | -1,1% |
| 60 | 65 | 4189 | 21,2% | 4189 | 21,2% | 0 | 0,0% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

In table 7, the effects are compared for the case in which low noise car shares are increased from 5 to 100 percent inside the quiet zone, and from 5 to 20 percent outside the quiet zone (scenarios Q6 and Q8).

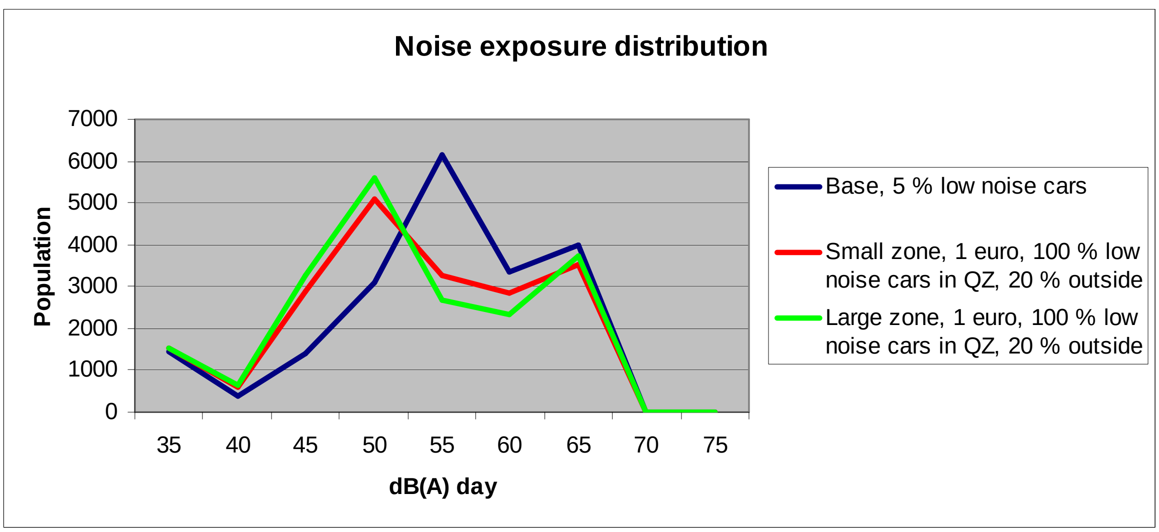
Table 7 Noise exposure distribution of residents

| From dB(A) | to dB(A) | Q6 | % of total population | Scenario Q8 | % of total population | Difference Q8 - Q6 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1548 | 7,8% | 1548 | 7,8% | 0 | 0,0% |
| 35 | 40 | 604 | 3,1% | 651 | 3,3% | 47 | 0,2% |
| 40 | 45 | 2895 | 14,6% | 3249 | 16,4% | 354 | 1,8% |
| 45 | 50 | 5078 | 25,7% | 5582 | 28,2% | 504 | 2,5% |
| 50 | 55 | 3248 | 16,4% | 2666 | 13,5% | -582 | -2,9% |
| 55 | 60 | 2861 | 14,5% | 2321 | 11,7% | -540 | -2,7% |
| 60 | 65 | 3537 | 17,9% | 3754 | 19,0% | 217 | 1,1% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

As the share of low noise vehicles increases, fewer vehicles are affected by the fees. Therefore, increasing the level of low noise vehicles for residents to a hundred percent will increase traffic again, although with low noise vehicles. In this case, the zone enlargement is more beneficial for residents that are exposed to higher noise levels (>50 dB(A))

The effect of the increased share of resident low noise vehicles can also be shown on the following graph (figure 35):

Figure 35 Noise exposure distribution of residents in scenarios Q0, Q2, Q4 and Q5




To sum up: the enlargement of the quiet zone, given the 1 Euro noise fee, did not improve noise exposure for noise levels over 45 dB(A). An important reason for this was that available parking facilities outside the zone were not assumed to exist. But, when low noise car ownership increases, improvements occur for noise levels over 50 dB(A).

## 5.8 Other effects

Beside noise effects, also other effects emerge in the different scenarios. Traffic flow changes imply effects on other emissions like $CO_2$, other air pollution and safety. Revenue is another obvious factor in the noise fee scenarios.

As the main traffic effect is that people park their cars outside the quiet zone area (if they have that choice), most of the other effects will be related to the noise map area. The total vehicle kilometres in the area changes very little, less that one percent in most scenarios. Changes in vehicle types will have a much higher impact, as in the scenario where the share of low noise vehicles increases to 100 percent. Therefore, it is not really meaningful to consider effects like $CO_2$ and air pollution in this case. Safety effects are also likely to be small, but may be ambiguous. On one hand, reduced car volumes would lead to fewer accidents, but on the other hand the remaining cars are less noisy and more difficult to become aware of, specifically for blind people. This may be a concern when implementing a quiet zone.

Revenues are specific to the noise fee scenarios. In the small zone case, most car drivers will choose not to pay the fee. The revenue will therefore be rather modest, and is estimated to about 150 thousand Euros per year. This holds for both the 1 Euro and the half Euro scenario. The lower fee in the half Euro scenario is compensated by the higher demand. In the enlarged zone case, where many will not have the option to park outside the zone, revenues will be higher, about 3 million Euros per year. Increases in low noise vehicle ownership will of course reduce the expected revenue. In practice, the revenue will depend heavily on to what extent people can find nearby parking.

## 5.9 Implementation

Although implementation issues have not been a focus of this project, it may still be useful to discuss some related issues here.

