DELIVERABLE 1.1.2[1]

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ACRONYM	**CITYHUSH**
TITLE	Identification of boundary conditions required to obtain Q-Zones
Work Package 1	***Acoustically green city areas - Q-Zones***
1.1	***Tools for creating Q-Zones***

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SEVENTH FRAMEWORK PROGRAMME

1 see List of Deliverables, DoW – Annex I to the contract, p.32
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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

WP 1.1-2 aims at finding boundary conditions of Q_Zone design with respect to Q_Zone entry/exit conditions, Q-Zone size and Low Noise Vehicle Ownership levels. This is achieved by performance of traffic and noise simulations in different reference situations, with a degree of sophistication function of available data and models.

0.2 DESCRIPTION OF THE WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT

Five different European cities have been chosen (see deliverable D 1.1.1) to evaluate the effects of establishing prospective Q-Zones. The evaluation was based on geographical data, traffic data, population data and assumptions on population behaviour. Traffic models were created and these were then used to simulate noise distributions for various hypothetical Q-Zone scenarios. The difference in the noise situation of these scenarios with the current situation has been compared and are presented in this deliverable.

0.3 FINAL RESULTS

For the five test sites, a varying number of scenarios have been simulated. The results have been discussed above in their specific site context. Although the results are specific to the chosen sites, we will try to generalise the results at least to some extent, building on similarities as well as differences.

We may start by recognising that introducing a Q-Zone implies a reduction of the road network capacity. The impact of such a capacity loss will be more or less severe, depending on the initial use of the network, i.e. the congestion level. The higher the congestion level, the higher the price in terms of increased travel total times in the network. Likewise, the larger the zone, the larger the congestion effect of the implementation. Sufficient network capacity will obviously be a major condition for introducing a Q-Zone.

If there is little traffic zoning in the city, a main effect of the Q-Zone will be to push through traffic away to the remaining network. For congested networks, this may imply increased travel times for a large part of the network. It may however appear a bit unfair to contribute the cost of mitigating through traffic just to the noise effects of the Q-Zone introduction. In many cities, zoning systems have been introduced for improving the environment in a number of aspects, including all kind of emissions, safety and other living conditions. It has not been possible to make an evaluation of all these aspects in this project, but they should also be considered by decision makers. It should also be noted that traffic zoning is also likely to reduce ambient noise, which may otherwise constrain the potential of the Q-Zone. Therefore, a traffic-zoning scheme may also imply a favourable condition for a Q-Zone introduction. It goes without saying that traffic zoning in itself will reduce noise levels, but then a Q-Zone concept is required to utilise the potential of new vehicle technology for further noise reductions. The traffic zone (or environmental zone) concept could also be extended to include the Q-Zone dimension.

Other favourable conditions like tunnels for through traffic may also exist. In such cases, ambient noise levels are likely to be much lower which increases the potential of a Q-Zone introduction.

0.3.1 Q-Zone size considerations

Because of the potentially strong effect of Q-Zone introduction on congestion, the initial size of a Q-Zone cannot be very large. A minimum size will be defined by the impact of ambient noise, which depends on local factors such as distances to major surrounding roads and local topology. A question may then be if the zone size can be expanded as the level of low noise vehicles increases. Then it can be expected that fewer drivers will have to change route because fewer drivers will have (banned or charged) standard vehicles, and consequently the effect on congestion would be lower. However, the rate of transformation of the vehicle fleet is very slow, and in the recent national Swedish transport plan reaching a level of only 5 percent was forecast for the year 2020. This view is supported also by a market outlook to the EU Climate Change Commission (AEA 2009). It is obvious that a reduction of the redistributed traffic of about 5 percent will be very small, and that an expected increase of low noise vehicles will not be a driver for Q-Zone size enlargement for the next 10 – 15 years. A level of 20 percent is of course even further away, although the speed of transformation can be expected to increase as the technology matures.

0.3.2 Low Noise Vehicle Ownership considerations

The level of low noise vehicle ownership inside the Q-Zone may be more easily affected than the outside level. Depending on the Q-Zone policy, incentives to acquire low noise vehicles may be much stronger for Q-Zone residential households than for other households. Exempting Q-Zone households from a ban/charge may be necessary at the time of Q-Zone introduction, but will provide less incentive to change vehicle at least for a transition period. After this period, a ban or fee will provide some incentive, and additional incentives may be provided like free street parking for low noise vehicles. If the Q-Zone is introduced already at the exploitation of a new area, the transition period can even be skipped – standard vehicles might not be allowed in the new area. Assumptions of higher levels of low noise vehicle ownership are therefore motivated. Our simulations show that high levels of low noise vehicle ownership are necessary to bring about more significant noise reductions, especially in cases where traffic zoning has already taken place.

0.3.3 Noise fee level considerations

The noise fees that have been studied are to be paid on Q-Zone entry or exit. The fee levels that have been simulated (0.5 - 2 Euros per entry or exit) give almost the same results as the ban does. This is more outspoken in those cases where the traffic simulation allows for route choice only. This effect is because the extra delay for changing route is for most drivers too small to match the fee. As there is a cost of fee collection, and as the size of the zone is small which implies a low number of paying vehicles, it has not been motivated to simulate even smaller fees. The choice between a ban and a fee is more a choice between ease of monitoring and giving some flexibility to drivers. In this project, we have however not tried to calculate monitoring or fee collection costs.

0.4 POTENTIAL IMPACT AND USE

The deliverable identifies boundary conditions for Q-Zones in different contexts, giving city planners insight in Q-Zone design and its potential effects. It also demonstrates a methodology to assess effects of tailor-cut designs that are necessary for a successful Q-Zone implementation

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

This deliverable was produced by

KTH, being responsible for the deliverable and for traffic simulations

ACC, for providing noise mapping for Bratislava, Bristol and Essen

ACL, for providing noise mapping for Stockholm and Gothenburg

TPTA, for providing data for the Gothenburg test site

0.6 CONCLUSIONS

We conclude that for a Q-Zone to give a significant and efficient noise reduction the following requirements need to be met:

- There must be enough street capacity to accommodate diverted traffic in order to avoid congestion effects (i.e. diverted traffic must not increase noise levels outside the Q-Zone)
- The ambient noise level needs to be low to allow a reasonable noise reduction potential
- Policies to promote low noise vehicle ownership close to 100 percent within the Q-Zone are necessary to achieve significant noise reductions, particularly in already traffic zoned areas

We also conclude that

- The choice between ban or a 1 Euro fee is mainly a choice between ease of monitoring and giving some flexibility to driver
- The level of low noise vehicle ownership is not likely to increase in such a way in the next 10-15 years that it will affect the consideration of the Q-Zone size.

We recommend that

- Detailed traffic forecasting and noise mapping tools are used in each case where a Q-Zone is considered, to be able to assess potential effects inside and outside the potential Q-Zone
- These tools are also used to optimise the Q-Zone design with respect to effects inside and outside the potential Q-Zone

1 BACKGROUND

Q-zones (QZ) is a major concept in the CityHush project. A Q-zone is an area where a significantly lower level of traffic noise (at least 5 dB)is maintained by allowing only low noise vehicles (LNV) to enter. To be able to take advantage of LNV technology, a certain LNV ownership is required. To filter out the standard vehicles, a ban or a suitable fee on standard vehicles to enter or leave the QZ is needed. As a consequence of being penalized for driving in QZ, drivers not having a LNV will change their routes to roads outside the QZ. This will add to congestion and to noise levels outside the QZ. The smaller the QZ, the smaller the added congestion and noise outside the QZ. There is also a minimum size of the QZ, because of ambient noise. The QZ therefore needs to be large enough not to be too much influenced by ambient noise. An introduction of QZ therefore requires the following questions to be answered:

- What is the minimum size required?
- What fee level (or ban) is required?
- What levels of LNV ownership are required?
- How large is the congestion effect of the QZ?
- How are noise levels outside the QZ affected?

The answers to these questions reflect boundary conditions for establishing a QZ. The idea of WP 1 is to identify these boundary conditions, and to do so in a real setting as the answers to the questions to a large extent will depend on local conditions. We cannot test different QZ designs in reality, so to be able to answer the questions we will have to use simulation techniques for traffic and noise predictions.

As traffic and other conditions may differ between European cities, five test sites reflecting different traffic conditions in Europe have been subject to simulations. The cities that have been selected for these WP's are Bratislava (Slovakia), Bristol (UK), Essen (Germany), Gothenburg and Stockholm (Sweden).

The outline of the deliverable is as follows. First, we describe the methods that are used for traffic simulation and noise mapping. Then we describe how the simulations are applied and their results for each test site (in alphabetical order). We then proceed by discussing the full set of results as a whole, and finally conclude to what extent boundary conditions for Quiet Zones can be defined.

2 METHODS

The objective is to identify boundary conditions to obtain QZ. We solve this by modelling traffic for a set of different conditions and then calculating the corresponding noise effects. From the resulting set of noise maps conditional on traffic scenarios, we conclude what conditions are required for a QZ to be established. The approach involves traffic simulation methods and noise mapping methods that are described in this chapter.

2.1 TRAFFIC SIMULATION

2.1.1 Introduction

In the Cityhush project, we want to change current traffic flows by traffic management policies to reduce noise in quiet zones. We want to asses effects of different policies with respect to different QZ designs and different low noise vehicle ownership conditions. We need to assess impacts inside as well as outside the QZ, in order to take all effects of the QZ implementation into account. We study QZ implementation in major European cities with various levels of traffic congestion, which makes it necessary to cover large parts of the street network. This is because pushing traffic away from QZ may add to congestion effects outside the QZ, and these effects may propagate widely.

Traffic flows is a result of peoples travel decisions in the following dimensions:

- Making a trip
- Destination
- Mode
- Route
- Time of day

Peoples choices in these dimensions are conditional on a number of demand related factors, which can be grouped into three categories

- Traffic network characteristics (travel times, costs etc.)
- Destination characteristics (supply of activities of different types)
- Socio economic characteristics (individual preferences and resources, house-hold characteristics)

Implementing a QZ implies a change in network characteristics, and the traffic flow effects of this change will be the result of people's choices given the above-mentioned factors. This means that all decision dimensions are depending on all types of factors. For example, a network change will affect not only the route decision, but also the mode, destination and trip making decision.

To be able to calculate the new traffic flows, we ideally need to simulate people's decisions in the dimensions listed above, based on the demand related factors. Methods to perform such simulations have been developed and are in use in many cities, although with a varying degree of sophistication. The development of a simulation application is a major task, which is therefore not part of the Cityhush project. Such applications are also software specific, requiring corresponding software licenses.

In the EU-project IMAGINE (Improved Methods for the Assessment of the Generic Impact of Noise in the Environment), the suitability of traffic models for noise modelling was considered (Report 2.2 Suitability of traffic models for noise modelling). The conclusions were in short that "There is no superior type of traffic model to deliver input for traffic noise models. Depending on the study area (e.g. major roads, or agglomerations), several traffic model types are capable to deliver the required output." In each case, the practical situation in terms of data and model availability needs to be taken into account.

In Cityhush, the test sites were therefore chosen with respect to the existence of at least a simple simulation application from which data could be used in Cityhush. These data were then imported into the Emme 3 Travel demand forecasting software, for which the Cityhush partner KTH has the necessary competence and licenses.

2.1.2 Traffic model adaptation for Cityhush

For Cityhush, site specific Emme 3 applications had to be established for Bratislava, Bristol and Essen, using data from other software. For Stockholm and Gothenburg, existing traffic models (the national Swedish forecasting system Sampers) could be used. The adaptation involved three major steps.

- Data import
- Value of time distribution and vehicle class implementation
- Validation

Data import is mostly a trivial data handling procedure, although the conversion of functional relationships required contacts with local authorities and consultants. It will be further described in the site specific sections.

An important issue in the Cityhush project is to what extent people will react on the implementation of noise charges. If noise fees are introduced, drivers will have to decide whether they should pay the fee and pass the QZ, or make a detour probably at the price of increased travel time. This decision will depend on the value of time for each driver. Using an average value of time for all drivers will not give a realistic picture of the noise charge effect, as we know that there is a considerable variation in value of time in the car driving population (Borjesson et al 2012). To accommodate this variation, an approach had to be established, in which drivers were sorted into a number of groups with a specific value of time, and where the route choice decision was separately treated for each group (a so-called multi user class network assignment). The sorting was made using the mean values of time for different travel purposes reported in Heatco (Shires and de Jong 2006), assumed to be lognormally distributed. (Borjesson et al 2012). The Heatco mean values are found in table 2.1

Table 2.1 Heatco mean car values of time, Euro/h

Car VoT Euro/h	Business	Commute	Other
Slovakia	12,6	5,73	4,81
Germany	27,78	9,48	7,95
Sweden	30,55	10,82	9,07
UK	29,37	10,24	8,59
EU Average	24	10,29	8,63

The distributions vary between sites, and are reported in the site-specific sections.

In addition to the value of time classes, separate user classes also had to be introduced for standard vehicles (having to pay fees) and low noise vehicles (not having to pay). In some cases, also heavy trucks were identifiable, and then they were given a special class to be able to calculate the share of heavy vehicles required for the noise simulation.

Before using the new applications, a validation was carried out. In some cases, counts were available to validate against, in other cases original assignment results were available. The validations are described in appendix A1.

2.1.3 Noise fee definition

There are different ways of implementing a noise fee. An explicit analysis of different noise fee systems has not been included in the Cityhush project, but some assumption has to be made to be able to undertake the traffic simulations. Experience from road charging systems implies that the costs of monitoring can be quite high. Therefore, a simple system has been assumed. This system requires a fee to be paid on each entry and exit to/from the QZ. This means that only the zone border needs monitoring. It also implies that through traffic is heavier penalized than traffic to or from the zone. The simplest way to monitor this system is to require prepaid tickets registered on the vehicle license plate, and then use random camera monitoring. Unpaid passages are then billed an extra fee. In the future, more sophisticated devices using GPS information can of course be envisaged.

2.1.4 Scenario analysis

In order to establish boundary conditions for Quiet Zones, effects of different sizes, fee policies and low noise vehicle ownership (LNVO) were investigated in each site by simulating scenarios defined by different combinations of these aspects. In table 2.2 the different levels of the investigated dimensions are shown.

Table 2.2 Scenario factor levels

Dimension	Levels
Fees	Ban, 0.5 Euro per border passage, 1 or 2 Euros per border passage
Size	Large, medium, small
LNVO inside/outside zone	1 % / 1%, 5 %, / 5 %, 20% / 20 %, 20% / 5 %, 100 % / 20 %

If all combinations of levels would be tested in all sites, over 200 simulations would be required. This would not be possible within the limits of Cityhush resources, so a reduced set of combinations has been applied. The reductions mainly concern zone sizes and fee levels, and vary from site to site.

2.2 NOISE MAPPING

2.2.1 Noise Model adaptions

For each test-site within the selected cities the available noise model from the first round of strategic noise mapping had to be updated and improved. The positions of all road axes had to be reviewed and the positions were corrected where necessary. A new segmentation of the road network was undertaken in such a way, that a definite assignment of each road section in the noise model to the road-section-specific traffic data from the traffic model could be ensured. Within a database the traffic data (number of passenger cars and speed) from the traffic model was converted to a compatible format for the noise modelling.

An expansion from the 12-h-traffic data to 24-h-traffic data was undertaken to additionally determine the strategic noise indices Lde and Lden. Together with the available data from the noise models of each City including road-segment-specific heavy-traffic-data and road surface categorization, noise relevant input data for modelling could be allocated to each defined road segment by an interface created for the CadnaA noise prediction software used in the project.

2.2.2 Acoustical interpretation of low emission vehicles

The acoustical interpretation of low-noise-vehicles was modelled by reducing the emissions of standard vehicles by 10 dB. This simple estimation considers the much quieter propulsion of an electric drive compared to a combustion engine and the existence of low noise tyres (which are assumed for future low-emission-cars).

2.2.3 Scenario analysis with noise maps and single number values

By using a calculation cluster for all traffic scenarios grid calculations (10m x 10m, height 4m) were undertaken and noise maps showing the Lden noise levels were predicted. For a better comparison of the influence of changing traffic data we also produced difference maps (scenario – base case). For a simple comparison of different scenarios the single-number-value "arithmetic average noise level Lde" was calculated separately for the Q-Zone and the surrounding test-site(without the Q-Zone area). For the test sites Bratislava, Bristol and Essen we calculated the "arithmetic average noise level L_{DEN}.

Within the investigations for the work package "Identify boundary conditions required to obtain Q-zones (WP 1.1)" the effects on noise will be shown by determination of areal noise distribution and statistics.

3 BRATISLAVA TEST SITE

3.1 General Information City of Bratislava

Bratislava is the capital of Slovakia. The city covers a total area of 368 square kilometres, and has a population of about 450,000. The population density is 1.222 persons/km².

Figure 3.1 Map of Bratislava. *Map supplied by Mapa Slovakia, s.r.o.*

The city is located on both sides of the river Danube (Donau). The central part includes the old town, and is shown in figure 3.2. On this figure, smaller parks can be seen on the northern side of the river, as well as a larger green recreational area on the southern side.

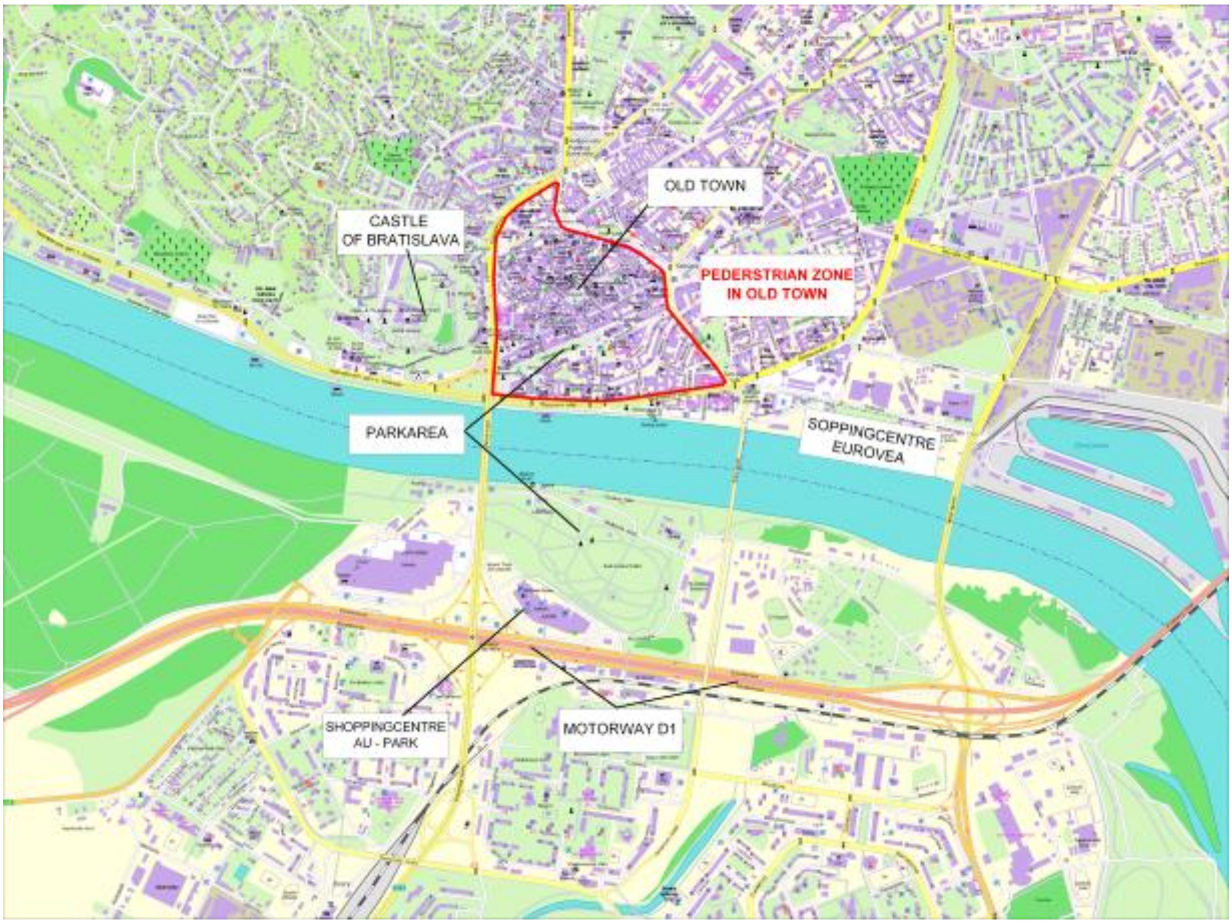

Figure 3.2 Central part of Bratislava. *Map supplied by Mapa Slovakia s.r.o.*

The old city centre is already largely a pedestrian area. Pedestrian areas are indicated by the checked areas in Figure 3.2. A more detailed view of the old city centre can be seen in Figure 3.3.

Figure 3.3 Pedestrian areas of the old city centre in central Bratislava. *Ortofotomap supplied by EUROSENSE/Geodis Slovakia.*

3.2 TEST SITE SELECTION

3.2.1 Noise conditions

For Bratislava, noise mapping has been undertaken for the whole Bratislava Conurbation area in the year 2007 (Fig 3.4). From this map, it can be seen that the central parts suffer from high noise levels. Figure 3.5 shows the central parts of the city. Major roads along the riverbanks cause large noise disturbances in the central areas south of the old town. These disturbances also extend to the other side of the river, where a green recreation area is situated.

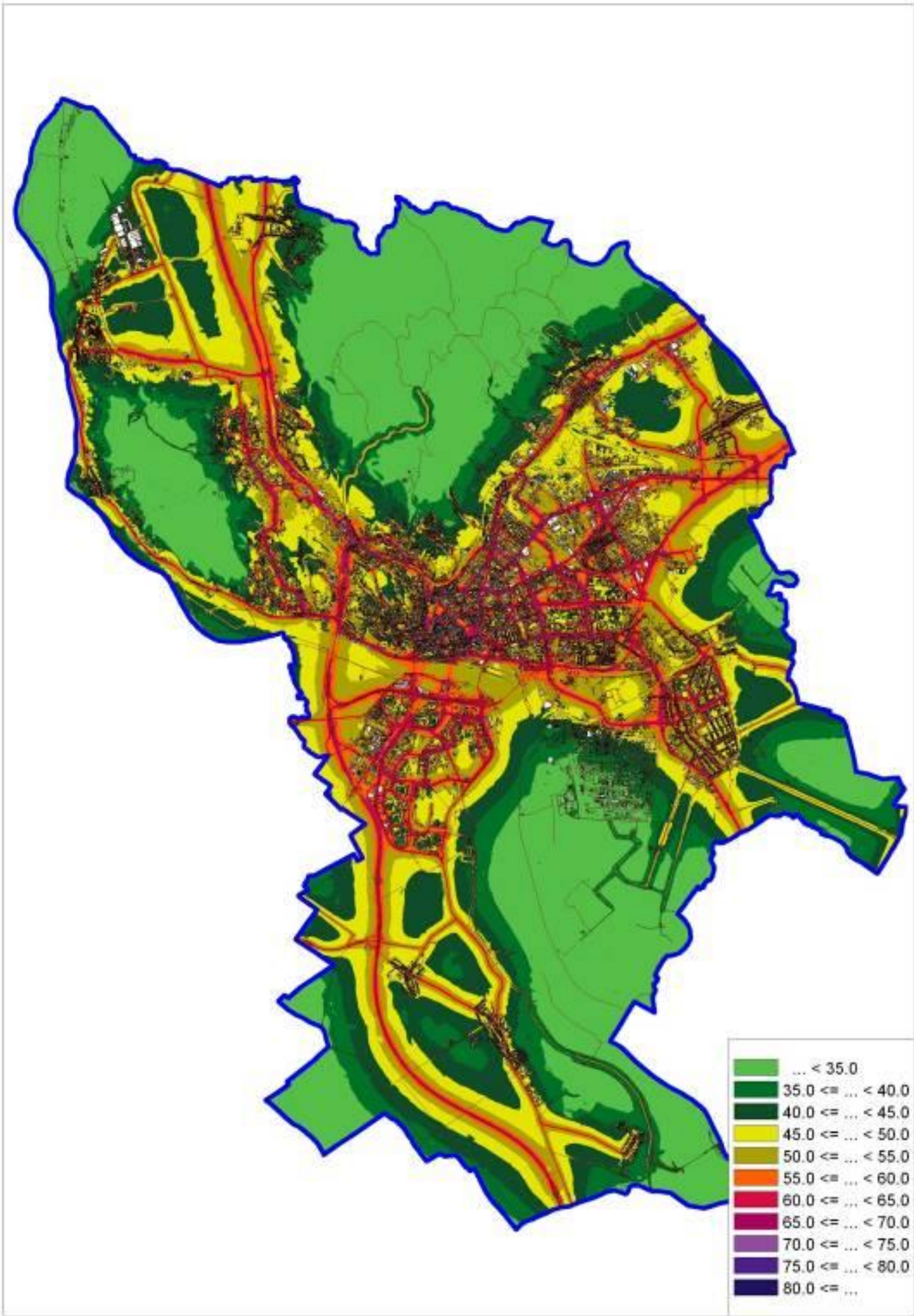

Figure 3.4 Road Noise map for Bratislava (dB(A) L_{den} noise levels)

Figure 3.5 Road Noise map for central Bratislava (dB(A) L_{den} noise levels) Comment, Q-Zone boundary?

3.2.2 Potential for Q-zones

The City of Bratislava is already planning for and developing areas along the Danube River. The Danube embankment offers excellent possibilities to create an enjoyable recreation environment, and reshaping of the dockland areas to a mix of commercial and residential land use is under way. These developments are located east (the Eurovia project) and west (the River Park project) of the area south of the old town.

3.2.3 Selected Q-zone area

After discussions with local representatives of the City of Bratislava and a visit to the site, transforming the area south of the old town to a Q-zone seemed to be the most interesting Q-zone application in Bratislava. This area also includes a park-like avenue, bordering the pedestrian area of the old town. The arterial going along the riverbank is a major challenge, and different ways of handling this will be analyzed. The intended Q-zone is marked with blue in figure 3.6.

Figure 3.6 Intended Q-zone area (red line). *Ortofotomap supplied by EUROSENSE/Geodis Slovakia* Available noise model

3.2.4 Digital terrain model

The terrain model is important for noise calculation and to determine the ground type i.e. soft or hard, for the determination ground attenuation. Also the shielding effects of hills and embankments are considered within the calculation of noise levels.

Figure 3.7 shows a visualization of the elevation model in which the area height is represented by colour.

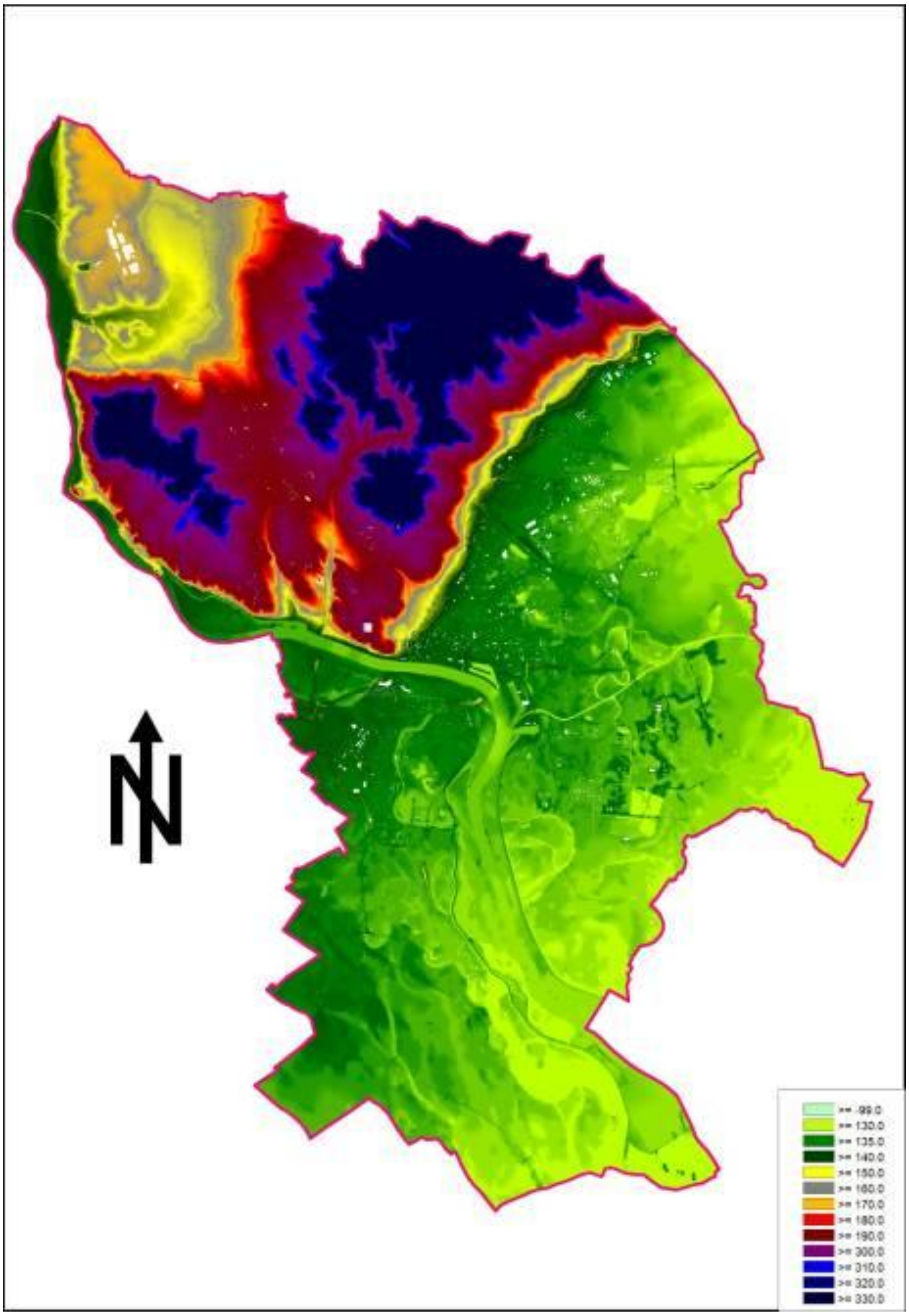

Figure 3.7 Topography map for the City of Bratislava

The lowest point of the investigation area is located approximately 125 m above sea level and the highest point is more than 420 m absolute altitude. The DTM model was created from the photogrammetric data with CadnaA software.

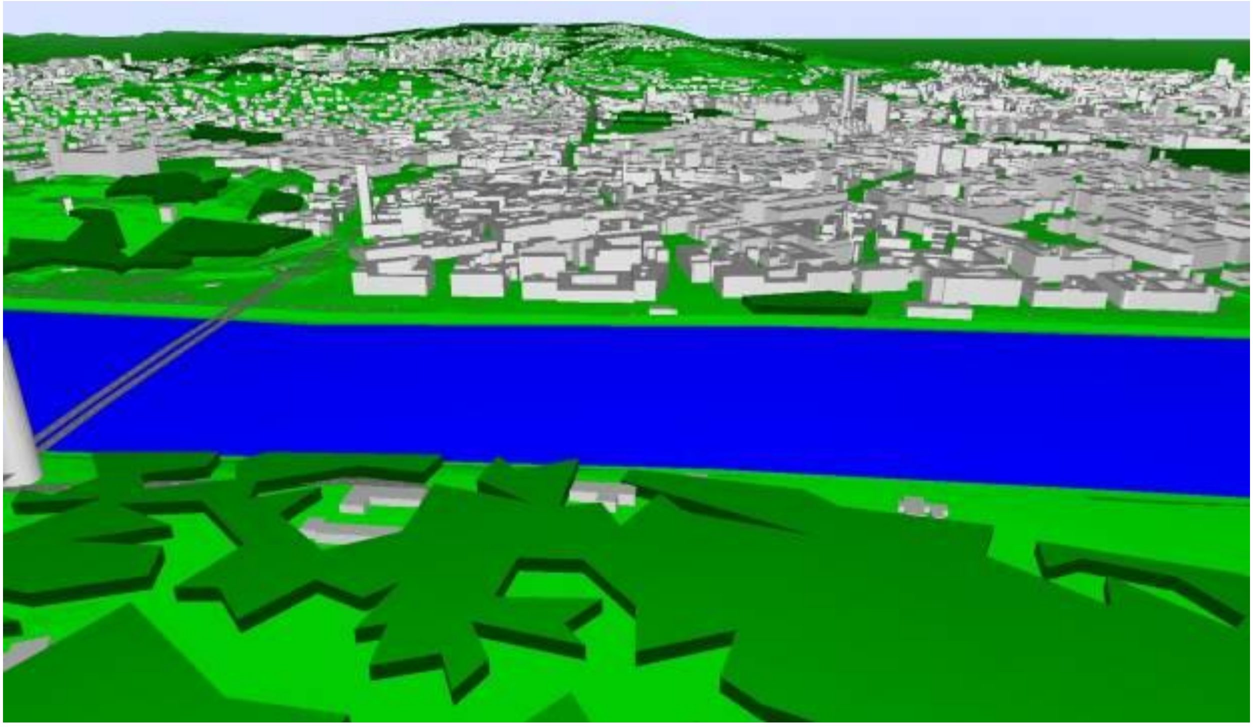

Figure 3.8 3D model of selected Q-Zone area (*data from photogrammetry adapted in CadnaA*)

3.2.5 Road and traffic information

The traffic model noise calculations for Bratislava take account of all roads with traffic. The traffic flow on particular road sections was set using a mathematical model applied in the PTV Visum program.

Total length of roads studied is about 1,922km. The most important roads in terms of the highest traffic flows are:

- North-west highway D1 connected to highway D2 with directions to Czech republic and Hungary

3.2.6 Rail and tram information

The noise map which was processed in 2007 also took noise from railways and trams into consideration. In Bratislava 177 km of train lines were studied as well as 73 km of tramlines.

3.2.7 Noise barriers

Altogether, there are 21,456 meters of noise barrier installed in the Bratislava area. The total length of noise barriers alongside roads is 20,655 meters. The barriers are mainly installed along highways and major access roads to the city.

The location of barriers along the motorway corridor and the main train lines are shown in the figure 3.9.

Figure 3.9 Noise barriers (red line) along the D1 motorway (near the Q-Zone area).

Figure 3.10 shows the structural design of the barriers along the motorway D1.

Figure 3.10 Noise barriers along the D1 motorway.

Figure 3.11 shows the construction noise barriers around the major road.

Figure 3.11 Photo showing noise barriers alongside a major road.

3.2.8 Buildings and inhabitants

The city of Bratislava has about 450,000 inhabitants. There are about 34,200 buildings of which about 26,150 are residential (approx. 76.5%). In total, there are 183,500 flats and residential units.

3.3 AVAILABLE TRAFFIC MODEL

3.3.1 Network model

A Visum application exists for Bratislava. It was developed in context with the noise mapping, and comprises the municipality of Bratislava. Data from this application has been made available to the CityHush project. The network contains 302 zones, 3,833 nodes and 10,472 links.

The application only considers car traffic. Network Information on buses etc. is not available. Public transport bus, tram and train lines are also not included in the database.

The network is shown in figure 3.12 as a Visum screenshot.

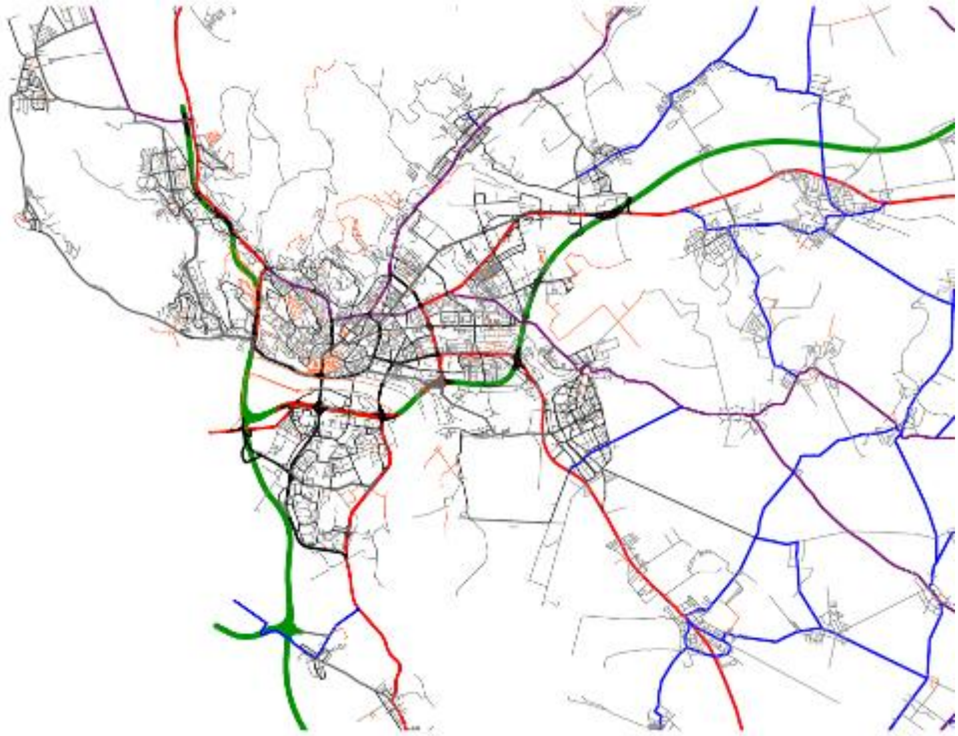

Figure 3.12
Visum network for Bratislava municipality

Figure 3.13 shows the network for the central parts of Bratislava. All streets are included in the network. Pedestrian streets are coloured in red.

Figure 3.13
Visum network for central Bratislava

3.3.2 Demand models

Traffic is assigned on an all day basis, thus giving 24 hours flows. Congestion is accounted for by using a general volume-delay function at all regular links (i.e. not connectors).

Travel demand is constrained to one vehicle type. An OD matrix for the all day traffic has been developed using a gravity model calibrated with traffic counts from 130 count locations. There is no specific trip generation model and no specific mode choice model.

3.3.3 CityHush adaptation

The network and the OD matrix have been exported from the Visum system to the Emme system. Since all streets were already contained in the network, there was no need to enhance the network. The model transfer was validated using the Visum assignment results. Details regarding the validation are found in Appendix A1.

The assignment is based on time, and as the simulation scenarios will imply fees on specific links, a conversion from monetary units to time units was necessary to reflect the impedance on such links (as described in Chapter 2.1.2). The conversion was made using assumptions on values of time and their distribution in the population as described in Chapter 2.1.2. In figure 3.14, the resulting distribution of values of time for Bratislava is shown.

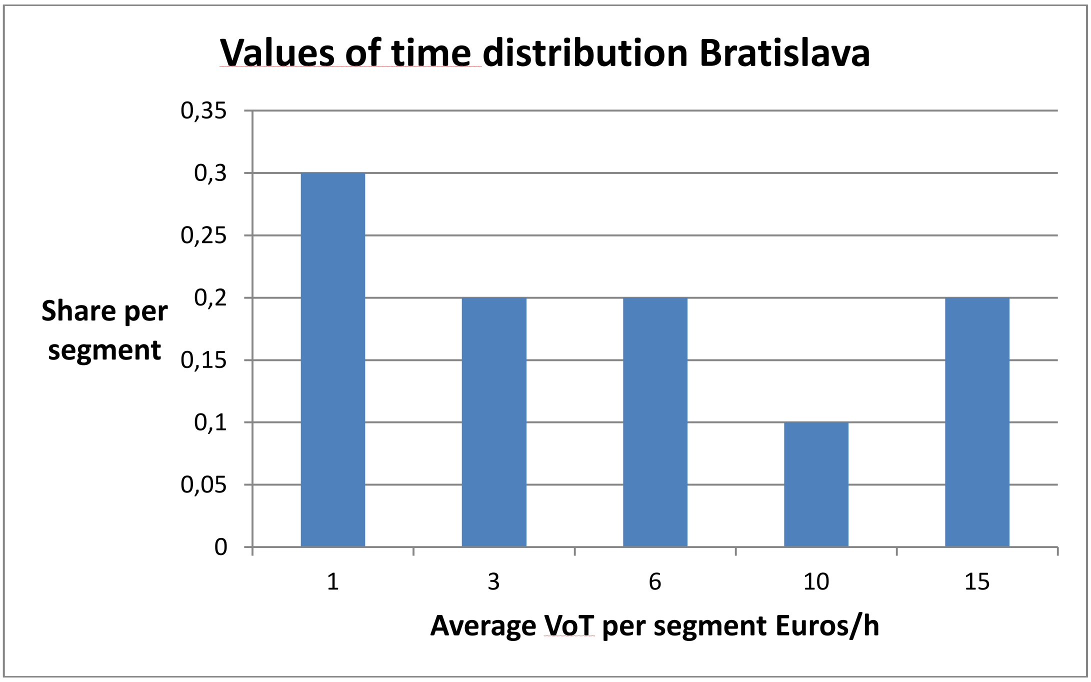

Figure 3.14 Distribution of values of time in Bratislava for car trips (2003 prices)

The fact that only car traffic is included in the traffic models means that policy simulations will affect car traffic only. Heavy trucks were not separable in the data, and an average assumption on the share of heavy vehicles had to be used (5 percent).

3.4 TRAFFIC SIMULATIONS

The Visum Bratislava application only allowed traffic simulation using a fixed traffic matrix in our case. Therefore, only route choice effects were considered. This means that mode and destination choice effects are not been considered. Traffic reductions within the Quiet Zone may therefore be somewhat underestimated, and redistribution effects somewhat overestimated.

3.4.1 Simulated scenarios

For Bratislava, the following set of traffic scenarios was simulated:

Table 3.1 Simulated scenarios for Bratislava

Scenario nr	Zone	Fee, Euros/passage	Inside LNVO percentage	External LNVO percentage
1	none	none	1	1
2	large	ban	1	1
3	large	1	1	1
4	large	2	1	1
5	small	ban	1	1
6	small	1	1	1
7	small	2	1	1
8	none	none	5	5
9	large	ban	20	5
10	large	1	20	5
11	large	2	20	5
12	none	none	20	20
13	large	ban	100	20
14	large	1	100	20
15	large	2	100	20

3.4.2 QZ borders

Two different Q-Zones were defined for Bratislava, a small and a large Q-Zone (figure 3.6).

3.4.3 Establishing a QZ - simulation results

Traffic effects

We now present the simulation results of an introduction of the small QZ (defined in the previous section) by banning all non-resident standard vehicles. The following figure shows the base case (the bandwidths are proportional to traffic volumes):

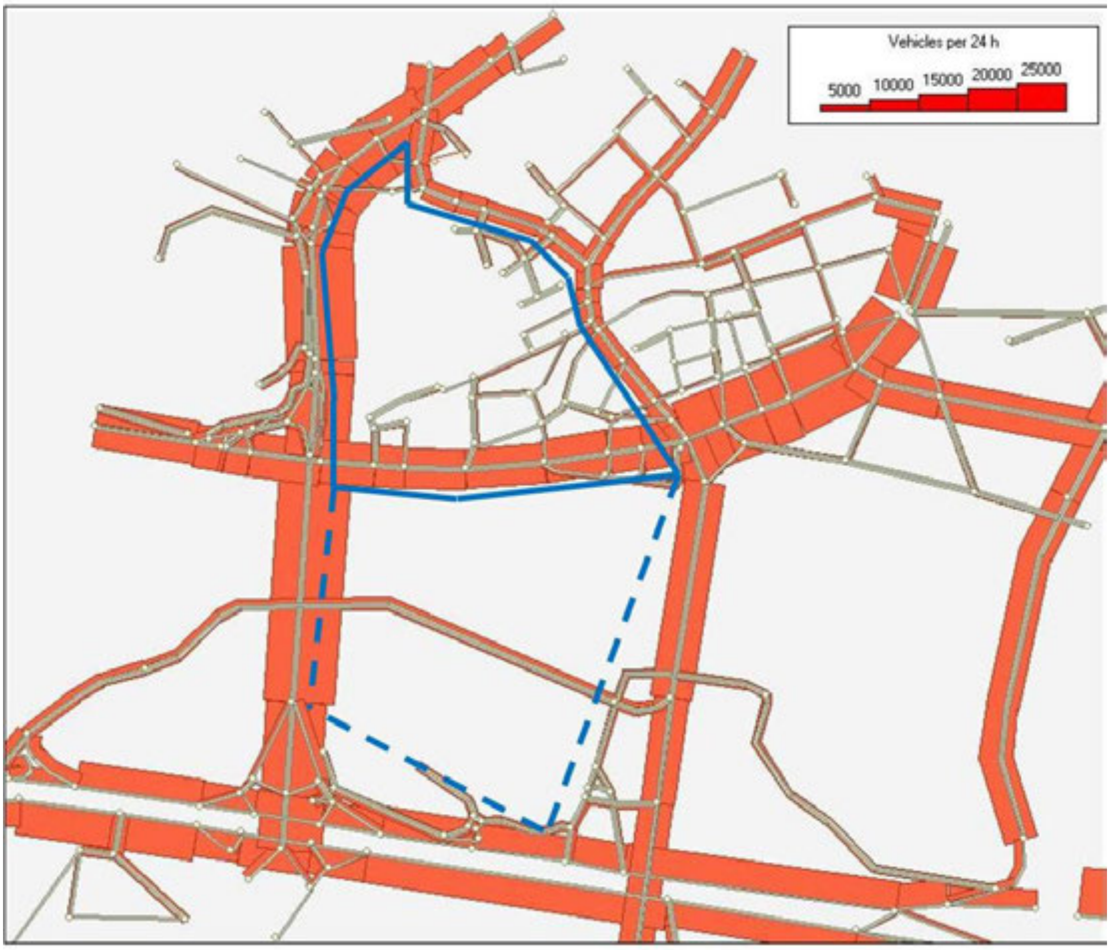

Figure 3.15 Base case

On the next figure the maximum effect of traffic reduction (obtained by banning all non resident standard vehicles in the small Q-Zone is shown. In order to make the difference to the base case more visible, the figure shows the changes in traffic volumes (red is increase and green is decrease with respect to the base case) in the same scale.