Implementing a quiet zone requires, in addition to necessary municipality decisions on the extent of the zone, a classification of low noise vehicles. Such a classification can be based on information in the car register, as in the case of other Low Emission Zone (LEZ) classifications already in use. Currently the European emission standard class system is used for this purpose in several countries, which could be extended to also include a low noise class - let us call this class Euro 0.

Given that vehicles are classified, it is possible to regulate their use, as in the case of LEZ applications. The first quiet zone scenario implied a total ban of all standard vehicles, which means that only Euro 0 class vehicles would be allowed. If there already is a system setup to obtain stickers corresponding to a Euro 0 class, additional administrative cost would be low. Enforcement could be undertaken in the same way as for other LEZ applications.

In the case of noise fees, it is necessary to find a mechanism for either a per passage debiting (as is assumed in the studied scenarios) or a per day debiting. It is also necessary to define who is responsible for the payment, the driver or the vehicle owner. Assuming the latter (as is the case for instance in the Stockholm congestion charging system), a payment system needs to be defined. With current techniques, at least two options are conceivable - one is to register the license plate and to issue an invoice after the passage, and the other one is to require a prepaid ticket. The first system is used in Stockholm, and the second system is used in Milan. For enforcement, licence plates are recorded (by cameras) in both cases. The choice of a system would depend on the expected revenues, and if there is already a system in use that can just be extended. In the case of a per day fee, there is of course the risk that some noisy vehicles having paid a day fee would use it several times, which would reduce the effect somewhat.

# 6 CONCLUSIONS

For the Stockholm case study on quiet vehicles combined with traffic control, a small part of Södermalm was chosen to be the test site. This part of Södermalm was already subject to traffic zoning, implying that most of the through traffic is already driven away. The current situation is therefore characterised by relatively high flows on some of the boundary streets, and more modest flows on the streets inside the zone area.

Low noise vehicles, such as the Toyota Prius electric hybrid car, with reduced tyre/road noise provide about a 7 dB(A) noise reduction (25-40 km/h) as compared to standard cars (like the Volvo V70 petrol car).

The share of low noise cars in the total car fleet is currently very low, and even if it is likely that many car makers will introduce similar technologies in the future, it will take a substantial time before the low noise car share is large enough to bring about a significant general noise reduction in a mixed traffic flow of standard cars and low noise vehicles. The project idea is therefore to use traffic control to separate low noise vehicles from standard vehicles to provide quiet zones in limited town areas.

The separation can be done in different ways. One is to ban all standard cars and allow only low nose vehicles in a particular area. Such policies are now becoming more and more common when other types of disturbances are concerned, like NOx and particles. In many cities, it is now mandatory to have a permission to enter protected areas, a permission which is given conditioned on the type of vehicle and its emission levels.

Another way of separating low noise vehicles from standard vehicles is to impose a fee for entering and/or leaving the area in stead of a total ban. Such a policy is also used for other disturbances, for instance in Milan, where a charging system for entering the inner city is differentiated according to emission levels defined by the Euro vehicle class system. The per day fees range from 0 - 10 Euros.

In this case study, we have studied the effects of banning all standard cars as well as imposing noise fees. The study has been carried out by using the regional model in the national Swedish forecasting system Sampers. The model reflects traveller behaviour by taking into account different substitution possibilities like route choice, mode choice and destination choice. The results of traveller behaviour in terms of car flows in different scenarios have been input in the CadnaA noise mapping software, resulting in noise maps and noise disturbance distributions of the residing population for these scenarios.

A total ban of standard cars will provide a substantial noise reduction within the area. The main effect is a redistribution of moderately disturbed residents in the 50 -55 dB(A) segment to noise levels in the 35 - 45 dB(A) segments. Residents subject to more severe noise disturbance are likely to be living on the boundary streets and will not benefit from traffic reductions within the zone. The ban will also, to a minor extent, increase noise levels outside the area.

The 1 Euro noise fee scenario will give similar but smaller effects. After all, some drivers will, at least in some cases, choose to use their standard cars despite the fee. The main effect is a redistribution of moderately disturbed residents in the 50 -55 dB(A) segment to noise levels in the 35 - 50 dB(A) segments. The more severely disturbed residents are affected to almost the same extent as in the case of a total ban of standard cars in the zone. A sensitivity study with respect to traffic simulation methods showed that these effects may be somewhat overestimated but still significant.

The half Euro noise fee scenario gives different effects in that it brings about larger noise increases in the surrounding than the other scenarios. This is due to that the fee is not large enough to make people change mode or destination, but only to make some changing their routes (if not having their destination within the area) or to park outside the area and accept a longer walk distance to their destination. In this case, the reduced car traffic in the surroundings caused by mode or destination changes will take place to a much lesser extent. There will still be noise reductions within the zone, although smaller than in previous scenarios, but there will also be noise level increases in the surrounding area. The extent is such that the share of residents in the 55+ dB(A) segment increases from about 35 percent in the previous scenarios to about 45 percent in the half Euro scenario. Effects are summarised in figure 36:

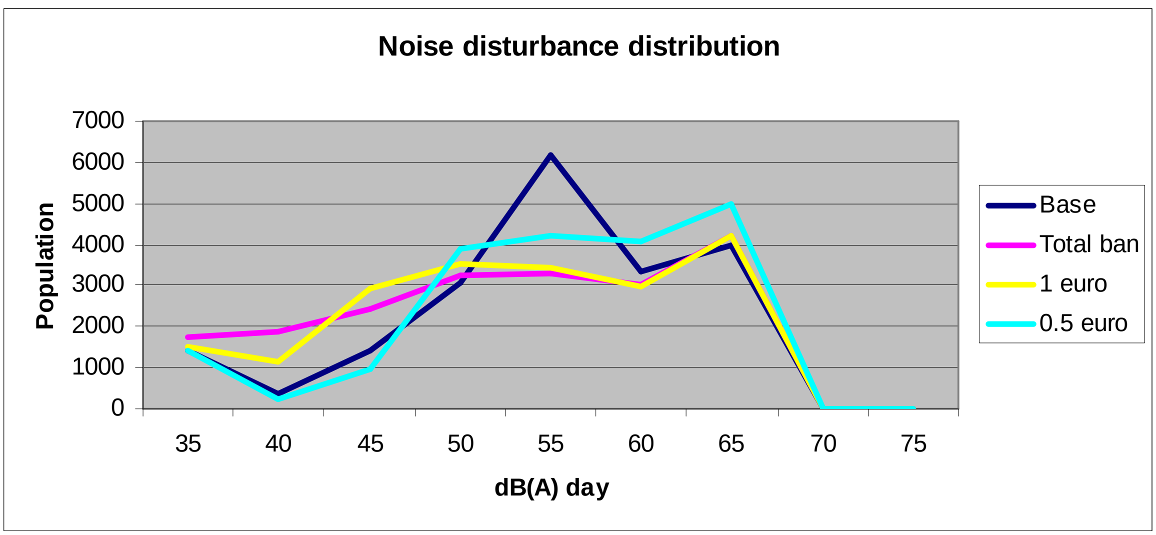



Figure 36 Noise disturbance distributions for different scenarios.

We also studied effects of increased low noise vehicle ownership. As was discussed above, the 1 Euro scenario (Q2) effectively moved people in the 50 – 60 dB(A) range to lower levels. An increase of low noise car ownership inside the quiet zone to 100 percent would reduce this effect to some extent, mainly by a larger number of low noise vehicles entering the quiet zone. A further increase of low noise car ownership from 5 to 20 percent outside the zone would have a different effect, as it would reduce noise exposure also on the bordering streets which are more exposed to traffic noise. The effect of the further increase of low noise vehicles among resident outside the quiet zone is therefore that exposure in the 65 – 70 dB(A) range would be reduced. The result is also a further increase of low noise vehicles inside the quiet zone, moving exposure levels from the 40 – 50 dB(A) range to the 50 - 55 dB(A) interval.

Finally we studied effects of an increased zone size. An enlargement of the quiet zone, given the 1 Euro noise fee, did not improve noise exposure for noise levels over 45 dB(A). An important reason for this was that available parking facilities outside the zone were not assumed to exist. But, when low noise car ownership increases, improvements occur for noise levels over 50 dB(A).

The final conclusion for this case study would then be that even in the case of an already traffic zoned situation, substantial noise reductions can be brought about by banning standard cars or by imposing noise fees. It is however important to impose fees high enough to bring about mode and destination shifts and not only changes route or parking behaviour. It is time to consider bans and charging systems not only for air pollution but also for noise emissions.

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# 8 APPENDIX 1 – MICRO SIMULATION SENSITIVITY ANALYSIS

## 8.1 INTRODUCTION

The quiet zone scenarios have been analysed using the Sampers forecasting system, with the setting normally used for Stockholm transport project analysis. As described in Chapter xx, the Sampers system uses a macrosimulation approach (the Emme/2 system) for network assignment. There were two reasons for using the Sampers system in this work package. The first reason was that it was calibrated and validated for the Stockholm situation. The other reason was that it also covered the whole Stockholm area, thus making it possible to take into account a wide range of travel behaviour options for travellers in terms of mode and destination shifts when imposing restrictions on car use within the quiet zone.

Traffic volume and speed are main contributors to traffic noise. Volumes and speeds result from the network assignment process. In the macro simulation approach, these are calculated from functions describing the relationship between flow and speed. These functions are often called volume delay functions, and are then formulated as travel time for a certain link length as a function of the link volume, shaped as in figure A1:

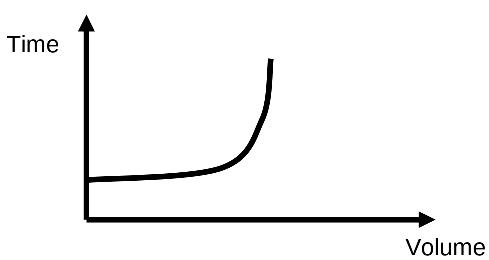


Figure A1 Volume time function

For low volumes, the speed does not change very much – it is only when flows are close to capacity that speed decreases significantly. Although these functions are estimated on observed flows, they can not be expected to exactly describe the flow-speed relation on every single street. Normally, as in the Stockholm case, a set of functions is estimated and used. The functions differ with respect to speed restrictions and the degree of disturbances (traffic signals, parked cars, entries and exits to and from the road, walk and bicycle conflicts etc.) that are expected to occur. For the quiet zone, the function with the highest degree of disturbance was used (as for other inner city streets). The results reflect the average expected speeds and volumes, not taking into account particularities for a specific link that may affect driver behaviour.

The micro simulation approach, described in more detail in other work packages (see Deliverable D2.13), is an approach that models vehicle movements directly, based on driver behaviour and interaction between drivers as well as the exact physical properties of the network (like traffic signals and extra lanes for turning movements etc). Also the distance between junctions will affect driver behaviour (on short links it is less likely that drivers reach their desired speed) and hence speeds. Therefore, more variation also in average speed on the different links can be expected when using the micro simulation approach.

Although micro simulation may reflect driver behaviour and network properties quite well, the extent to which it can reflect disturbances like walk and bike conflicts is still limited. It can therefore be expected that a micro simulation of the same network will result in a higher general speed level as compared to the macro simulation approach, where disturbances have been taken into account in the flow speed functions.