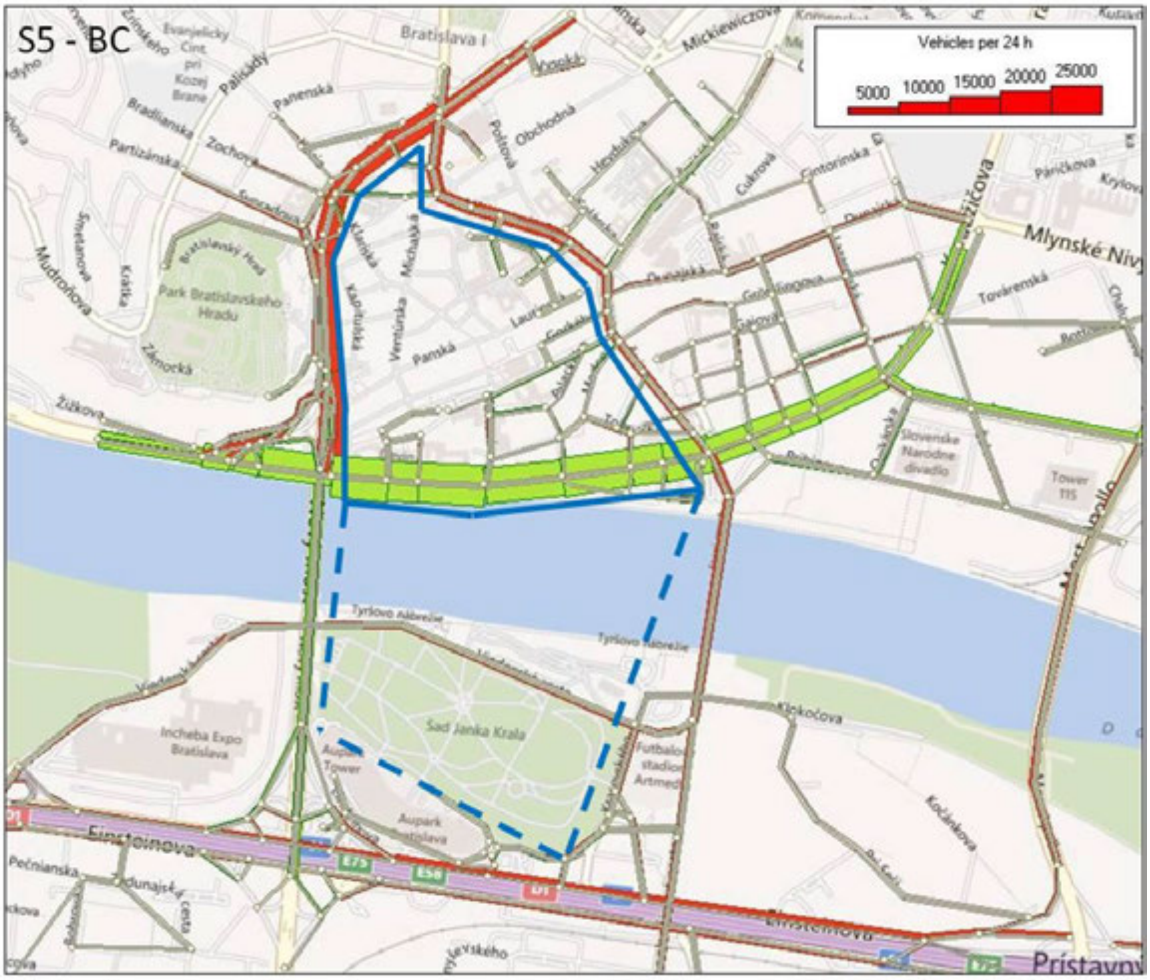

Figure 3.16 Traffic volume difference between scenario 5 and Base Case

Within the Q-Zone, the standard vehicle ban leads to a traffic volume reduction by xx percent. The traffic reduction results from car drivers choosing routes outside the Q-Zone, and so traffic is redistributed to other streets, adding to congestion on those. This will affect the travel times of drivers not previously driving through the Q-Zone, which may make these drivers to change route. These effects may spread to a large part of the network, not only to the immediate neighbourhood. Travel time effects are therefore calculated for the whole Bratislava area.

The travel times will increase by 8000 hours per day due to the standard vehicle ban in the small Q-Zone. This effect needs to be considered together with the noise effects. The distance driven increases by 120000 vehicle km. The average time increase is about half a minute per trip, and the average trip length increase is about 150 m per trip.

Noise effects

Figure 3.17 shows the noise distribution within the test-site Bratislava for the base-case.

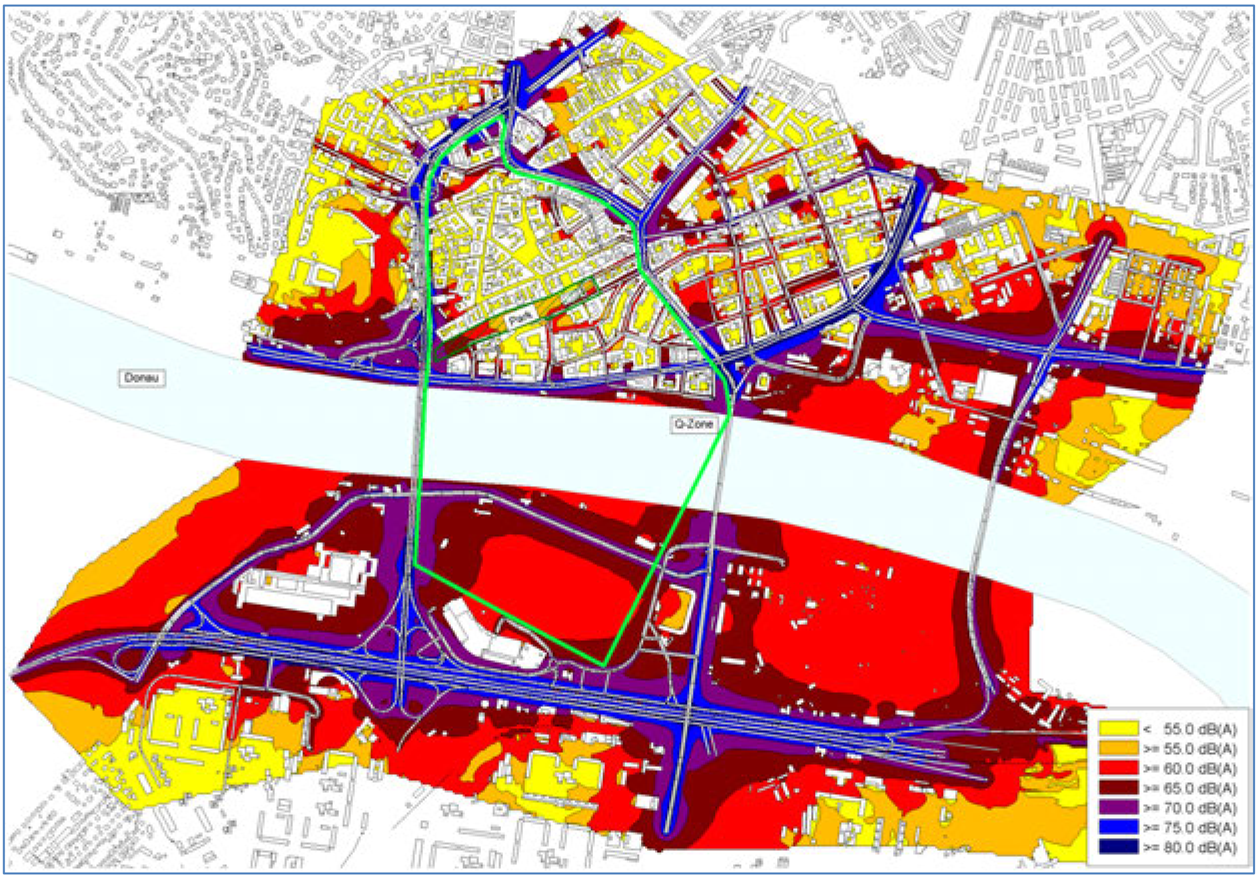

Figure 3.17 Noise situation (Lden) in the base case on the test site in Bratislava. The boundary of the large Q-Zone is also shown.

Here the 4-lane main roads can be identified as major sources of noise. The cause for this, is their high volume of traffic.

In figure 3.18 the noise distribution in the case of a ban of non residential standard vehicles within the Q-zone (scenario 5) is shown, where a decrease of noise within the Q-zone can be recognized. Very clearly, reductions of the noise levels can be identified along the major road passing through the Q-Zone at its southern end near the riverbank.

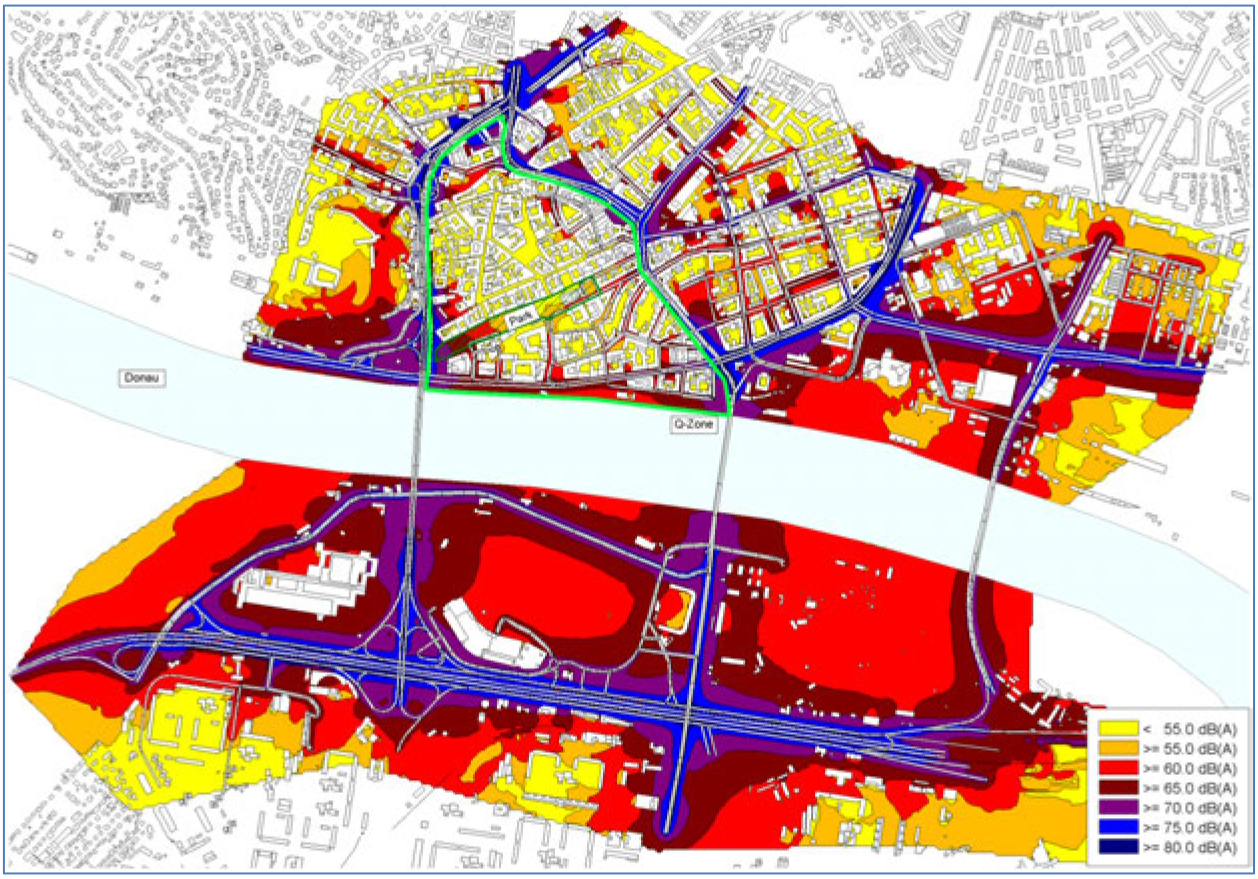

Figure 3.18 Noise situation (Lden) in scenario 5 (S20) on the test site in Bratislava. The boundary of the small Q-Zone is also shown.

The figure 3.19 (difference map scenario 5 - base case) allows localization of the changes of the noise situation within the test-site. Here it can be seen, that the traffic redistribution caused by the ban of non residential standard vehicles produces noise reductions within the Q-zone but also noise increases can be seen outside the Q-zone.

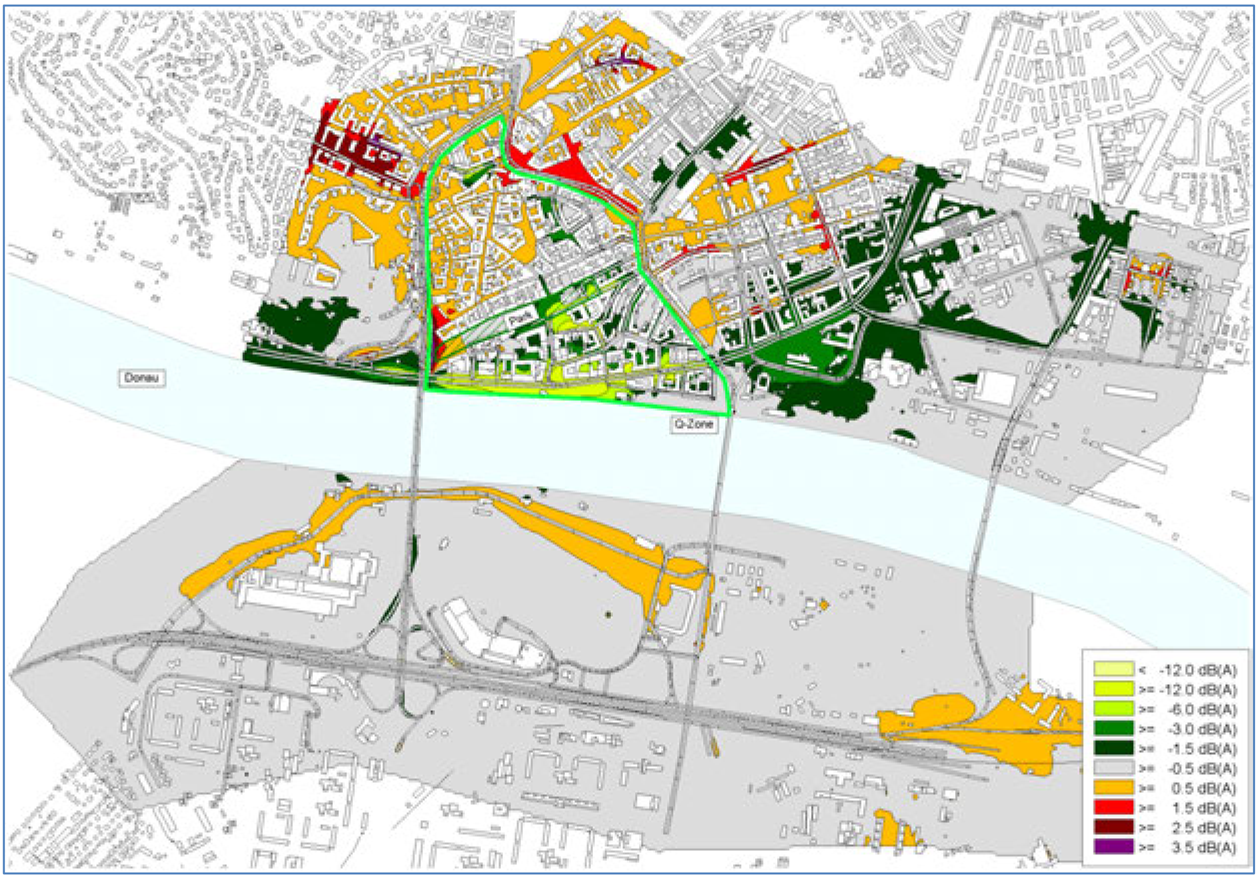

Figure 3.19 Noise difference (Lden) in scenario 5 (S20) compared to the base case on the test site in Bratislava. The boundary of the small Q-Zone is also shown.

On average, implementing the small Q-Zone in Bratislava by banning all non-residents vehicles, results in a reduction of average noise levels in the Q-Zone by 1.2 dB. It also results in a small increase of average noise levels outside the Q-Zone by 0.1 dB.

3.4.4 Introducing noise fees

Traffic effects

Instead of a ban, noise fees can be introduced. That will enable drivers to trade off the time gain by going through the zone and the noise fee. The effect of noise fees as compared to a ban depends on the extent of time gain, the size of the fee and the distribution of values of time in the driver population.

It turns out that the impact of noise fees is only marginally smaller than the ban effect. The 2 Euro fee achieves almost the same volume reduction as in the ban scenario, and the 1 Euro fee achieves practically the same reduction. The time delays when fees are introduced will be smaller, and as drivers with higher values of time to a larger degree will go through the zone, the value of the added congestion will be more than proportionally reduced. The traffic difference between the noise fee levels is very small, and the fee revenue is proportional to the fee.

Noise effects

In the following figures 3.20 and 3.21 the noise distribution across the test site is shown in the case that fees of 1 € or 2€ respectively are introduced for entering or exiting the Q-zone with non residential standard vehicles. Both scenarios show a reduction of noise within the Q-zone.

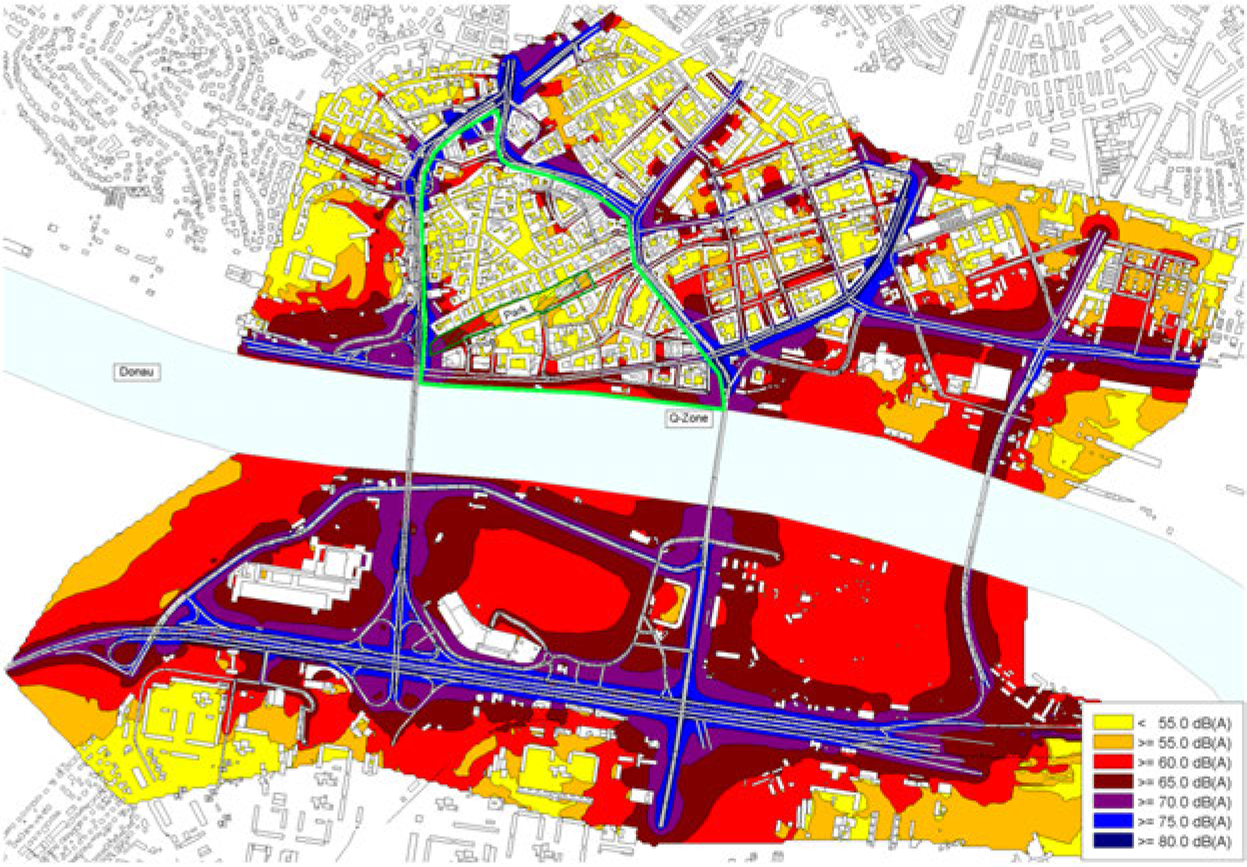

Figure 3.20 Noise difference (Lden) in scenario 6 (S21) compared to the base case on the test site in Bratislava. The boundary of the small Q-Zone is also shown.

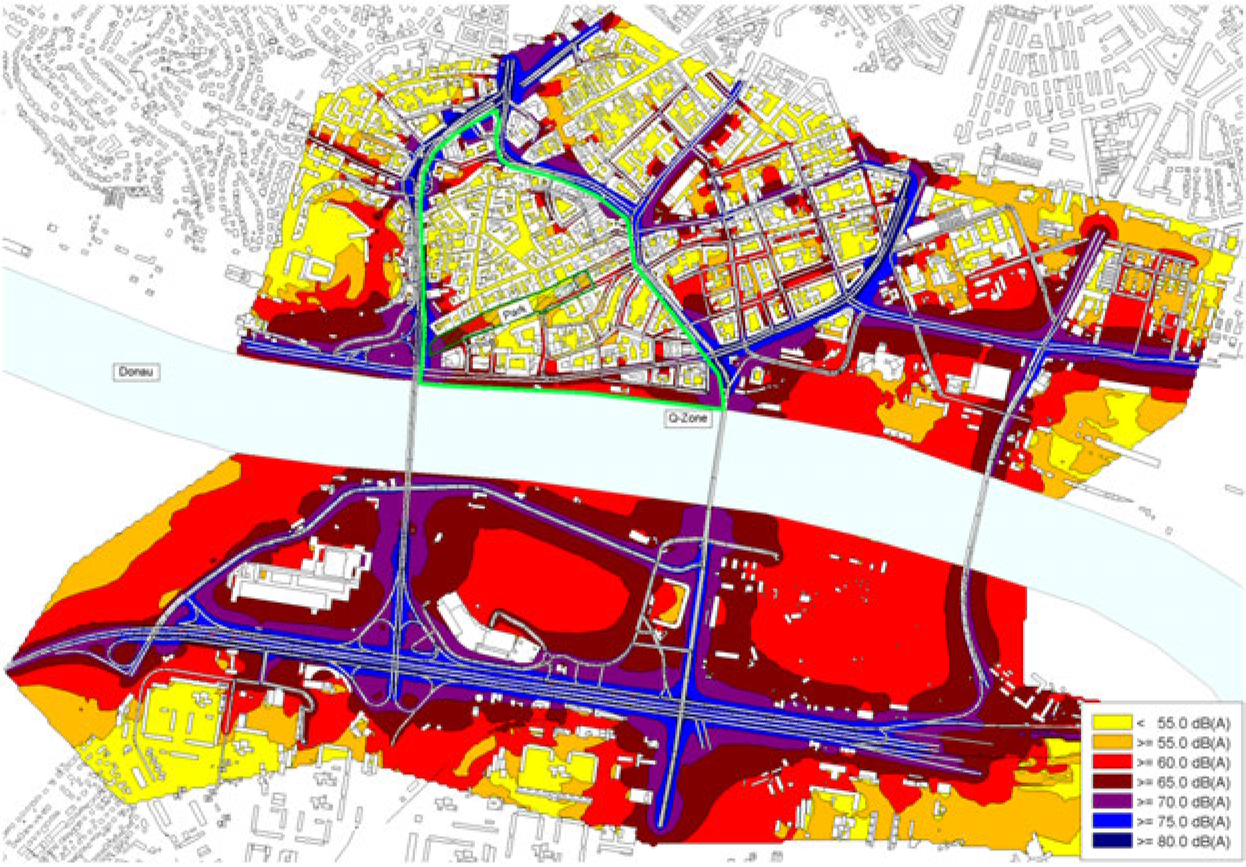

Figure 3.21 Noise situation (Lden) in scenario 7 (S22) on the test site in Bratislava. The boundary of the small Q-Zone is also shown.

Figures 3.22 and 3.23 (difference maps base case – scenario 6 and scenario 7 respectively) allow localizing the changes of the noise situation within the test-site. The effects on noise levels across the test site by introducing passage fees through the Q-Zone are similar to the effects caused by the traffic ban inside the Q-Zone. Noise reductions can be identified inside the Q-Zone but again noise increases are produced outside. This is again a result of the traffic distribution in consequence of drivers choosing alternative routes outside the Q-Zone to avoid the charged fees.

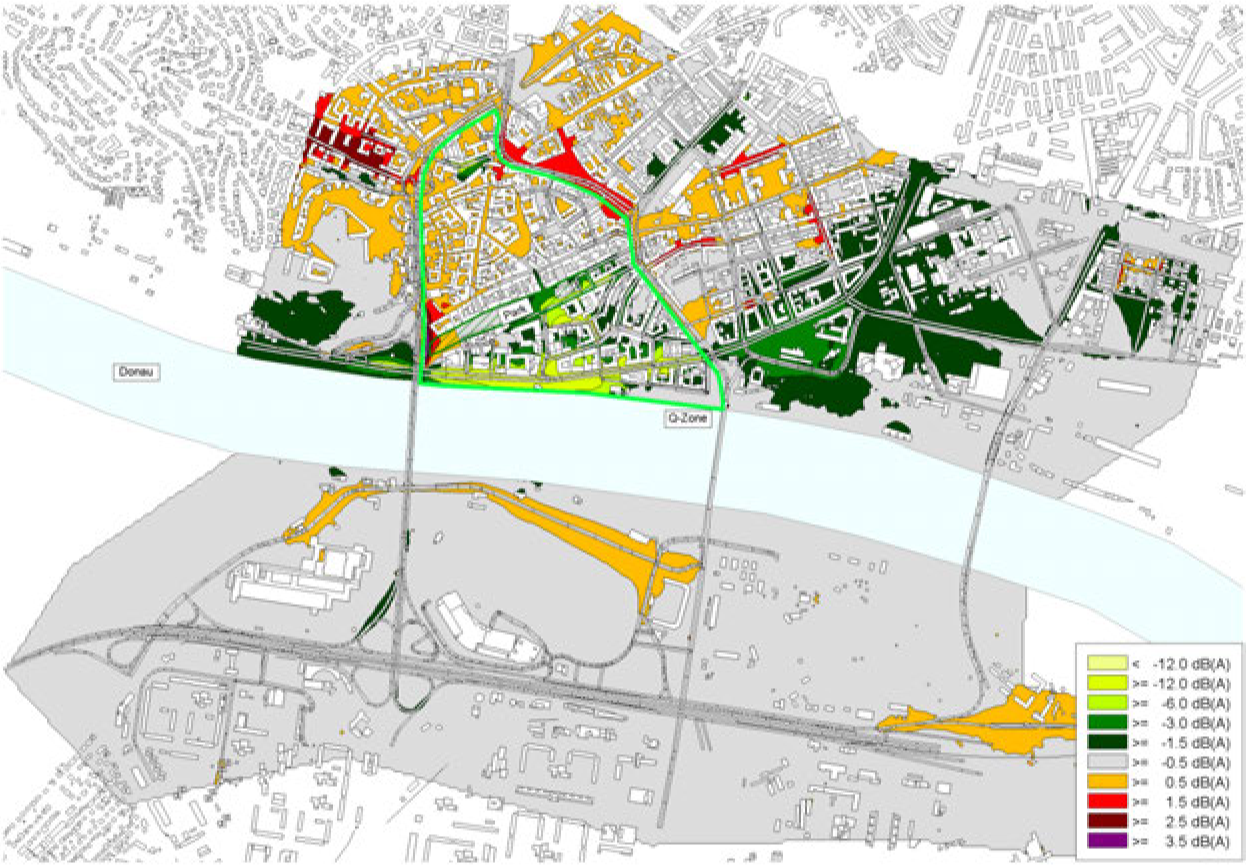

Figure 3.22 Noise difference (Lden) in scenario 6 (S21) on the test site in Bratislava. Here a 1 Euro fee is imposed to exit and enter the Q-Zone with a standard vehicle. The boundary of the small Q-Zone is also shown.

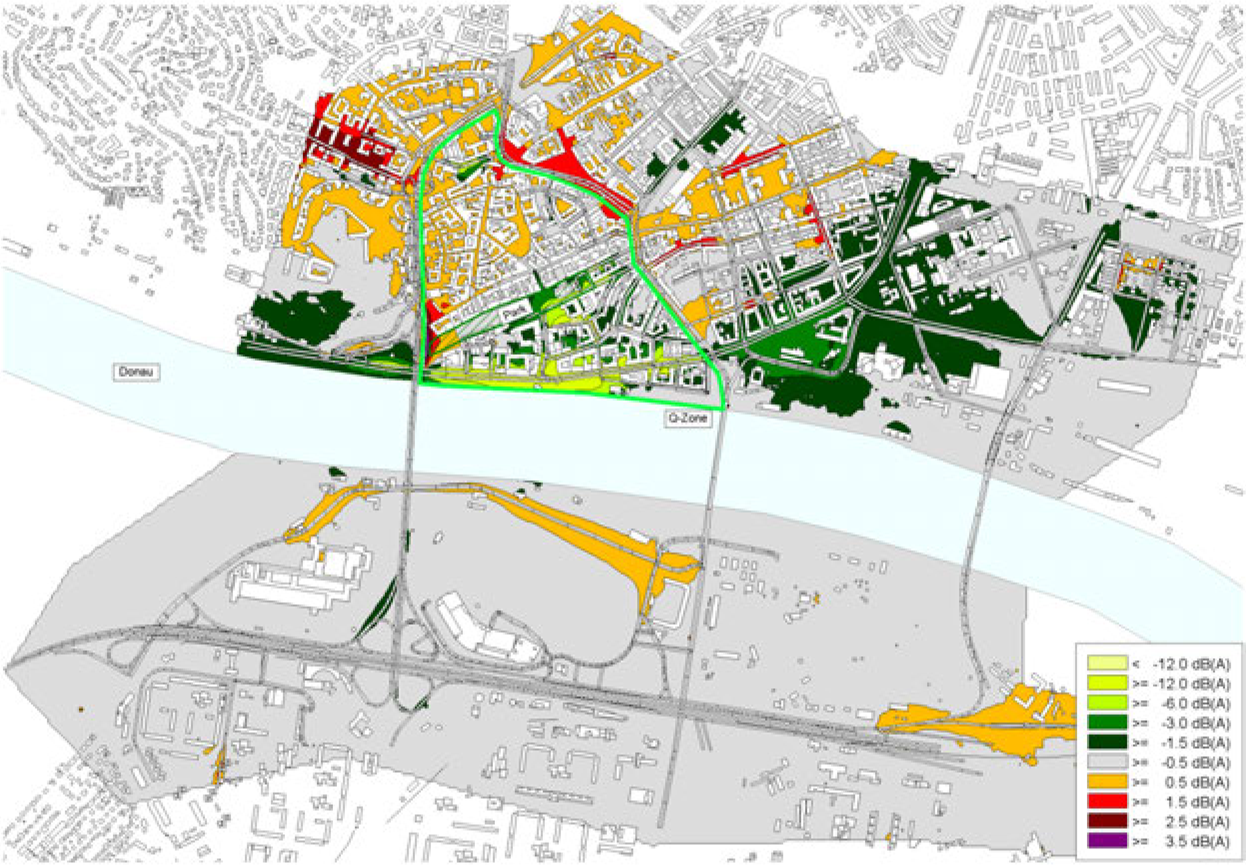

Figure 3.23 Noise difference (Lden) in scenario 7 (S22) on the test site in Bratislava. Here a 2 Euro fee is imposed to exit and enter the Q-Zone with a standard vehicle. The boundary of the small Q-Zone is also shown.

The average effects are almost the same as for the ban scenario.

3.4.5 Enlarging the QZ

Traffic effects

An enlargement of the QZ is shown in figure3.24. Enlarging the zone will obviously decrease traffic volumes in a larger area. But the traffic volume in the extended area is not very large, and therefore the reduction of traffic volumes in the large QZ is about the same as in the smaller QZ. As more drivers now will change route, and as less capacity is available, congestion effects will increase. The total travel time increase is now 8500 hours per day, and the increased travel distance is 140000 vehicle km.

Figure 3.24 shows the effect of enlarging the zone (again with respect to the base case).

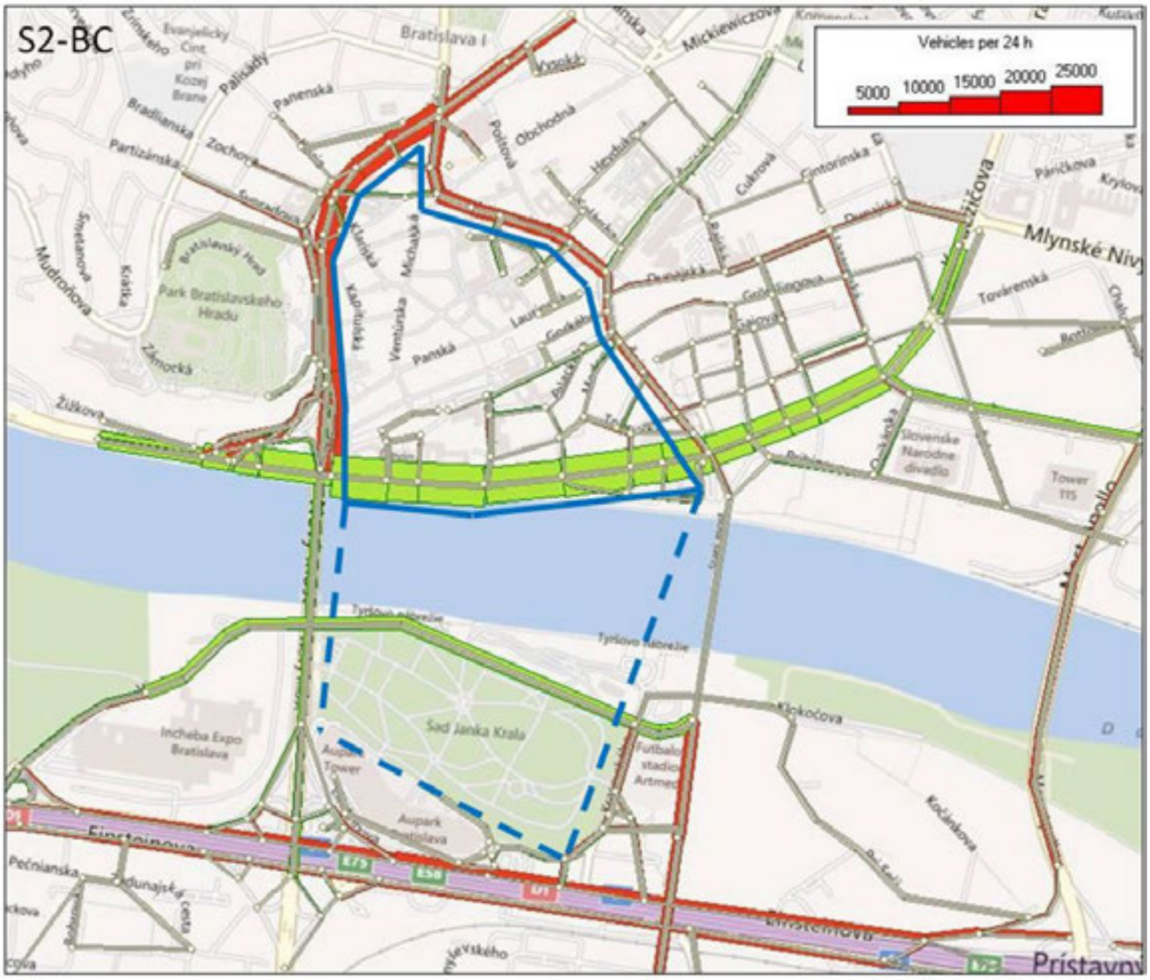

Figure 3.24 Traffic volume difference between scenario 2 and the base case

Noise effects

In figure 3.25 the noise distribution in case of a ban of non resident standard vehicles within the defined large Q-zone (scenario 2) is shown. Compared to the base case (figure 3.26) a reduction of noise within the extended Q-zone can be recognized.

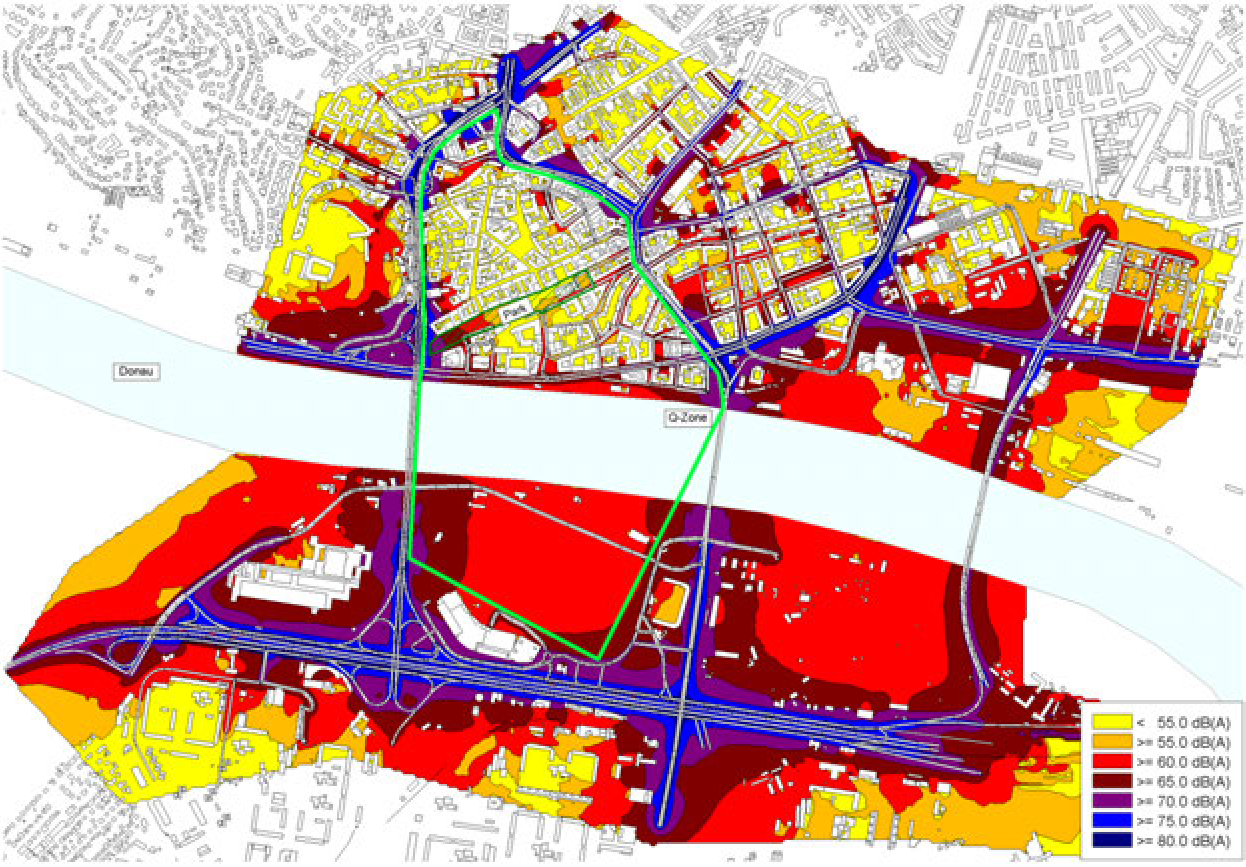

Figure 3.25 Noise situation (Lden) in scenario 2 (S17) on the test site in Bratislava. The boundary of the large Q-Zone is also shown.

The difference map shown in figure 3.26 reveals the noise reduction that can be expected by introducing the enlarged Q-Zone. Moderate noise improvements can be identified inside the Q-Zone particularly on the southern side of the river Danube. Noise reductions can also be seen outside the Q-Zone to the west. Likewise to the scenarios discussed above, we find a range of areas where the noise levels increase. This is seen as a result of traffic being redistributed from the Q-Zone area to outside areas.

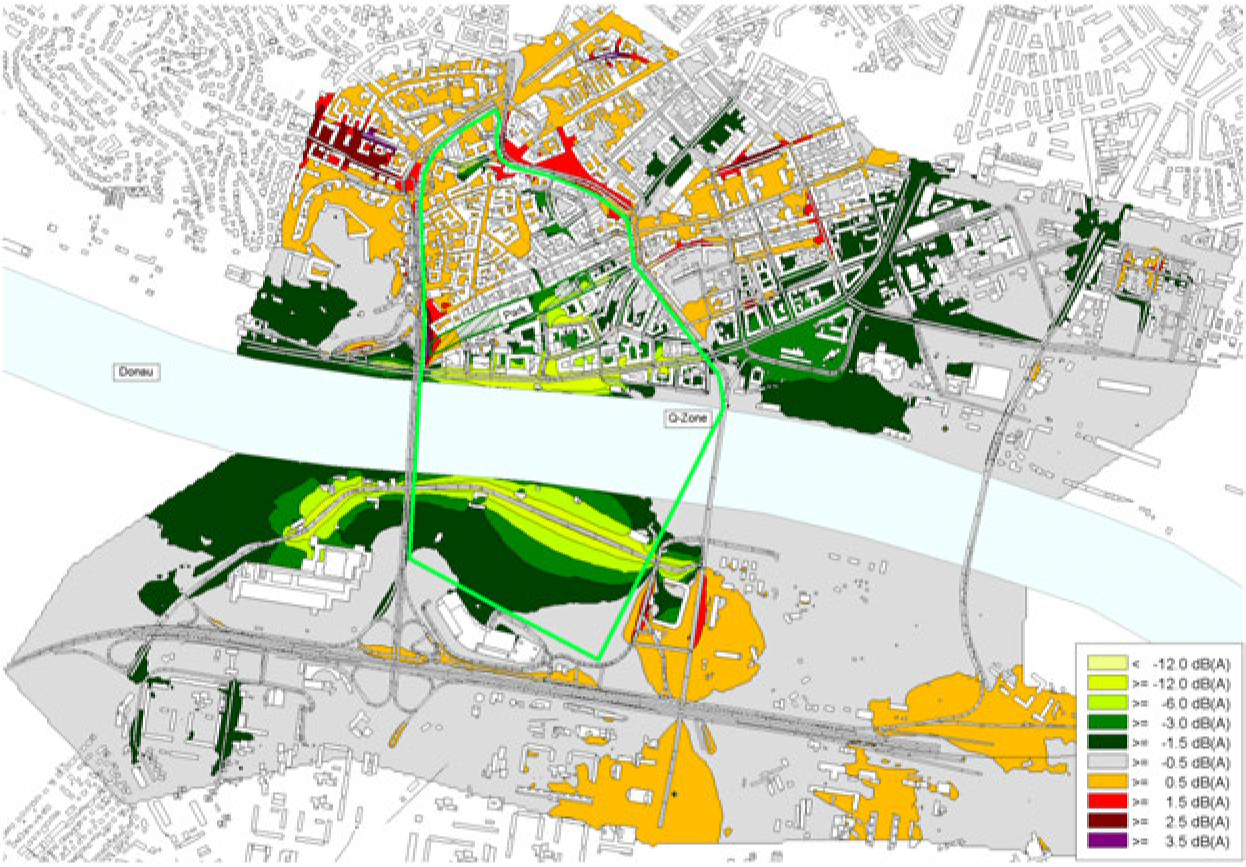

Figure 3.26 Noise difference (Lden) in scenario 2 (S17) compared to the base case on the test site in Bratislava. The boundary of the large Q-Zone is also shown.

The average reduction of noise is now 1.7 dB(A) for the Q-Zone, which is a larger reduction than that of the small zone observed above. The initial level of the large Q-Zone is higher than that of the small Q-Zone (62.9 dB(A) vs. 59.7 dB(A), cf. Table 3.2).

3.4.6 Increasing the low noise vehicle ownership

Traffic effects

Establishing a QZ basically gives two types of noise reductions in the zone – a traffic volume reduction and a vehicle related reduction (the LNV effect). Over time, higher levels of low noise vehicle ownership can be expected. A generally increased LNV ownership will "restore" the volume decrease effect. Depending on the policy for QZ residents, low noise vehicle ownership may increase earlier for QZ residents than for other residents. Incentives may be that resident exemptions are ended after some time, or that subsidies of some kind (like free parking for LNV) are introduced. Increased levels of low noise vehicle ownership will affect the QZ concept in different ways. A LNV ownership increase inside the QZ will increase the share of LNV vehicles generated internally. A LNV ownership increase outside the QZ will increase the number of vehicles that will enter the QZ as they are not longer prohibited or charged a fee.

Noise effects

We investigated different LNVO ratios in relation to the residential population inside and outside of the Q-Zone according to table 3.1 in chapter 3.5.1.

The forecasts of the effects that different proportions of low noise vehicle ownership have on the noise levels across the test site are shown figures 3.27 and 3.28.

Figure 3.27 shows the effects of an increased LNVO without any other restrictions applied to the Q-Zone. The map shows the noise reduction across the test site for the scenario with an assumed LNV ownership of 20 % inside and 20% outside the Q-Zone. On average we can observe reductions in noise level of 0.8 dB inside and outside the Q-Zone.

Figure 3.27 Noise difference (Lden) between scenario 12 (20 % LNVO inside and 20% outside) and the base case (S16 - S27)

A much higher improvement can be expected by implementing a Q-zone with strong restrictions (ban for standard vehicles) and the assumption of a 100 % LNV-ownership inside and 20 % outside the defined (large) Q-zone. The resulting difference levels ca be seen in figure 3.28:

Figure 3.28 Noise difference (Lden) in scenario 13 (S28) compared to the base case on the test site in Bratislava. The boundary of the large Q-Zone is also shown.

In this case, the average reduction of the noise level inside the Q-Zone is 2.8 dB and 1 dB outside it. The redistribution effects are smaller and also masked by the LNVO increase.

3.4.7 Simulation summary

In table 3.2 the results of all simulations compared to the base case are listed. This includes traffic effects as well as noise effects. For traffic, the percent reductions of the total distance driven by standard vehicles within the Q-Zone are shown, as well as the changes in total travel time and the total distance driven for the whole network of Bratislava. For noise, the average noise levels within zone and the average noise levels in the surrounding test site area are shown at first. The final columns contain the cumulated sizes of those areas in the Q-Zone that show noise levels of more than 5 dB below the base case average noise level across the Q-Zone (absolute and relative numbers). Depending on the noise level distribution in the Q-Zone, the base case might already reveal parts of the Q-Zone with noise levels more than 5 dB below the base case average (but for Bratislava this was not the case). A complete set of noise maps and noise difference maps are available in Appendix 1.

Table 3.2 Bratislava simulation summary

Scenario	Percentage of standard vehicles in QZ of base case traffic	Percentage of low noise vehicles in QZ of base case traffic	Total travel time change (hours/day)	Total distance change (vehicle km/day)	Average noise level Lden in QZ[2) (arithmetic) [dB(A)]	Average noise level Lden in remaining test area[1) (arithmetic) [dB(A)]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [m²]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [%]
1	99%	1 %	-	-	62.9 L 59.7 S	63.4 L 63.6 S	(1025400) L (488300) S	-
2	17%	3%	8498	139319	61.2	63.4	111100	10.8
3	19%	3%	3091	29521	61.2	63.3	110000	10.7
4	19%	3%	3244	37067	61.2	63.3	110400	10.8
5	17%	3%	7994	124797	58.5	63.7	56500	11.6
6	19%	3%	2832	25571	58.6	63.6	55600	11.4
7	19%	3%	2710	26835	58.6	63.6	56300	11.5
8	95%	5%	0	0	*)62.7	63.2	0	0.0
9	15%	16%	7202	130165	61.0	63.2	120900	11.8
10	16%	17%	2546	27489	61.0	63.1	117300	11.4
11	16%	17%	2425	30316	61.0	63.1	116500	11.4
12	80%	20%	0	0	*)62.1	62.6	0	0.0
13	7%	57%	3666	81983	60.1	62.4	170700	16.6
14	8%	57%	1301	19171	60.2	62.4	152600	14.9
15	8%	57%	1413	24093	60.2	62.4	152900	14.9

1) Test-site without Q-Zone 2) Q-Zone without park area

*) Reference for these values (S8 and S12) is the large (L) Q-Zone. Some reference needed to be defined in this case, as both scenarios do not stipulate a Q-Zone.

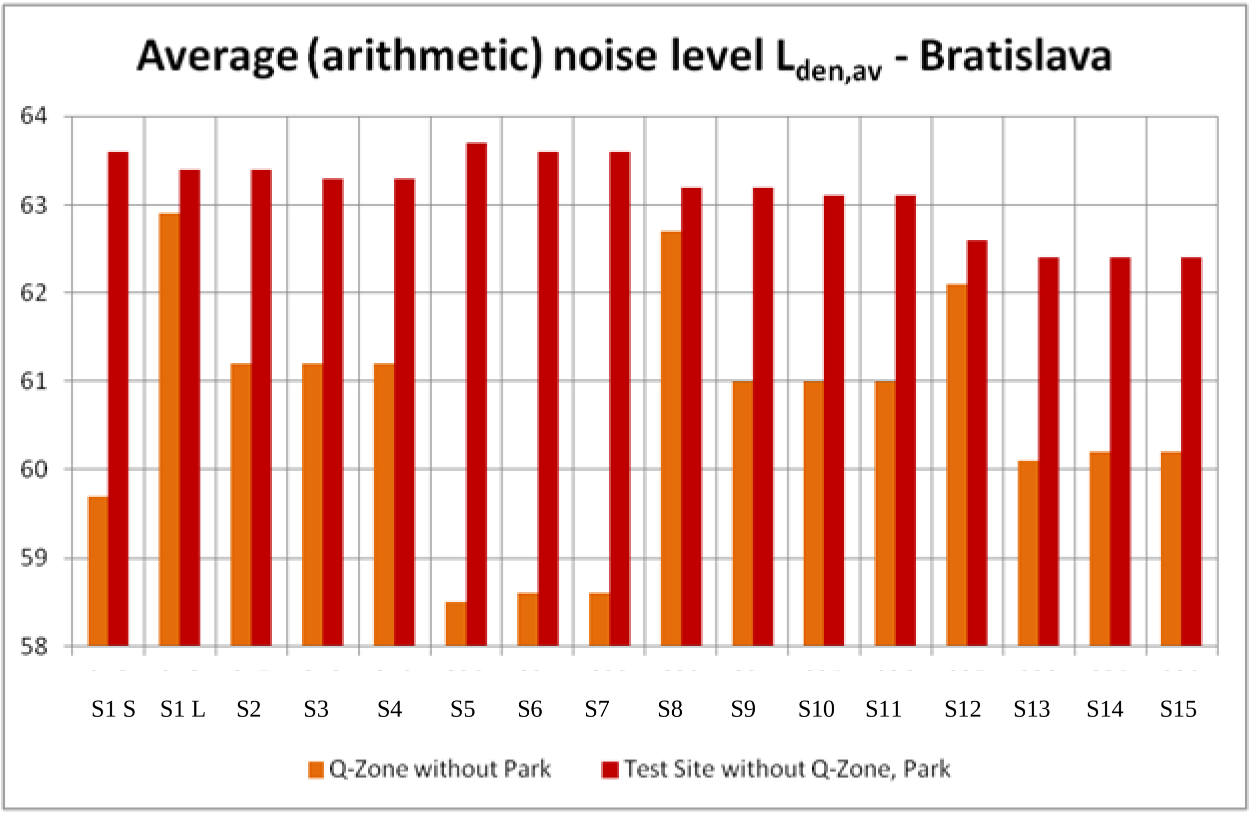

Figure 3.29 Average (arithmetic) noise level Lden, av for the various scenarios on the test site in Bratislava

Discussion

Introducing a Q-Zone in Bratislava as described above will have a large impact on traffic in the whole area. Traffic volumes within the Q-Zone will decrease, but at the price of increased congestion in the rest of the network. This is because of the initial high level of congestion, reflected in the average travel times being more than twice as long as free flow travel times. The higher the level of congestion, the more severe the effect of reducing network capacity will be (which is what the Q-Zone introduction implies).

Introducing a Q-Zone in Bratislava causes only small noise reductions in the zone, and increased noise levels outside the zone. It is only in the scenario where the LNV ownership inside the zone is 100 percent that there is a noticeable noise reduction (of 2.8 dB). In the case of the small Q-Zone, the noise gain is also accompanied by increased noise levels outside the Q-Zone. The small amount of noise reduction also comes at a high price in terms of increased travel times.

Overall, introducing a Q-Zone as described above gives a very limited noise effects, coming at a high price in terms of increased travel times and in some cases increased noise levels outside the Q-Zone. There is a number of reasons for this result:

- High initial level of congestion. This makes the price in terms of travel time increases high.
- High level of ambient noise. Major roads close to the Q-Zone area contribute to a high level of ambient noise. This limits the potential of noise reduction considerably.
- Only private cars were assumed to be equipped with low noise drivelines

4 BRISTOL TEST SITE

4.1 GENERAL INFORMATION ON THE CITY OF BRISTOL

Bristol is the largest city in South West England. The city covers a total area of 332 square kilometres, and has a population of about 421,000. The population density is 1,268 persons/km². Figure 4.1 shows Bristol and the surrounding area.

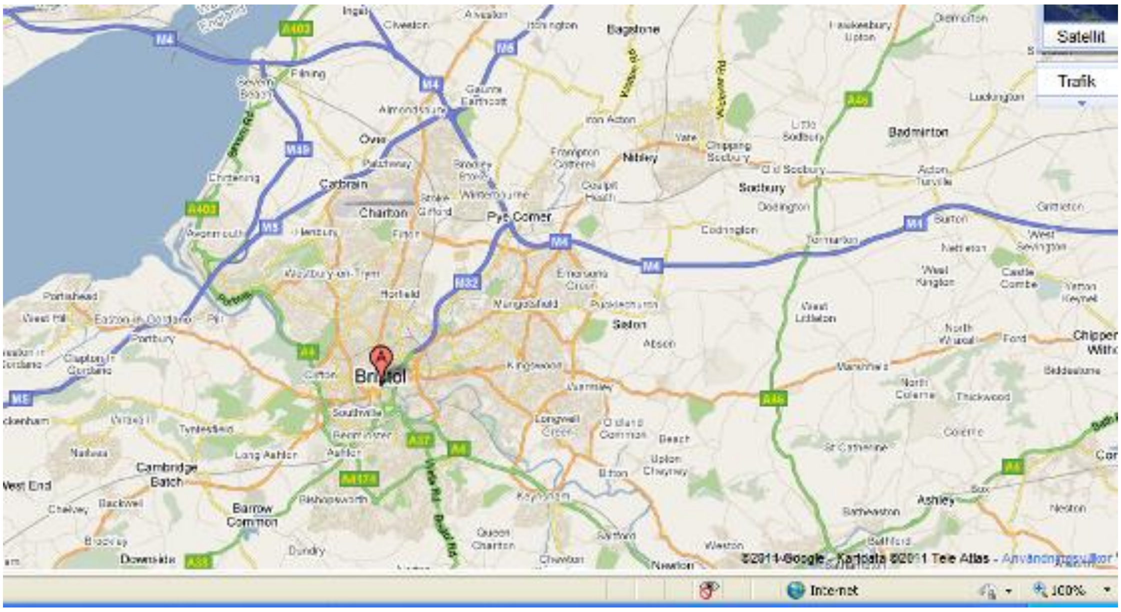

Figure 4.1

Bristol and surrounding area

The city is located close to the mouth of the river Severn. The river Avon runs through the central part of Bristol as is shown in Figure 4.2. On this figure, larger parks can be seen situated on the northern side of the river, as well as a smaller park in the Old City area.

Figure 4.2

Central Bristol

4.2 TEST SITE SELECTION

4.2.1 Noise conditions

For Bristol, noise mapping was undertaken for the whole Bristol area in 2006 and 2007. The noise conditions for the agglomeration of Bristol are presented on the resulting noise map (Figure 4.3). Traffic from the M32 motorway results in high noise levels within the central parts of the city. Figure 4.4 shows the central parts of the city.

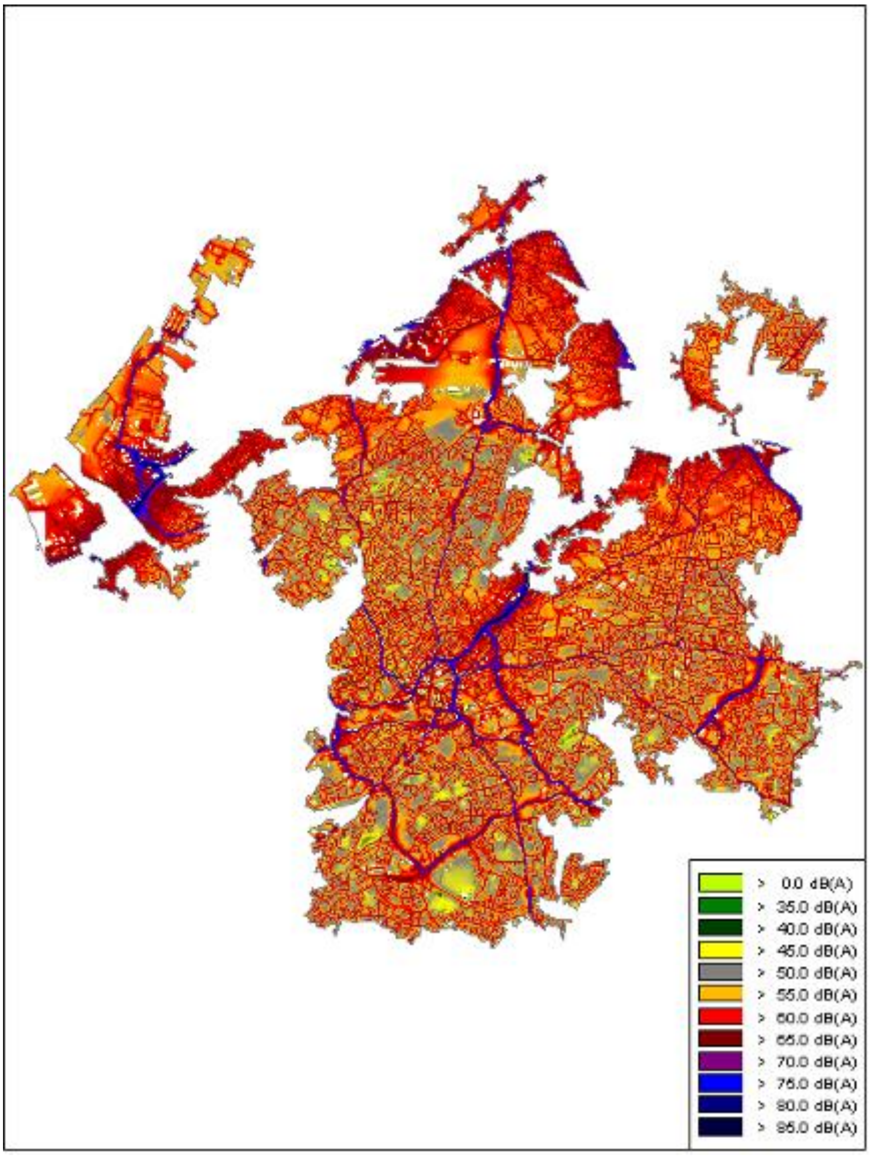

Figure 4.3

Noise map for Bristol agglomeration showing L_{den} (from Noise Mapping England Project)

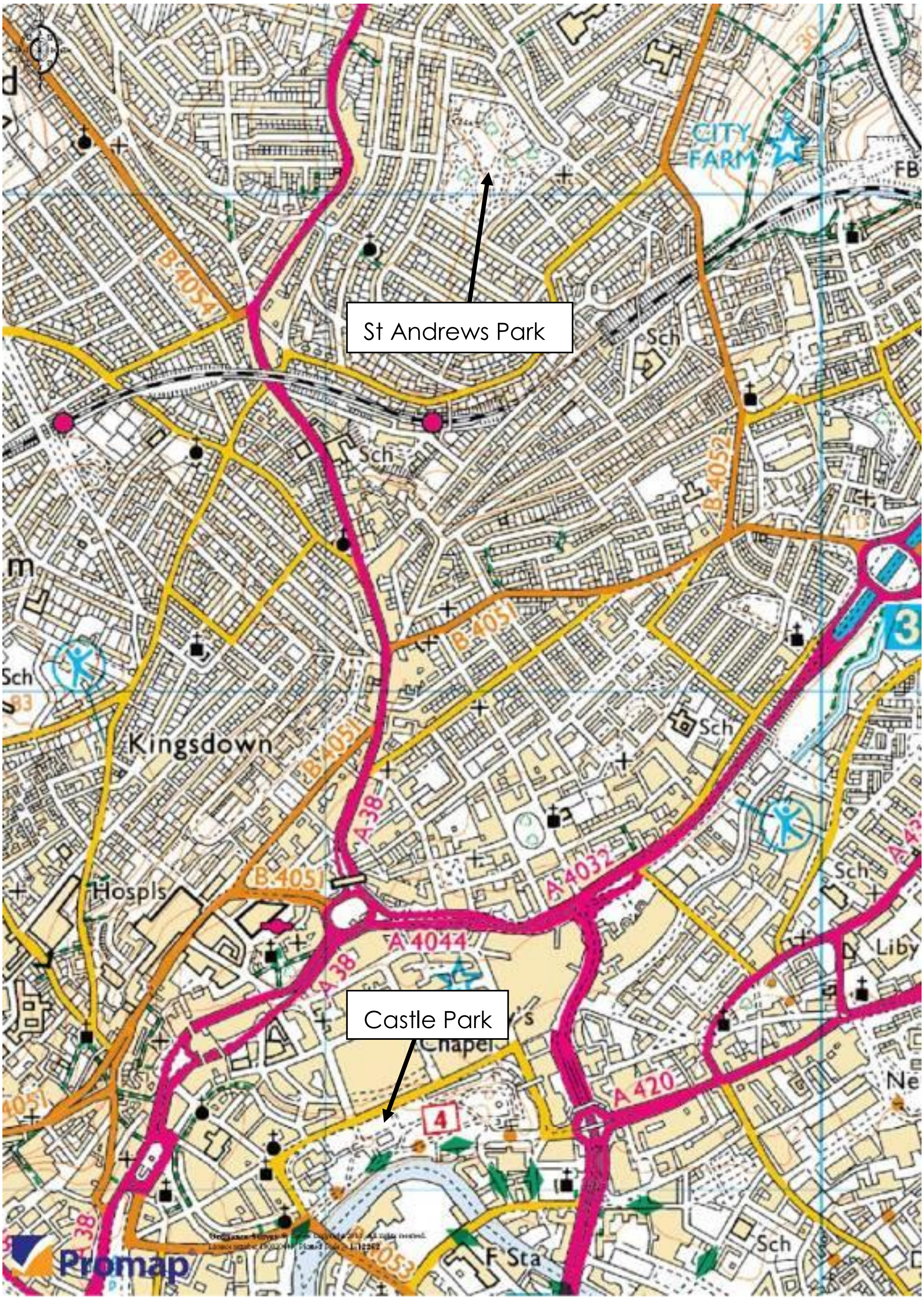

Figure 4.4 Noise map showing central area of Bristol and embedded parks

4.2.2 Potential for Q-zones

The City of Bristol is very hilly, when moving away from the river valley. This means that the landscape often provides natural noise barriers. With respect to park areas, it is mainly those in the central parts that are subject to noise disturbance. The two main park candidates for a Q-zone area that emerge following a site visit are St Andrews Park in the Montpelier area and Castle Park in the Broadmead area. The Redcliff area facing Castle Park on the opposite side of the river is partly a residential area and partly an industrial area. Creating a Q-zone in this area would enable the area to be developed into an attractive residential neighbourhood.

4.2.3 Selected Q-zone area

Castle Park:

After discussions with local representatives of the City Council and a site visit, transforming the area around Castle Park (and the opposite side of the river) to a Q-zone appeared to provide an interesting opportunity for a Q-zone application in Bristol. This is particularly the case as the area on the opposite side of the river to Castle Park is due to be redeveloped into residential flats/apartments, having previously been used as a commercial/industrial site. This area also includes a park-like avenue, bordering the pedestrian area of the old town. The arterial route going along the riverbank presents a major challenge, and different ways and options of handling this will be analyzed. The park usage is likely to consist mainly of shoppers and local workers from nearby businesses/shops. The intended Q-zone is likely to fall within the area indicated by the blue circle in Figure 4.5.

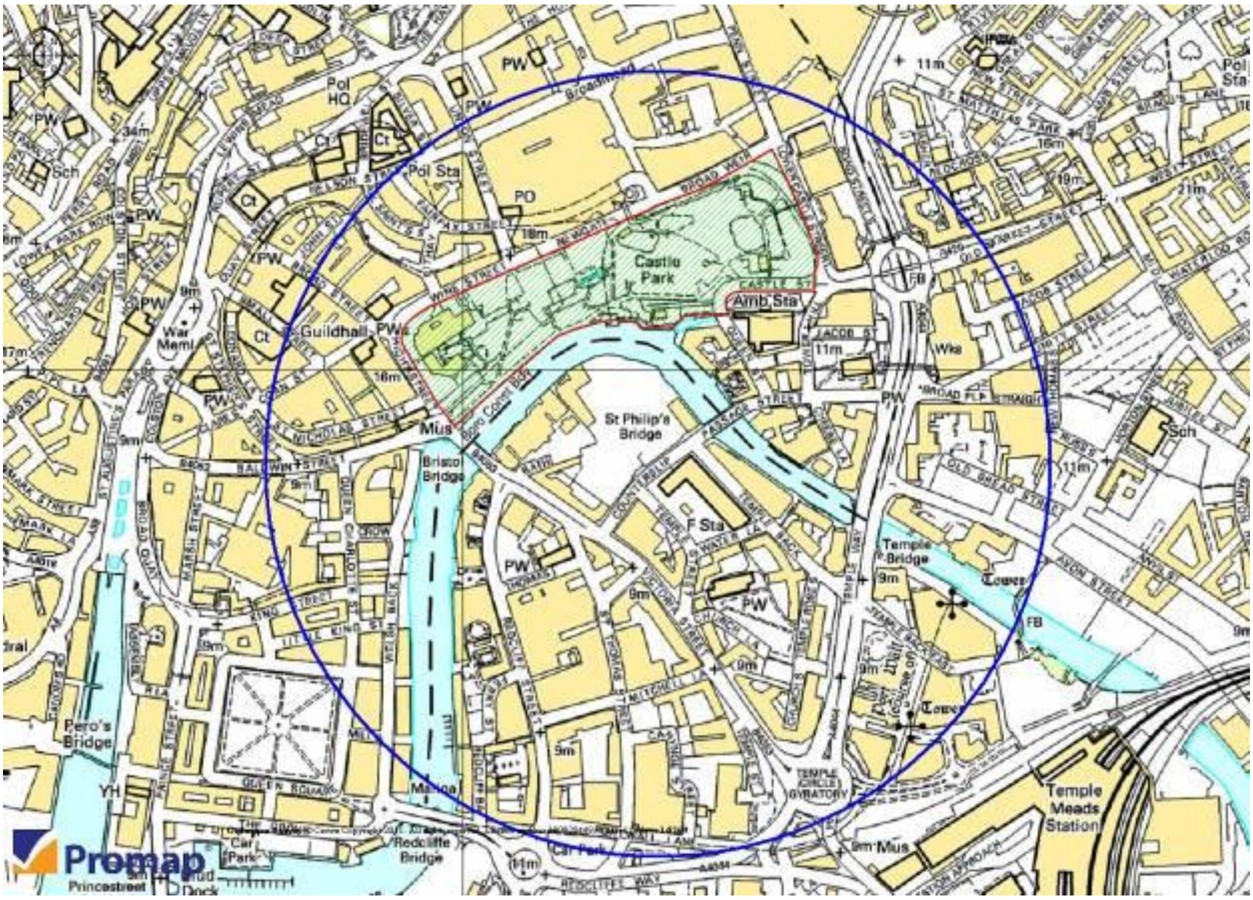

Figure 4.5 Map indicating Castle Park, Bristol (Q-Zone to be defined within circled area)

<u>St Andrews Park</u>:

Another potential site located north of Castle Park is St. Andrews Park, which has different characteristics in comparison to Castle Park as the area surrounding it is predominantly residential, also the park has a sloping orientation, which again could result in interesting challenges with respect to establishing a Q-Zone and embedded park. The usage of this park in comparison to Castle Park will also differ in that it appears to mainly target family usage. This area potentially lends itself better to the provision of a Q-Zone (with an embedded park) as the road layout surrounding the park has potential options for redirection of traffic onto nearby larger roads with greater traffic capacity. The intended Q-zone is likely to fall in the area indicated by the blue circle in Figure 4.6.

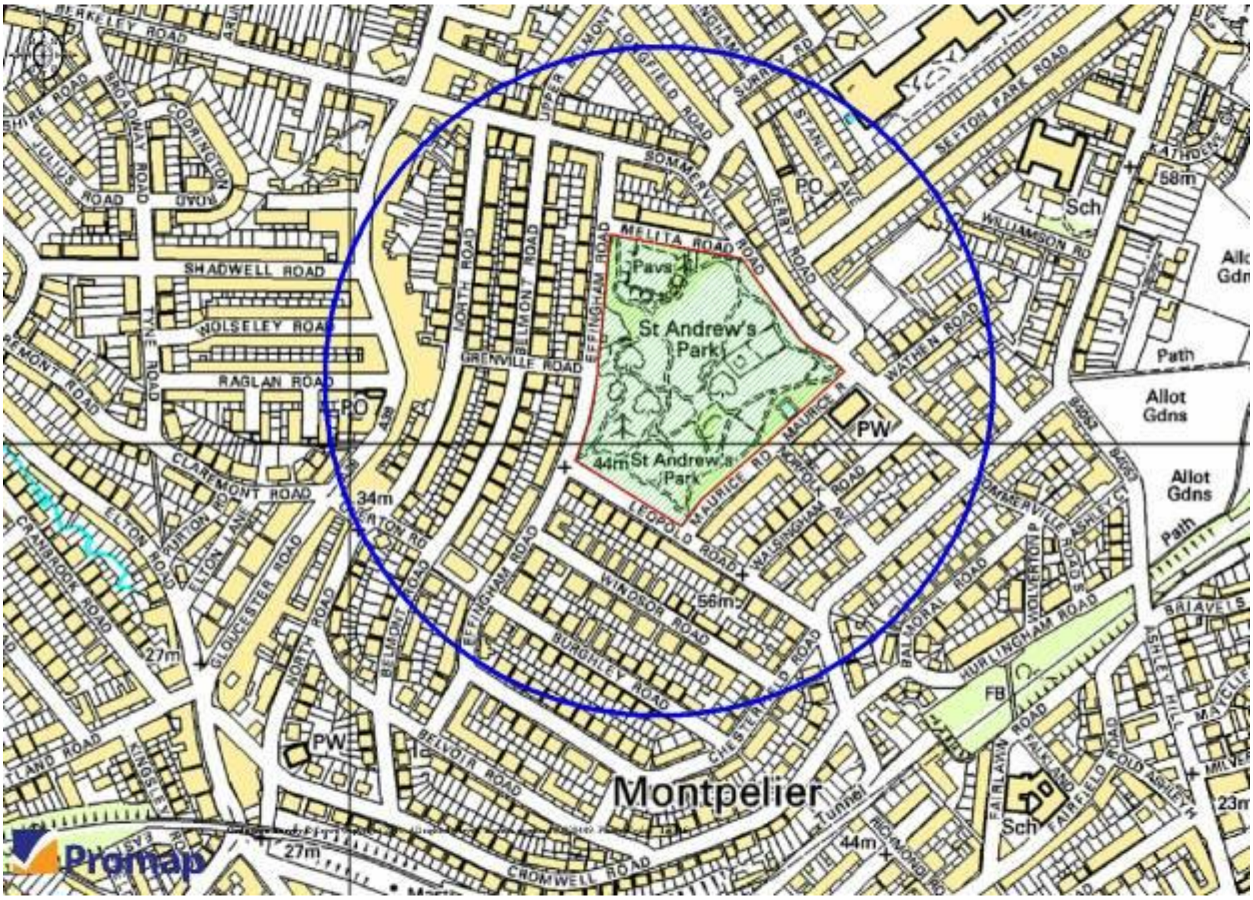

Figure 4.6 Map indicating St Andrews Park, Bristol (Q-Zone to be defined within circled area)

4.3 Available noise model

4.3.1 Digital terrain model

The terrain model is important for noise calculation and to determine the overall ground attenuation characteristics. Also the hillside situation and shielding from topographical features etc can be taken into account.

Figure 4.7 shows a visualization of the elevation model in which the area height is represented by colour.

The ground model dataset has been checked following the transfer from ArcView (shp) into CadnaA (cna).

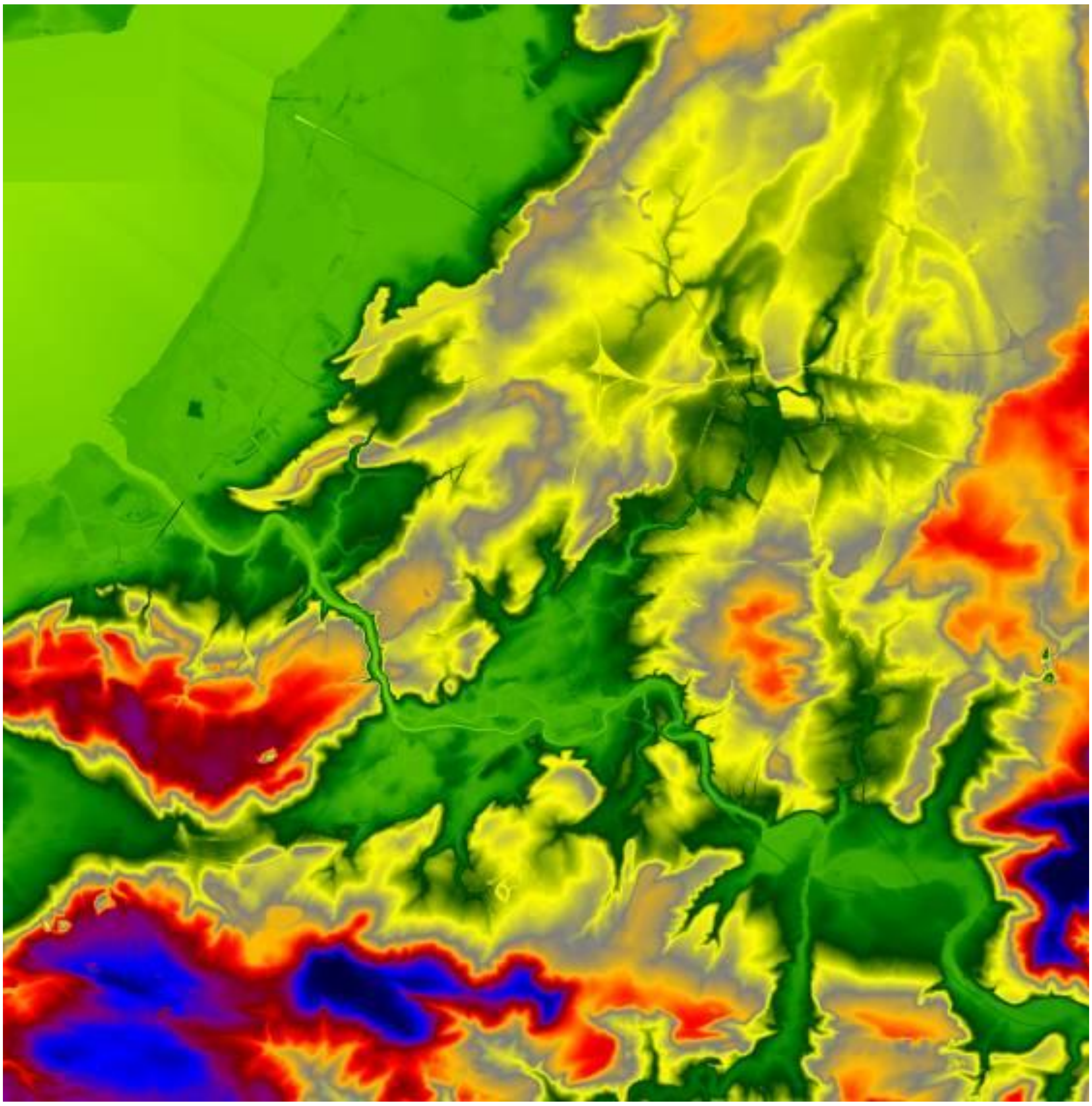

Figure 4.7 Topography for Bristol

4.3.2 Road and traffic information

The traffic model of Bristol considers all major roads, irrespectively of their traffic load. In the available model all roads with a traffic flow of greater than 185 vehicles / 18 h vehicles were considered. The following illustration shows the regarded road system for the whole of Bristol City:

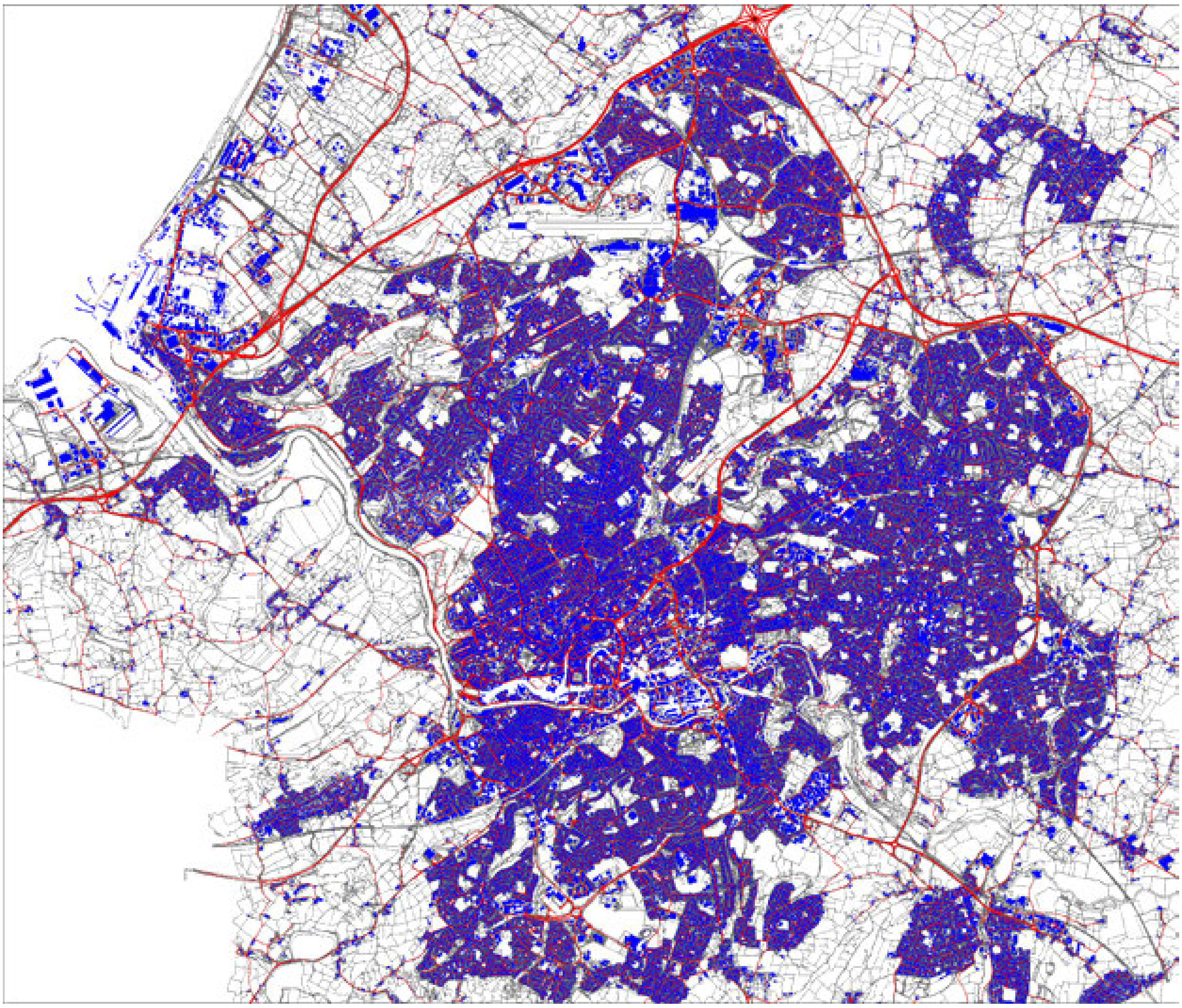

Figure 4.8

Roads, buildings and noise barriers of Bristol

In relation to the 'Noise Mapping England' project about 2775 km of roads were studied. The most important (most travelled) roads as part of the CITYHUSH project and in relation to the embedded parks and surrounding Q-Zones are as follows:

- A38 (which affects both parks)
- A4044
- Sommerville Road (along north-east boundary of St. Andrews Park)

The relevant traffic parameters were obtained from Bristol City Council.

Information provided by the Highways Agency on speed limits and road surface types were carried over into the model, where this data was not held by Bristol City Council

The road network dataset was checked for completeness following transfer from ArcView (shp) into CadnaA (cna). This ensured the correct transfer of all roads without any loss of data.

This check was carried out for motorway and non-motorway roads separately.

Besides the quantity checking, several components e.g. number of vehicles , traffic speed, surface type and curb to curb distance were also reviewed to ensure that they are within sensible limits and had transferred correctly into CadnaA.

All calculation settings were double checked to ensure a maximum of correctness to the interim noise model results which are then transposed to L_{DEN} etc.

4.3.3 Rail and tram information

Bristol does not have a tram system, however one of Bristol's main railway stations is located near to the edge of the potential Q-Zone surrounding Castle Park.

4.3.4 Noise barriers

The noise barrier data was imported into CadnaA, the noise barrier dataset was then checked for quantity to ensure the complete transfer of data. All barrier heights were reviewed to ensure they were within sensible limits and had imported correctly, i.e. checked for negative and extraordinarily high values.

4.3.5 Buildings and inhabitants

The City of Bristol has about 421,000 inhabitants. There are about 284,000 buildings in Bristol. The height and the usage (residential building, school, hospital, commercial use) for each of these buildings was known.

The building datasets were checked for completeness following the transfer of building data from ArcView (shp) into CadnaA (cna). This ensured that all buildings were transferred correctly without any loss of data.

Secondly, the height of the buildings was also checked. This means that the lowest and the highest value from the dbf file were compared with the lowest and highest value from the corresponding cna file. Having this information enables the production of 3D maps such as the one shown in Figure 4.9, it is also possible to overlay noise data, as shown by the coloured grid.

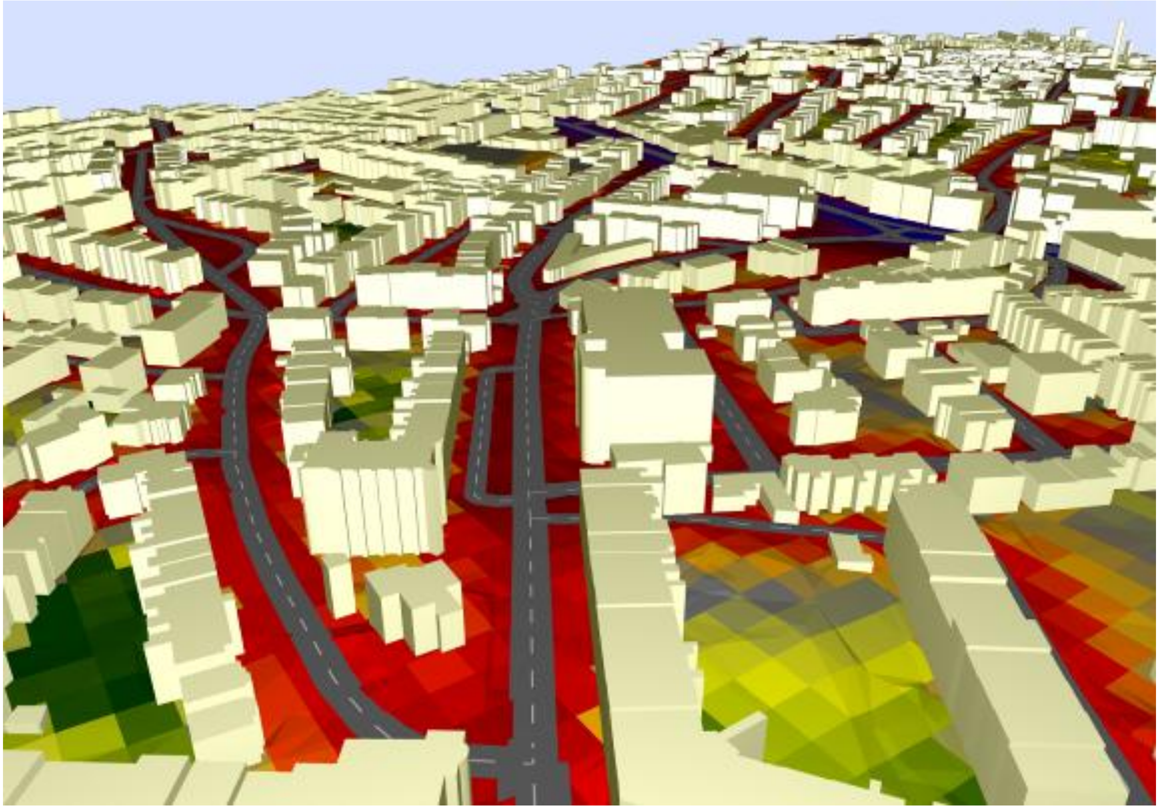

Figure 4.9 3D detailed map of Bristol, showing coloured noise grid

4.4 AVAILABLE TRAFFIC MODEL

4.4.1 Network model

Different traffic models exist for Bristol. For the CityHush project, data from a Saturn software application was made available. The application was used in context with previous noise mapping, and comprises the city of Bristol. The Saturn application concerns car and HGV traffic. The network contains 263 zones, 1580 nodes and 3,400 links. Public transport was not included in the Saturn application.

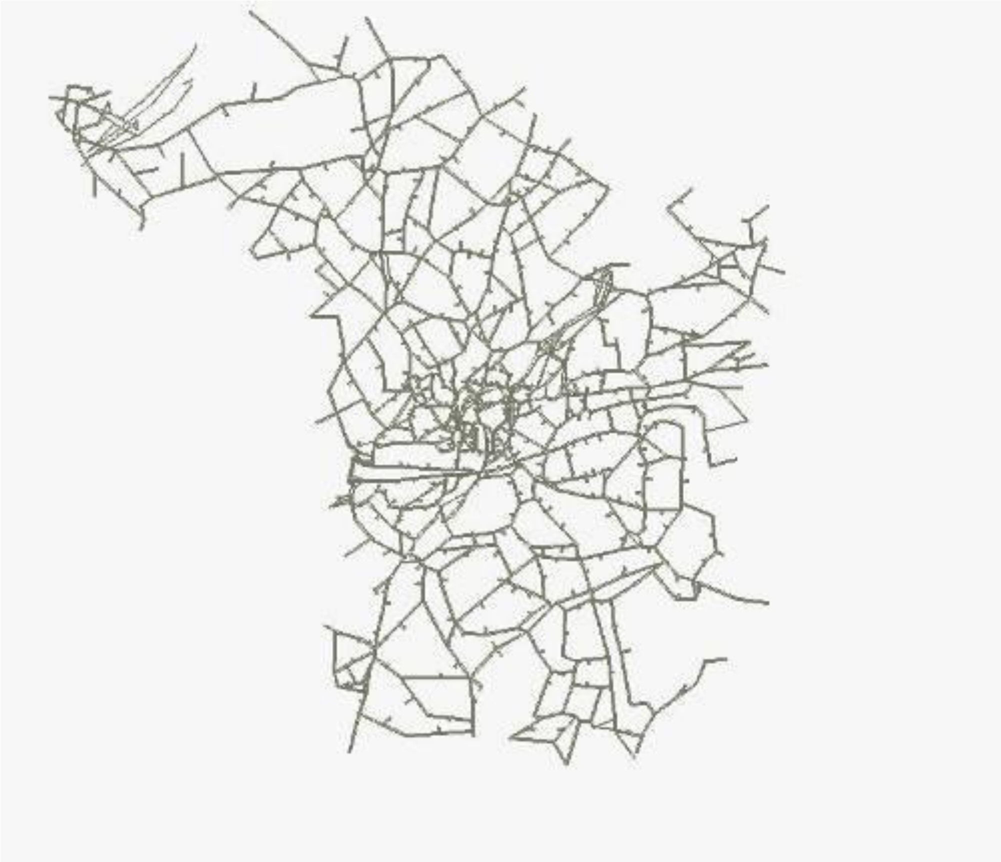

Figure 4.10
Emme network for Bristol

Figure 4.11 shows the network of the central parts of Bristol. All streets except very minor roads are contained in the network. The intended Q-zone area is marked with blue.

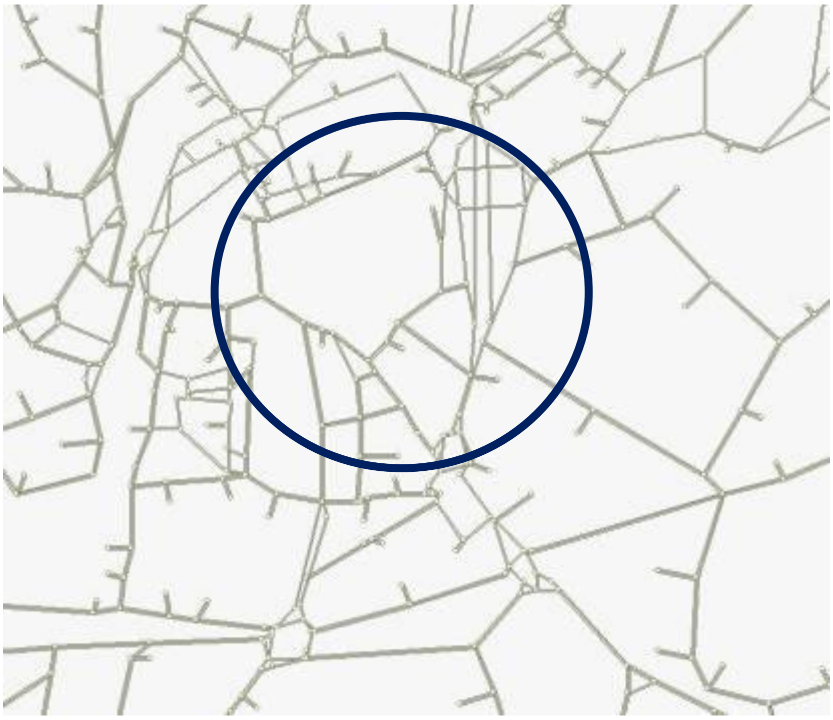

Figure 4.11
Emme network for central Bristol (circle indicates approximate position of Q-Zone)

4.4.2 Demand models

In the Saturn application, traffic assignment is done for the AM peak hour. Congestion is treated by using link specific volume-delay functions for all regular links (i.e. not connectors).

Travel demand includes separate matrices for private cars and trucks. The Saturn application does not include mode or destination choice effects.

4.4.3 CityHush adaptation

Due to the fact, that new developments within the test-site “Castle Park” will take place and residential buildings are under construction, an average density of inhabitants was used to determine the number of people affected within the test-site. Therefore a fictive number of HAP could be determined for each investigated scenario and compared to each other.

The network and the OD matrix have been exported from the traffic model to the Emme3 system. There is no need to enhance either the network nor the zoning system. The model transfer was validated using counts that were available from the Saturn database. Details regarding the validation are found in Appendix A1.

As the simulation scenarios will imply fees on specific links, a conversion from monetary units to time units is necessary to reflect the impedance on such links. This conversion is included in the database for private cars and trucks separately. For private cars, a further distribution of the demand into user classes with different values of time (reflecting different willingness to pay noise charges) was done along the principles discussed in Chapter 2.1.2. Trucks were as a class having the highest value of time. The distribution of private cars on values of time is shown in Figure 4.12

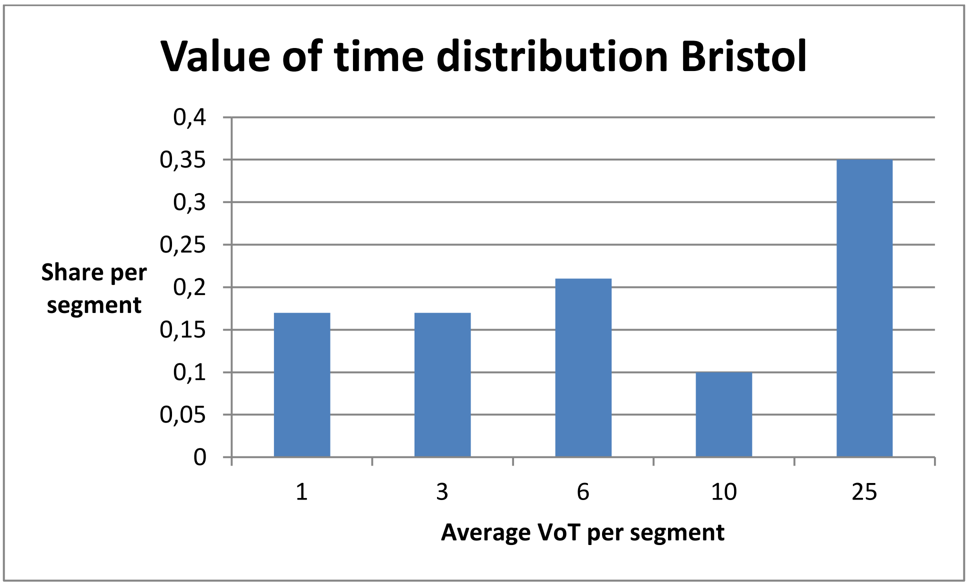

Figure 4.12 Distribution of values of time in Bristol for car trips (2003 prices)

The Saturn application concerned only the AM peak hour. In order to establish average day values for traffic flows, an off peak demand was generated by taking a share of the peak traffic. This share was calculated by using counts for a number of links that had been made available to the Cityhush project. Different shares were used for cars and trucks. The same value of time distribution was applied to both peak and off peak demand. The day values of traffic flows, speeds and shares of heavy traffic was calculated using grossing up factors obtained from the full day counts just mentioned.