The quiet zone concept relies on the use of cars with lower driveline noise, and tyre/road noise reductions for these vehicles to preserve the lower driveline noise advantage also for higher speeds. Speed is therefore particularly important when analysing effects of introducing quiet zones. Consequently it was decided to perform a sensitivity test by micro simulating the base scenario and one quiet zone scenario.

## 8.2 MICRO SIMULATING THE QUIET ZONE

### 8.2.1 Network

Micro simulation is computationally more burdensome than the macro simulation approach. It also requires more detailed data. Therefore, it would be out of scope to simulate large areas. For this work package, we have chosen to simulate the quiet zone area including a possible extension. This network was coded based on the digital map used for the noise mapping program. Number of lanes, signals etc. were added by manual observation of the network (figure A2 below):

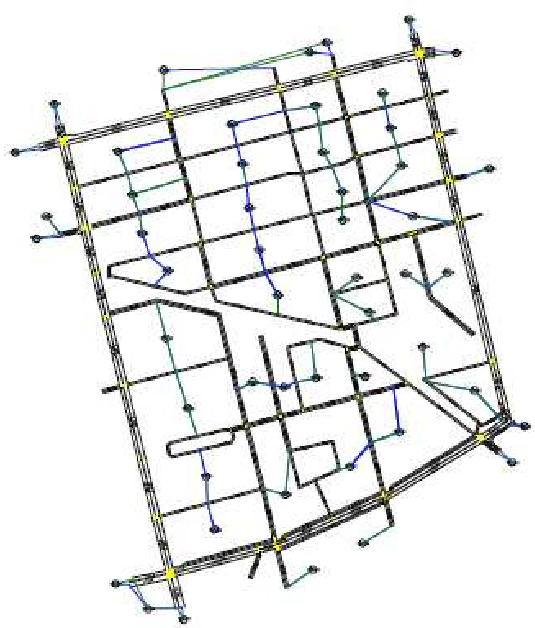

Figure A2 Micro simulation network

In addition to the regular streets and junctions, the figure also shows points of origin and destination and artificial links connecting these points to the real street network.

### 8.2.2 Demand

Micro simulation is a dynamic method, and in order to be able to simulate vehicle movements with proper regard to interactions between drivers, the network needs to be loaded with regard to real departure times. Therefore, the demand needs to be subdivided into a number of time slices, sequentially being loaded onto the network. To make this as realistically as possible, traffic counts conducted in context with the evaluation of the congestion charging experiment were used to get the hourly distribution over the day (see figure A3). This distribution, recorded at the toll facilities, may be more concentrated to the peaks than the traffic in the quiet zone is, but no other useful measurements were available.

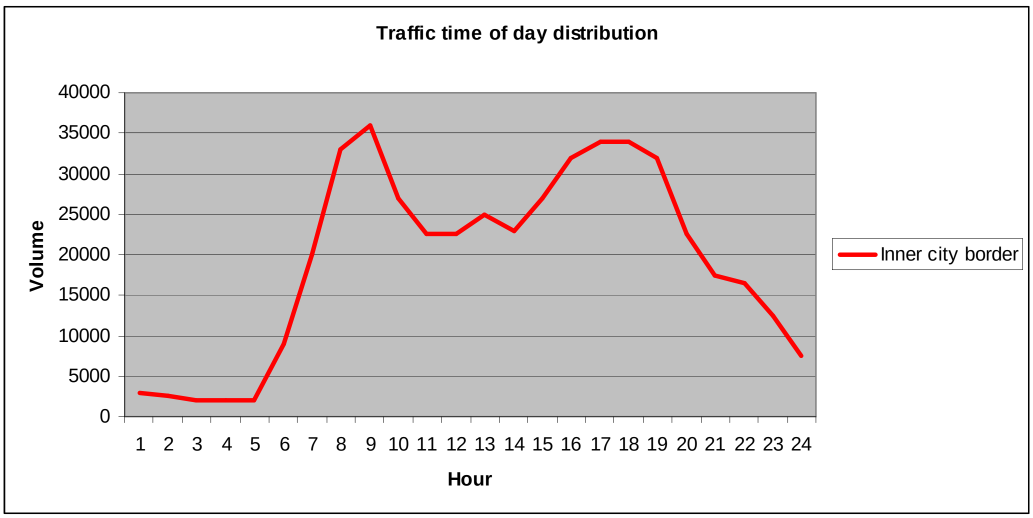


Figure A3 Inner city cordon time of day distribution

Then, the peak and off peak matrices were used to obtain matrices for the different hours of the day. The demand matrices were the same as for the macro simulation approach, but aggregated to the zones of the micro simulation network. The aggregation was done by development of so called traversal matrices. This means that trips having their origin or destination (or both) outside the quiet zone are assumed to originate or end at the nodes where they would enter or exit the network in the macro simulation. In this way, total demand in the micro simulation is consistent with total demand in the macro simulation, although differently distributed over the day. Travel behaviour effects like choice of parking, mode shift and destination shift are the same, only route choice within the quiet zone network and speeds will differ.

### 8.2.3 Validation

There was only one flow count available on the quiet zone network after the introduction of the congestion charges (Folkungagatan, at the red arrow in figure A4 below

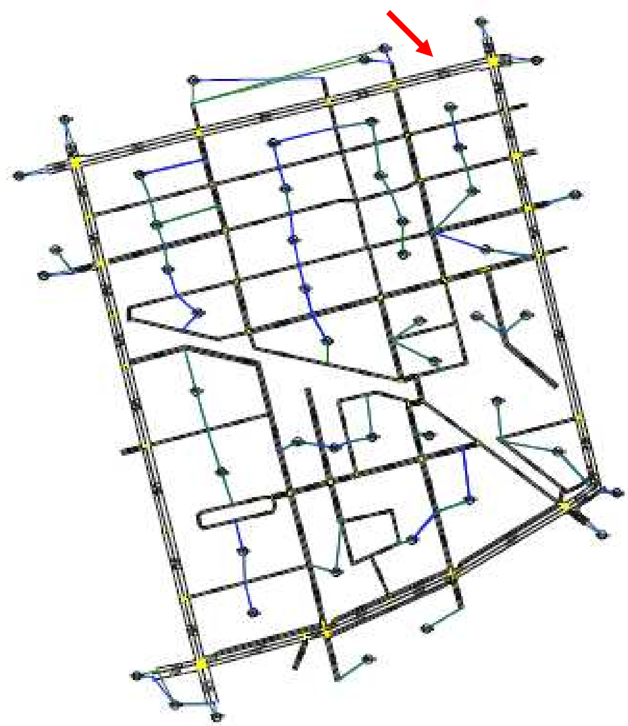

Figure A4 location of count post

The observed 0-24 value was 10 100 vehicles, giving a day value of about 7 500 vehicles according to the time of day distribution used. This can be compared to the macro simulation value of 7 100 vehicles and the micro simulation value of 7 600 vehicles. No corresponding speed measurements were available. The Swedish National Society for Road Safety has undertaken speed measurements on some 30 km/h speed limit streets, but these measurements are constrained to undisturbed vehicles and do consequently not give a good description of the average speed. These measurements report average speeds close to those of the micro simulation, suggesting that the micro simulation speeds are at least somewhat overestimated but also that the macro simulation speeds may be underestimated. Consequently, the validation must be regarded as limited. Still, the micro simulation exercise may provide some insight as a sensitivity test.

## 8.3 SCENARIO COMPARISON

In this sensitivity analysis, the base scenario (Q0M) and the 1 Euro noise fee (Q2M) scenarios have been subject to micro simulation. In figures A5 and A6 below, the base scenario volumes for scenario Q0, i.e. the macro simulation, is shown together with the differences between Q0M (i.e. the micro simulated base scenario) and Q0. Red bars indicate differences where the micro simulation gives higher flows, and green the opposite.

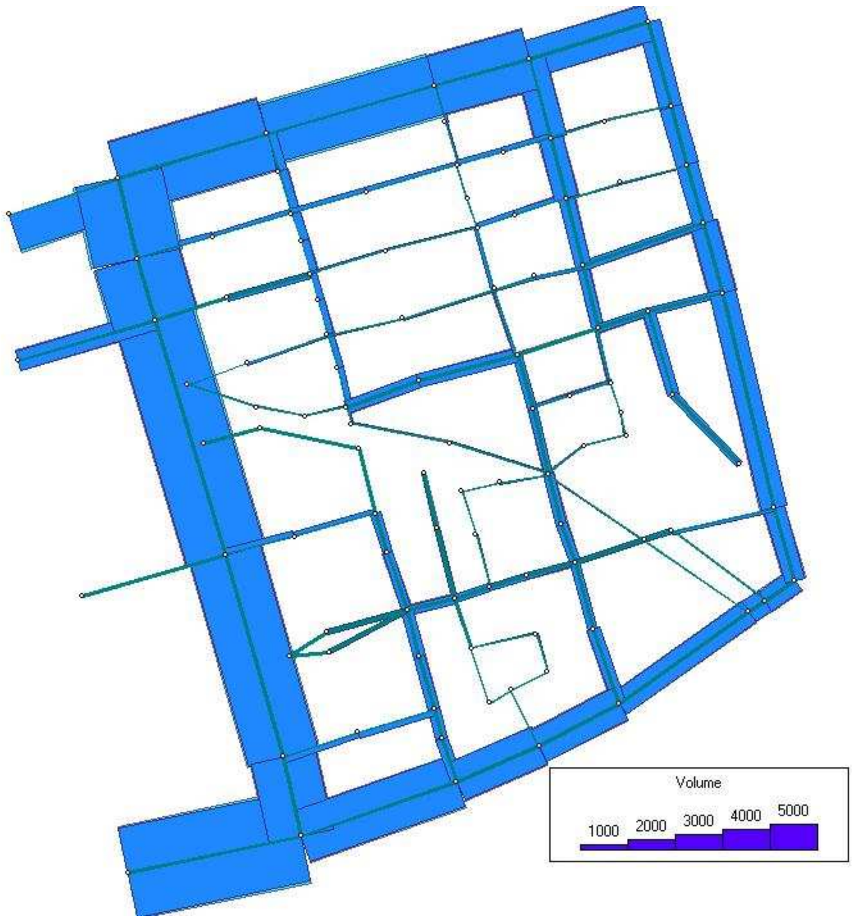


Figure A5 Macro simulation base scenario flows (Q0)