4.5 TRAFFIC SIMULATIONS

The Saturn Bristol application only allowed for traffic simulations concerning private cars and trucks in our case. No effects with respect to changes of modes, destinations or travel frequency are therefore included. Traffic reductions within the Quiet Zone may therefore be somewhat underestimated, and redistribution effects somewhat overestimated.

4.5.1 Simulated scenarios

For Bristol, the following set of traffic scenarios was simulated:

Table 4.1 Simulated scenarios for Bristol

Scenario nr	Zone	Fee, Euros/passage	Inside LNVO percentage	External LNVO percentage
1	none	none	1	1
2	Q-Zone	ban	1	1
3	Q-Zone	0.5	1	1
4	Q-Zone	1	1	1
8	none	none	5	5
9	Q-Zone	ban	20	5
10	Q-Zone	0.5	20	5
11	Q-Zone	1	20	5
12	none	none	20	20
13	Q-Zone	ban	100	20
14	Q-Zone	0.5	100	20
15	Q-Zone	1	100	20

4.5.2 Q-Zone borders

The Q-Zone is defined as shown in Figure 4.13. The yellow line indicates the Q-Zone border. For Bristol, only one Q-Zone size was defined. An enlargement to the north was seen as infeasible, as there is a large shopping centre for which car accessibility is very important. An enlargement to the east would also be questionable as there is a large arterial in that area. An enlargement to the west would not add much as car traffic is already constrained in that area. Finally, an enlargement to the south would also not add much, as this area will already be heavily affected by the original borders (it may be regarded as being included, which will be shown later).

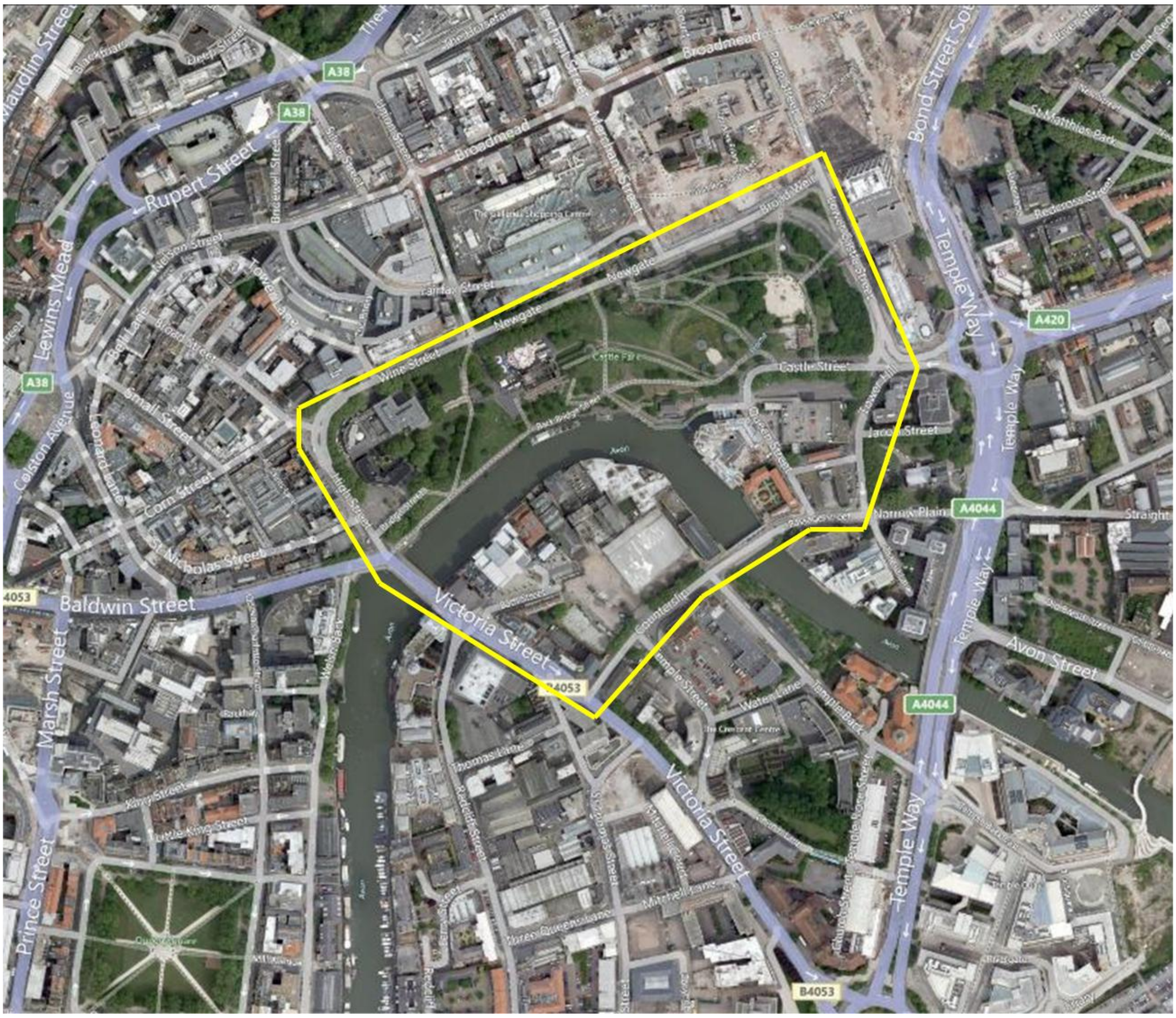

Figure 4.13 Bristol Quiet Zone border (yellow)

4.5.3 Establishing a Q-Zone - simulation results

We now present the simulation results of an introduction of the Q-Zone (defined in the previous section) by banning all non-resident standard vehicles. Figure 4.14 shows the base case (the bandwidths are proportional to traffic volumes) for the peak period:

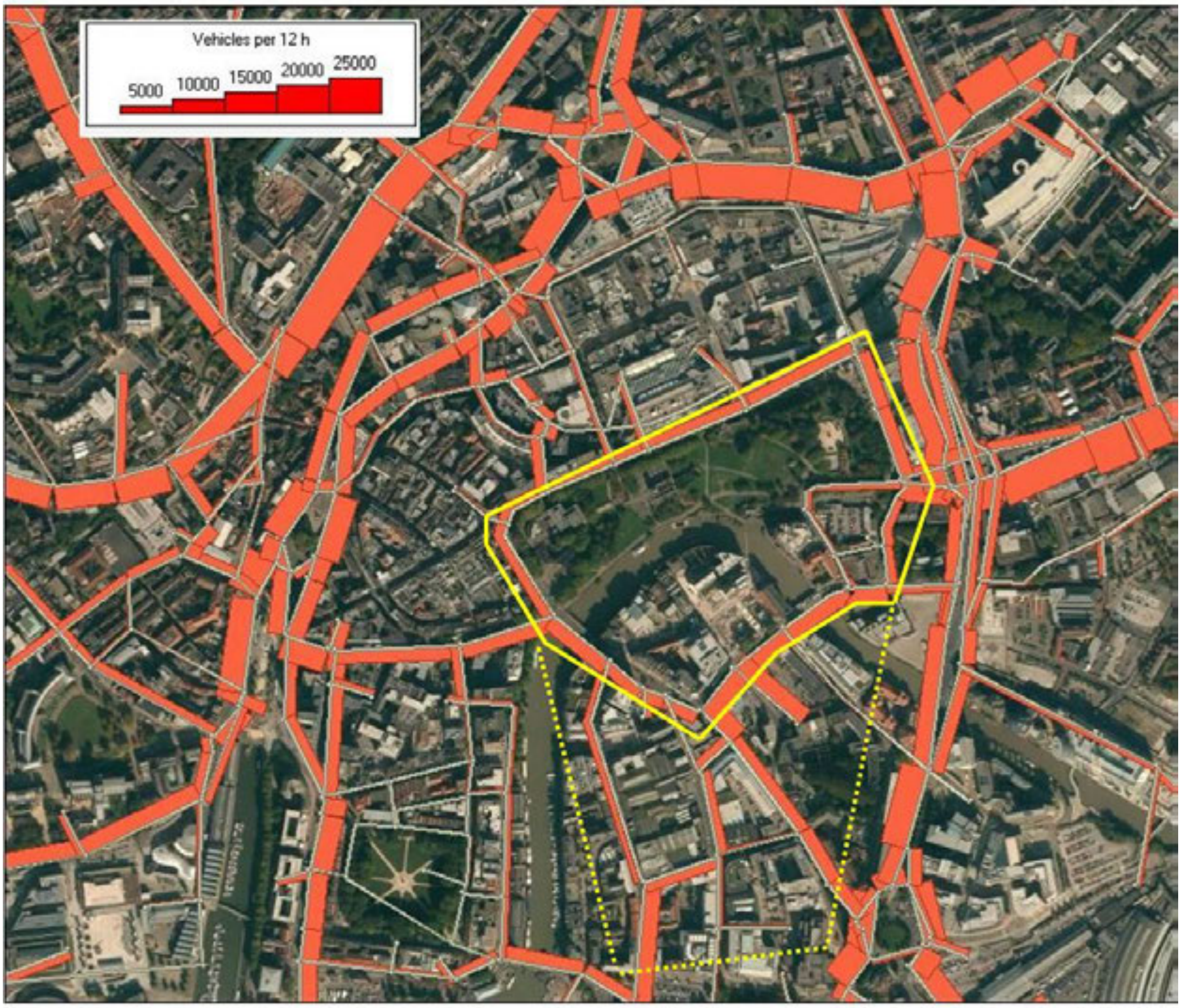

Figure 4.14 Base case traffic volumes

On the next figure, the difference to the base case is shown using the same scale for traffic flow difference as for traffic flows in the preceding figure. In figure 4.15 green bands indicate traffic reductions, and red bands indicate traffic increase. One can see that traffic is redistributed from the Q-Zone to roads outside the Q-Zone. One can also see that the area south of the Q-Zone also benefits from reduced traffic as if it was included in the Q-Zone. This is because streets inside the Q-Zone were previously used for through traffic, and the redistribution of this traffic affects also this area (shown with the dashed yellow line).

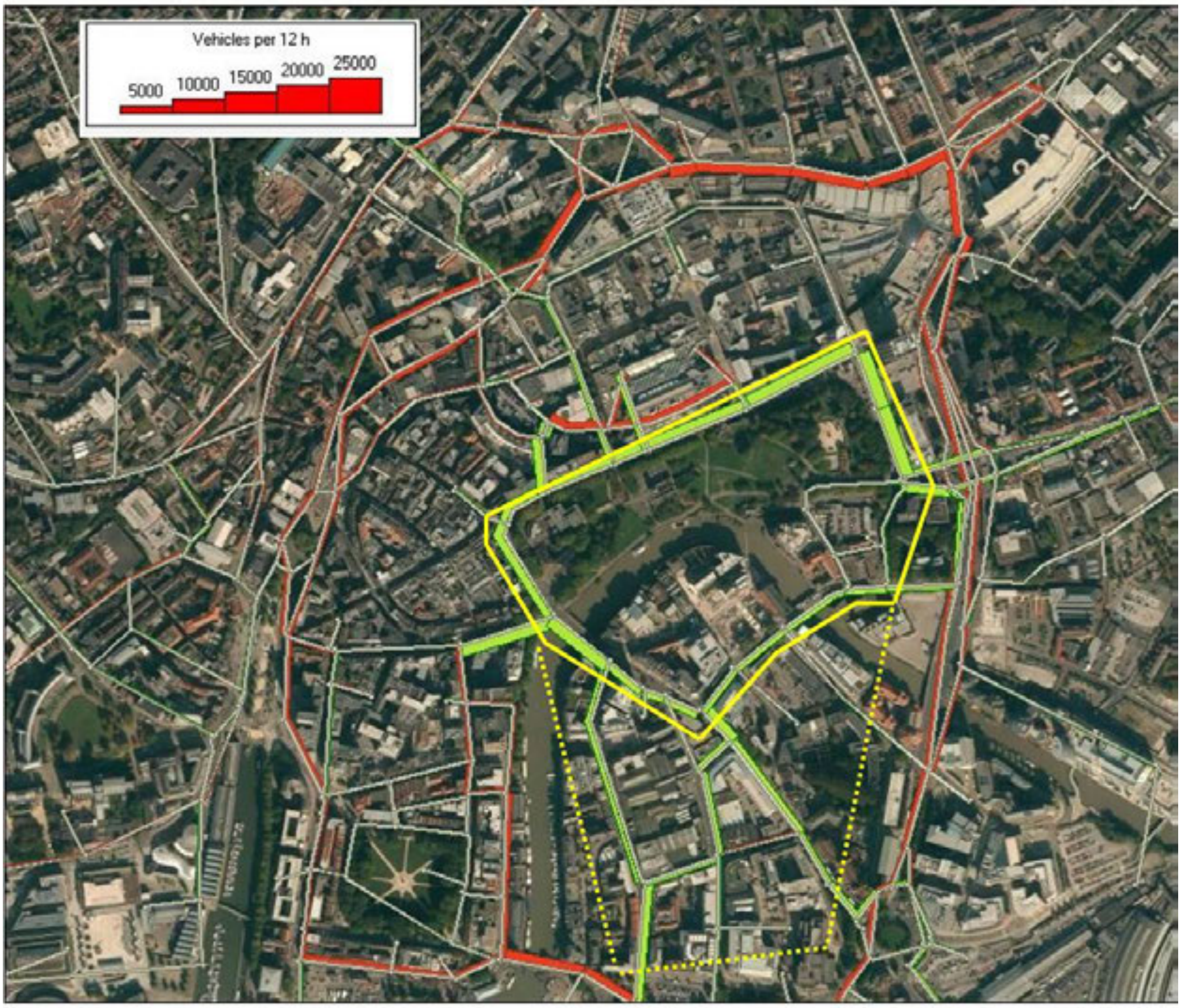

Figure 4.15 Difference between Q-Zone standard vehicle ban and base case,

Traffic effects

As for the Bratislava case, the redistributed traffic will cause additional congestion in the network outside the Q-Zone. The total travel time increases by 340 hours per day due to traffic redistribution caused by the Q-Zone introduction. This corresponds to 0.3 percent of the total travel time in the Bristol area, which is a much lower impact than was caused by the Q-Zone introduction in Bratislava. This is mainly due to two reasons – one is that the initial level of congestion is lower in Bristol, and the other one is that no major arterial is included in the Q-Zone.

4.5.4 Introducing noise fees

Traffic effects

Introducing noise fees instead of a ban makes it possible for car drivers to trade a travel time gain against a fee. In Bristol, this is done to the extent that the traffic reduction of standard vehicles in the zone will be 38 percent instead of 40 percent (of the base case traffic). The total travel time increase will be reduced to 80 percent of the increase in the ban case. This means that a small part of the drivers suffering large delays implied by the Q-Zone will prefer to pay the fee. Reducing the fee from one euro to half a Euro per entry/exit will not affect these figures.

The following difference map (figure 4.16) shows the effect by implementing a 1-Euro fee compared to the base case:

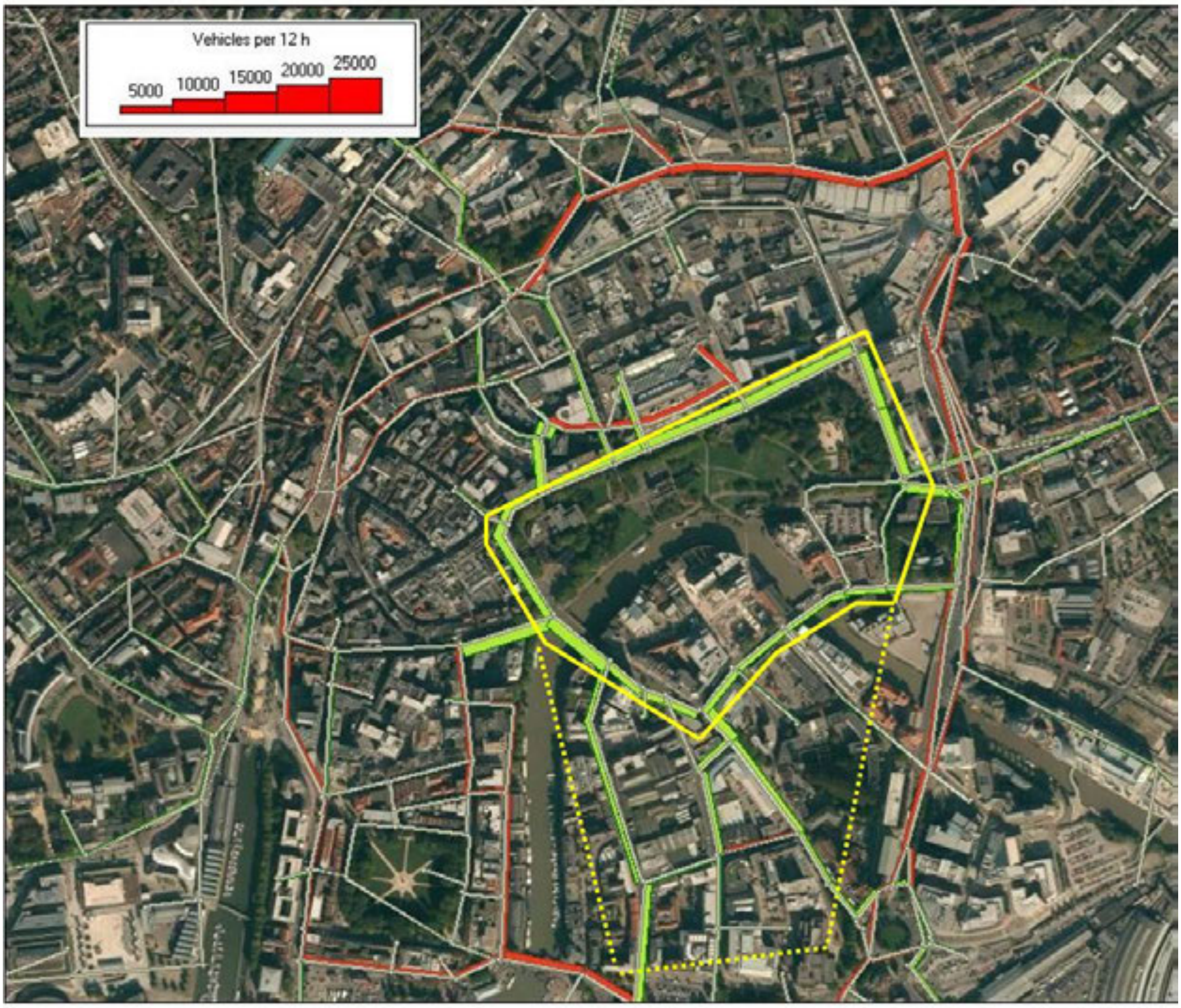

Figure 4.16 Traffic volume difference between scenario 4 and Base case

Noise Effects

The following figure shows the noise differences of scenario 2 (S2) with the base case. In scenario 2 we assumed a ban of non resident standard vehicles in the Q-Zone and an LNVO of 1% in- and outside the Q-Zone. We can see a reduction in noise levels in the Q-Zone but also a significant amount of areas with an increase in noise levels.

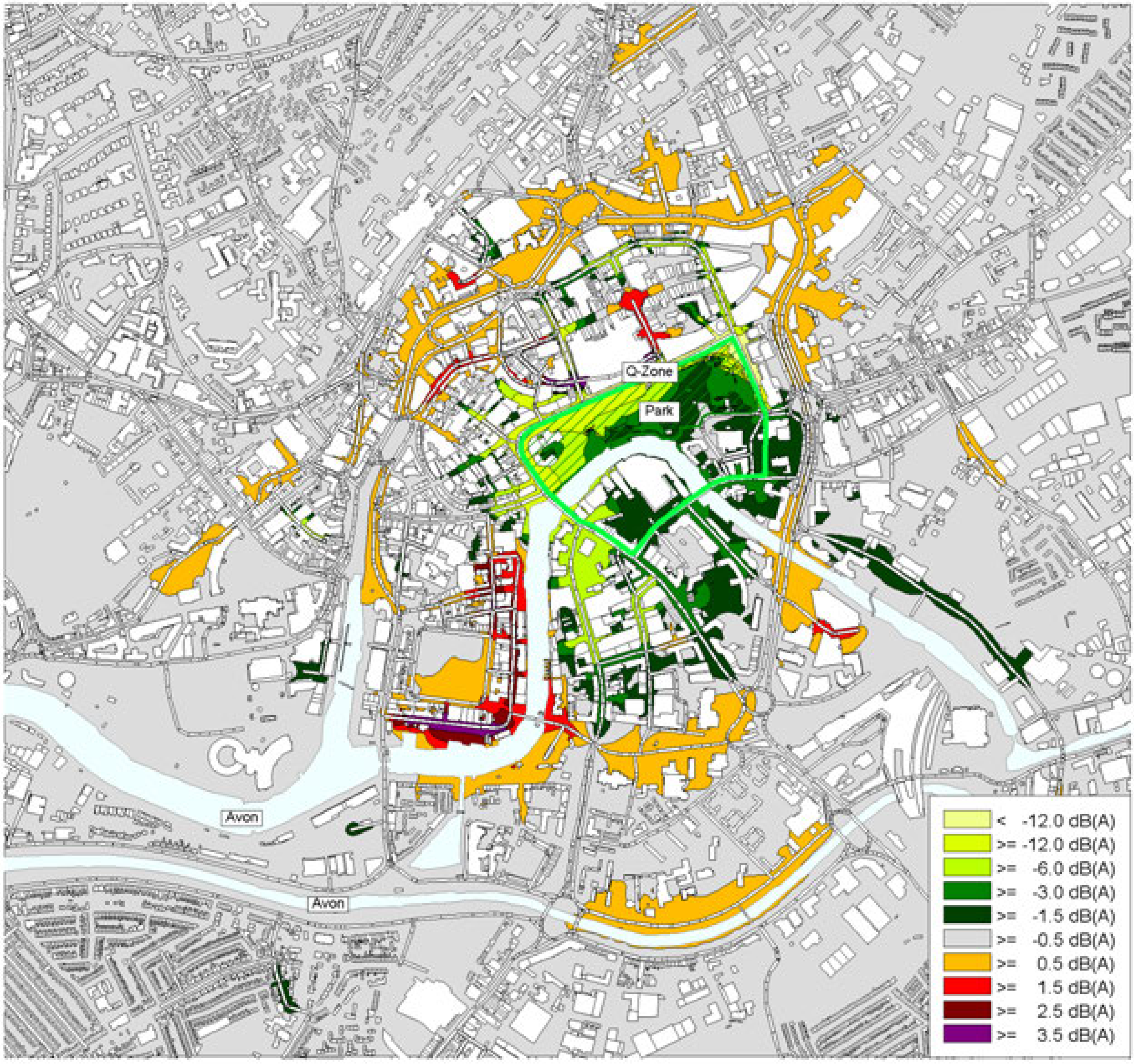

Figure 4.17 Noise difference (Lden) in scenario 2 (S2) compared to the base case on the test site in Bristol. The boundary of the Q-Zone is also shown.

4.5.5 Increasing the low noise vehicle ownership

Traffic effects

As LNV ownership levels increase, the number of standard vehicles will be reduced. In stead, the number of LNV vehicles will increase, so the volume effect caused by the bans or fees will be offset to some extent. The time cost of the bans/fees will be somewhat reduced in the case where LNV ownership increases to 20 percent outside the Q-Zone and 100 percent inside the Q-Zone.

Noise effects

The following difference map (figure 4.18) shows the effect by implementing a 1-Euro fee together with 100/20 % LNVO (inside/outside) compared to base case:

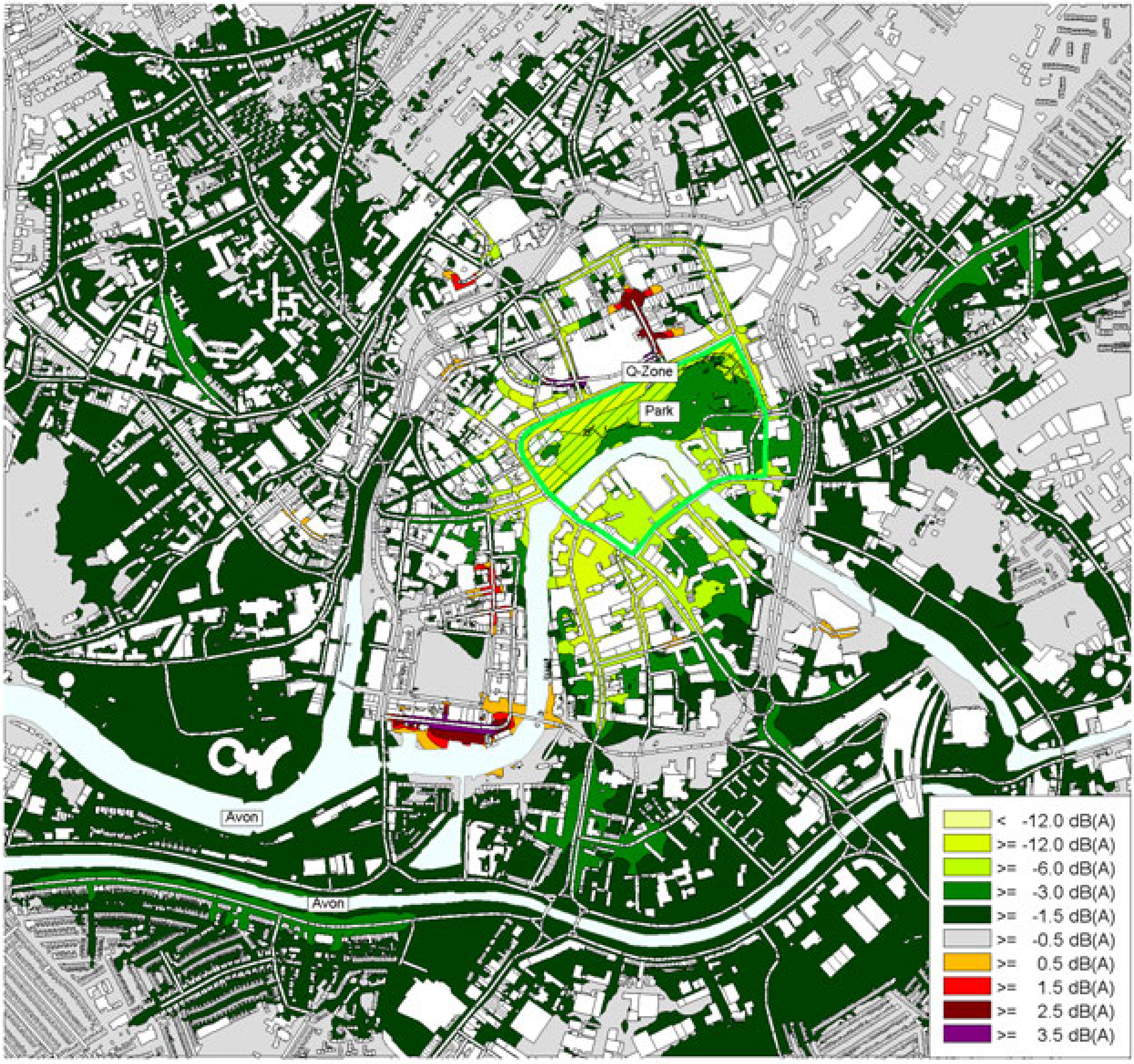

Fig 4.18 Noise difference (Lden) in scenario 15 (S15) compared to the base case on the test site in Bristol. The boundary of the Q-Zone is also shown.

A marked reduction in average noise levels can be noted for the Q-Zone, the park and a range of areas around the Q-Zone particularly to its south. Additionally it can be noted that a large range of areas across the test site also show a reduction in noise levels. There are a few areas to the north and the south west of the Q-Zone, which show an increase in noise levels. These locations could be described as having a hot-spot character, which implies a limited spread of their area but with a concentrated and considerable increase in noise.

4.5.6 Simulation summary

In table 4.2 the results of all simulations compared to the base case are listed. These include traffic effects as well as noise effects. For traffic, the percent reductions of the total distance driven by standard vehicles within the Q-Zone are shown, as well as the changes in total travel time and the total distance driven for the whole network of Bratislava. For noise, the average noise levels within zone and the average noise levels in the surrounding test site area are shown at first. The final columns contain the cumulated sizes of those areas in the Q-Zone that show noise levels more than 5 dB below the base case average noise level across the Q-Zone (absolute and relative numbers). A complete set of noise maps and noise difference maps are available in Appendix 1.

Table 4.2 Bristol simulation summary

Scenario	Percentage of standard vehicles in Q-Zone of base case traffic	Percentage of low noise vehicles in Q-Zone of base case traffic	Total travel time change (hours/day)	Average noise level Lden in Q-Zone (arithmetic) [dB(A)]	Average noise level Lden in remaining test area[1)] (arithmetic) [dB(A)]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [m²])	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [%]
1	99%	1 %	-	63.7	64.1	(133500) L	-
2	40%	1%	0,27%	62.0	64.1	31900	23.9
3	42%	1%	0,22%	61.8	64.0	30800	23.1
4	42%	1%	0,22%	61.8	64.0	30800	23.1
8	95%	5%	0,00%	63.6	64.0	0	0.0
9	37%	8%	0,34%	61.5	63.8	35400	26.5
10	38%	8%	0,23%	61.5	63.8	32200	24.1
11	38%	8%	0,23%	61.5	63.8	32200	24.1
12	81%	19%	0,00%	63.0	63.6	0	0.0
13	20%	35%	0,20%	59.8	63.3	44300	33.2
14	22%	36%	0,18%	59.8	63.3	42600	31.9
15	22%	36%	0,18%	59.8	63.3	42600	31.9

[1)] Test-site without Q-Zone

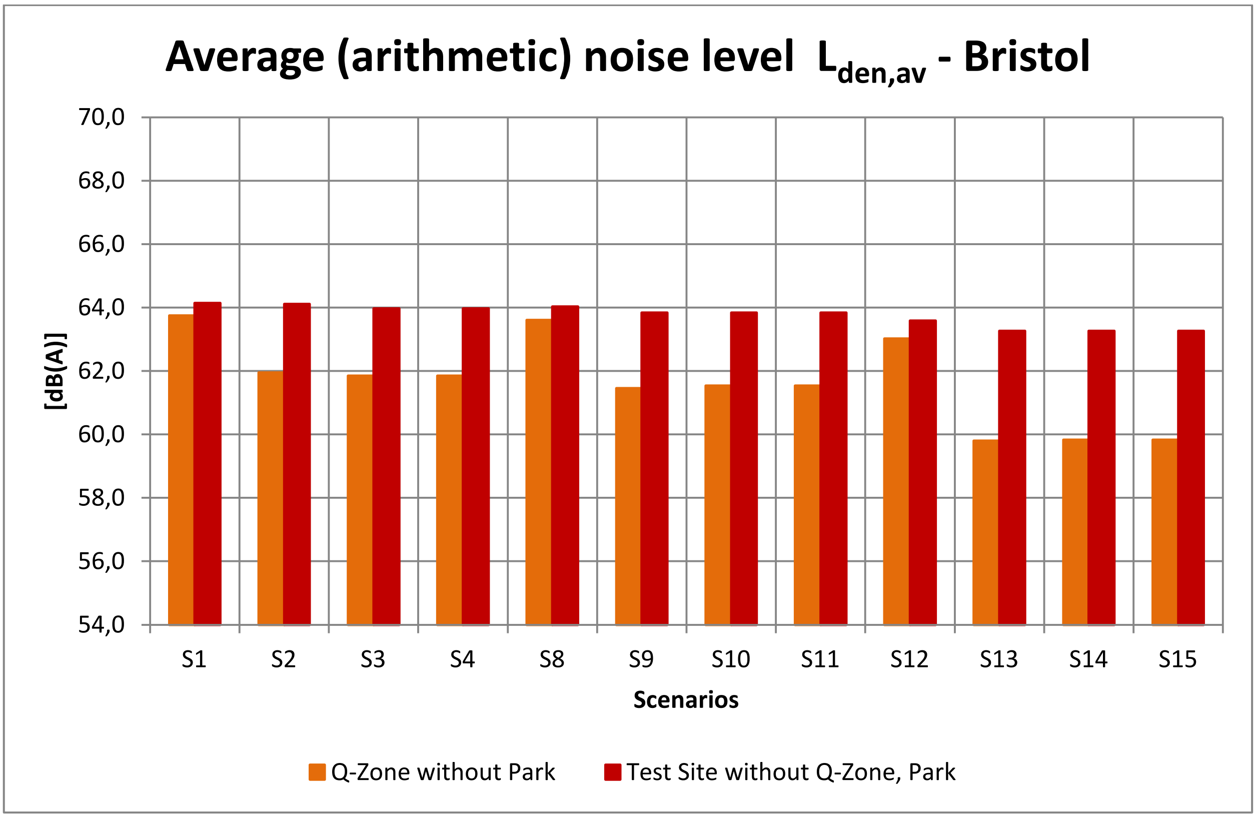

Figure 4.19 Arithmetic average noise level Lden,av for the various scenarios on the test site in Bristol

Discussion

Implementing a Q-Zone in Bristol results in noise reductions in the Q-Zone in all scenarios, most of which are relatively minor. Outside the Q-Zone there are no average increases in the Lden for any of the forecasted scenarios. More so, we can also see a slight reduction in noise levels for the test site in most scenarios.

Nevertheless there are areas inside the test site that are negatively affected by the measures taken in the Q-Zone although the average levels show an improvement. These areas can be identified by studying the noise difference maps as shown in figure 4.18.

We can summarize:

- Trend: Scenarios show an improvement of the noise situation over a range of areas, particularly in the Park and the Q-Zone
- The noise situation also improves in some areas outside the Q-Zone for most scenarios
- Most scenarios also show negative effects (areas which show an increase in noise) somewhere in the test site

5 ESSEN TEST SITE

5.1 GENERAL INFORMATION CITY OF ESSEN

The City of Essen is located in Germany in the federal state of North Rhine-Westphalia. The total area of investigation covers 210 km² and has a population density of 2,750 inhabitants per km².

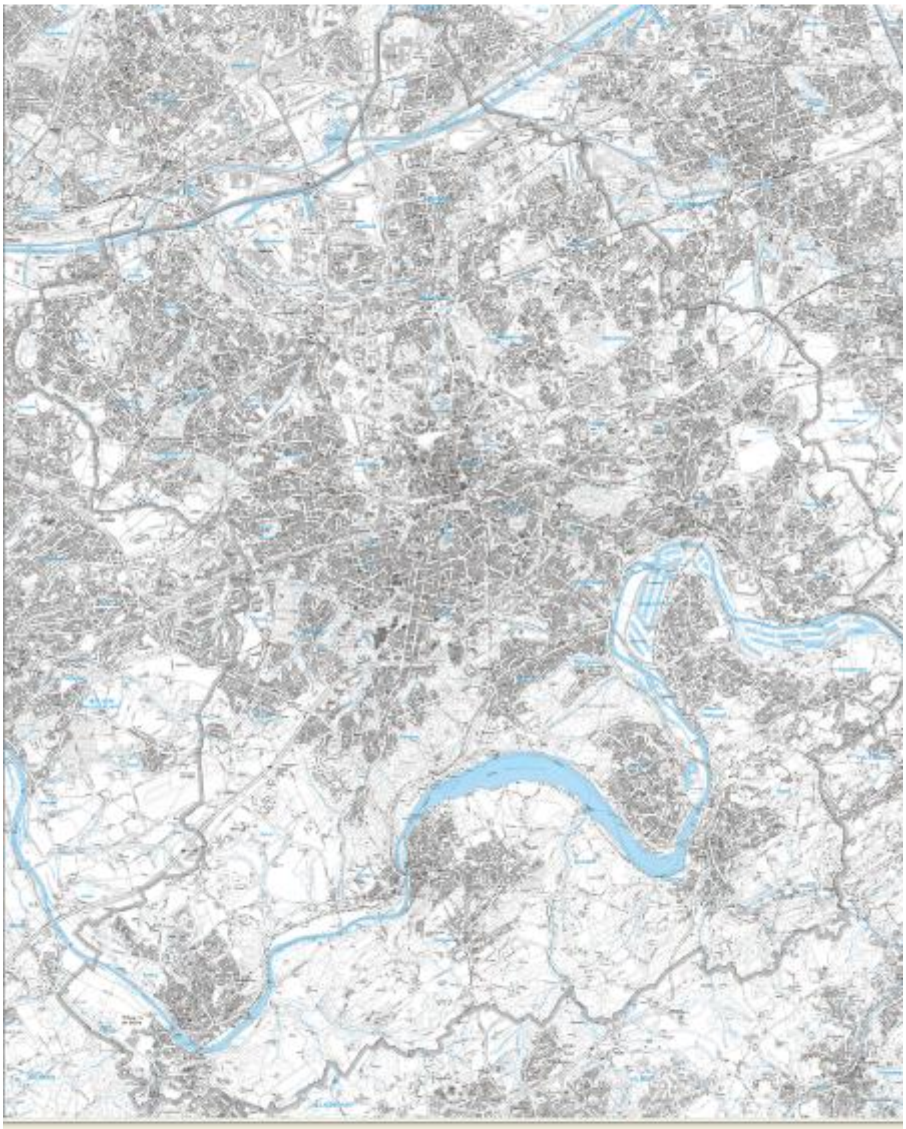

Figure 5.1 Essen.

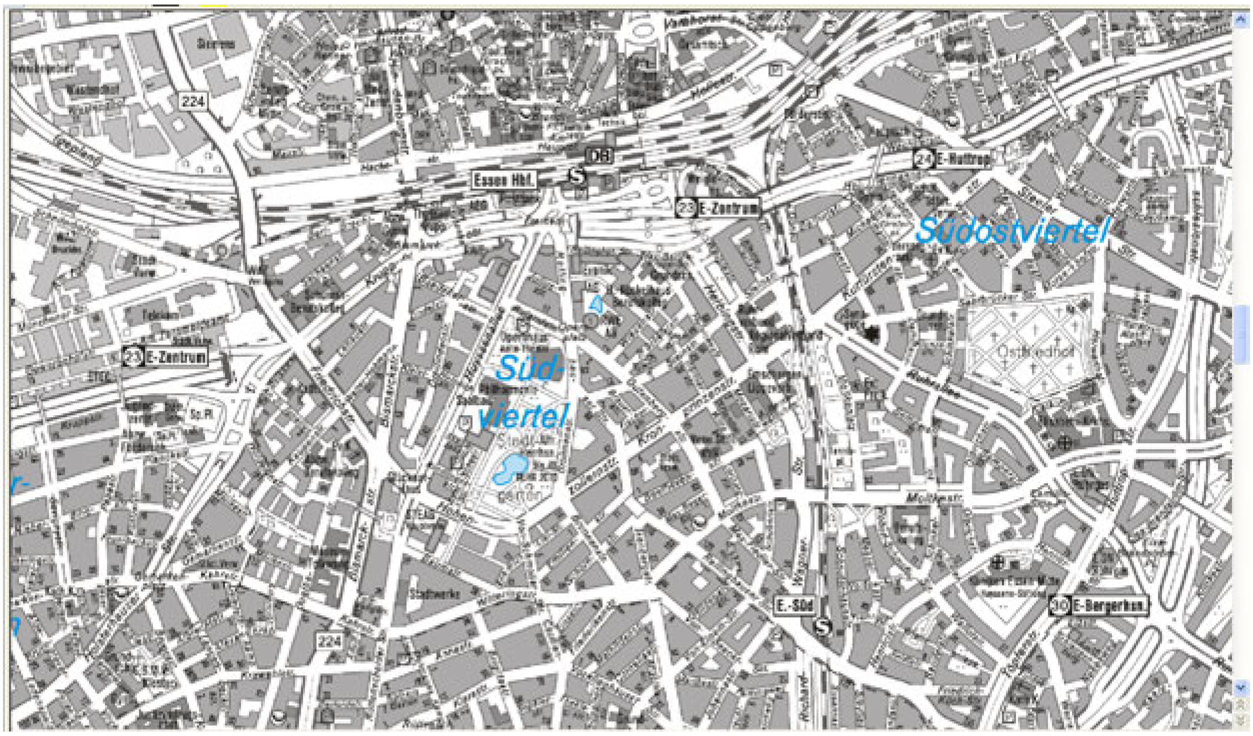

Figure 5.2

Central part of Essen.

5.2 TEST SITE SELECTION

5.2.1 Noise conditions

For Essen, the general noise conditions are presented in the noise map (Figure 5.3). Traffic from the motorway A 40 results in high noise levels within the central parts of the city. Figure 5.5 identifies more detailed noise conditions for the central parts of the city.

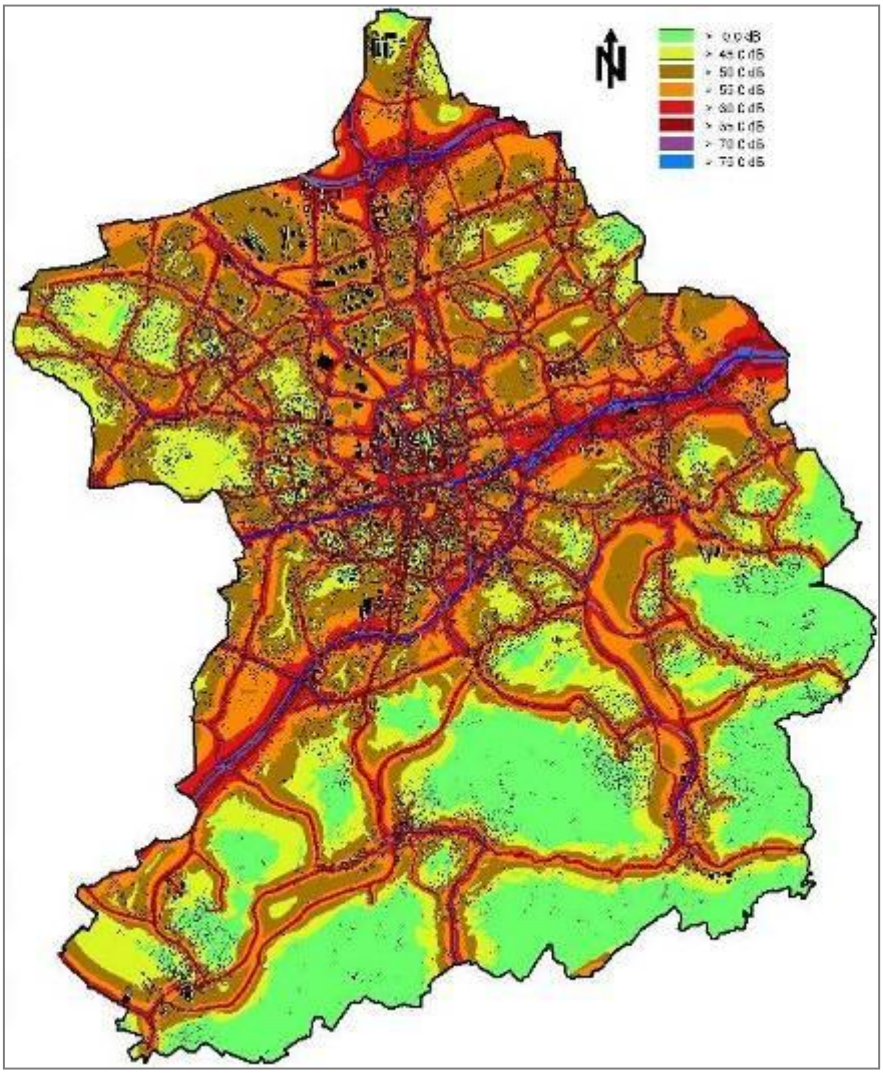

Figure 5.3

Noise map for Essen (dB(A) L_{den} noise levels)

In the noise calculation program the results for the current situation for tram and road traffic noise are presented as modelled noise contours at the surface height of 4 metres and also at façade noise levels. The following illustrations provide an impression of the computed parameters:

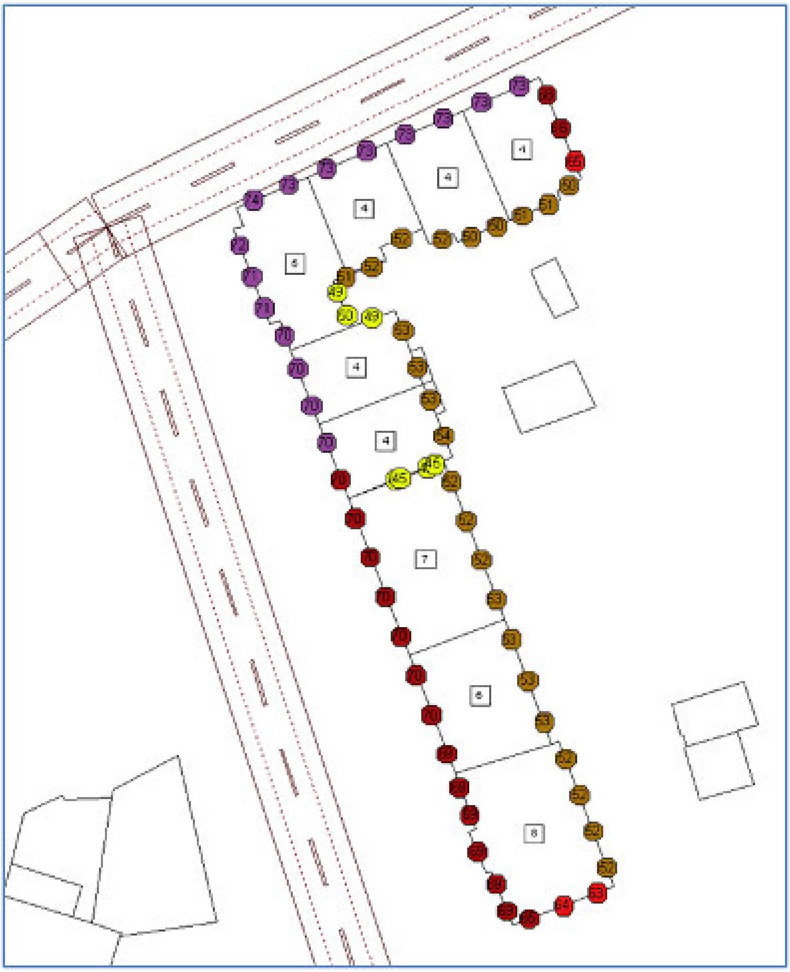

Figure 5.4 Façade noise levels on a block of buildings

Figure 5.5 More detailed noise map showing an area of Essen

It is also possible to calculate additional scenarios as required.

For all residential buildings the facade levels were calculated, see Figure 5.4 above, which gives an example of a building over the defined limits, Figure 5.6 below identifies those locations alongside the transport network where noise levels exceed 70 dB(A) L_{DEN} and 60 dB(A) L_{NIGHT}.

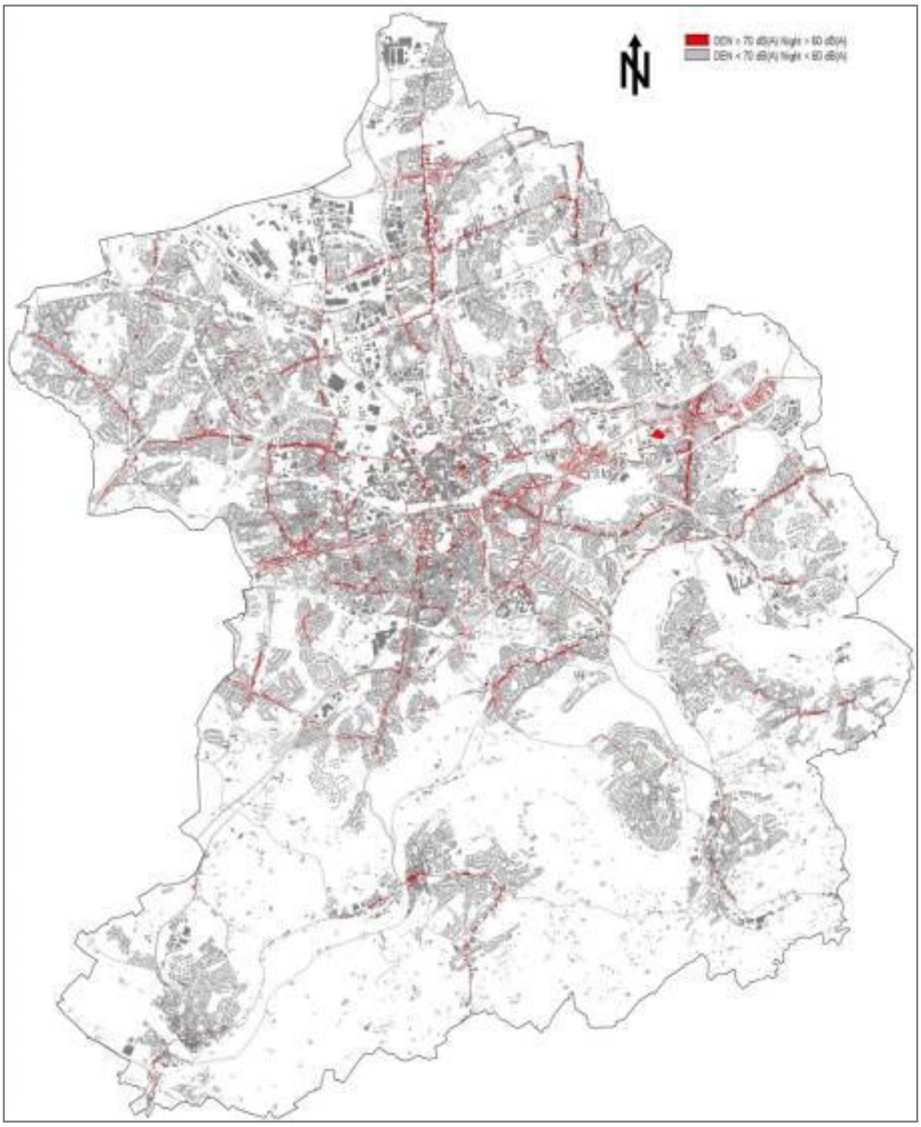

Figure 5.6

Residential buildings along main roads with facade levels exceeding limiting values

In total, there are 31,380 inhabitants in approximately 8,170 buildings where façade noise levels exceed 70 dB(A) for the whole day(DEN) from road traffic noise. At night 32,100 people in 8,500 buildings are exposed to façade noise levels over the 60 dB(A) level.

5.2.2 Potential for Q-zones

The central parts of Essen contain relatively few parks. The most obvious candidate for an embedded park is the Stadtgarten (fig 5.7). The park is surrounded by commercial and residential areas. A tramway line runs along the northern side of the park. From the noise map shown in Figure 5.8 it can be seen that road traffic is the dominant source of noise along all sides of the area.

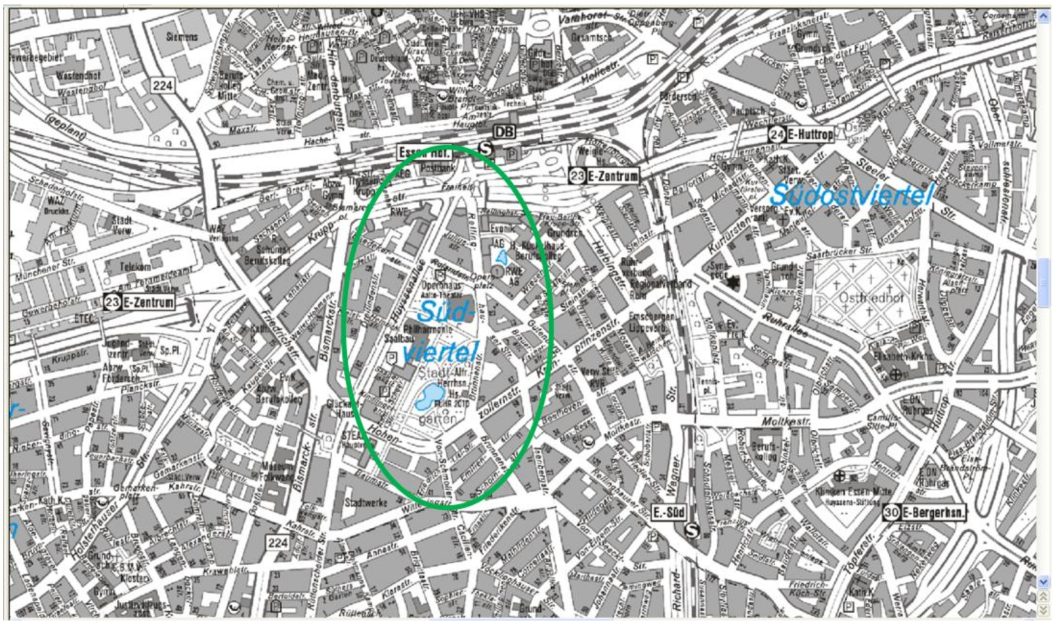

Figure 5.7

Stadtgarten park in central Essen

Figure 5.8

Noise map for central Essen

5.2.3 Selected Q-zone area

Following a site visit, the area marked in fig 5.9 was chosen as the intended Q-zone area for investigation. The figure actually shows two differently shaded areas, a large Q-Zone and small Q-Zone. Later we will introduce additional areas, with which further Q-Zone investigations were made.

Figure 5.9 Intended Q-Zone in Essen

The Q-Zone contains an embedded park (Stadtgarten), which is outlined in figure 5.10.

Figure 5.10 Intended Essen Q-zone embedded park

5.3 AVAILABLE NOISE MODEL

5.3.1 Digital terrain model (DTM)

The terrain model is important for noise calculation and to determine the ground type i.e. soft or hard, for the determination ground attenuation. Also the shielding effects of hills and embankments are considered within the calculation of noise levels.

Figure 5.11 shows a visualization of the elevation model in which the area height is represented by colour.

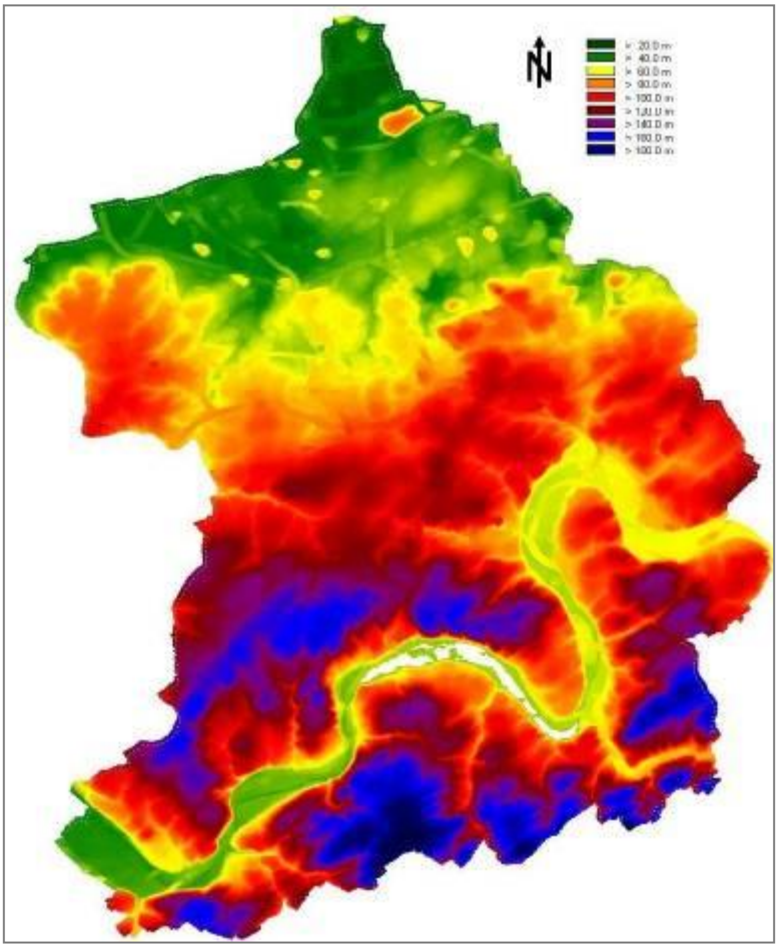

Figure 5.11
Topographic map of the City of Essen

The lowest point of the investigation area is located 20 m above sea level and the highest point is at 205 m absolute altitude.

5.3.2 Road and traffic information

The traffic model of Essen considers all major roads and also contains community roads with daily traffic flows exceeding 1500 vehicles per day. The following illustration shows the road system for the whole of Essen City which has been utilised for the study:

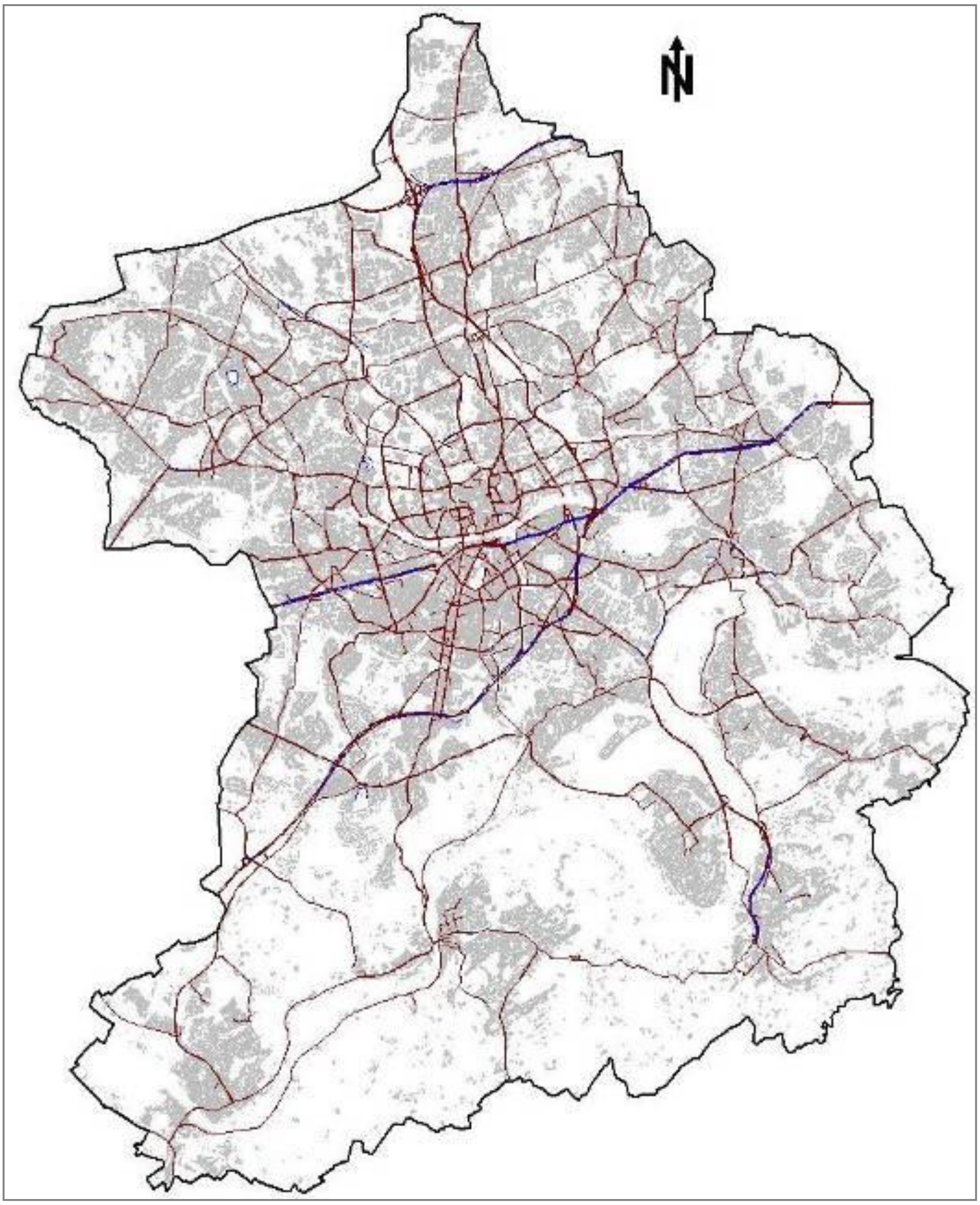

Figure 5.12
Roads, buildings and noise barriers of Essen

All together about 730 km of roads have been studied. The most important (highest traffic flows) roads are:

- West-east direction: BAB 40
- Southwest – east direction: BAB 52
- In the north: BAB 41

The relevant traffic parameters e.g. traffic flow, heavy vehicles, speed, etc. were obtained from the city administration.

The daily traffic flow was distributed over day times, evening and night. The heavy vehicles contribution was known exactly for most of the roads for the whole of the time. However, for those roads which had no data the standard parameters from the German directive VBUS were used as default values.

Information provided by the city administration on speed limits and road surface types were utilised in the model.

5.3.3 Rail and tram information

In Essen data for trams and subways is available. The noise from subways running over ground was taken into consideration. These are presented with $L_{m,E}$ in the model. Exact parameters (number of trains, length, speed etc.) are also presented.

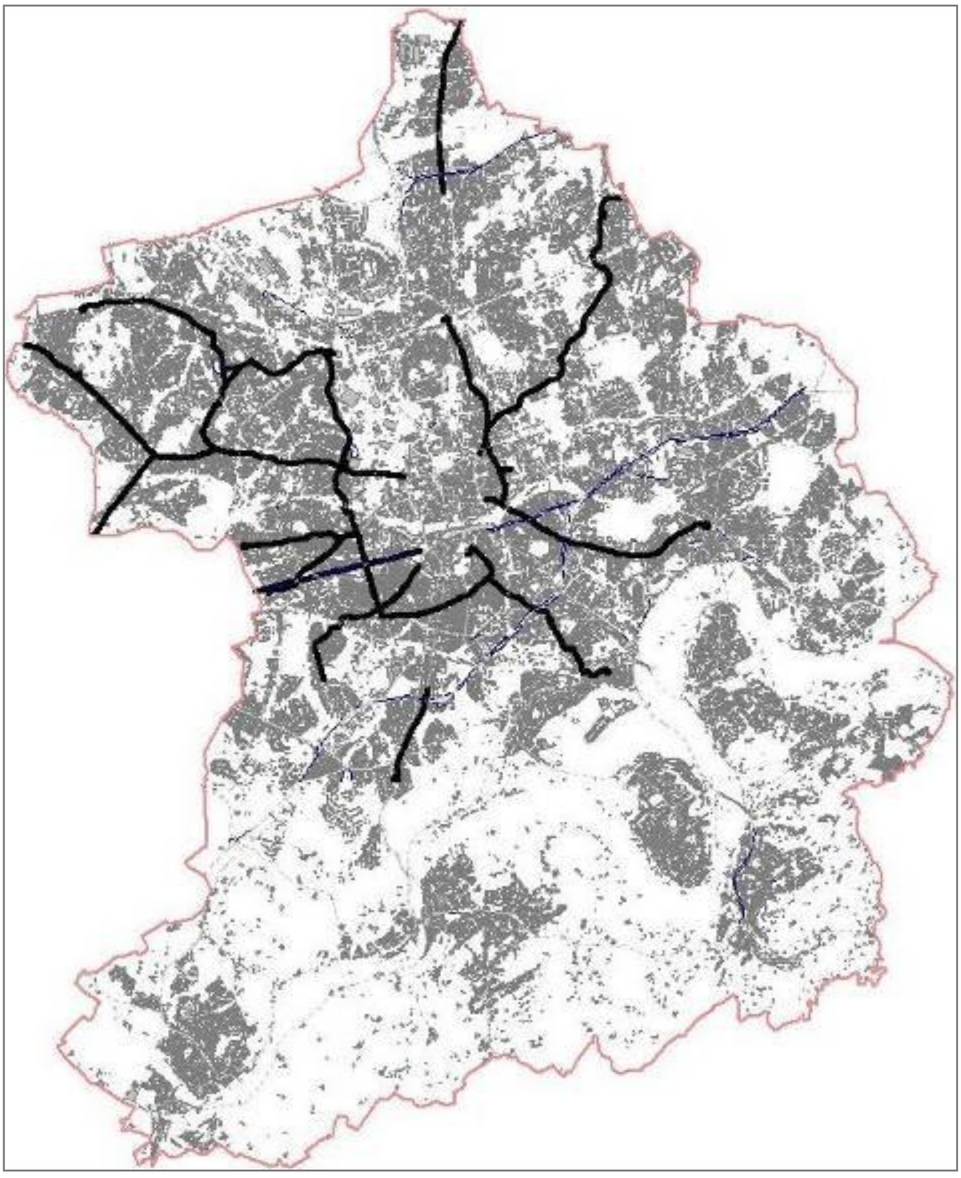

Figure 5.13

Tram and subway lines in the city of Essen

5.3.4 Noise barriers

The DTM also included data with respect to natural noise protection embankments/barriers.

The location of the built noise barriers (shown by blue lines) is evident in Figure 5.12. Most of the protection barriers are along the motorways as well as partly around cemeteries. Figure 5.14 shows a cemetery with noise protection.

Figure 5.14
Noise barrier around a cemetery

The noise barrier data was entered in to the model with its exact geometry, as well as height and absorptive properties. If the walls/barriers were on bridges, they would resemble an elevated wall, which is installed to obtain correct sound propagation from the road or railway in question.

5.3.5 Buildings and inhabitants

The city of Essen has about 591,100 inhabitants. There are about 171,400 buildings of which about 94,600 are residential buildings (approx. 55%). The height and the usage (residential building, school, hospital, commercial use) for each of these buildings is known.

Additionally there is noise modelling for certain industrial plants for which sound power level data is available. However, as the industrial plants make a relatively small contribution of noise to the overall noise levels they have not been further been considered in this study.

5.4 AVAILABLE TRAFFIC MODEL

5.4.1 Network model

For Essen, data from a traffic model application of the PSV system has been made available. The application contains car traffic in Essen and the surrounding region. For analysis within the Cityhush project, the data has been converted to the Emme network assignment software.

The network is shown in Figure 5.15 as an Emme screenshot.

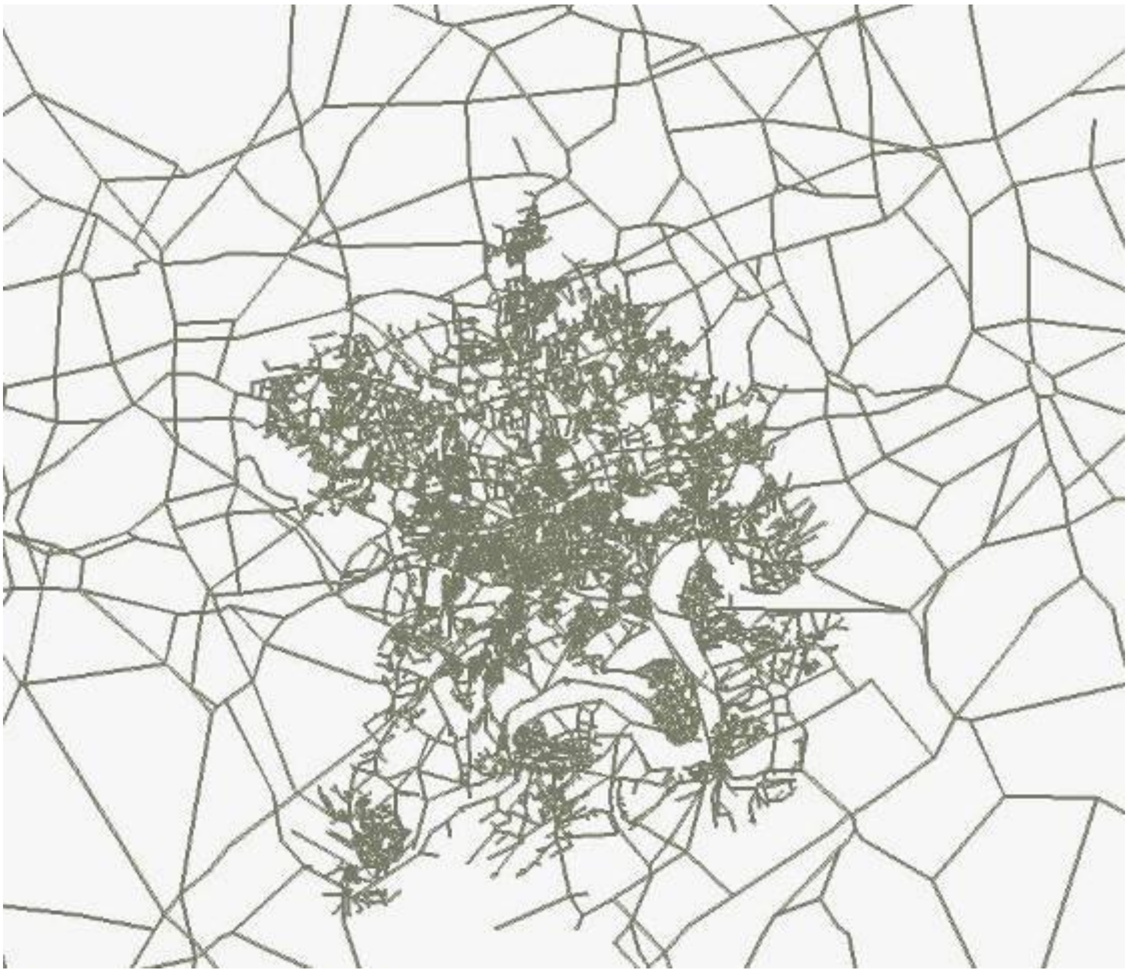

Figure 5.15 Emme network for Essen

Figure 5.16 shows the network of the central parts of Essen. All streets are identified within the network. The intended Q-zone area is marked with red.

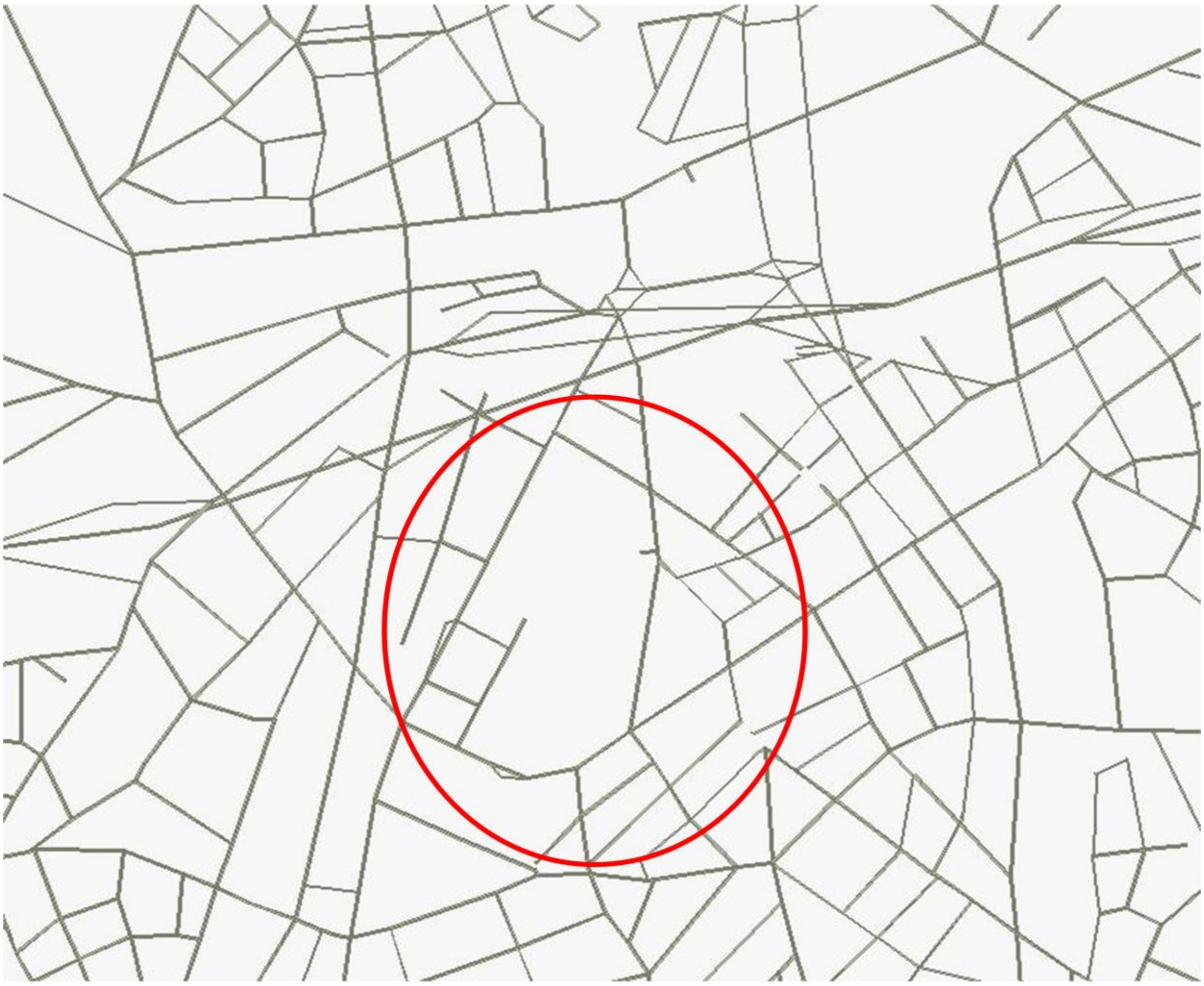

Figure 5.16
Emme network for central Essen

5.4.2 Demand models

In the PSV system, traffic assignment is done on an hourly basis. Link congestion is treated by using link specific volume-delay functions for all regular links (i.e. not connectors). Junction delay is modelled taking traffic signal setting into account.

Mode and destination choice is not treated in the current application. An Origin-Destination car matrix is available.

5.4.3 CityHush adaptation

The application has been transformed to an Emme application. No further network detail was required for the Cityhush application. The PSV Essen application is based on time, and as the simulation scenarios will imply fees on specific links, a conversion from monetary units to time units is necessary to reflect the impedance on such links. This conversion has been done using the Heatco (Shires and de Jong 2006) recommendations on values of time for Germany. As these recommendations concern the mean value of time, assumptions on the distribution of the mean value are needed to reflect differences in the willingness to pay noise charges. These assumptions have been based on recent value of time research. Effects on other noise sources will have to be calculated ad hoc using information from previous noise mapping in Essen.

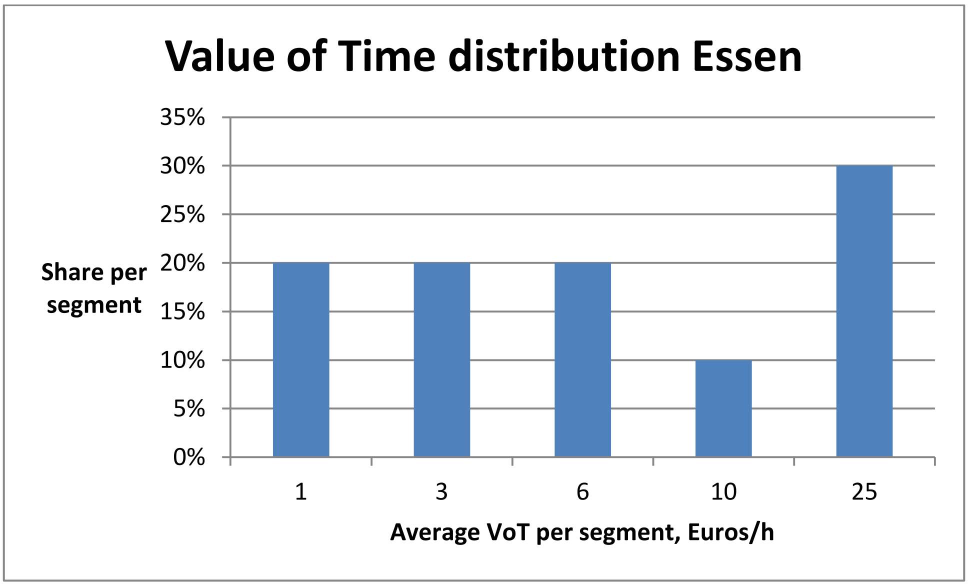

Figure 5.17 Distribution of values of time in Essen for car trips (2003 prices)

The PSV Essen application concerned only the morning peak. In order to establish average day values for traffic flows, an off peak demand was generated by taking a share of the peak traffic. This share was calculated by using counts for a number of links that had been made available to the Cityhush project. The same value of time distribution was applied to both peak and off peak demand. The day values of traffic flows, speeds and shares of heavy traffic was calculated using grossing up factors obtained from the full day counts just mentioned.

5.5 TRAFFIC SIMULATIONS

The PSV Essen application only allowed for traffic simulations concerning cars in our case. No effects with respect to changes of modes, destinations or travel frequency are therefore included. Traffic reductions within the Quiet Zone may therefore be somewhat underestimated, and redistribution effects somewhat overestimated.

5.5.1 Simulated scenarios

For Essen, the following set of traffic scenarios was simulated:

Table 5.1 Simulated scenarios for test site Essen

Scenario nr	Zone	Fee, Euros/passage	Inside LNVO percentage	External LNVO percentage
1	none	none	1	1
2	large	ban	1	1
3	large	1	1	1
4	large	0.5	1	1
5	small	ban	1	1
6	small	1	1	1
7	small	0.5	1	1
8	none	none	5	5
9	large	ban	20	5
10	extra large	ban	1	1
12	none	none	20	20
13	large	ban	100	20
15	large	0.5	100	20

5.5.2 Q-Zone borders

For Essen, three zone sizes were defined (small, large, extra large). The small Q-Zone is defined as shown in Figure 5.18. The green solid line indicates the Q-Zone border of the small Q-Zone, and the dashed green line indicates the extension to the large Q-Zone. The park Stadtgarten is in the centre of the Q-Zone. The yellow dashed line shows the border of the extra large zone increment, including a major arterial.

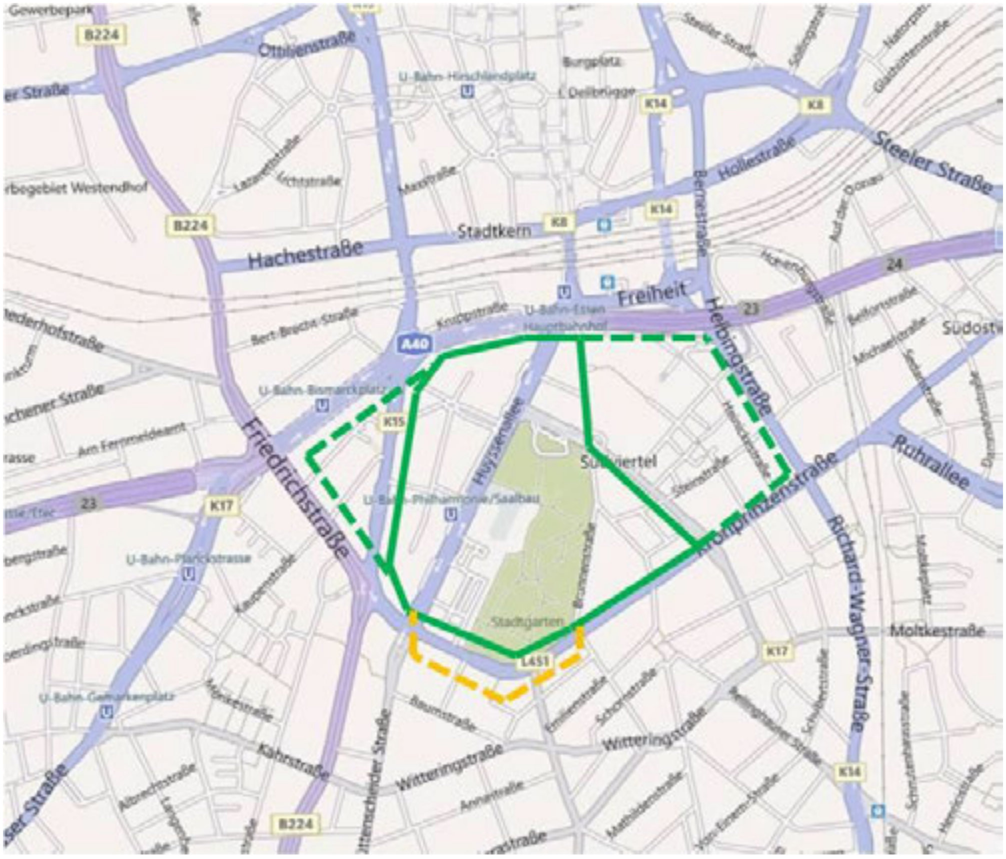

Figure 5.18 Essen Quiet Zone borders. Small (S) solid green, large (L) dashed green, XL-extention dashed yellow.

5.5.3 Establishing a Q-Zone - simulation results

Traffic effects

We now present the simulation results of an introduction of the small Q-Zone (defined in the previous section) by banning all non-resident standard vehicles. The following figure shows the base case (the bandwidths are proportional to traffic volumes) for the peak period:

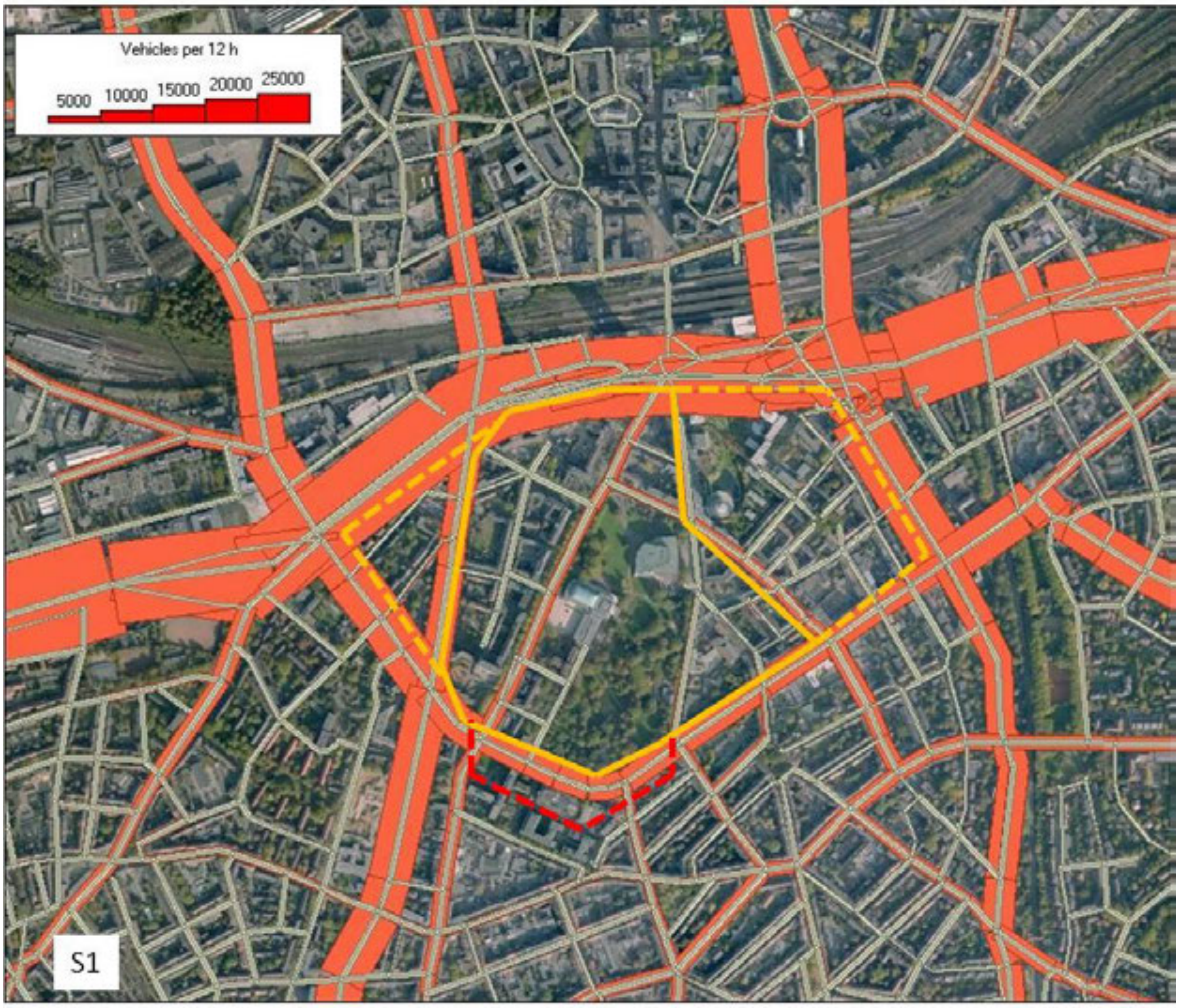

Figure 5.19 Base case day traffic vilumes

On the next figure (figure 5.20), the difference to the base case is shown using the same scale for traffic flow difference as for traffic flows in the preceding figure. Here green bands indicate traffic reductions, and red bands indicate traffic increase. One can see that traffic is redistributed from the Q-Zone to roads outside the Q-Zone.

The redistribution effect is clearly visible. This also results in additional congestion in the network outside the Q-Zone. The total travel time increases by about 1300 hours per day due to traffic redistribution caused by the Q-Zone introduction.

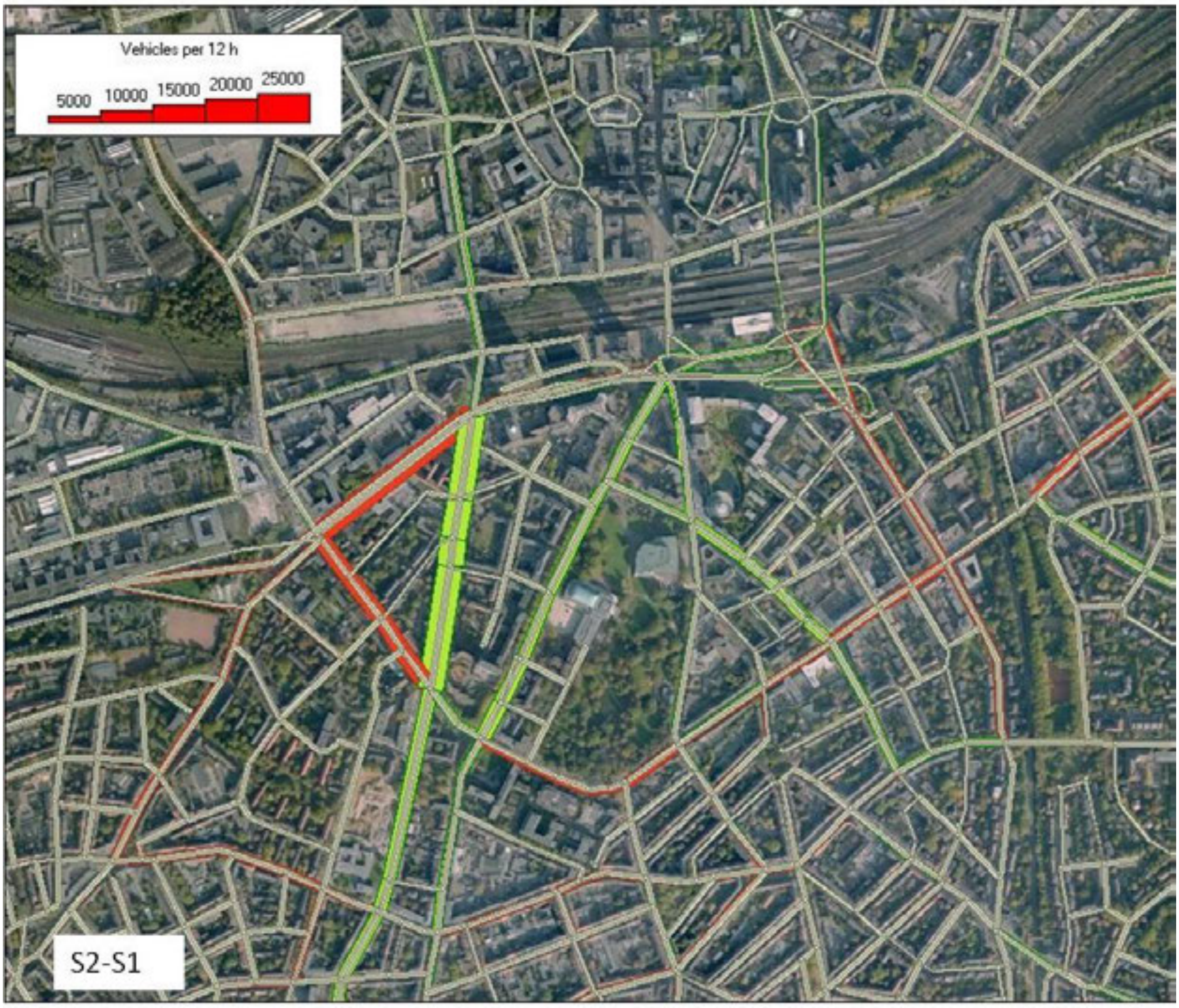

Figure 5.20 Difference between Q-Zone standard vehicle ban and base case, day traffic

Noise effects

The following difference map shows the effects on noise distribution of scenario 2 (S2) *Q-Zone standard vehicle ban* compared to *base case* with the large (L) variant of the different Q-Zone configurations. It can be seen that some areas inside and outside the Q-Zone show reductions in Lden noise levels. However, there are also a some areas, which show increases in noise level in and outside the Q-Zone.

The average effect is a 2.6 dB(A) reduction of the average noise level inside the Q-Zone and an increase of 0.1 dB(A) outside the Q-Zone.

Fig 5.21 Noise difference (Lden) in scenario 2 (S2) compared to the base case on the test site in Essen. The boundary of the large (L) Q-Zone is also shown.

5.5.4 Introducing noise fees

Traffic effects

Introducing noise fees instead of a ban makes it possible for car drivers to trade travel time gain against a fee. The road network in Essen is fairly dense, and the geographical topology does not add further constraints like water or mountains. Therefore it is not difficult to find close substitutes (in travel time) for routes through the Q-Zone. Paying noise fees will therefore not be very interesting for car drivers, even with high values of time, as they will easily find routes that are almost as fast as those passing the Q-Zone.

Noise effects

Scenario 3 (S3) assumes a noise fee of 1 Euro for exiting and entering the Q-Zone. The noise difference map is shown for the large Q-Zone. The result is very similar to that of scenario 2 which we discussed above. Again, some areas inside and outside the Q-Zone show reductions in Lden noise levels, but there are also a considerable amount of regions which show increases in noise level in and outside the Q-Zone.

Fig 5.22 Noise difference (Lden) in scenario 3 (S3) compared to the base case on the test site in Essen. The boundary of the large Q-Zone is also shown.

5.5.5 Varying the Q-Zone size

Traffic effects

If the Q-Zone size is reduced to the small zone defined in figure 5.18 then the redistribution effect is quite small, because the base case traffic volumes are small compared to main streets. Although the reduction of traffic volumes within the Q-Zone is almost 100 percent of the base case traffic, the reduction is only about 10 percent of the traffic volume in the extra large Q-Zone. Therefore, the additional congestion in the network outside the Q-Zone is relative small. The total travel time increases by 75 hours per day due to traffic redistribution caused by the Q-Zone introduction. This corresponds to a very small share of the total travel time in the Essen area, being quite large.

The small and the large Q-Zones are still affected by traffic flows to the south of the park. The largest zone size (XL) includes these road links in the Q-Zone, with an additional decrease in traffic volume. The number of vehicle km is decreased by about 95 percent in this case. The congestion effect is, perhaps surprisingly, less than the congestion effect of the medium sized Q-Zone (900 hours as compared to 1300 hours). This may happen because other routes are now chosen by those affected by the Q-Zone extension, which may in turn impact travel times in other parts of the network. The reason why the largest Q-Zone may imply less added travel time than the medium zone is that car drivers choose the route that minimizes their own travel time, not the route that minimizes the total travel time.

Figure 5.23 shows the effect of changing the zone to the small zone size (again with respect to the base case and the same scale as before).