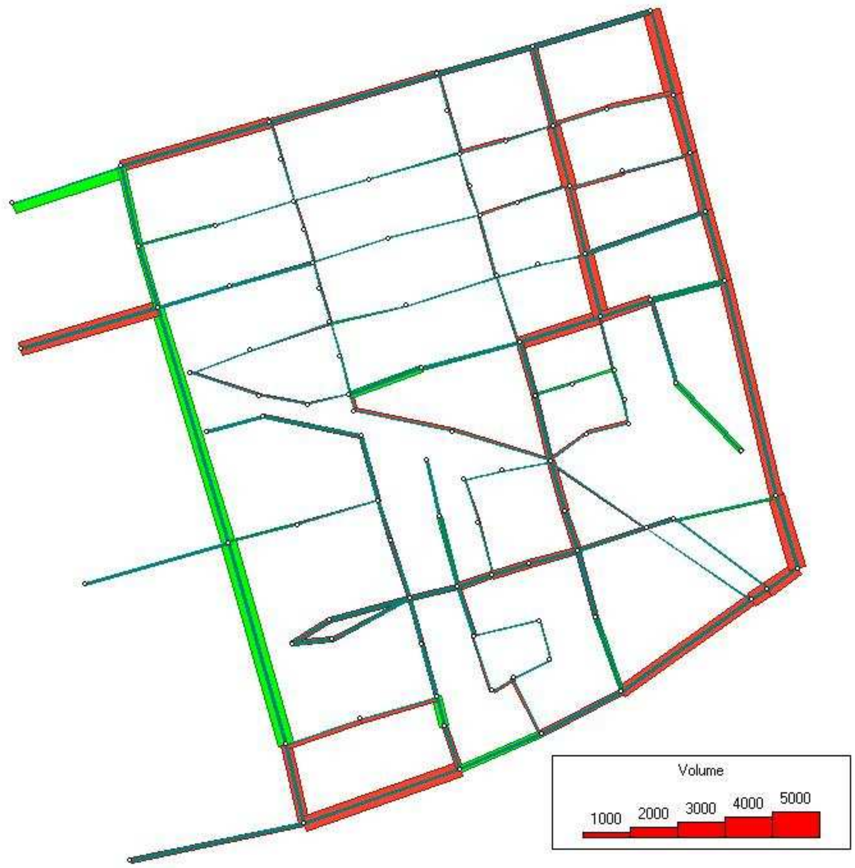


Figure A6 Difference between micro and macro simulation base scenario flows (Qom – Q0)

The main difference is that the eastern boundary streets have higher flows in the micro simulation case, as well as the adjacent parallel streets. The differences are however not large with respect to noise impact. A more important difference is related to speed. In the diagram below (figure A7), macro simulation speeds are plotted against micro simulation speeds.

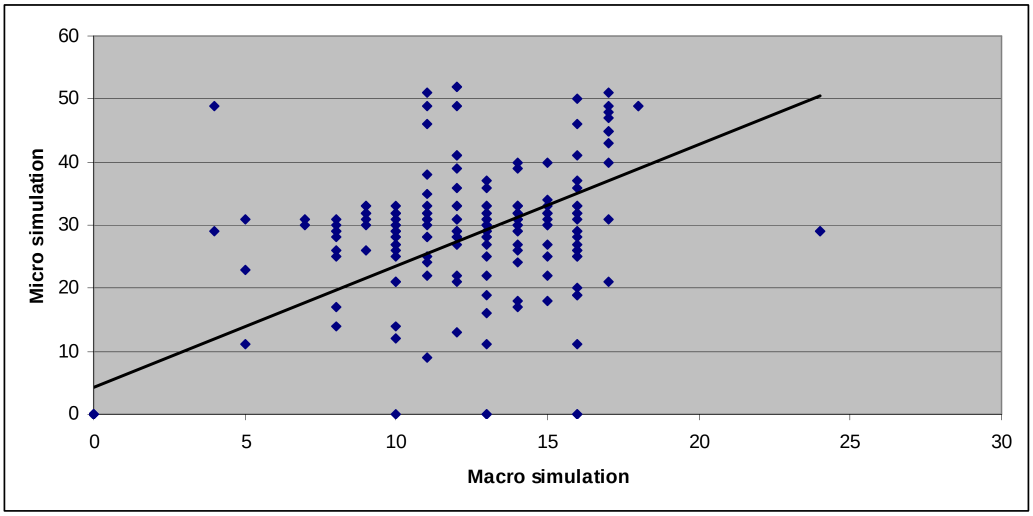


Figure A7 macro and micro simulation link speeds

As can be seen from the diagram, there is not only a large variation, but there is also a big difference in the mean values. In fact, micro simulation speeds are more than twice the macro simulation value (the volume weighted means for Q0 and Q0M respectively are 13 and 31 km/h, and the unweighted means are 10 and 24 km/h). These differences are due to the differences between using the speed flow relationship of the macro simulation application and using the more detailed vehicle movement simulation rules in the micro simulation approach. As mentioned in chapter ZZ, this kind of difference may be expected as the macro speed flow function have taken traffic flow disturbances into account using empirical data, whereas the micro simulation has not. Speed variation between links may however be better described in the micro simulation application, as the macro speed flow functions are assumed to be identical for all links with the same speed restriction.

## 8.4 NOISE EFFECTS

In terms of noise analysis, the micro simulation scenario means that we have moved to another speed range, which will affect the noise impact as noise effects will be lower for higher speeds. In fact, the speed range in the micro simulation is closer to the assumption made on the expected noise reduction of 7 dB (described in chapter ZZ). The macro approach will therefore underestimate noise effects of the quiet zone, and the micro simulation will slightly overestimate the effect.

In figure A8 and A9, the noise map for the macro (scenario Q0) and the micro (scenario Q0M) traffic simulations are shown.