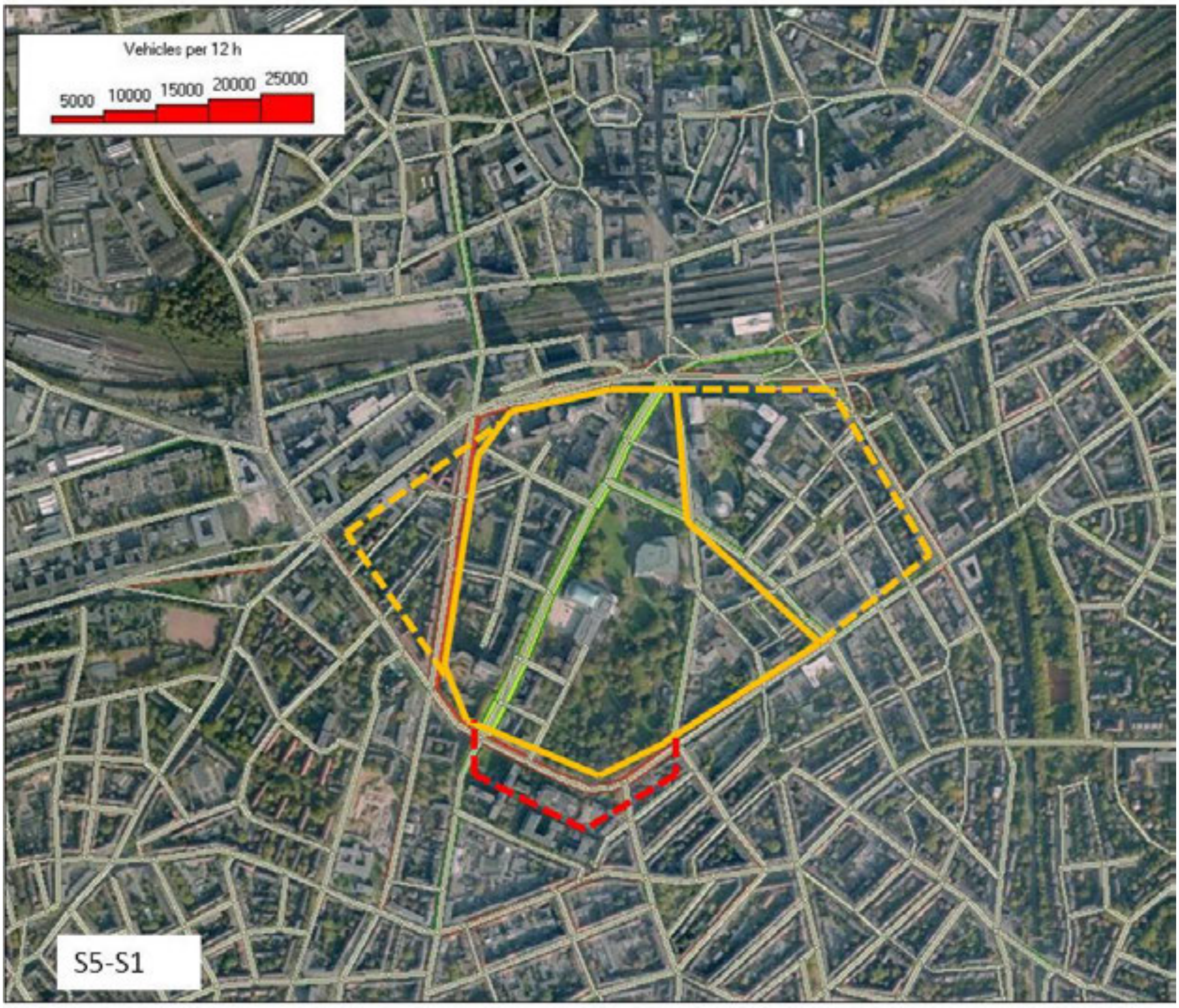

Figure 5.23 Difference between Scenario 5 and Base Case, day traffic

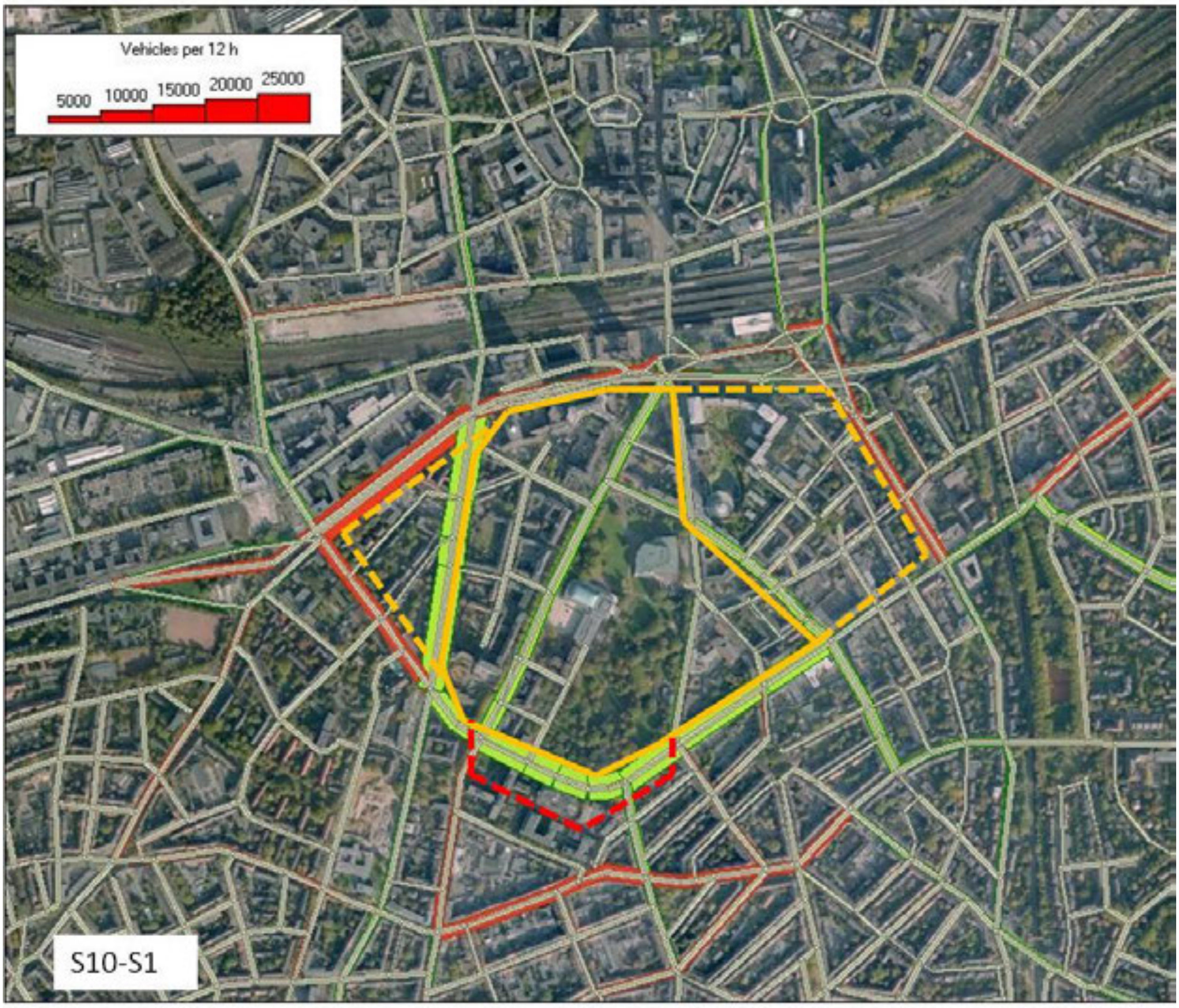

Figure 5.24 Difference between Scenario 10 and Base Case, day traffic

Noise effects

The effects of the chosen extra large (XL) Q-Zone (with ban for non-resident standard vehicles) on noise compared to base case is shown in the following difference map (Figure 5.25): A marked reduction in average noise level can be noted for a majority of the regions inside the Q-Zone. There are also a few areas outside the Q-Zone that benefit from a slight reduction in noise. These areas are located along those roads that lead directly to and from the Q-Zone, and therefore traffic is reduced along them. Again, there are a fair number of regions, which suffer from increased noise levels as a result of the Q-Zone implementation.

The average effect is a reduction of the average noise level inside the Q-Zone of 3.9 dB, and an increase of 0.1 outside the Q-Zone.

Fig 5.25 Noise difference (Lden) in scenario 10 compared to the base case on the test site in Essen. The boundary of the extra large (XL) Q-Zone is also shown.

5.5.6 Increasing the low noise vehicle ownership

Traffic effects

As LNV ownership levels increase, the number of standard vehicles will be reduced. Instead, the number of LNV vehicles will increase, so the volume effect caused by the bans or fees will be offset to some extent. The time cost of the bans/fees will be somewhat reduced in the case where LNV ownership increases to 5 percent outside the Q-Zone and 20 percent inside the Q-Zone, and even more reduced in the case where LNV ownership becomes 20 percent outside the Q-Zone and 100 percent inside the Q-Zone.

Noise effects

The following difference map shows the effect of the ban scenario together with 100/20 % LNVO (inside/outside) compared to base case, with a traffic ban inside the Q-Zone for the large scaled Q-Zone.

The difference map shows a reduction in average noise throughout a majority of regions throughout the test site. A marked reduction of noise can be noted in some areas inside the Q-Zone. At the western boundary of the Q-Zone increases in noise need to be drawn to attention, as well as for a few other locations. Still, the magnitude of the area in which noise is reduced clearly surpasses that of the regions with increases of noise.

The average effect is a reduction of the average noise level of 3.5 dB inside the Q-zone, and a reduction of 0.7 dB outside the Q-Zone.

Fig 5.26 Noise difference (Lden) in scenario 13 (large zone) compared to the base case on the test site in Essen.

5.5.7 Simulation summary

In table 5.2 the results of all simulations compared to the base case are listed. This includes traffic effects as well as noise effects. For traffic, the percent reductions of the total distance driven by standard vehicles within the Q-Zone are shown, as well as the changes in total travel time and the total distance driven for the whole network of Bratislava. For noise, the average noise levels within zone and the average noise levels in the surrounding test site area are shown at first. The final columns contain the cumulated sizes of those areas in the Q-Zone that show noise levels more than 5 dB below the base case average noise level across the Q-Zone (absolute and relative numbers).

Table 5.2 Essen simulation summary

Scenario	Percentage of standard vehicles in Q-Zone of base case traffic	Percentage of low noise vehicles in Q-Zone of base case traffic	Total travel time change (hours/day)	Total distance change (vehicle km/ day)	Average noise level Lden in Q-Zone[2] (arithmetic) [dB(A)]	Average noise level Lden in remaining test area[1] (arithmetic) [dB(A)]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [m²]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [%]
1	99%	1%	-	-	62.6 S 62.6 L 63.0 XL	61.6 S 61.6 L 61.6 XL	(373700) S (591300) L (628300) XL	-
2	38%	2%	1300	22364	60.0	61.7	153100	25.9
3	38%	2%	857	15304	60.0	61.7	153400	25.9
4	39%	2%	813	16704	60.1	61.7	152000	25.7
5	91%	1%	75	8448	59.4	61.6	98800	26.4
6	91%	1%	75	8448	59.4	61.6	98800	26.4
7	91%	1%	167	7380	59.4	61.6	98800	26.4
8	95%	5%	0	0	*)62.4	61.5	0	0.0
9	36%	11%	708	16336	59.9	61.6	157300	26.6
10	6%	2%	896	27896	59.1	61.7	287100	45.7
12	80%	20%	0	0	*)61.8	60.9	0	0.0
13	28%	39%	236	14776	59.1	60.9	171100	28.9
15	28%	38%	294	11508	59.2	60.9	170700	28.9

[1] Test-site without Q-Zone [2] Q-Zone without park area

*) Reference for these values (S8 and S12) is the large (L) Q-Zone. Some reference needed to be defined in this case, as both scenarios do not stipulate a Q-Zone.

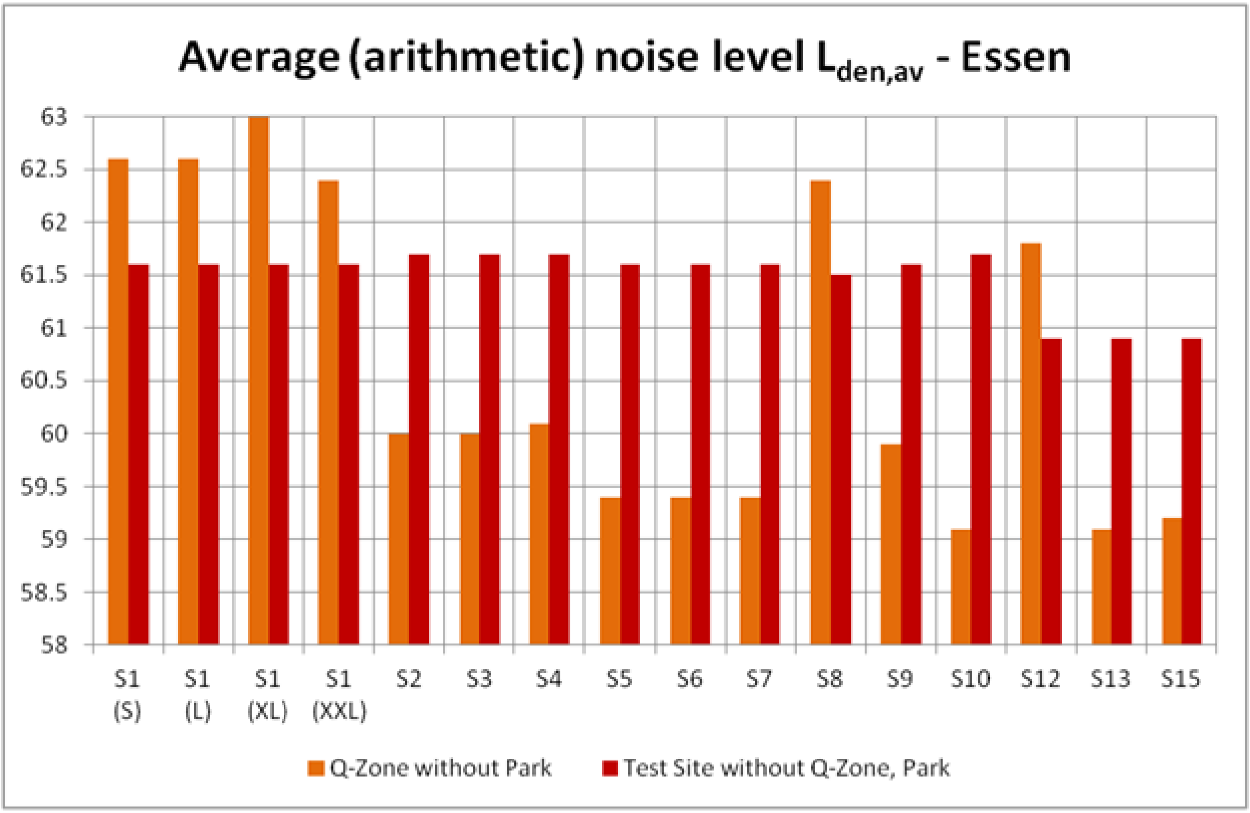

Figure 5.27 Arithmetic average noise level Lden,av for the various scenarios on the test site in Essen

Discussion

When the small Q-Zone, banning non-resident standard vehicles entering or exiting the Q-Zone, is introduced, the average arithmetic noise level is reduced by about 3 dB. The same reduction is also obtained on average when noise fees in the range 0.5 – 1 Euros per entry or exit are applied instead of the ban.

If the Q-Zone is enlarged to the large Q-Zone, the noise level is reduced by about 2.5 dB(A) compared to the large zone Base Case. Noise fees in the range 0.5 – 1 Euros will have the same effect.

These noise reductions are modest, because the potential for noise reductions is rather low, as there is a heavily used road bordering the Q-Zone, giving high levels of ambient noise in the Q-Zone. If this road is included in the Q-Zone (as in scenario 10, XL), noise levels in the Q-Zone are reduced by almost 4 dB. The share of the Q-Zone that has a noise level below 5 dB(A) is also much higher – 45 percent, as compared to 25-30 percent in the other scenarios. It comes however at a price – there is a much higher increase in vehicle kilometres, caused by redistribution effects.

An increased LNVO only (in scenario 8 up to 5 percent, in scenario 12 up to 20 percents) gives only small effects – 0.2 and 0.8 dB respectively. When the large Q-Zone is introduced with a 100 percent resident LNVO and 20 percent non-resident LNVO, noise levels are reduced by 3.5 dB(A).

The Essen case shows that

- It is difficult to achieve substantial noise reductions if not major roads are included.
- Including major roads may imply increased detour effects and associated increase in vehicle kilometres

6 GOTHENBURG TEST SITE

6.1 GENERAL INFORMATION ON THE CITY OF GOTHENBURG

Gothenburg is the second largest city in Sweden. The urbanised area covers a total area of 412 square kilometres, and has a population of about 510 000. The population density is 1 200 persons/km².

Figure 6.1 Gothenburg.

The city is located on the Swedish west coast around the mouth of the river Göta Älv. The central parts are built close to the river, and surrounded by canals. Gothenburg has a large harbour and much of the space along the river is used for harbour related activities.

Figure 6.2

Central part of Gothenburg.

6.2 TEST SITE SELECTION

6.2.1 Noise conditions

For Gothenburg, noise mapping has been undertaken for the whole Gothenburg area in the year 2007. The Gothenburg noise conditions (Leq 24 h) are presented on the resulting noise map (Figure 6.3). Traffic from the motorway E6 brings high noise levels to the central parts. Figure 6.4 shows noise conditions for the central parts of the city.

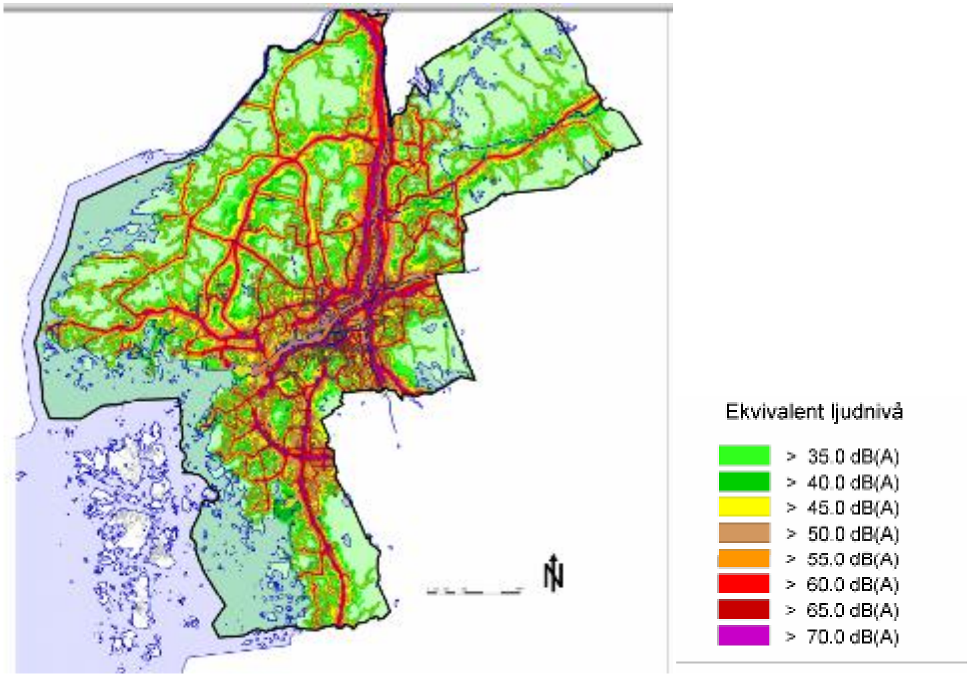

Figure 6.3

Noise map for Gothenburg (dB(A) L_{eq24h} noise levels)

Figure 6.4

Noise map for central Gothenburg (dB(A) L_{eq24h} noise levels)

6.2.2 Potential for Q-zones

The central parts of Gothenburg contain several parks that are hit by noise disturbance. These parks have been subject to investigations with respect to use and environmental status. The Cityhush Gothenburg municipality partner suggested three main alternatives for a park surrounded by a Q-zone emerged as shown In Figure 6.5.

Figure 6.5

Parks in central Gothenburg

The Trädgårdsföreningen is the largest park, It is shown in more detail in Figure 6.6, where also noise level measurements are reported (shorter intervals).

Figure 6.6

Noise levels in the Trädgårdsföreningen park (db(A))

According to the investigation, the park is used for a number of different recreation purposes like resting, walking, playing, experiencing water and flowers and also for cultural events. The two other parks are smaller and not as much used as the Trädgårdsföreningen.

6.2.3 Selected Q-zone area

After discussions with the Gothenburg municipality partners, the Trädgårdsföreningen park appeared to have the highest potential to be part of a Q-zone. The intended Q-zone area is shown on Figure 6.7

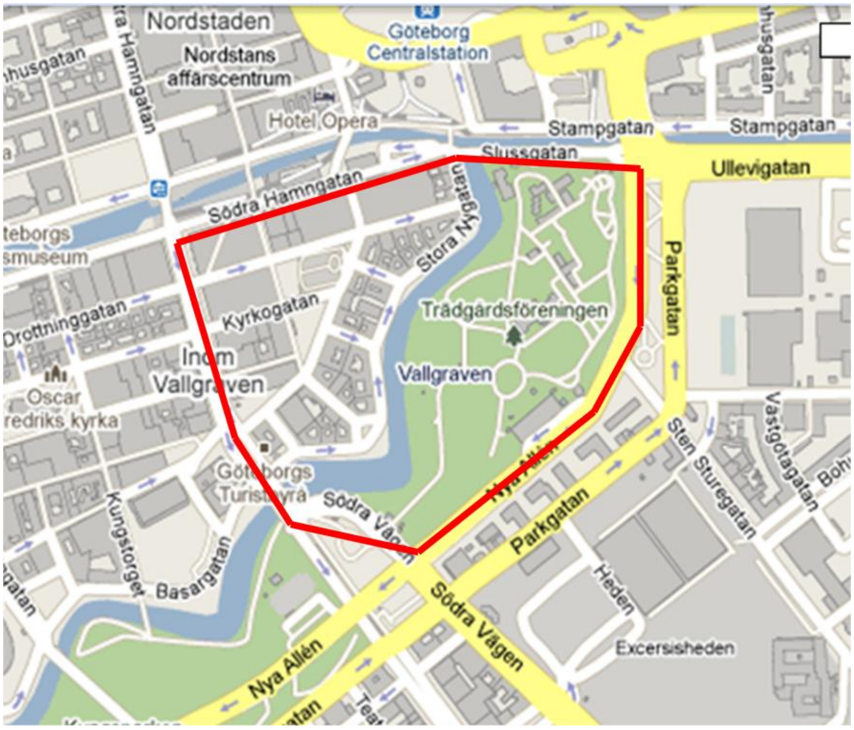

Figure 6.7

Intended Q-zone area

6.3 AVAILABLE NOISE MODEL

6.3.1 Digital terrain model

A new terrain model was supplied by Gothenburg municipality and has been adapted for noise mapping purposes.

Figure 6.8

The Gothenburg data terrain model

6.3.2 Road and traffic information

In the noise mapping of Gothenburg a lot of the inner city roads had estimated numbers on traffic and heavy vehicle percentages. For CityHush an updated traffic model has to be used for sufficient accuracy. The latest measured traffic flows will be supplied by Gothenburg municipality and introduced in the model.

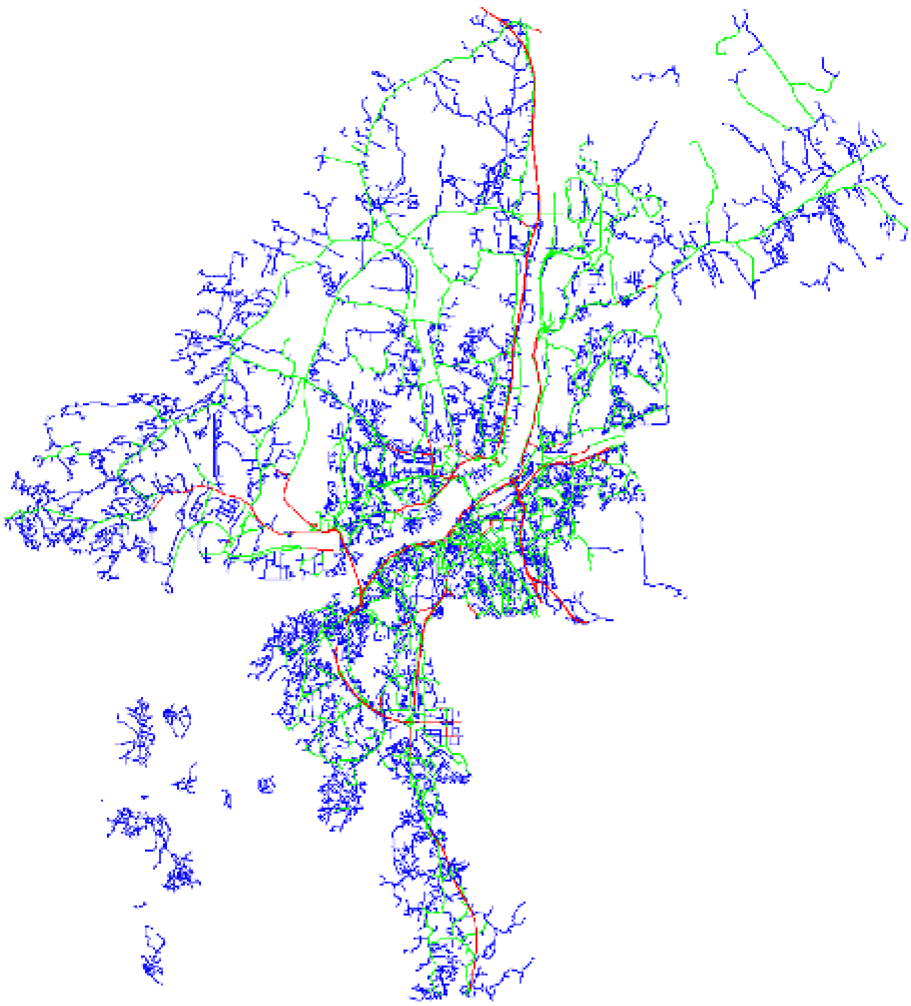

Figure 6.9

Gothenburg roads used in previous noise mapping, blue roads have estimated traffic, green roads have measured traffic below 1000 cars/hour, red roads have measured traffic above 1000 cars/hour

6.3.3 Rail and tram information

Tram and rail information will be used where applicable and is available on the Gothenburg tram system and for national rail traffic.

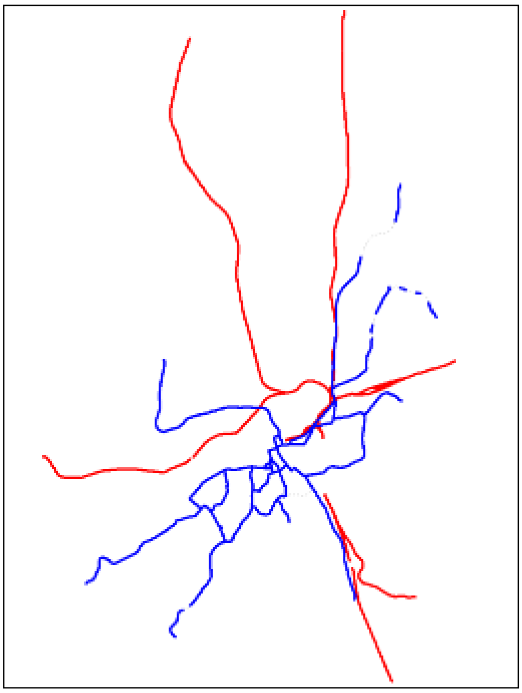

Figure 6.10 Gothenburg tram (Blue) and Rail system (Red)

6.3.4 Noise barriers

Location and height of existing noise barriers is included in the material from the previous noise mapping. Updates will be made from the data supplied by Gothenburg municipality.

Figure 6.11 Noise barriers in Gothenburg

6.3.5 Buildings and inhabitants

Information on inhabitants and buildings is available from the noise mapping material.

Figure 6.12

Buildings and inhabitants in Gothenburg. Dwellings are green and other buildings grey

6.4 AVAILABLE TRAFFIC MODEL

6.4.1 Network model

Gothenburg is included in the national Sampers forecasting system. The Emme network assignment model is integrated in the Sampers system. For CityHush, the Sampers regional model for the Western part of Sweden is used. It contains 2700 zones and 65 000 links. Public transport lines are also included in the model.

The network is shown in Figure 6.13 as an Emme screenshot.

Figure 6.13

Emme network for Gothenburg

Figure 6.14 shows the network of the central parts of Gothenburg. All streets except very minor roads are contained in the network. The intended Q-zone area is marked with red.

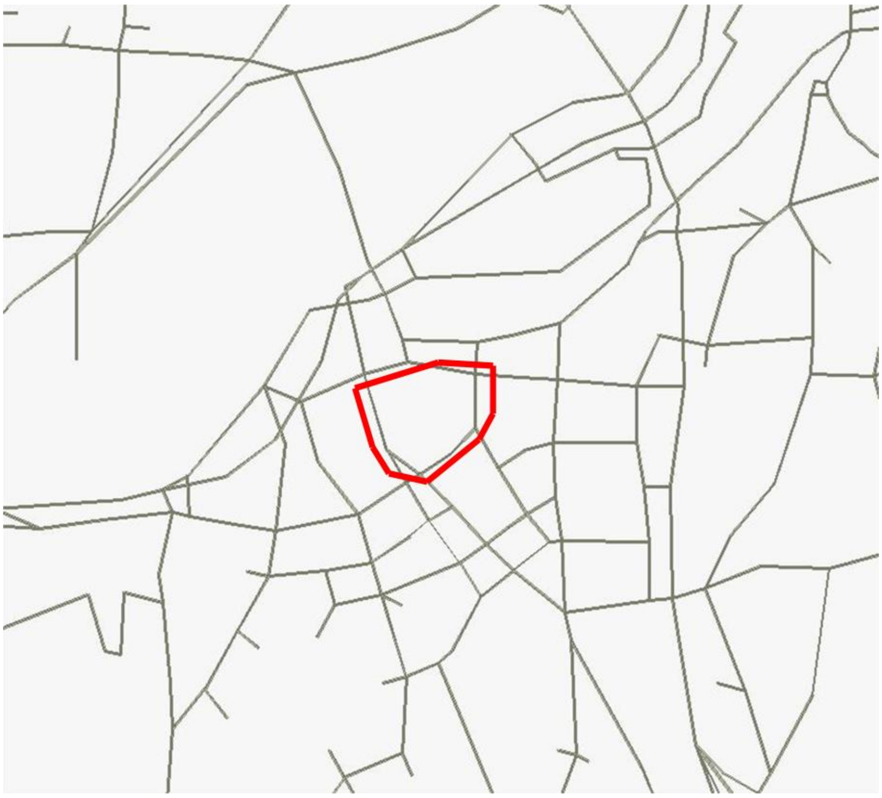

Figure 6.14

Emme network for central Gothenburg

6.4.2 Demand models

In the Sampers system, traffic assignment is done for the morning peak hour and one midday hour. Congestion is treated by using link specific volume-delay functions for all regular links (i.e. not connectors). Multiclass assignment is used, in order to regard different values of time.

The travel demand models in Sampers include mode and destination choice models.

6.4.3 CityHush adaptation

More detail needed to be added to the central part of the network for links as well as zones. The assignment is based on time, and as the simulation scenarios will imply fees on specific links, a conversion from monetary units to time units is necessary to reflect the impedance on such links. This conversion was done using the Sampers system values of time. The resulting value of time distribution is shown in Figue 6.15.

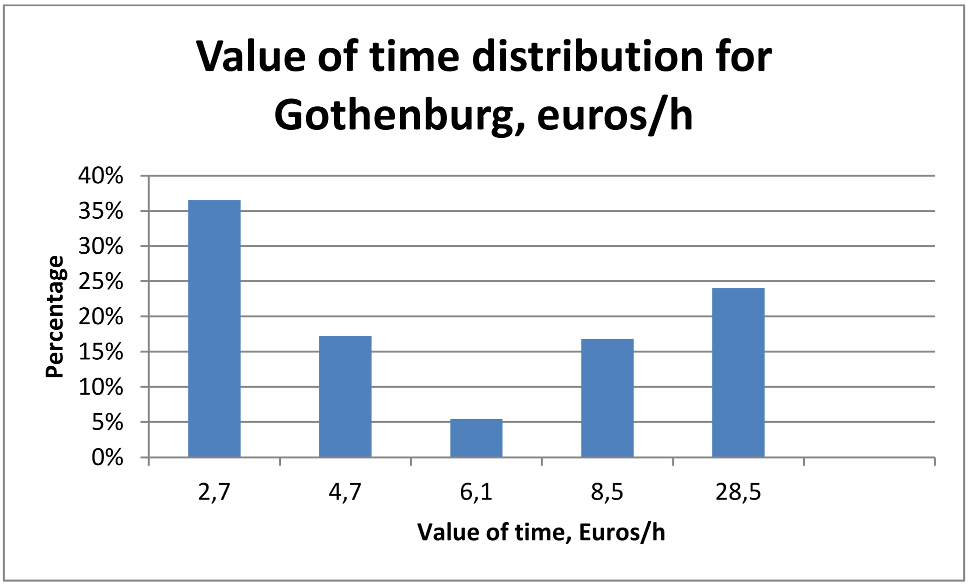

Figure 6.15 Value of time distribution for Gothenburg, Euros/h

6.5 TRAFFIC SIMULATIONS

The Sampers Gothenburg application allows for traffic simulations concerning not only car route choice but also mode and destination choice. Therefore, effects with respect to changes of modes, destinations and travel frequency are also included.

6.5.1 Simulated scenarios

For Gothenburg, the following set of traffic scenarios was simulated:

Table 6.1 Simulated scenarios for Gothenburg

Scenario nr	Zone	Fee, Euros/passage	Inside LNVO percentage	External LNVO percentage
0	-	none	1	1
1	small	Low noise vehicles only	1	1
3	large	Low noise vehicles only	1	1
5	small	Noise fee 5 kr	1	1
7	large	Noise fee 5 kr	1	1
13	large	Noise fee 5 kr	100	20
15	-	none	20	20
16	small	Low noise vehicles only	100	20

6.5.2 Q-Zone borders

For Gothenburg, two zone sizes were defined. The Q-Zone's are defined as shown in Figure 6.16. The yellow solid line indicates the small Q-Zone border, and the dashed yellow line indicates the extension to the larger Q-Zone. The park Trädgårdföreningen is in the centre of the Q-Zone. The park borders to a major arterial, consisting of two parallel unidirectional streets which are separated by a 30 – 60 meter land stripe. These streets of course contribute to the noise in the park. The small Q-Zone is defined to include the closest street, whereas the larger zone includes also the second street.

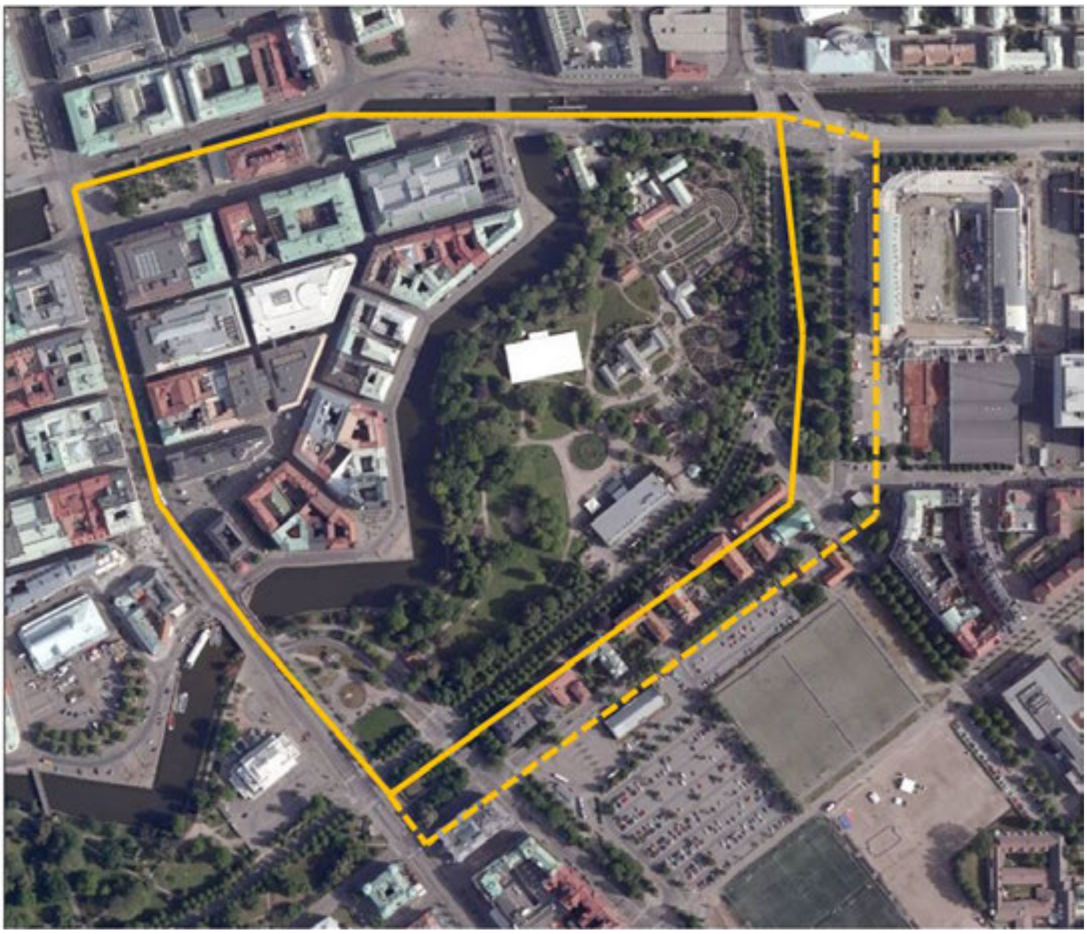

Figure 6.16 Gothenburg Quiet Zone borders (yellow)

6.5.3 Establishing a Q-Zone - simulation results

Traffic effects

We now present the simulation results of an introduction of the Q-Zone (defined in the previous section) by banning all non-resident standard vehicles. The following figure shows the base case (the bandwidths are proportional to traffic volumes) for the peak period:

Figure 6.17 Base case day traffic volumes

On the next figure, the difference to the base case is shown using the same scale for traffic flow difference as for traffic flows in the preceding figure. On figure 6.16 green bands indicate traffic reductions, and red bands indicate traffic increase. The obvious effect is that the flow on the street along the park is strongly reduced (figure 6.18).

Figure 6.18 Difference between Q-Zone standard vehicle ban and base case, day traffic

Noise effects

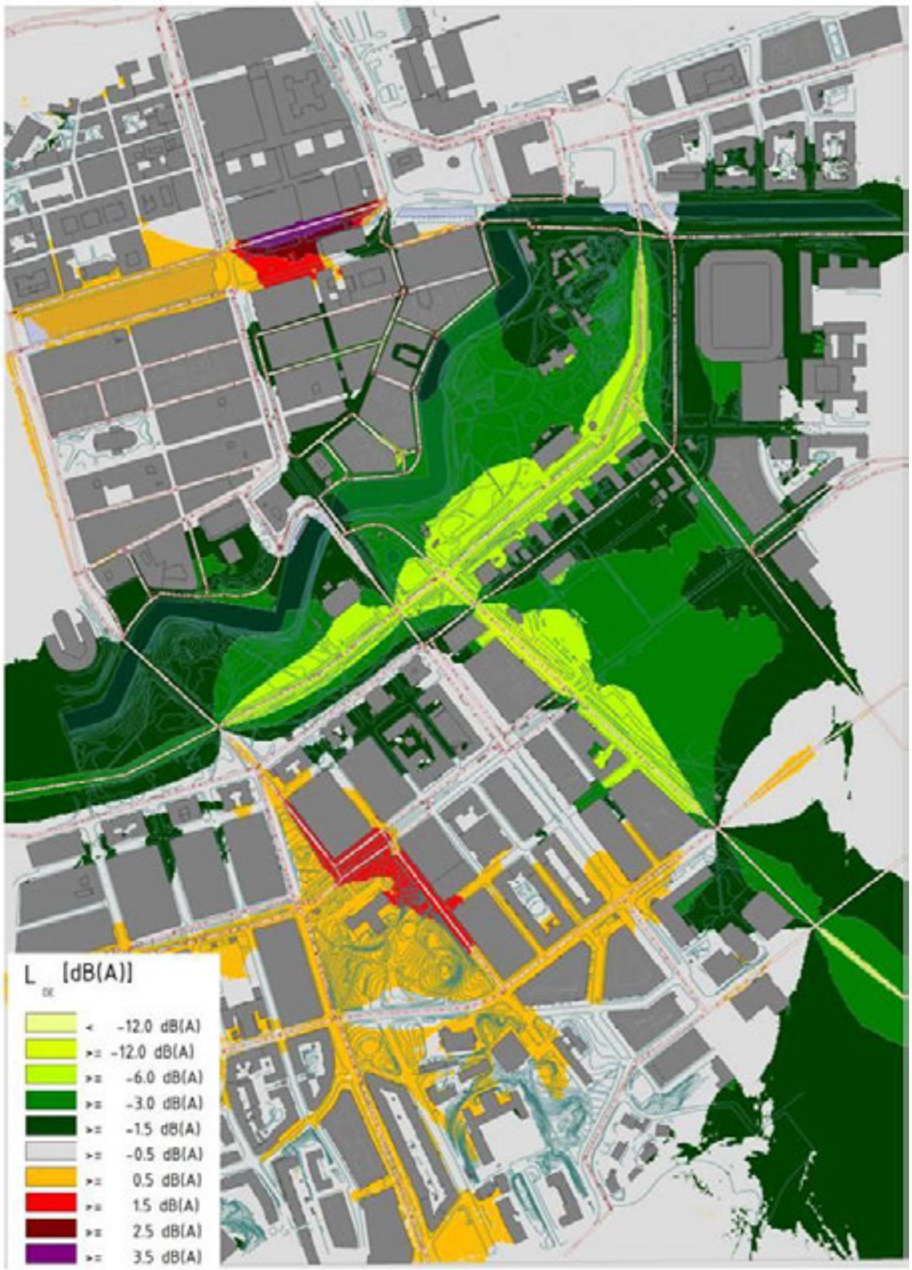

Figure 6.19 Noise difference between Q-Zone standard vehicle ban and base case

Banning non resident standard vehicles will improve the situation in the Q-Zone with up to 6 dB(A). Redistribution effects may cause lower as well as higher noise levels outside the zone, mostly to a minor extent. One exception is along a major street leading to the Q-Zone from the south, where noise levels decrease up to 6 dB(A). Another exception is a part of a street close to the northern boundary street, where the noise level increases by over 3 dB(A). The average noise level in the Q-Zone decreases by 1.9 dB(A), and the average noise level outside the Q-Zone is also reduced, but only by 0.4 dB(A).

6.5.4 Introducing noise fees

Traffic effects

When noise fees are introduced, the traffic reduction is off course less. When a 5 SEK (0.5 Euro) fee is imposed, the reduction of standard vehicles mileage in the Q-Zone is reduced by 40 percent, whereas the reduction with the ban was over 60 percent.

Noise effects

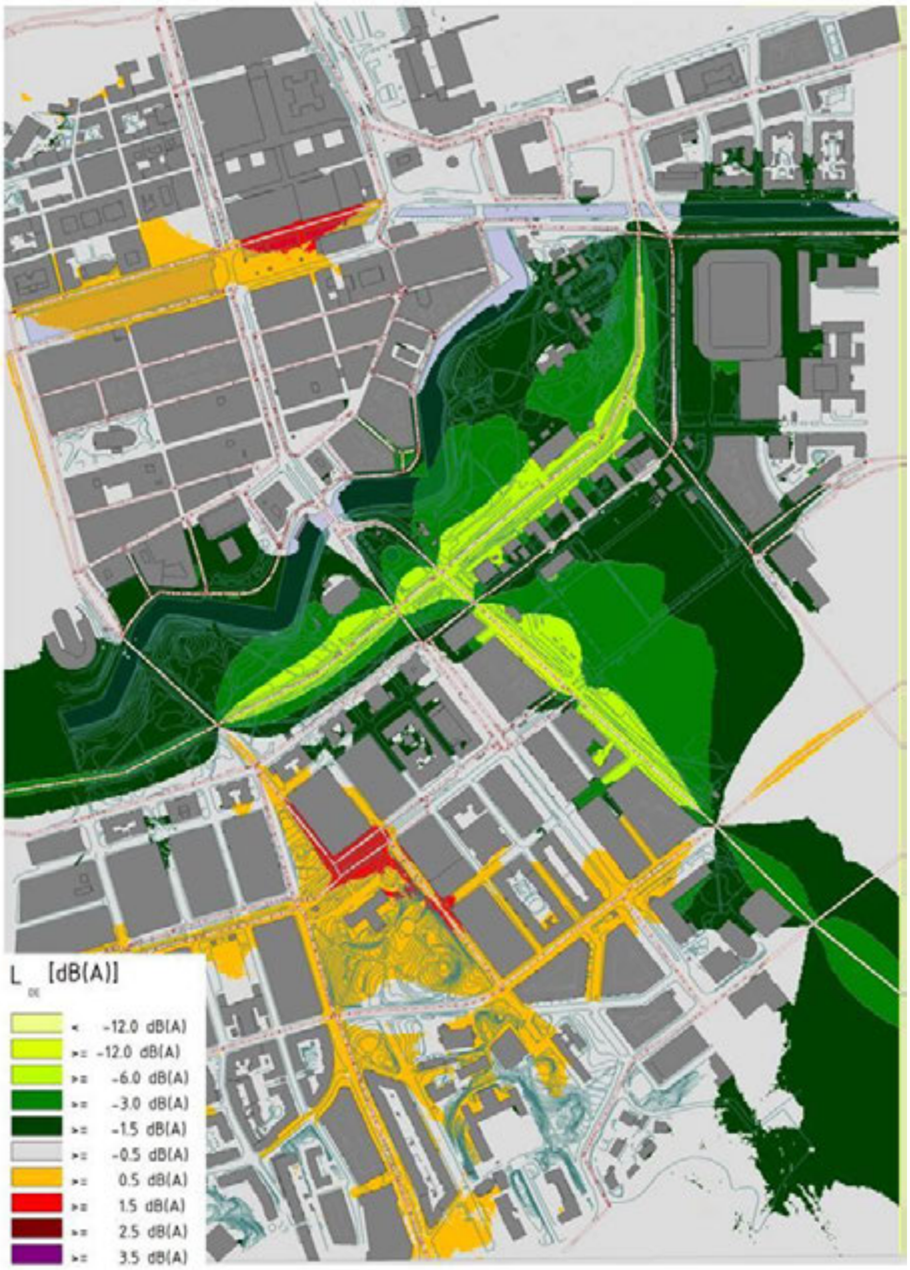

Figure 6.20 Noise difference between Q-Zone 0.5 Euro standard vehicle noise fee and base case

The fee gives a smaller traffic effect than the ban, making noise effects correspondingly smaller. The general picture is the same, but weaker. The noise level decreases by 1.3 dB(A) inside the Q-Zone, and by 0.3 dB(A) outside the Q-Zone.

6.5.5 Enlarging the Q-Zone

Traffic effects

When the Q-Zone is enlarged by including also the parallel second link along the park, traffic is consequently reduced also on that link. In figure 6.21, that effect is visible, and also a small redistribution effect to streets south of the Q-Zone (scenario with banning non resident standard vehicles).

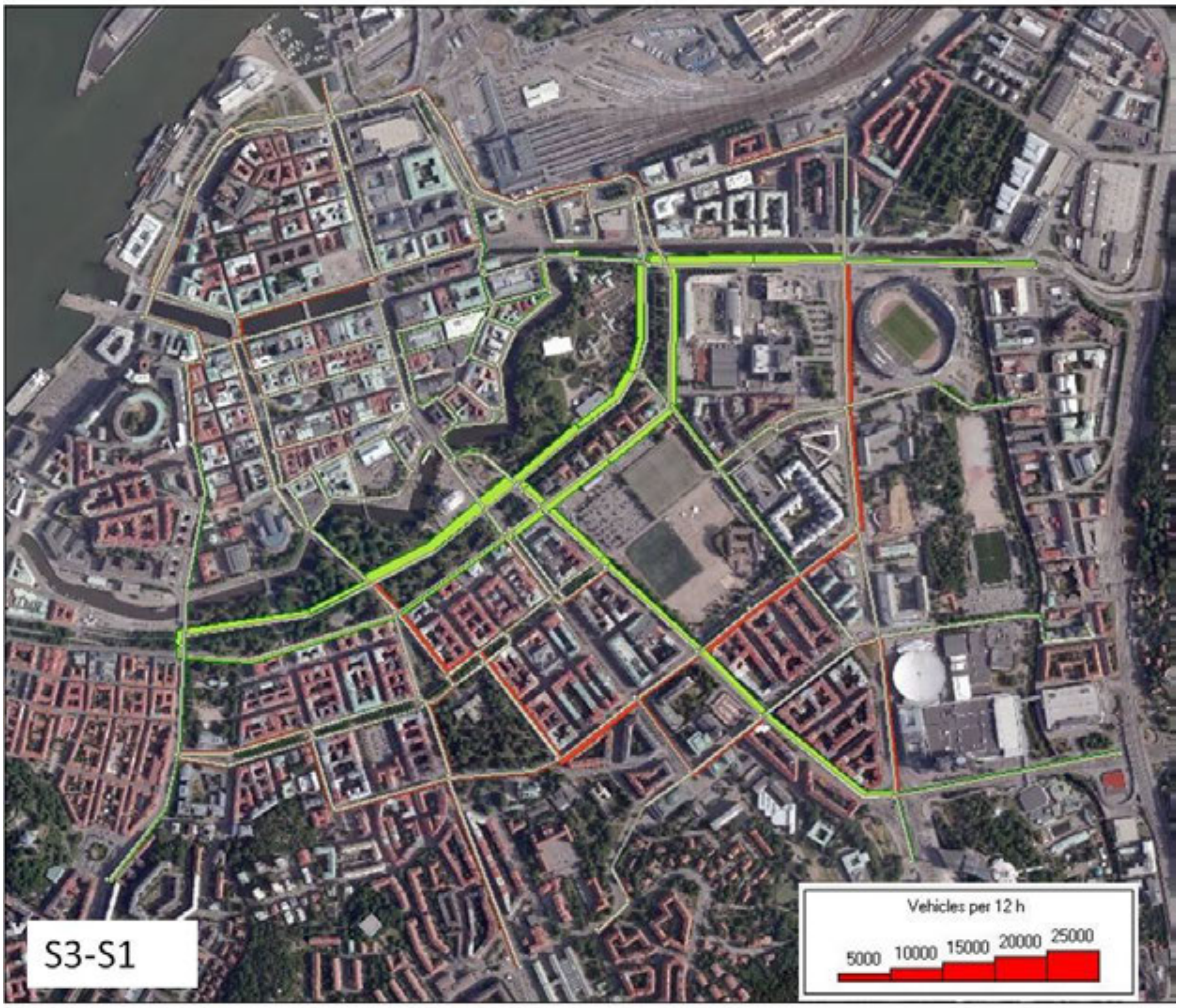

Figure 6.21 Traffic volume difference between a large Q-Zone ban and the Base case

Noise effects

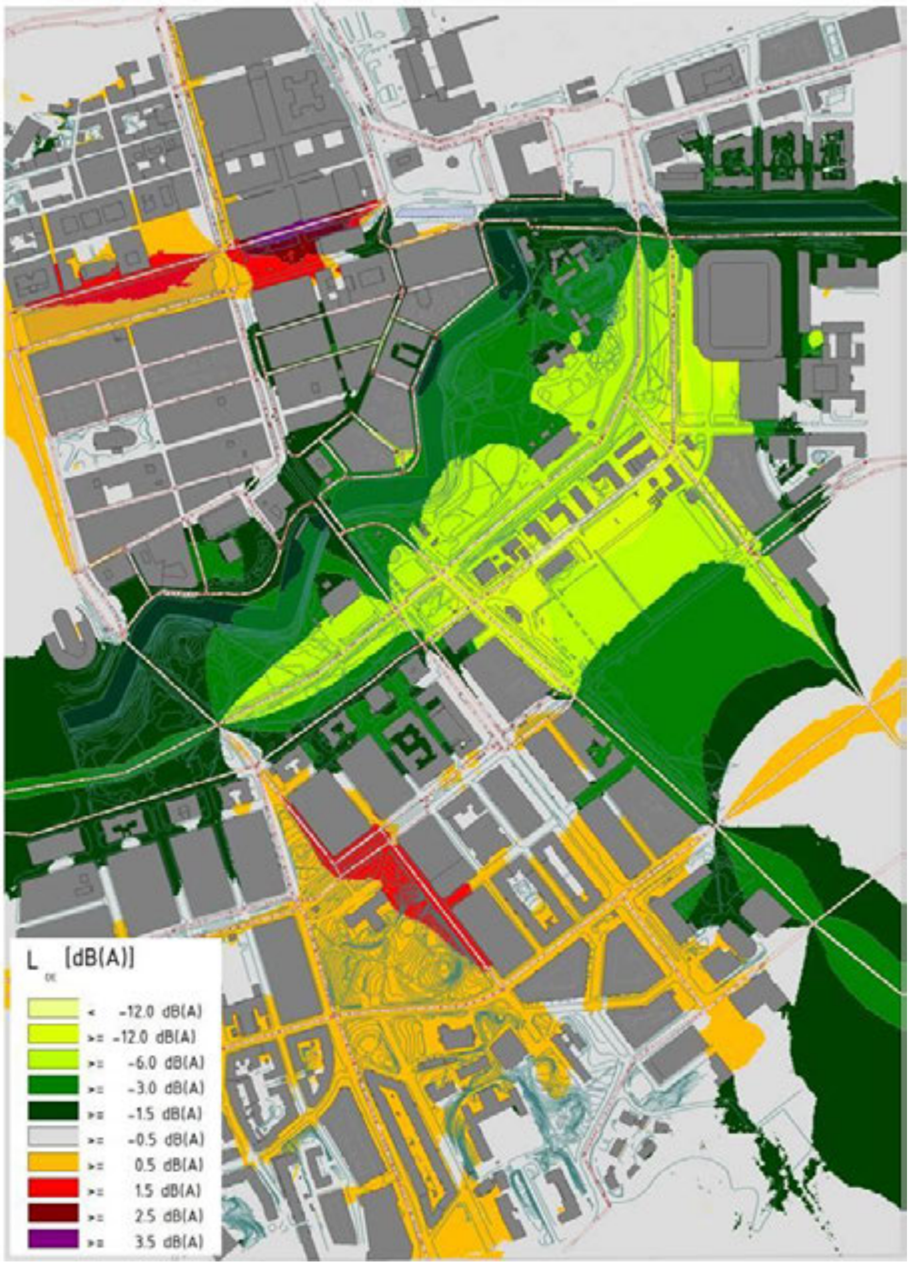

Figure 6.22 Noise difference between a large Q-Zone ban and the Base case

The main gain of this extension is that the built areas along the extension now experiences improvements up to 12 dB(A), as compared to improvements only up to 1.5 dBA() with the small Q-Zone. As could be expected, traffic redistribution now causes noise increases in larger areas, but as in previous scenarios, there are still areas outside the Q-Zone that experiences noise decreases. These effects are clearly visible on the figure. The average noise level within the Q-Zone decreases by 3.2 dB(A), and the noise level outside the Q-Zone decreases by 0.4 dB(A).

6.5.6 Increasing the low noise vehicle ownership

Traffic effects

The maximum reduction of standard vehicles - over 90 percent – among the tested scenarios is obtained with the highest levels of Low Noise Vehicle Ownership (LNVO). In this case, however, these vehicles comprise about 85 percent of the base case total mileage (1 percent in the base case). This will offset some of the gain achieved by the reduction of standard vehicles.

Noise effects

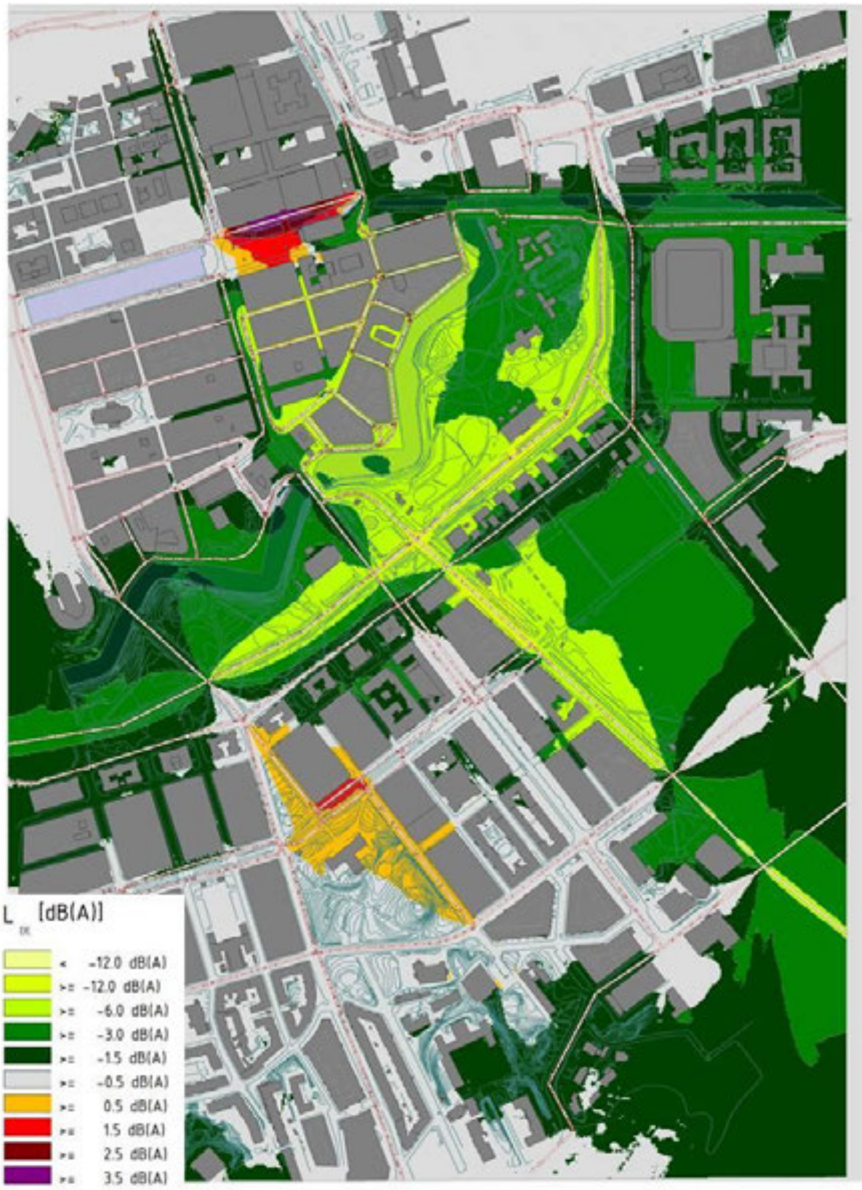

Figure 6.23 Small Q-Zone scenario with highest LNVO levels and banned standard vehicles compared to Base Case

As can be seen on figure 6.23, there is now a larger area experiencing noise improvements up to 6 dB(A). Compared to the case where the LNVO is 1 percent inside and outside the Q-Zone, a ban will now give an increase of the area with noise exposure less than 5 dB(A) of the base case situation by 50 percent. Redistribution effects are also less severe, and the average noise levels decrease by 3.6 dB(A) inside the Q-Zone, and by 0.9 dB(A) outside the Q-Zone.

6.5.7 Simulation summary

In table 6.2 the results of all simulations compared to the base case are listed. This includes traffic effects as well as noise effects. For traffic, the percent reduction of the standard and low noise vehicle mileage within the zone is shown, as well as changes in total travel time and total driven distance. For noise, the average noise level within the Q-Zone and the average noise level in the surrounding area is shown (also in figure 6.24) as well as the area with average noise exposure less than 5 dB(A) of the base case average (absolute and relatively).

In contrast to the previous test sites, negative changes of travel time and distance result from some scenarios. This should not necessarily be seen as benefits – they are consequences of changes in modes and destinations, which are included the Gothenburg forecasting model. These changes also imply costs to the individuals changing their behaviour, but which are less severe than the cost of maintaining their original mode and destination choice.

Table 6.2 Gothenburg simulation summary

Scenario	Q-Zone	Percent-age of standard vehicles in QZ of base case traffic	Percent-age of low noise vehicles in QZ of base case traffic	Total travel time change	Total distance change	Average noise level in QZ	Average noise level in surroun-ding area	Area with noise exposure < 5 dB of BC average	Area with noise exposure < 5 dB of BC average
		[%]	[%]	[hours/ day]	[vehicle km/day]	Lde [dB(A)]	Lde [dB(A)]	[m²]	[%]
BC_M	medium	99%	1%	0	0	58,3	56,0	14485	6%
G1	medium	37%	2%	-640	-40440	56,4	55,6	41832	17%
G5	medium	60%	2%	160	-160	57,0	55,7	29625	12%
G15	medium	81%	19%	0	0	57,9	55,5	15800	6%
G16b	medium	7%	86%	-1360	-72000	54,7	55,1	64820	26%
BC_L	large	99%	1%	0	0	59,1	55,8	19348	7%
G3	large	30%	1%	-1280	-52640	55,9	55,4	85064	30%
G7	large	48%	1%	40	-8240	56,6	55,5	41604	15%
G13	large	26%	36%	-240	-17120	55,5	54,9	90684	32%

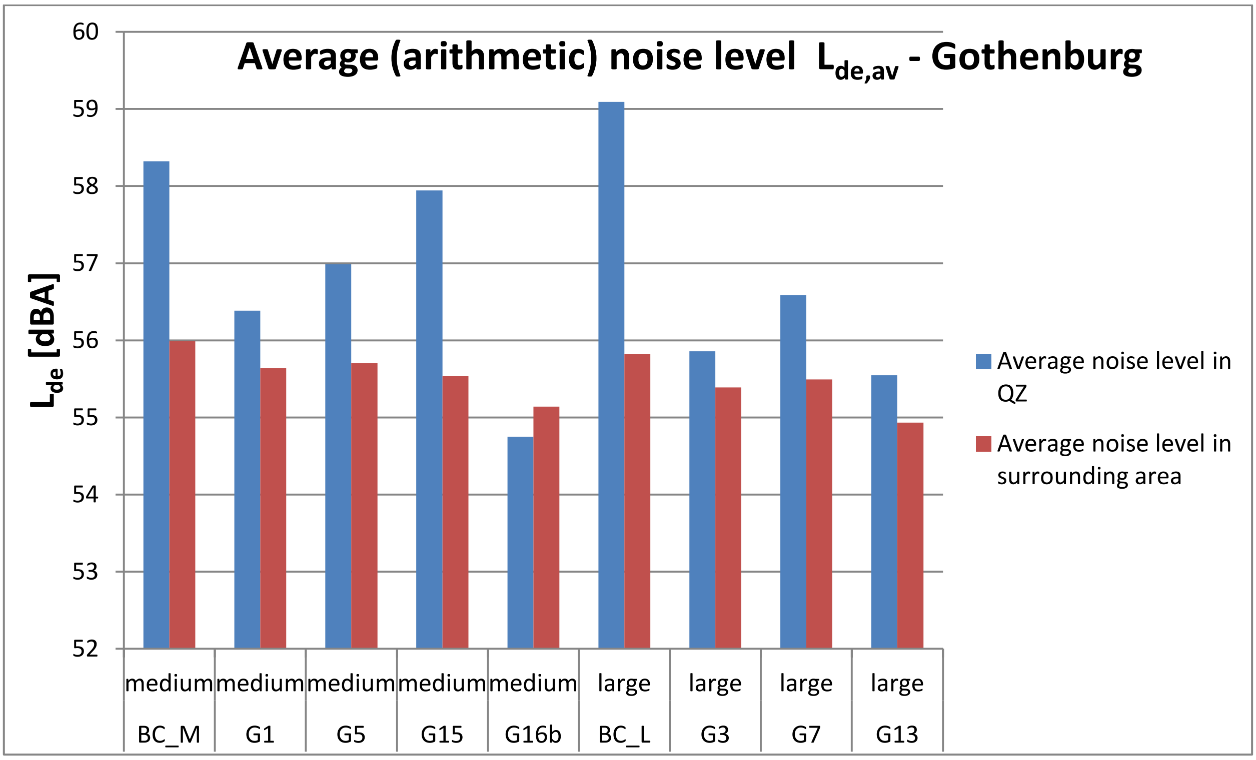

Figure 6.24 Average arithmetic noise levels in Gothenburg scenarios

Discussion

In Gothenburg, the introduction of the small Q-Zone gives a reduction of the average noise level in the Q-Zone of about 2 dB(A) when non-residents standard vehicles are banned. For the large zone, a reduction of about 3 dB(A) is achieved. If a noise fee of 0.5 Euros per entry or exit is introduced, a reduction of about 70 percent of the reduction with a ban is achieved.

The mere increase of the LNVO from 1 to 20 percent areawide gives about half a dB(A) noise reduction. But when a ban is introduced (medium Q-Zone) and the resident LNVO is increased to 100 percent, a noise reduction of about 3.5 dB(A) is achieved – almost the double. If a 0.5 Euro noise fee is established in the large zone under the same LNVO conditions, the average noise reduction will be about the same. This is the scenario which gives the largest improvement of percent area with more than 5 dB(A) noise reduction (about 30 percent).

In all cases, the noise level in the surrounding area is also reduced (marginally). This is because redistribution effects are small, which in turn depends on the fact that the area is already traffic zoned – there is no through traffic to redistribute.

The Gothenburg case shows that

- Q-Zones that are introduced in already traffic zones areas are not likely to bring about as large average effect as in areas which suffer from high levels of through traffic
- Higher levels of LNVO can still give significant improvements in terms of percent area with noise levels lower than 5 dB(A) of the base Case average

7 STOCKHOLM TEST SITE

7.1 General Information on the City of Stockholm

Stockholm is the capital of Sweden. The municipality of Stockholm covers an area of 188 square kilometres, and has a population of about 840,000. The population density is 4,500 persons/km².

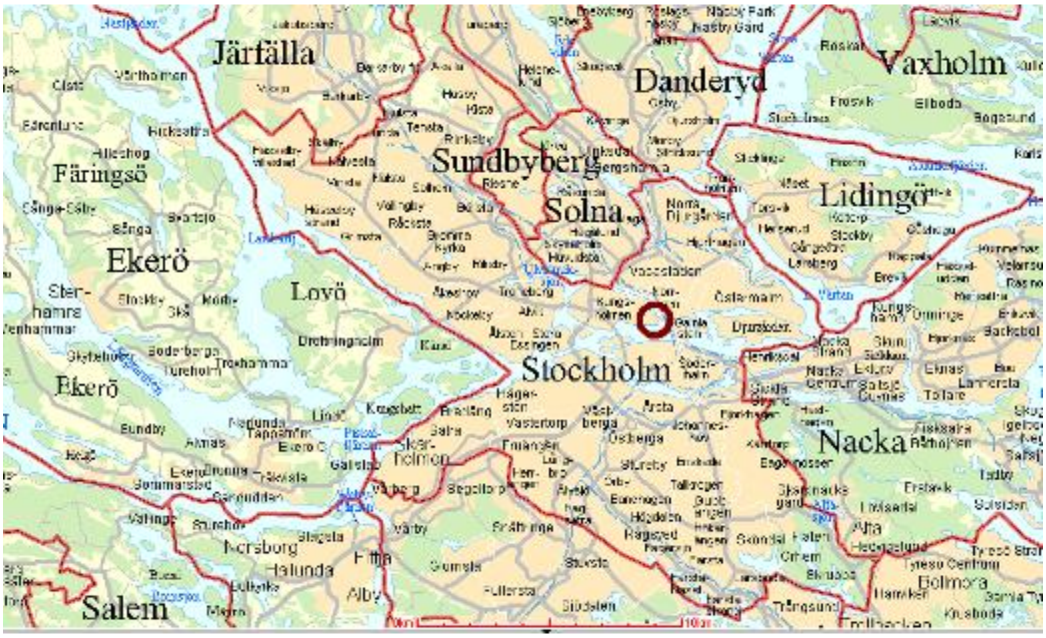

Figure 7.1 Stockholm.

The city is located on the border between the Mälar Lake and the Baltic Sea. It contains many islands connected by bridges. The inner city is shown in Figure 7.2.

Figure 7.2

Stockholm inner city.

7.2 TEST SITE SELECTION

7.2.1 Noise conditions

For Stockholm, noise mapping has been undertaken for the whole municipality, and was finished in the year 2006. The Stockholm noise conditions are presented (in Leq 24h) on the resulting noise maps (Figure 7.3). Figure 7.4 shows the central parts of the city.

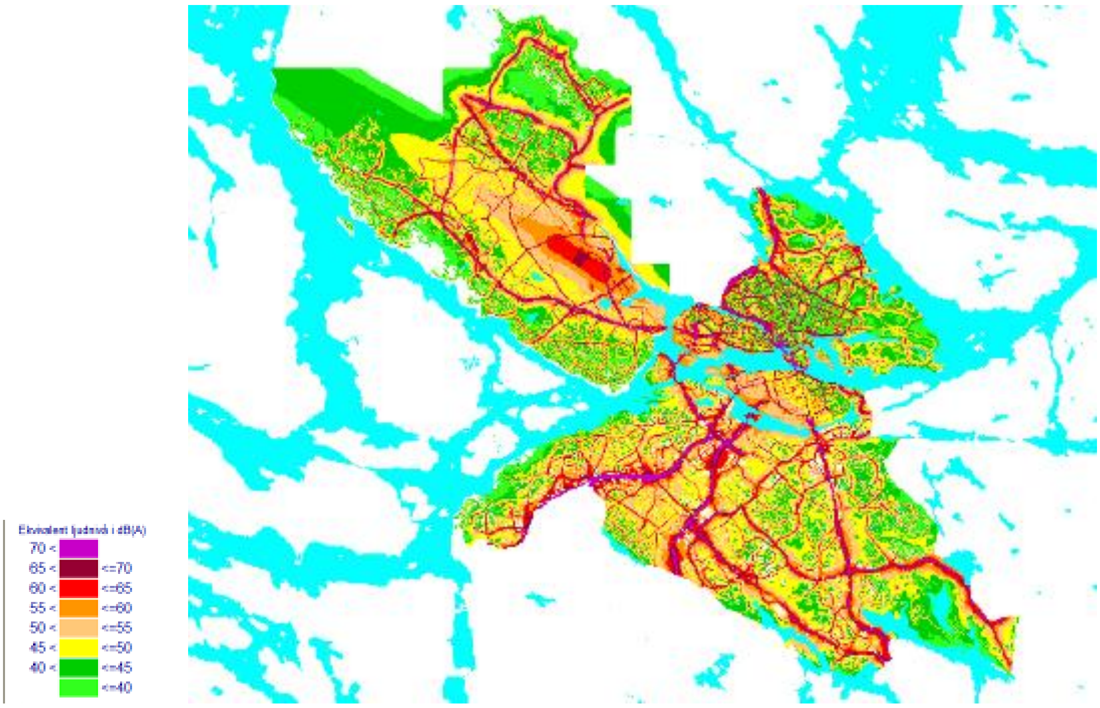

Figure 7.3

Noise map for Stockholm (noise levels in L_{eq24h})

Figure 7.4 Noise map for central Stockholm (noise levels in L_{eq24h})

7.2.2 Potential for Q-zones

The western part of the Södermalm island is more severely hit by noise disturbance than many other parts of the inner city. This area also contains larger and smaller parks that would benefit from being included in a Q-zone. As there are several possible parks to include In a Q-zones, this area provides an opportunity to study different zone sizes which is one of the WP objectives. Another reason to choose Södermalm is that there is a discussion on extending the current ban on studded tyres on Hornsgatan (red in Figure 7.5) to a larger part of the island.

Figure 7.5 Södermalm island

7.2.3 Selected Q-zone area

After discussion with the Stockholm Municipality partner, it was decided to choose the area indicated on Figure 7.6. The area is not only disturbed by car traffic – a railway line also crosses part of the area. The area contains several parks, and is also suitable for testing smaller Q-zone sizes. A smaller zone size is shown in Figure 7.7. A third, smaller, zone size is shown in Figure 7.8

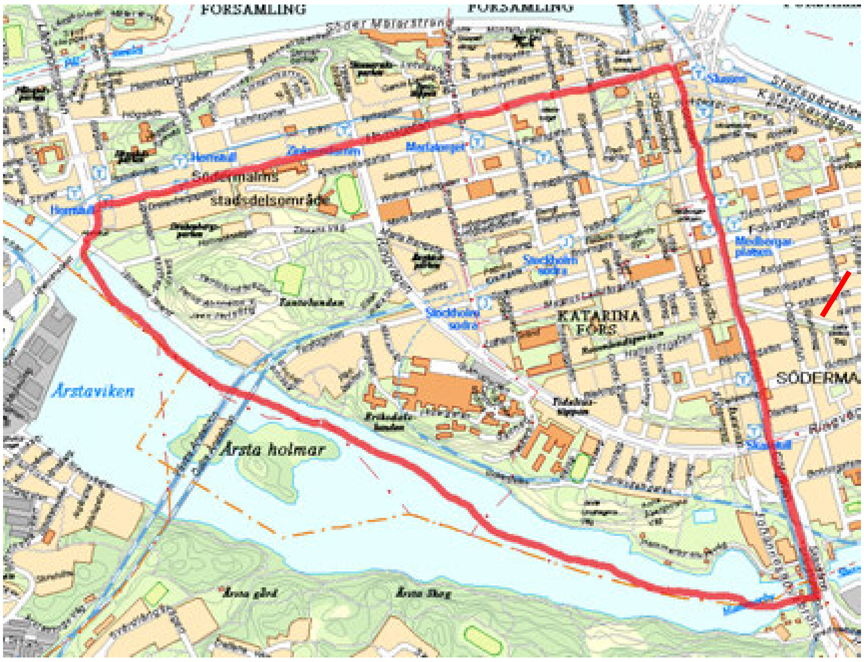

Figure 7.6

Intended Q-zone area

Figure 7.7

Smaller Södermalm Q-zone

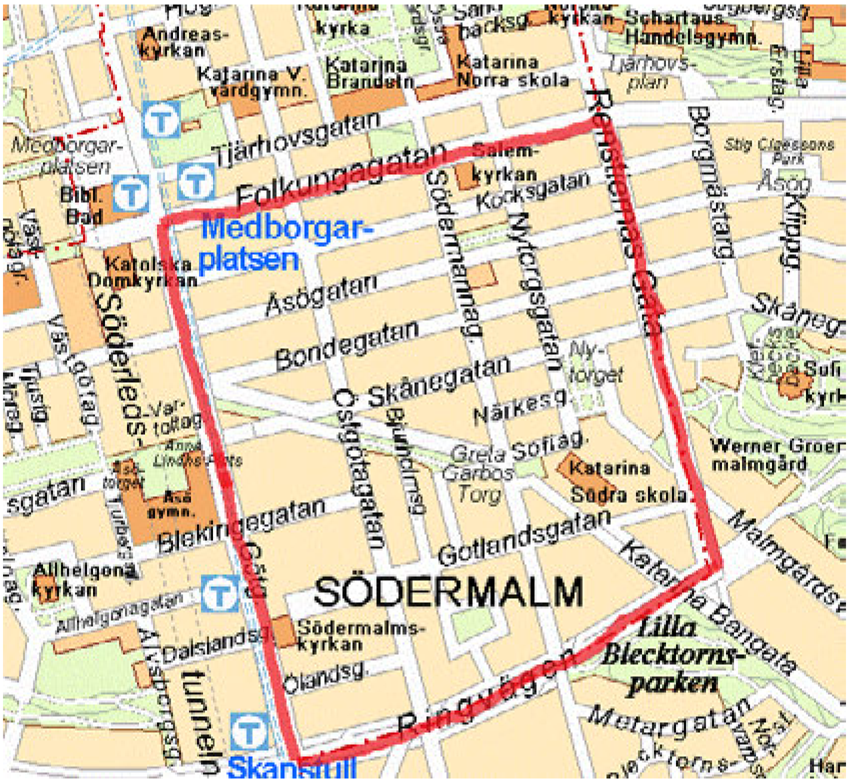

Figure 7.8

Smallest Södermalm Q-zone

7.3 AVAILABLE NOISE MODEL

7.3.1 Digital terrain model

A digital terrain model was created when the noise mapping was done. The relevant part of the city is shown in Figure 7.9.

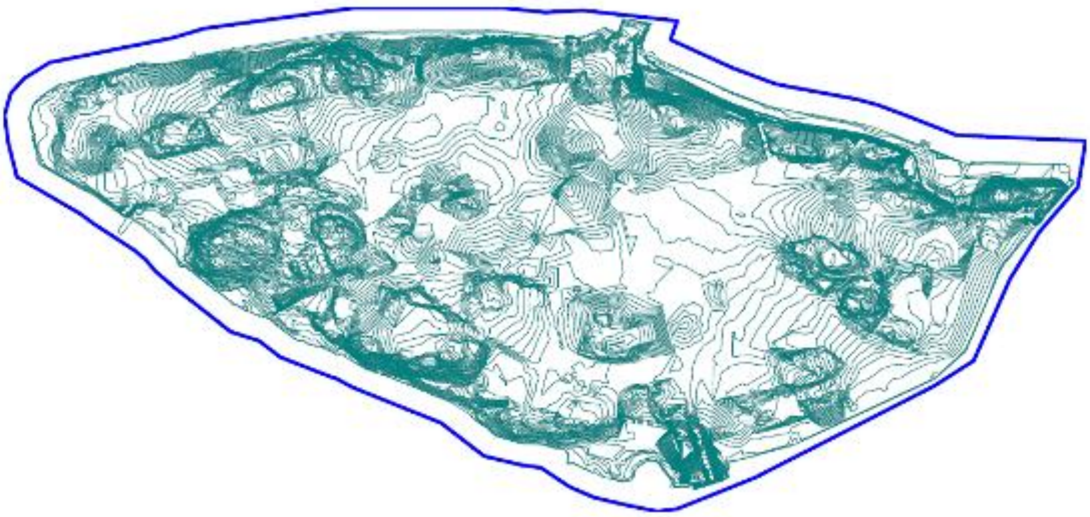

Figure 7.9

The digital terrain model for the island Södermalm

7.3.2 Road and traffic information

The roads that were used in the noise mapping are shown in Figure 7.10. The figure also shows the speed that was used for each link in the original noise map (for the simulations, speeds were calculated depending on congestion).

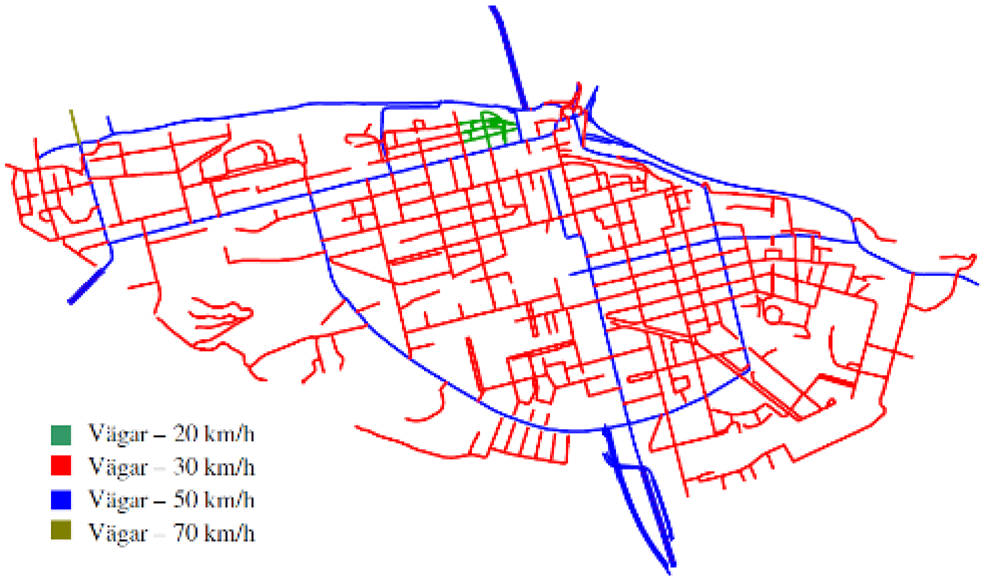

Figure 7.10

Roads used for noise mapping

7.3.3 Rail and tram information

The parts of Södermalm island affected by rail and tram noise can be seen in Figure 7.11.

Figure 7.11

Rail and tram noise

One national railway line is relevant for the selected part of the city. It enters the island in the southeast via two parallel bridges, and then goes into a tunnel. The trains leave the tunnel in the central northern part of the island and enter a bridge. This line is causing the noisy spots in the southeast and the north. It also causes the central noisy spot, due to an opening in the tunnel. That opening will be closed by 2017 when a major reconstructing for the commuter trains will be finished.

One eastbound regional railway line starts in the northern central part. It causes the noise in the east and contributes to the noise in the north.

Two subway lines cross the island, leaving their tunnel in the north and in the south. Therefore they create the noise in the south and contributes to the noise in north.

7.3.4 Noise barriers

Noise barriers are included in the Stockholm noise mapping. For the island of Södermalm only one noise barrier is relevant. It is located at the central railway line, in the southeast of the island. That noise barrier was not erected (or at least not included) when the noise map in Figure 7.11 was created.

7.3.5 Buildings and inhabitants

The buildings included in the noise mapping are shown in Figure 7.12. There may be slight differences between this map and Figure 7.11. The railway noise mapping was made earlier.

Figure 7.12

Buildings included in the noise mapping

In the noise mapping the number of exposed inhabitants was calculated according to the European Noise Directive. For the entire city the number of people exposed to more than 55 dB(A), LDEN from road traffic was 271,415. For the island of Södermalm the number was 40,624. The corresponding number for rail and tram traffic were 49,819 for the city and for Södermalm 2 382.

7.4 AVAILABLE TRAFFIC MODEL

7.4.1 Network model

Stockholm Is included in the national Sampers forecasting system. The Emme network assignment model is integrated in the Sampers system. For CityHush, a version containing 1,500 zones and 30,000 links was used. Public transport lines are also included in the model.

The network is shown in Figure 7.13 as an Emme screenshot.

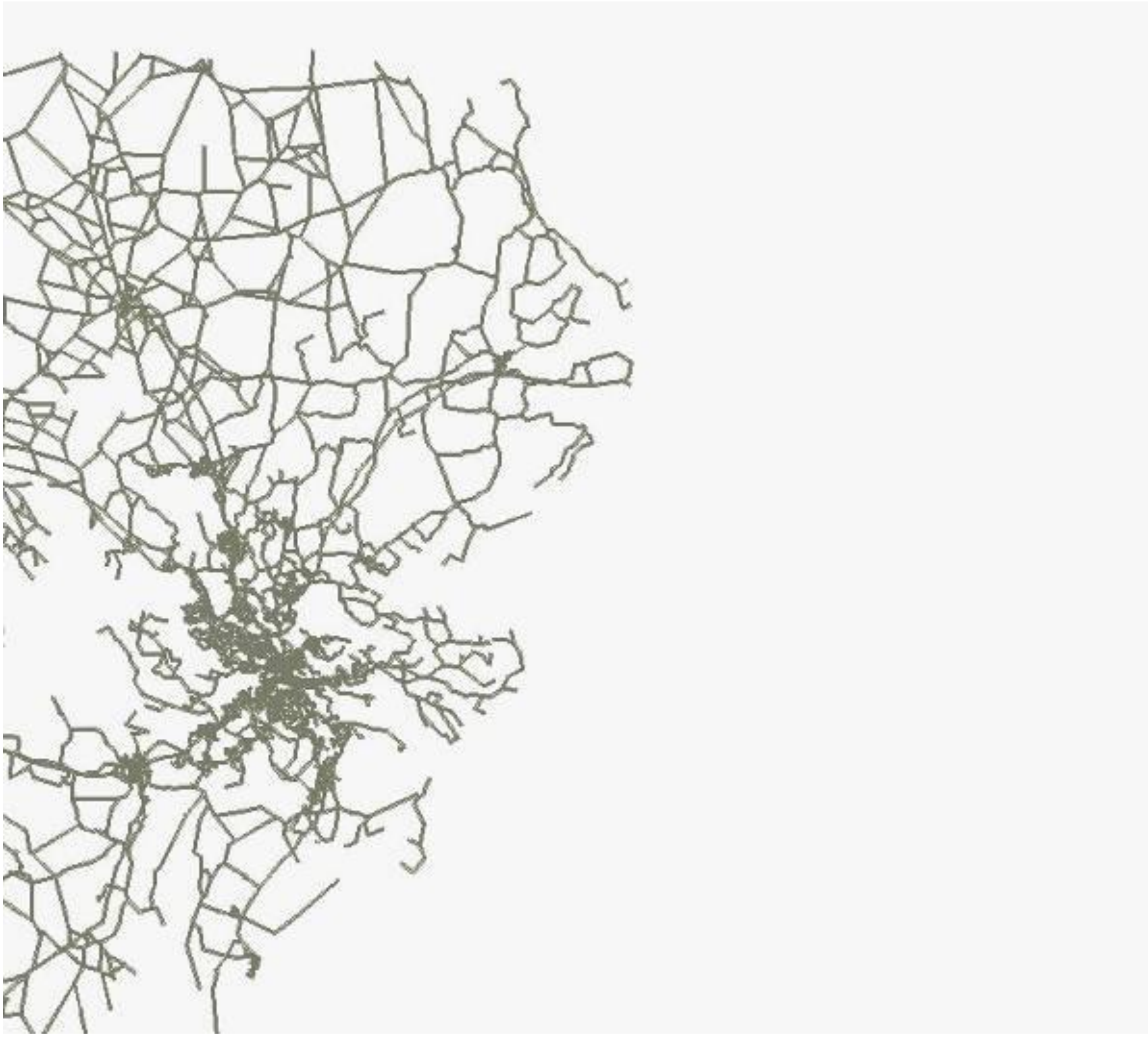

Figure 7.13 Emme network for Stockholm

Figure 7.14 shows the network of the central parts of Stockholm. All streets except very minor roads are contained in the network. The intended Q-zone area is marked with red.

Figure 7.14
Emme network for central Stockholm

7.4.2 Demand models

In the Sampers system, traffic assignment is done for the morning peak hour and one midday hour. Congestion is treated by using link specific volume-delay functions for all regular links (i.e. not connectors). Multiclass assignment is used, in order to regard different values of time.

The travel demand models I Sampers include mode and destination choice models.

7.4.3 CityHush adaptation

More detail needs to be added to the Södermalm part of the network for links as well as zones. The assignment is based on time and cost, as there is already a congestion charging system in operation. A conversion from monetary units to time units is necessary to reflect the cost impedance of congestion charges as well as noise fees. This conversion is done using the Sampers system values of time. The resulting value of time distribution is shown in Table bsd.

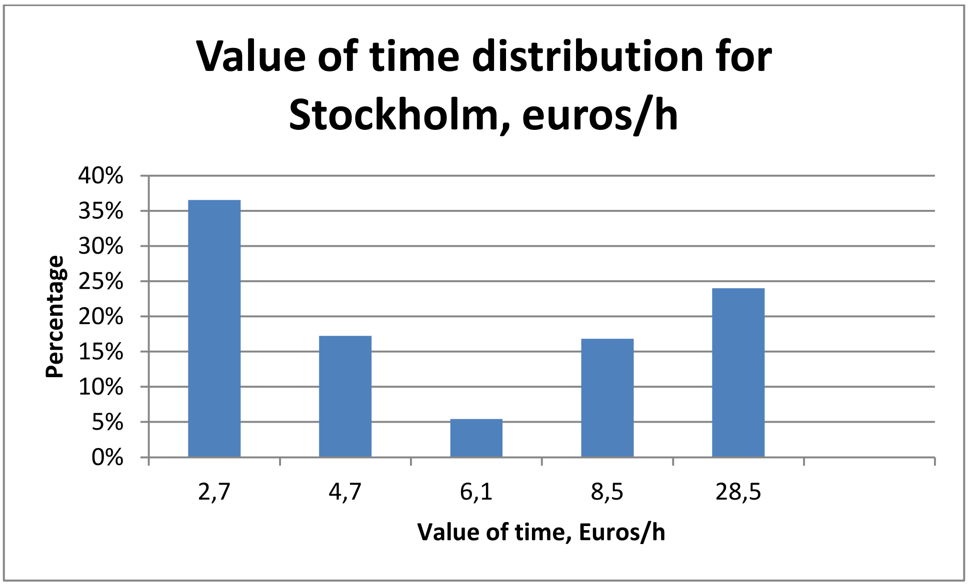

Figure 7.15 Value of time distribution for Stockholm, Euros/h

7.5 TRAFFIC SIMULATIONS

The Sampers Stockholm application allows for traffic simulations concerning not only car route choice but also mode and destination choice. Therefore, effects with respect to changes of modes, destinations and travel frequency are also included.

7.5.1 Simulated scenarios

For Stockholm, the following set of traffic scenarios was simulated:

Table 7.1 Simulated scenarios for Stockholm

Scenario nr	Zone	Fee, Euros/passage	Inside LNVO percentage	External LNVO percentage
0	-	none	1	1
1	small	Low noise vehicles only	1	1
2	medium	Low noise vehicles only	1	1
3	large	Low noise vehicles only	1	1
4	large	Noise fee 10 kr	1	1
5	large	Noise fee 5 kr	1	1
6	medium	Noise fee 10 kr	1	1
7	medium	Noise fee 5 kr	1	1
8	small	Noise fee 10 kr	1	1
9	small	Noise fee 5 kr	1	1
10	large	Low noise vehicles only	20	5
11	large	Noise fee 5 kr	20	5
12	large	Low noise vehicles only	100	20
13	large	Noise fee 5 kr	100	20
14	-	none	5	5
15	-	none	20	20
16	medium	Low noise vehicles only	100	20

7.5.2 Q-Zone borders

For Stockholm, three zone sizes were defined. The Q-Zone's are defined as shown in Figure 7.16. The yellow solid line indicates the small Q-Zone border, the solid red line indicates the medium Q-Zone and the dashed red line indicates the enlargement of the medium zone to the largest Q-Zone.