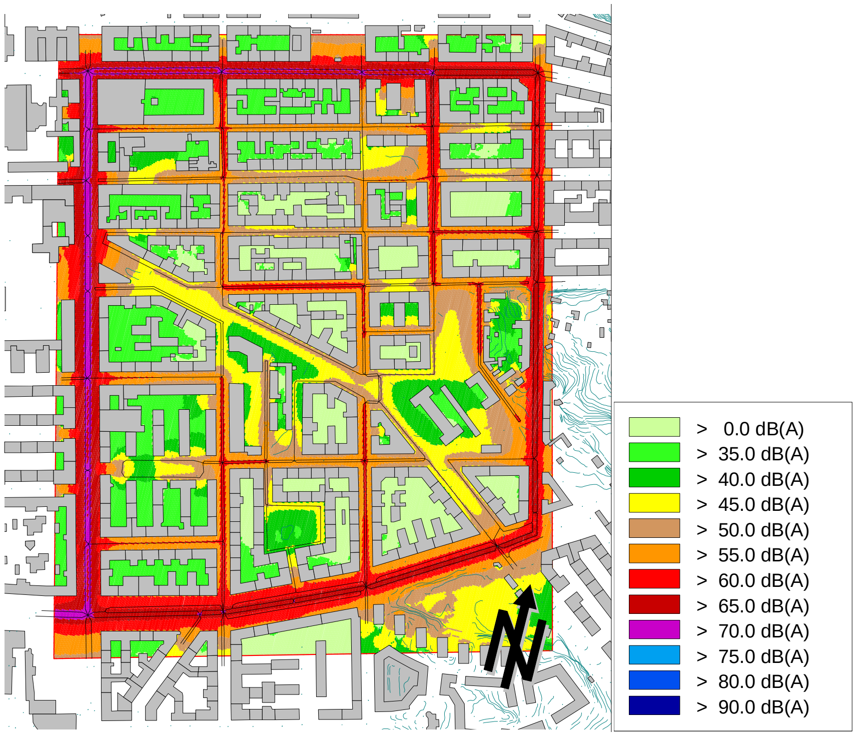


Figure A8 Macro simulation base scenario noise map (Q0)

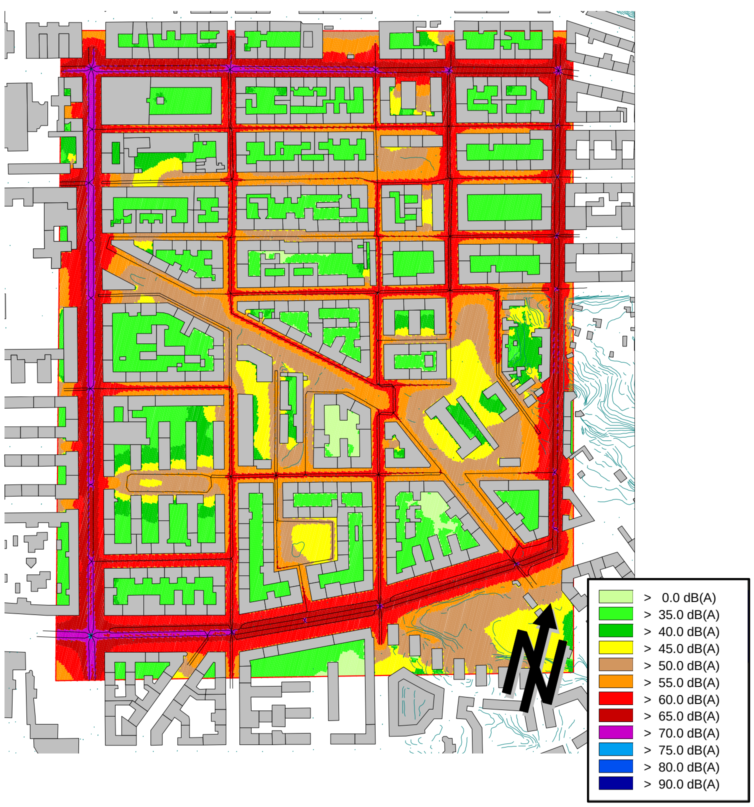


Figure A9 Micro simulation base scenario noise map (Q0M)

As can be seen from the plots, the general noise level will be higher in the micro simulation case.

The effects of the 1 Euro noise fee in the macro simulation (scenario Q2) and in the micro simulation (Scenario Q2M) compared to the base scenarios can be compared in the noise difference plots in figures ZZ and ZZ below:

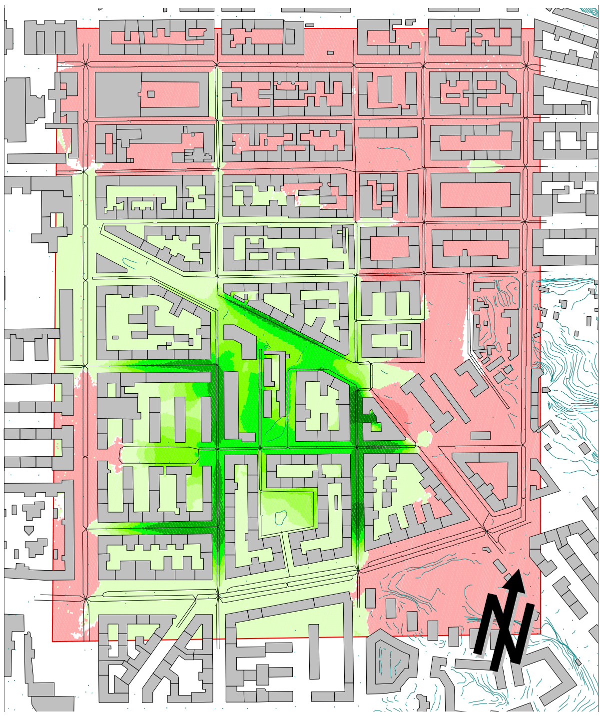


Figure A10 Noise difference compared to base scenario (dB(A) day), macro simulation