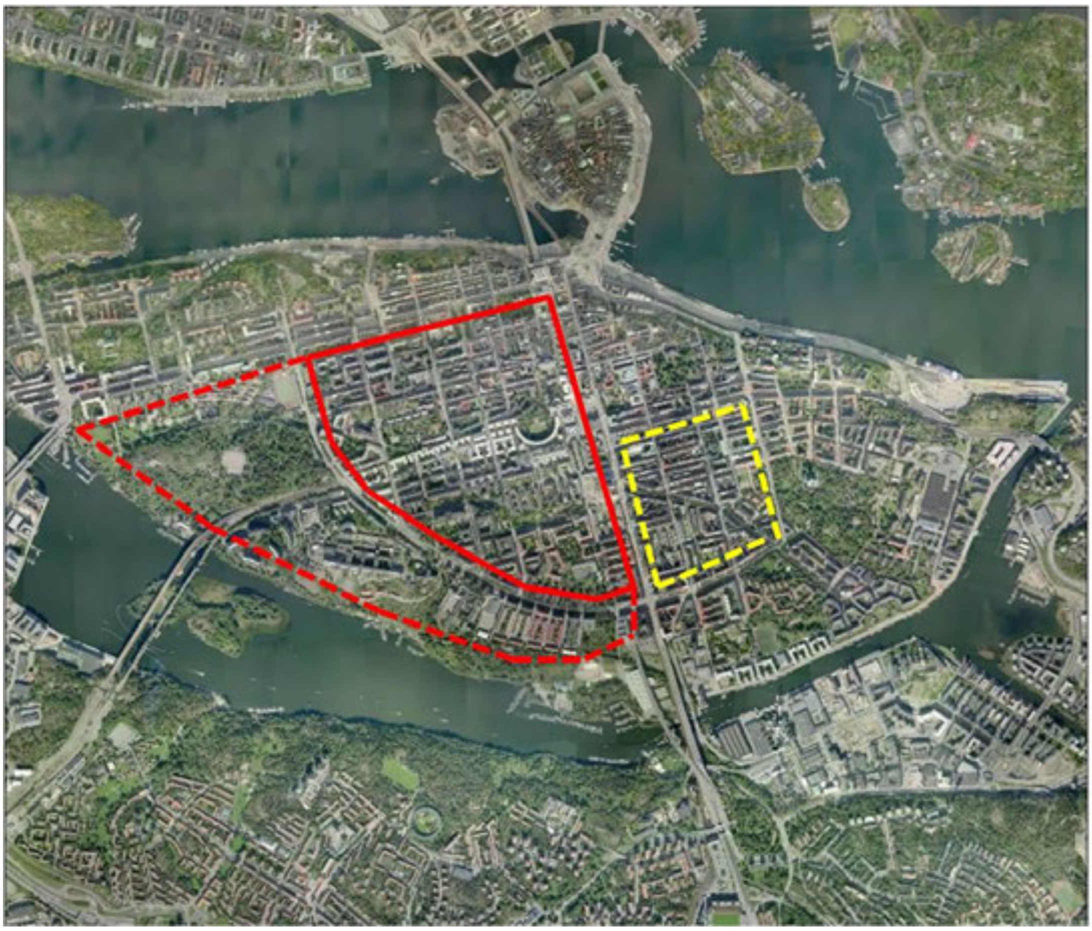

Figure 7.16 Stockholm Quiet Zone borders

7.5.3 Establishing a Q-Zone - simulation results

Traffic effects

We now present the simulation results of an introduction of the medium Q-Zone (defined in the previous section) by banning entry and exit of all standard vehicles. The following figure shows the base case (the bandwidths are proportional to traffic volumes) for the peak period:

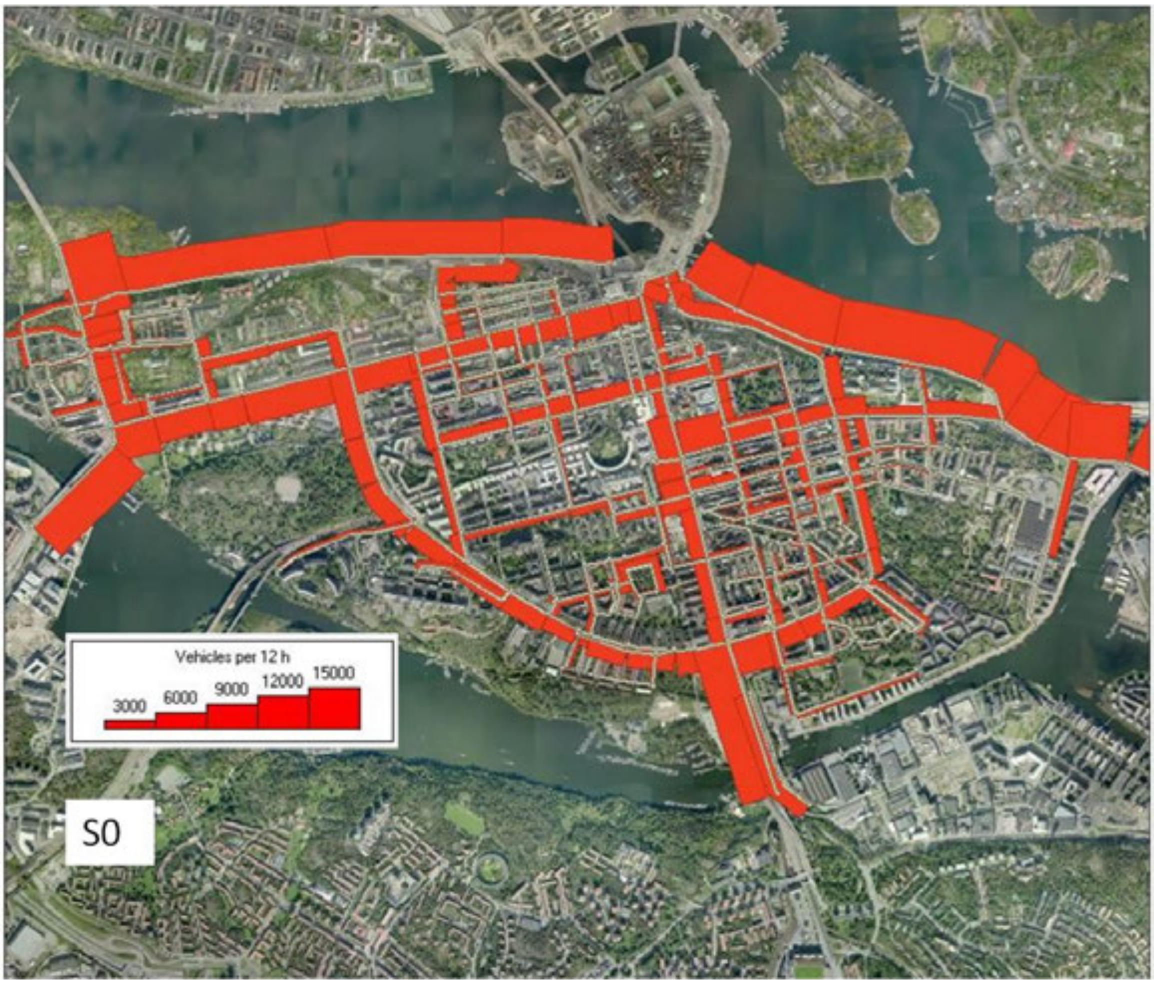

Figure 7.17 Base case day traffic volumes

On the next figure, the difference to the base case is shown using the same scale for traffic flow difference as for traffic flows in the preceding figure. On figure 7.18 green bands indicate traffic reductions, and red bands indicate traffic increase.

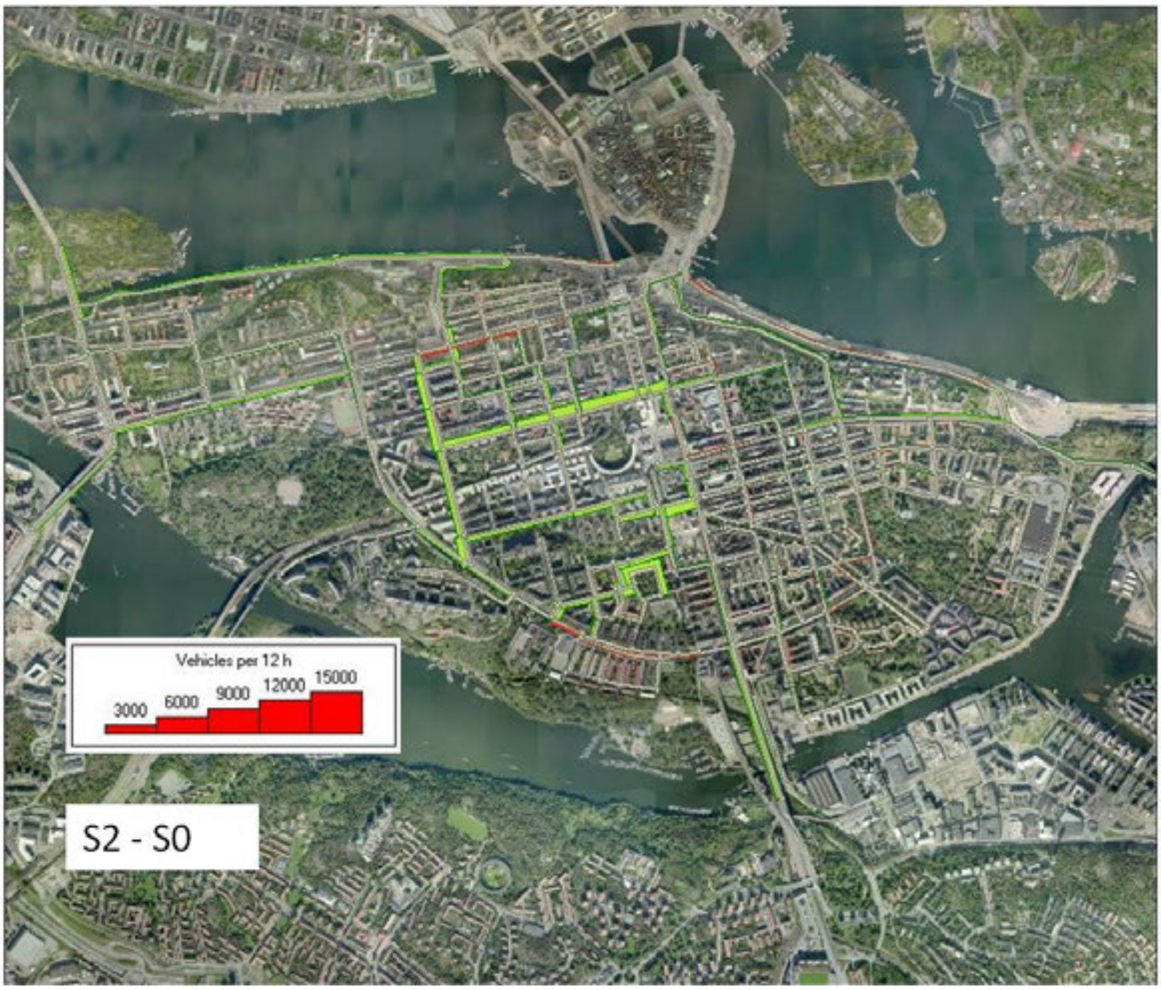

Figure 7.18 Difference between Q-Zone standard vehicle ban and base case, day traffic

About half of the total traffic volume in the Q-Zone will be reduced by the ban. There are no large redistribution effects, mainly because most of the original traffic had its origin or destination in the Q-Zone. There is only a slight increase on the southern bordering street. The explanation is that the model allows for substitution of mode and destination in addition to route changes. By introducing the ban, switching mode and/or destination becomes unavoidable. Most of the remaining traffic in the zone will have both origin and destination within the Q-Zone. The neighbouring small Q-Zone is not visibly affected.

Noise effects

Figure 7.19 Difference between Q-Zone standard vehicle ban and base case, day traffic

Banning non resident standard vehicles gives noise level improvements in the range up to 6 dB(A) in large parts of the Q-Zone. The average noise level improves by 2 dB(A) inside the Q-Zone, whereas the average noise level outside the Q-Zone remains unchanged.

Although not visible from total volumes, it appears that there are some noise effects on the neighbouring small Q-Zone area. This is because there are some changes in flows that are numerically quite small, but strong in a relative sense.

7.5.4 Introducing noise fees

Traffic effects

Introducing noise fees instead of a ban makes it possible to choose the previous mode, destination and route, but at a higher cost. This is reflected in the traffic volumes as a lower decrease of vehicle kilometres. Instead of a decrease of 50 percent, only a 30 percent reduction is obtained by the 1 Euro noise fee, If the noise fee is 0.5 Euro, the reduction will be 25 percent.

Noise effects

The fee scenarios imply smaller noise improvements than the ban scenario. The average noise level inside the Q-Zone improves by 1.3 and 1.1 db(A) respectively. The impact on the outside noise level is still small (an increase by 0.1 dB(A)).

Figure 7.20 Difference between Q-Zone 1 Euro fee scenario (medium Q-zone) and base case, day traffic

7.5.5 Q-Zone – zone size

Traffic effects

For Stockholm, three Q-Zone sizes were tested. The tested Q-Zone sizes are shown on figure 7.16. Figure 7.21 shows the effect of the extension to the large zone size (with the same scale as before) compared to the medium Q-Zone scenario with banned non-resident standard vehicles.

Figure 7.21 Difference between Q-Zone large and medium zone sizes, day traffic

There is a large traffic flow decrease on the extension, leading to a 55 percent reduction in the large Q-Zone, compared to the 30 percent reduction obtained by the medium Q-Zone introduction. The reduction within the medium zone is now a few percent less. The small increase on the already existing (medium) Q-Zone is because there is more scope for internal traffic when the Q-Zone becomes larger.

For the small Q-Zone, the result is shown in figure 7.22, using the same scale as before.

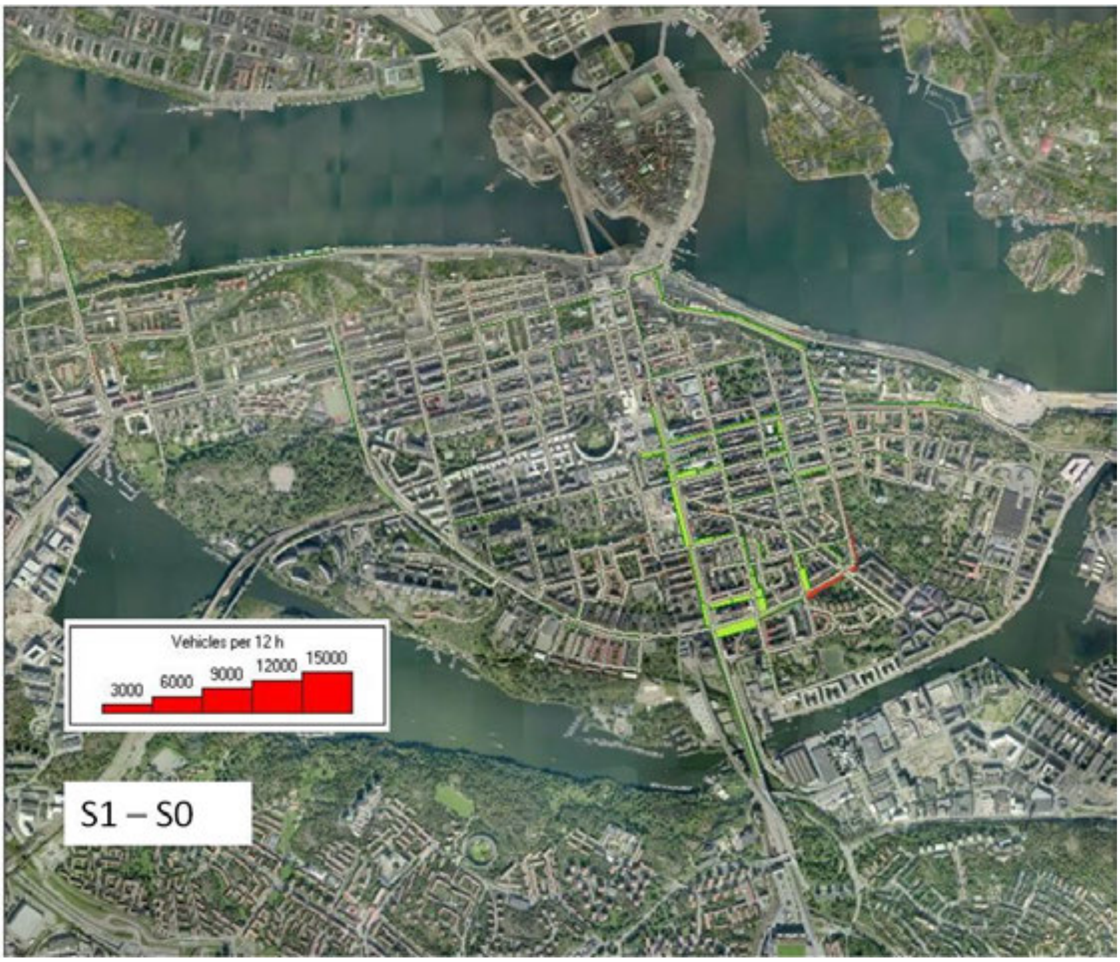

Figure 7.22 Traffic flows in Small Q-Zone compared to base case, day traffic

The traffic reduction is about 40 percent of the total vehicle km in the small Q-Zone. There is a reduction also on the bordering streets. The redistribution effect is quite small, because the base case traffic volumes are small. A small traffic increase on part of the southern bordering street is visible.

The traffic reduction is larger when the zone size increases. This can be expected as larger zone sizes are more likely to contain streets that are used for through traffic.

Noise effects

In figure 7.23, it can be seen that although the improved area has increased, the improvement levels are less outspoken. This is because with the large Q-Zone, some of the route choice effects are not there anymore – with the medium Q-Zone, car drivers could take the boundary street to avoid the fee or ban, but with the large Q-Zone, this does not pay off and the previous routes could be preferred again. The average noise level within the Q-Zone is improved by 2 dB(A), and the outside level is improved by 0.6 dB(A).

Figure 7.23 Large Q-Zone with banned standard vehicle compared to Base case

In figure 7.24, effects of introducing a small Q-Zone is shown. The average noise level within the Q-Zone is improved by 1.3 dB(A), and the outside level is unchanged. As is visible from the figure, although the outside level is unchanged, the distribution of noise levels has changed.

Figure 7.24 Small Q-Zone with banned standard vehicle compared to Base case

7.5.6 Increasing the low noise vehicle ownership

Traffic effects

As LNV ownership levels increase, the number of standard vehicles will be reduced. In stead, the number of LNV vehicles will increase, so the volume effect caused by the bans or fees will be offset to some extent. The time cost of the bans/fees will be somewhat reduced in the case where LNV ownership increases to 5 percent outside the Q-Zone and 20 percent inside the Q-Zone, and even more reduced in the case where LNV ownership becomes 20 percent outside the Q-Zone and 100 percent inside the Q-Zone. First, the change achieved by a general increase in LNVO to 20 percent is shown (figure 7.25). Then, In figure 7.26, the additional effect of a ban is shown.

Figure 7.25 Difference between 20 percent LNVO and 1 percent LNVO, no Q-Zone.

Figure 7.26 Medium Q-Zone scenario with highest LNVO levels and banned standard vehicles compared to 20 percent LNVO everywhere and no Q-Zone

The effect of the ban is larger when the LNVO is at its highest level. This is because now all residents will be driving LNV. The total vehicle kilometres is however almost as large as in the base case, so the volume effect of the ban is now lost as compared to the case with the lowest level of LNVO.

Noise effects

Figure 7.27 Medium Q-Zone scenario with highest LNVO levels and banned standard vehicles compared to Base Case

The noise effect of the medium Q-Zone ban policy with the highest LNVO is large compared to the base case. In large parts of the Q-Zone, effects between 6 – 12 dB are obtained and in some parts even effects over 12 dB(A) are achieved. The average improvement in the Q-Zone is 3.7 dB(A), and outside the Q-Zone the improvement is 0.8 dB(A). Similar effects are obtained also for the large zone.

7.5.7 Simulation summary

In table 7.2 the results of all simulations compared to the base case are listed. This includes traffic effects as well as noise effects. For traffic, the percent reduction of the standard and low noise vehicle mileage within the zone is shown, as well as changes in total travel time and total driven distance. For noise, the average noise level within the Q-Zone and the average noise level in the surrounding area is shown (also in figure 7.27) as well as the area with average noise exposure less than 5 dB(A) of the base case average (absolute and relatively).

In contrast to the previous test sites, negative changes of travel time and distance result from some scenarios. This should not necessarily be seen as benefits – they are consequences of changes in modes and destinations, which are included the Stockholm forecasting model. These changes also imply costs to the individuals changing their behaviour, but which are less severe than the cost of maintaining their original mode and destination choice.

Table 7.2 Stockholm simulation summary

Scenario	Q-Zone	Percentage of standard vehicles in QZ of base case traffic	Percentage of low noise vehicles in QZ of base case traffic	Total travel time change	Total distance change	Average noise level in QZ	Average noise level in surround-ing area	Area with noise exposure < 5 dB of BC average	Area with noise exposure < 5 dB of BC average
		[%]	[%]	[hours/day]	[vehicle km/day]	Lde [dB(A)]	Lde [dB(A)]	[m²]	%
BC	large	99%	1%	0	0	45,0	45,9	141600	6
S3	large	46%	1%	-4280	-20280	43,0	45,3	179480	8
S4	large	72%	1%	-1800	-56640	44,3	45,9	158160	7
S5	large	80%	1%	-960	-97040	44,5	46,0	154260	7
S10	large	41%	6%	-4600	-99120	43,2	45,6	175360	7
S11	large	72%	10%	-840	-9840	44,3	45,9	157760	7
S12	large	4%	16%	-4560	-95200	41,2	45,1	192440	8
S13	large	39%	50%	-4560	-95200	43,2	45,3	176200	8
BC	medium	99%	1%	0	0	45,0	45,6	87860	7
S2	medium	48%	1%	-2120	-56640	43,0	45,6	101380	8
S6	medium	71%	1%	1160	48480	43,7	45,7	97700	8
S7	medium	77%	1%	-400	-4040	43,9	45,7	96500	8
S14	medium	95%	5%	-200	-2400	45,0	45,6	86980	7
S15	medium	82%	18%	-520	3600	44,8	45,2	89000	7
S16	medium	9%	87%	-4600	-116000	41,3	44,8	106200	8
BC	small	99%	1%	0	0	47,1	45,3	27240	6
S1	small	59%	1%	-1200	-20280	45,8	45,3	30140	7
S8	small	69%	1%	280	-4000	46,2	45,4	29560	7
S9	small	73%	1%	760	0	46,4	45,4	29060	7

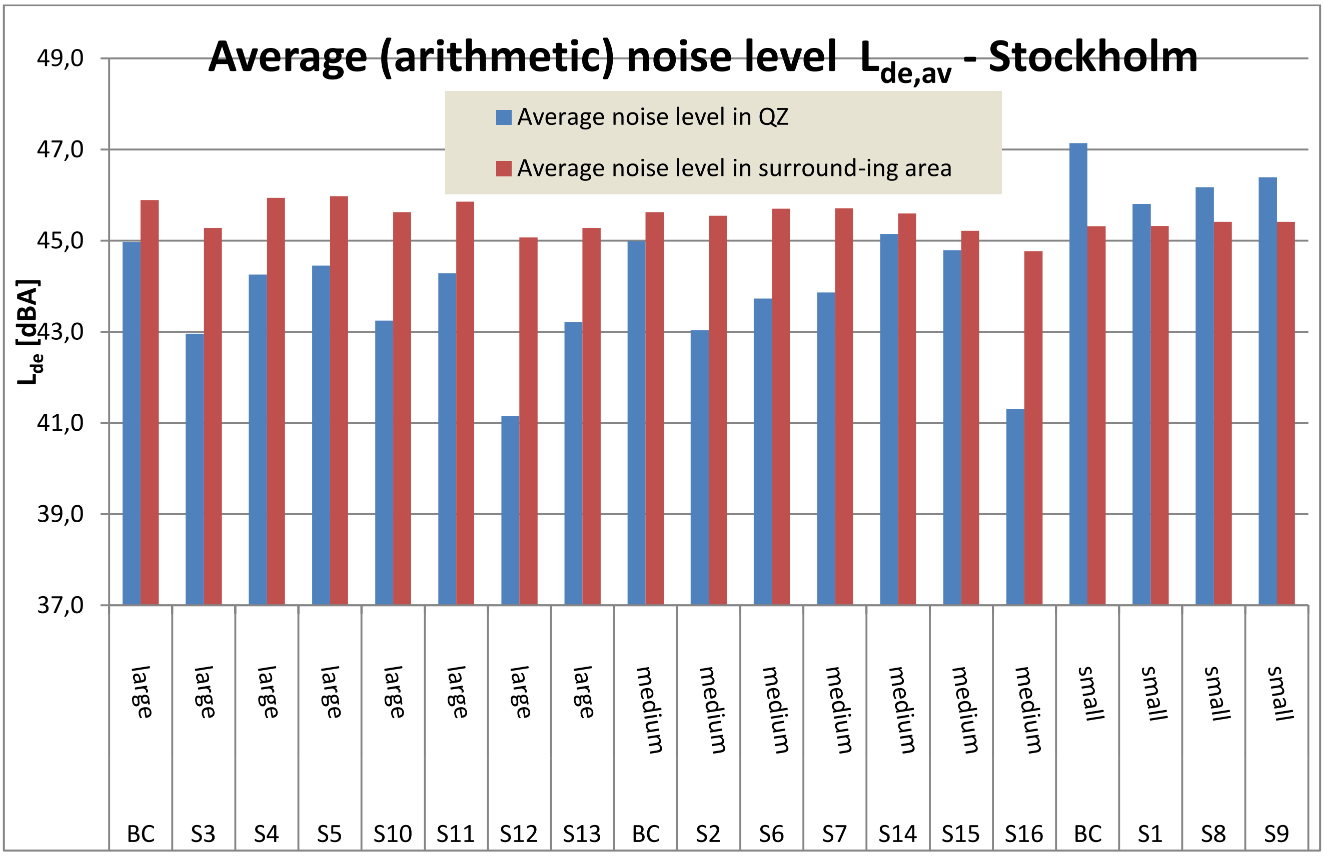

Figure 7.27 Average arithmetic noise levels in Stockholm scenarios

Discussion

In Stockholm, the introduction of the medium sized Q-Zone gives a reduction of the average noise level in the Q-Zone by 2 dB(A) when non-residents standard vehicles are banned. This is also the case when the large Q-Zone is introduced. The small Q-Zone give a smaller reduction (1.3 dB(A)). The introduction of a noise fee in the range 0.5 – 1 Euro per entry and exit instead of the ban reduces the reduction in all zone sizes, but the larger the zone size, the smaller the effect in terms of dB(A). The larger the zone, the larger the detour to avoid the fee – and the larger the probability that the driver will find it worthwhile to pay the fee and drive through the Q-Zone.

The mere increase of Low Noise Vehicle Ownership to 5 or 20 percent of all person cars will provide only small noise level effects, but when combined with a ban (and then also with a higher percentage of LNVO inside the Q-Zone) it will increase the effect significantly. The reduction of the average noise level will be 3.8 (large Q-Zone) or 3.7 (medium Q-Zone), which is almost the double effect compared to the case with 1 percent LNVO.

The area with a noise reduction of more than 5 dB(A)compared to the Base Case average does not vary much between scenarios – it is 7-8 percent, which can be compared to 6 percent in the Base Case.

In all cases, the noise level in the surrounding area is also reduced (marginally) or kept equal. This is because redistribution effects are small, which in turn depends on the fact that the area is already traffic zoned – there is no through traffic to redistribute.

The Stockholm case shows that

- Q-Zones that are introduced in already traffic zones areas are not likely to bring about as large average effect as in areas which suffer from high levels of through traffic
- Higher levels of LNVO can give significant noise level reductions even if there are only small Q-Zone traffic effects

8 GENERAL DISCUSSION

8.1 STREET NETWORK CAPACITY CONDITIONS

For the five test sites, a varying number of scenarios have been simulated. The results have been discussed above in their specific site context. Although the results are specific to the chosen sites, we will try to generalise the results at least to some extent, building on similarities as well as differences.

We may start by recognising that introducing a Q-Zone implies a reduction of the road network capacity. The impact of such a capacity loss will be more or less severe, depending on the initial use of the network, i.e. the congestion level. The higher the congestion level, the higher the price in terms of increased travel total times in the network. Likewise, the larger the zone, the larger the congestion effect of the implementation. Sufficient network capacity will obviously be a major condition for introducing a Q-Zone.

If there is little traffic zoning in the city, a main effect of the Q-Zone will be to push through traffic away to the remaining network. For congested networks, this may imply increased travel times for a large part of the network. It may however appear a bit unfair to contribute the cost of mitigating through traffic just to the noise effects of the Q-Zone introduction. In many cities, zoning systems have been introduced for improving the environment in a number of aspects, including all kind of emissions, safety and other living conditions. It has not been possible to make an evaluation of all these aspects in this project, but they should also be considered by decision makers. It should also be noted that traffic zoning is also likely to reduce ambient noise, which may otherwise constrain the potential of the Q-Zone. Therefore, a traffic-zoning scheme may also imply a favourable condition for a Q-Zone introduction. It goes without saying that traffic zoning in itself will reduce noise levels, but then a Q-Zone concept is required to utilise the potential of new vehicle technology for further noise reductions. The traffic zone (or environmental zone) concept could also be extended to include the Q-Zone dimension.

Other favourable conditions like tunnels for through traffic may also exist. In such cases, ambient noise levels are likely to be much lower which increases the potential of a Q-Zone introduction.

8.2 Q-ZONE SIZE CONSIDERATIONS

Because of the potentially strong effect of Q-Zone introduction on congestion, the initial size of a Q-Zone cannot be very large. A minimum size will be defined by the impact of ambient noise, which depends on local factors such as distances to major surrounding roads and local topology. A question may then be if the zone size can be expanded as the level of low noise vehicles increases. Then it can be expected that fewer drivers will have to change route because fewer drivers will have (banned or charged) standard vehicles, and consequently the effect on congestion would be lower. However, the rate of transformation of the vehicle fleet is very slow, and in the recent national

Swedish transport plan reaching a level of only 5 percent was forecast for the year 2020. This view is supported also by a market outlook to the EU Climate Change Commission (AEA 2009). It is obvious that a reduction of the redistributed traffic of about 5 percent will be very small, and that an expected increase of low noise vehicles will not be a driver for Q-Zone size enlargement for the next 10 – 15 years. A level of 20 percent is of course even further away, although the speed of transformation can be expected to increase as the technology matures.

8.3 LOW NOISE VEHICLE OWNERSHIP CONSIDERATIONS

The level of low noise vehicle ownership inside the Q-Zone may be more easily affected than the outside level. Depending on the Q-Zone policy, incentives to acquire low noise vehicles may be much stronger for Q-Zone residential households than for other households. Exempting Q-Zone households from a ban/charge may be necessary at the time of Q-Zone introduction, but will provide less incentive to change vehicle at least for a transition period. After this period, a ban or fee will provide some incentive, and additional incentives may be provided like free street parking for low noise vehicles. If the Q-Zone is introduced already at the exploitation of a new area, the transition period can even be skipped – standard vehicles might not be allowed in the new area. Assumptions of higher levels of low noise vehicle ownership are therefore motivated. Our simulations show that high levels of low noise vehicle ownership are necessary to bring about more significant noise reductions, especially in cases where traffic zoning has already taken place.

8.4 NOISE FEE LEVEL CONSIDERATIONS

The fee levels that have been simulated give almost the same results as the ban does. This is more outspoken in those cases where the traffic simulation allows for route choice only. This effect is because the extra delay for changing route is for most drivers too small to match the fee. As there is a cost of fee collection, and as the size of the zone is small which implies a low number of paying vehicles, it has not been motivated to simulate even smaller fees. The choice between a ban and a I Euro fee is more a choice between ease of monitoring and giving some flexibility to drivers. In this project we have however not tried to calculate monitoring or fee collection costs.

8.5 A QUANTITATIVE GENERALISATION OF THE SIMULATION RESULTS

The previous sections in this chapter represent a qualitative attempt to generalise the simulations results. It can be interesting also to attempt to make a quantitative generalisation of the results. In this section, such an attempt is presented.

One result parameter of the Q-Zone introduction is defined by the percentage of the Q-Zone area that experienced a noise reduction of more than 5 dB Lde,av. This result variable, which is comparable between sites and Q-Zone scenarios, has been related to the varying conditions of the simulations.

By regressing the noise reduction defined above on the variables describing the different conditions it was possible to get a quantitative measure of the impact of each variable on the percentage of area with noise reduction of more than 5 dB Lde,av. Table 8.1 shows the result in terms of parameter estimates and general fit to data. The impact of a certain policy (the percentage of the Q-Zone area that experienced a noise reduction of more than 5 dB Lde,av) is given by summing all variables multiplied by their parameters (but using either fee or ban). In Figure 8.1 the results are shown as bars, expressing the importance of each variable for the specific conditions indicated in the variable label. For example, the Fee bar shows the effect of a 0.5 and a 1 Euro fee.

Table 8.1 – Parameters of multiple regression model of percent area in Q-Zone with 5 dB lower Lde,av on simulation variables and site constants

Variable	**Const**	**Fee Euros**	**Ban 0/1**	**Zone size 1000 m^2**	**LNVOI percent**	**LNVOO percent**	**Bratislava 0/1**	**Bristol 0/1**	**Essen 0/1**	**Gothenburg 0/1**
Parameter	4,67	5,02	6,333	-0,00073	0,151	-0,586	0,634	13,779	15,704	-3,845
Std dev	3,86	2,30	2,524	0,00199	0,0493	0,235	2,808	3,754	3,018	3,811
t-value	1,2	2,2	2,5	-0,4	3,1	-2,5	0,2	3,7	5,2	-1,0
r2	0,74									

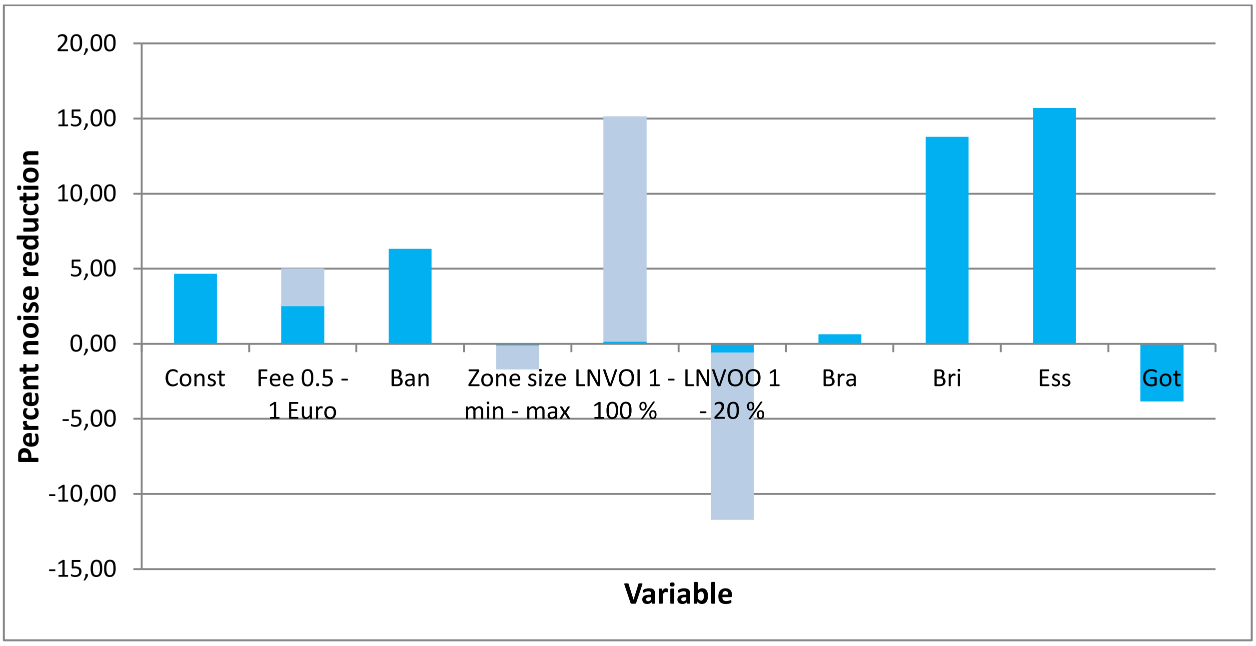

Figure 8.1 Effects of simulaton conditions and site constants

The figure shows that a 1 Euro fee gives almost the same result as a ban. It can also be seen that the zone size has a small (statistically insignificant) influence on the noise reduction. As can be expected, the Low Noise Vehicle Ownership (LNVO) Inside and Outside the Q-zone have a large influence. They have opposite effects, which can be expected – the higher the LNVO inside the Q-Zone (LNVOI), the more residents will use LNV's instead of standard vehicles, and the higher the LNVO outside the Q-Zone (LNVOO), the more vehicles can pass the Q-Zone without facing a fee or ban. The outside LNVO is more important per percent LNVO, as the number of vehicles outside the Q-Zone is much larger.

In addition to the variables reflecting the conditions in the simulations, there are also constants reflecting differences between sites. Two of these, the ones for Bristol and for Essen, are of the same magnitude as the maximum effects of the LNV ownerships. This makes it quite obvious that although the simulation conditions are important, the Q-Zone effect may also be subject to site specific conditions.

One such condition that is quite important and which may differ between sites is the existing degree of traffic zoning. If there is no traffic zoning in the potential Q-Zone, then the traffic will probably contain a large amount of through traffic. Such traffic is more easily affected by the Q-Zone policy than traffic that has its destination in the Q-Zone. This may explain why Essen and Bristol show a higher sensitivity to the Q-Zone introduction than Stockholm and Gothenburg (that are already traffic zoned).

8.6 Q-ZONE OPTIMIZATION EXAMPLE

In the preceding analysis, we have seen that there are many site-specific conditions that affect the result of a Q-Zone implementation. The effects of site specific conditions (like ambient noise levels, redistribution effects etc.) are often not well known in advance, but may have a large impact. The implementation of a Q-Zone therefore may have elements of trial and error, which one would prefer to handle by simulations and not in practice. We take the Essen site as an example of such a procedure.

Initially, and after a site visit, two zone sizes were suggested (small and large). The simulation showed however that both Q-Zone implementations had small noise effects (scenarios 1 – 7). The analysis also showed that the ambient noise level was too high for the Q-Zones to be able to give a substantial improvement. An important reason for the high ambient noise level was the high volume road close to the Q-Zone. Therefore, two larger zone sizes were tested, incorporating the high volume street in the Q-Zone (scenarios 10, 11 and 14). In scenario 10, the road south of the park is contained in the Q-Zone definition (the dashed yellow area in figure 8.2). Because of the redistribution effects in scenario 10 on the surroundings, scenario 11 and 14 were defined to allow through traffic on this road but at a reduced speed (30 km/h as opposed to the previous actual speeds of about 50 km/h), and to include the dashed red area south of the road. Scenario 11 assumes one percent LNVO in the total area, whereas scenario 14 assumes a 100 percent LNVO inside the Q-Zone and 20 percent LNVO in the rest of the area.

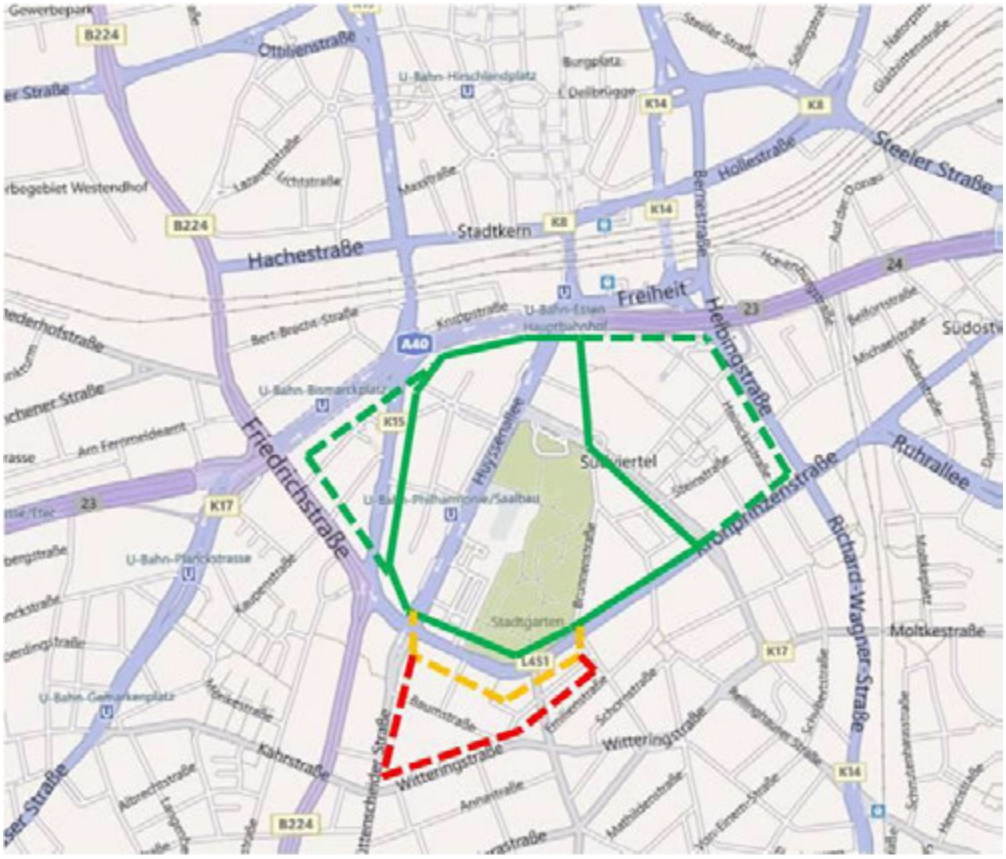

Figure 8.2 Essen Q-Zone borders

The full set of scenarios analysed for Essen is reported in table 8.2. The results are reported in table 8.3 and in figure 8.3.

Table 8.2 Simulated scenarios for test site Essen

Scenario nr	Zone	Fee, Euros/passage	Inside LNVO percentage	External LNVO percentage
1	none	none	1	1
2	large	ban	1	1
3	large	1	1	1
4	large	0.5	1	1
5	small	ban	1	1
6	small	1	1	1
7	small	0.5	1	1
8	none	none	5	5
9	large	ban	20	5
10	XL	ban	1	1
11	XXL	ban	1	1
12	none	none	20	20
13	large	ban	100	20
14	XXL	ban	100	20
15	large	0.5	100	20

Table 8.3 Essen simulation summary

Scenario	Percentage of standard vehicles in Q-Zone of base case traffic	Percentage of low noise vehicles in Q-Zone of base case traffic	Total travel time change (hours/day)	Total distance change (vehicle km/ day)	Average noise level Lden in Q-Zone (arithmetic) [dB(A)]	Average noise level Lden in remaining test area[1)] (arithmetic) [dB(A)]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [m²]	Area with minimum 5 dB reduction within the Q-Zone (total Q-Zone size base case) [%]
1	99%	1%	-	-	62.6 S 62.6 L 63.0 XL 62.4 XXL	61.6 S 61.6 L 61.6 XL 61.6 XXL	(373700) S (591300) L (628300) XL (697700) XXL	-
2	38%	2%	1300	22364	60.0	61.7	153100	25.9
3	38%	2%	857	15304	60.0	61.7	153400	25.9
4	39%	2%	813	16704	60.1	61.7	152000	25.7
5	91%	1%	75	8448	59.4	61.6	98800	26.4
6	91%	1%	75	8448	59.4	61.6	98800	26.4
7	91%	1%	167	7380	59.4	61.6	98800	26.4
8	95%	5%	0	0	62.4	61.5	0	0.0
9	36%	11%	708	16336	59.9	61.6	157300	26.6
10	6%	2%	896	27896	59.1	61.7	287100	45.7
11	23%	2%	1035	19248	59.7	61.7	171000	24.5
12	80%	20%	0	0	61.8	60.9	0	0.0
13	28%	39%	236	14776	59.1	60.9	171100	28.9
14	12%	43%	742	20868	58.6	60.8	199800	28.6
15	28%	38%	294	11508	59.2	60.9	170700	28.9

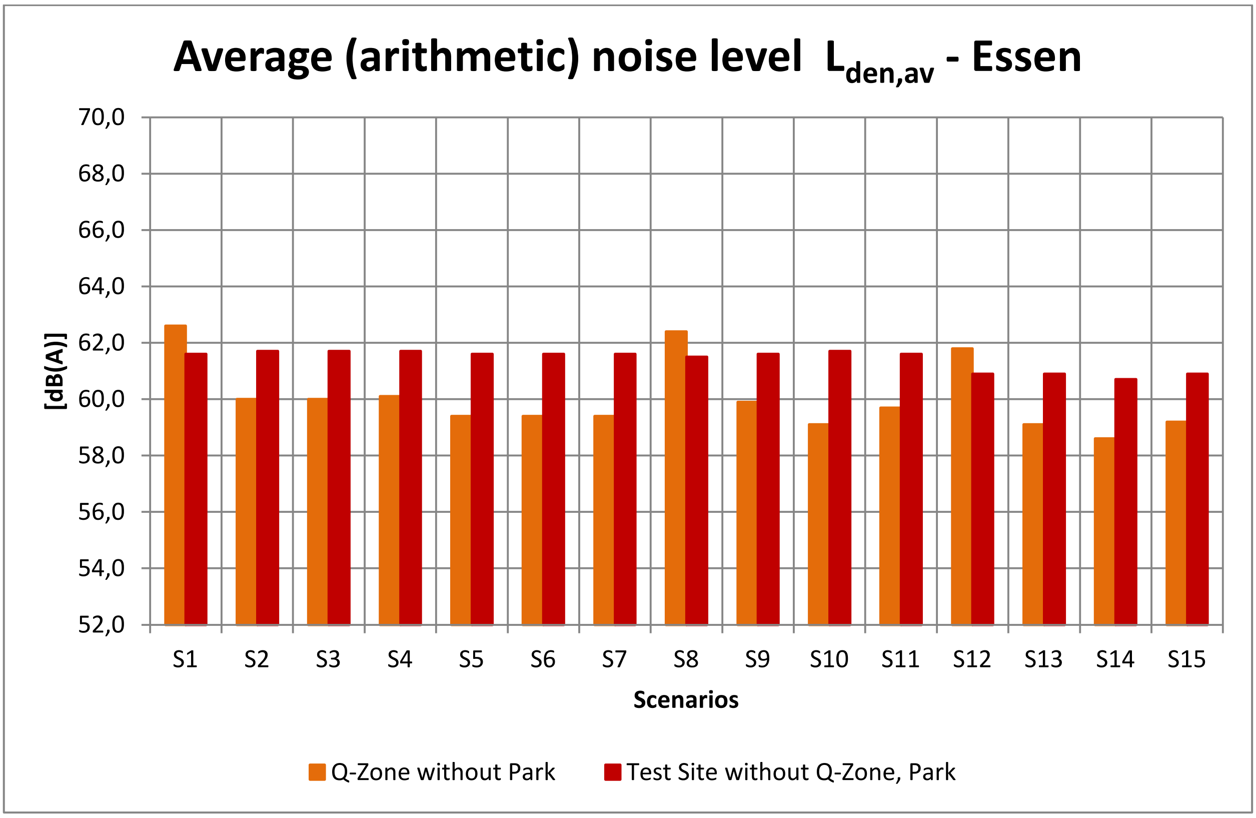

Figure 8.3 Average arithemetic noise levels for Essen

Allowing through traffic on the road south of the park increases the average noise level by 0.6 dB. The number of vehicle kilometres does not increase as much as in scenario 10, but travel times increase more (due to congestion effects). If increased LNVO levels are assumed (100 percent inside and 20 percent outside the Q-Zone), the noise reduction compared to the Base Case is 3.8 dB.

Scenario 14 gives a 0.5 dB larger noise reduction than scenario 13, and for a larger area, but at the price of increased travel times and distances. This example serves as an illustration of how the traffic forecasting tool and the noise mapping tool can be used to explore the possibilities to reduce traffic noise as efficiently as possible in each particular site. It is also possible to evaluate combined effects of traffic constraints and other nose mitigation means like barriers or façade insulation.

9 CONCLUSIONS AND RECOMMENDATIONS

To sum up, we conclude that for a Q-Zone to give a significant and efficient noise reduction the following requirements need to be met:

- There must be enough street capacity to accommodate diverted traffic in order to avoid congestion effects (i.e. diverted traffic must not increase noise levels outside the Q-Zone)
- The ambient noise level needs to be low to allow a reasonable noise reduction potential
- Policies to promote low noise vehicle ownership close to 100 percent within the Q-Zone are necessary to achieve significant noise reductions, particularly in already traffic zoned areas

We also conclude that

- The choice between a ban or a I Euro fee is mainly a choice between ease of monitoring and giving some flexibility to driver
- The level of low noise vehicle ownership is not likely to increase in such a way in the next 10-15 years that it will affect the consideration of the Q-Zone size.

We recommend that

- Detailed traffic forecasting and noise mapping tools are used in each case where a Q-Zone is considered, to be able to assess potential effects inside and outside the potential Q-Zone
- These tools are also used to optimise the Q-Zone design with respect to effects inside and outside the potential Q-Zone

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