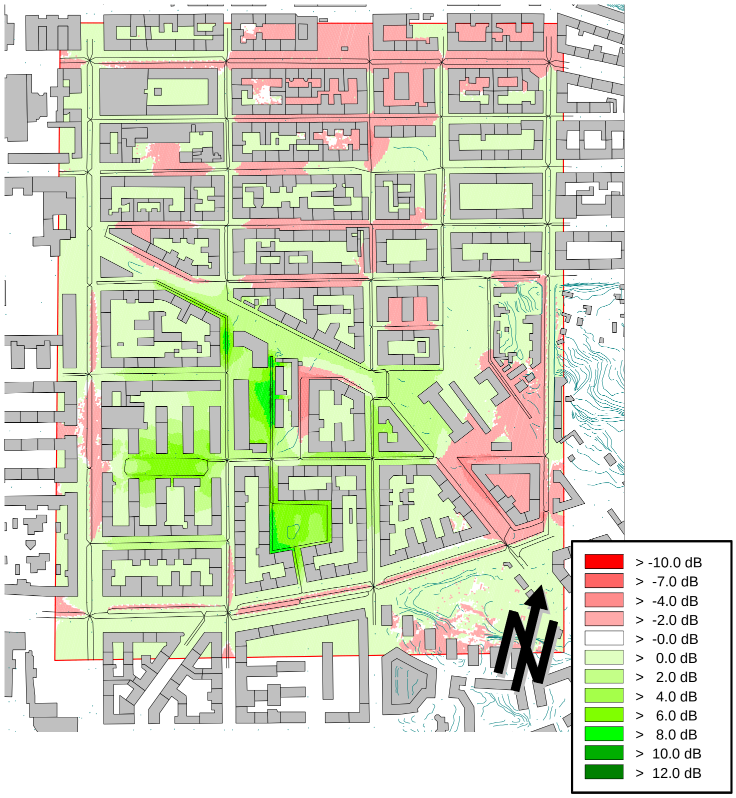


Figure A11 Noise difference compared to base scenario (dB(A) day), micro simulation

As can be seen from the figures, the noise reductions resulting from the micro simulation are less in the quiet zone area, but more widespread outside the quiet zone. This is due to differences in route choice between the simulation methods (see figures A5 and A6).

The ultimate aim of the quiet zone is to reduce noise disturbance. Then the levels of noise exposure are of interest in addition to the noise reductions. In the tables below, the noise exposure distributions are presented for the macro and micro simulations of the 1 Euro noise fee scenarios.

Table A1 Noise exposure distribution of residents, macro simulation

| From dB(A) | to dB(A) | Base (Q0) | % of total population | 1 Euro noise fee (Q2) | % of total population | Difference Q2 - Q0 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1424 | 7,2% | 1505 | 7,6% | 81 | 0,4% |
| 35 | 40 | 370 | 1,9% | 1157 | 5,9% | 787 | 4,0% |
| 40 | 45 | 1404 | 7,1% | 2950 | 14,9% | 1546 | 7,8% |
| 45 | 50 | 3086 | 15,6% | 3535 | 17,9% | 449 | 2,3% |
| 50 | 55 | 6158 | 31,1% | 3453 | 17,5% | -2705 | -13,7% |
| 55 | 60 | 3360 | 17,0% | 2982 | 15,1% | -378 | -1,9% |
| 60 | 65 | 3969 | 20,1% | 4189 | 21,2% | 220 | 1,1% |
| 65 | 70 | 6 | 0,0% | 6 | 0,0% | 0 | 0,0% |

Table A2 Noise exposure distribution of residents, micro simulation

| From dB(A) | to dB(A) | Base (Q0_M) | % of total population | 1 Euro noise fee (Q2_M) | % of total population | Difference Q6 - Q0 | % difference of total population |
|---|---|---|---|---|---|---|---|
| 0 | 35 | 1331 | 6,7% | 1415 | 7,2% | 84 | 0,4% |
| 35 | 40 | 321 | 1,6% | 436 | 2,2% | 115 | 0,6% |
| 40 | 45 | 110 | 0,6% | 570 | 2,9% | 460 | 2,3% |
| 45 | 50 | 1764 | 8,9% | 1935 | 9,8% | 171 | 0,9% |
| 50 | 55 | 5014 | 25,4% | 5835 | 29,5% | 821 | 4,2% |
| 55 | 60 | 6312 | 31,9% | 4698 | 23,8% | -1614 | -8,2% |
| 60 | 65 | 4716 | 23,8% | 4685 | 23,7% | -31 | -0,2% |
| 65 | 70 | 209 | 1,1% | 203 | 1,0% | -6 | 0,0% |

Higher speeds and different route choice makes the noise exposure distribution contain a higher population share in the 55-70 dB(A) range in the micro simulation case. The 1 Euro noise fee scenario mainly reduces the 55-60 dB(A) share by 8 percent units. This can be compared to the macro simulation case, where the main effect is a reduction of the population share in the 50-55 dB(A) range by 14 percent units.

## 8.5 CONCLUSION

Available information and characteristics of the macro and micro simulation approaches suggest that macro simulation speeds may be underestimated as compared to the real situation. On the other hand, speeds simulated by the micro simulation approach seem to be somewhat overestimated. The assumed noise reduction effect of 7 dB(A) for a low noise vehicle was related to the speed range up to 25 km/h, implying that noise reductions are underestimated with respect to the calculated speeds in the macro simulation case, but probably less so with respect to reality. The noise fee impact on traffic flows also differs between the macro and micro simulations, which is reasonable considering the greater simulation detail in the micro simulation. These differences give less noise reduction in the quiet zone, but also less noise increase outside the quiet zone. The net difference of the macro and the micro simulation is that the macro simulation results in a larger shift from medium noise levels to low noise levels, and that the micro simulation results in a smaller shift from higher noise levels to medium noise levels. In both cases, the quiet zone experiences significant noise reductions at the expense of smaller noise level increases outside the quiet zone. The true effects are likely to lie somewhere in between, implying that effects calculated using the macro simulation may be somewhat overestimated.