DELIVERABLE 2.15

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	Report on ranking of different noise source mitigation measures
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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

The objective in WP 2.3 is to study measures related to traffic management. In this report the aim is to rank all measures studied in concept of performance/cost, general applicability and general acceptance. Studied measures include the concepts of traffic control, mode shift, car ownership and car type choice impact and driver behaviour.

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

Results of measures studied in WP 2.3 form the basis of the ranking and discussion presented.

Traffic control and mode shift studies were made using the transport forecasting system Sampers, modelling travel demand and the transport system in Stockholm County. The most detailed results are vehicle flows per link for different time periods and transit loads for the same periods. Changes in flows and speed that occur for different traffic control strategies were used as input to create related noise maps. Noise calculations were made using the noise mapping software CadnaA (Datakustik GmbH, Munich). To handle differences in geographic representation and traffic data aggregation between the two modules an interface was developed and applied. (We have only studied traffic and noise levels for daytime conditions.)

Studys of measures to influence car ownership and car type choice were made by applying car ownership and car type models developed for the Swedish Rail and Road Administrations.

To study the impact of aggressive and less aggressive behaviour on noise levels the microscopic simulation environment Aimsun NG (TSS, Spain) was used. The changes in speed and acceleration/deceleration that occur for different scenarios were used as input to calculate effects on noise. In addition measures to make traffic run smoother may have an impact. Here we analysed an introduction of an Intelligent Speed Adaptation (ISA) system, affecting individual acceleration and deceleration behaviour. Together with acousticians at Acoustic Control a generalised and quick method to calculate the influence of driver behaviour on the total road noise was developed. The method is based on the distribution of speed/acceleration behaviour on the road studied and noise level corrections due to acceleration and deceleration presented in the Harmonoise project.

0.3 BACKGROUND INFO AVAILABLE AND THE INNOVATIVE ELEMENTS WHICH WERE DEVELOPED

Based on the work with setting up the Stockholm test site model environment and to develop necessary interfaces between the Stockholm forecasting model and the

CadnaA noise mapping software, we have demonstrated the importance of considering redistribution effects when using traffic control measures for noise abatement. We have also demonstrated the viability of quiet areas, using restrictions on noisy vehicles.

We have also demonstrated the potential of enhancing the share of low noise vehicles in the car fleet by using noise fees.

The concept to study driver behaviour impacts on noise levels using a microscopic traffic simulation model and a method to calculate the road traffic noise is new to our knowledge. Thus the total method and the interface between the two modules are innovative elements.

0.4 PROBLEMS ENCOUNTERED

During our work we did not encountered any major problems that made us reconsider the overall approach of the studies.

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

Partners involved were the Royal Institute of Technology (KTH) and Acoustic Control (ACL). Traffic simulations and traffic forecasts were made by KTH and together with ACL methods to calculate noise impacts were discussed and developed.

0.6 CONCLUSIONS

Below is a table showing a summary of all measures studied. Effects of a noise mitigation measure related to traffic management will always be network dependent and site specific. Here, we therefore present effects and costs less precise than for what is possible for physical noise mitigation devices, based on examples studied. It is important to understand that the relative changes presented in our examples are depending on the size of the modelled network, and serve here more as a reminder of the presence of such effects.

Scenario number	Location	Action	Noise reduction at site [dB(A)]	Cost [€]	Level of acceptance	Site specific limitation
1	Link specific road traffic noise	Close off road for car through traffic	Can give substantial noise reduction of 3-14 dB(A) (L_{DAY})	Low implementation cost	High for people living close to the road. Low for citizens exposed to higher levels due to redistribution effects and for people with decreased accessibility.	Extent of traffic diversion effects
2	Link specific road traffic noise	Decrease speed limit	Can give noise a reduction of 3 - 4 dB(A) (L_{DAY})	Low implementation cost	High for people living close to the road. Low for citizens exposed to higher levels due to redistribution effects and for people with decreased accessibility. Traffic safety gains may increase the acceptance.	Extent of traffic diversion effects
3	Area wide road traffic noise	Create quiet areas by restricting noisy vehicles by charges or road barriers	Has a potential to give substantial noise reduction of 3 - 14 dB(A) (L_{DAY})	High implementation cost	Possibly high for people living inside the area. Low for citizens exposed to higher levels due to redistribution effects and for people with decreased accessibility.	Extent of traffic diversion effects, supply of low noise vehicles and adjacent parking
4	Area wide road traffic noise	Increased frequency of public transport services	Generally small noise reductions	High implementation cost	High for people with increased accessibility. Low for people with higher noise exposure.	Other effects than noise impacts needs to be considered.
5	Area wide road traffic noise	Decreased ticket price for public transport	Generally small noise reductions	High revenue loss	High	Other effects than noise impacts needs to be considered.
6	Area wide road traffic noise	Area wide congestion charging schemes	Generally small noise reductions of 1 - 2 dB(A)	High implementation cost (should be exceeded by revenues)	Generally low for people living outside the area, higher for people living inside the area.	Other effects than noise impacts needs to be considered.

7	Road traffic noise	Make people drive less aggressive	About 1 dB(A)	Situation specific	Relatively high, (lower for men and professional drivers), (Transek 2006 and Vägverket 2002).	Increased supervision or ISA-systems is necessary.
8	Area wide road traffic noise	Noise fees to increase low noise vehicle ownership	Very long term effect About 1 dB(A) in a 10 year perspective	System costs, fee revenues	Depending on zone size and fee level	Supply of electric hybrid vehicles

The scenarios studied are of different character and are applied at specific roads/sites or work area wide. Therefore it is difficult to make a final ranking. Though, altogether the conclusion is that reduced speed limit is the measure of all studied that shows the largest potential. It gives relatively high noise reductions and low noise redistribution effects. It is an inexpensive and easy measure to implement. Moreover reduced speed also generally has a positive impact on traffic safety aspects and air quality. Together with noise reduction effects this would most likely lead to a relatively high level of acceptance. However, a large-scale application of speed reduction may face lower acceptance, if there are noticeable accessibility effects. The reduction of speed from 50 to 30 km in most residential streets in Stockholm was widely accepted (Trafikkontoret 2006). Reductions on longer stretches of arterial streets may face more resistance.

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

Input to this report were studies presented in the following deliverables:

D2.11 Small Prototypes for "Traffic Control Measures for Vehicles"

D2.12 Small prototypes for "Car ownership measures for vehicles"

D2.13 Small prototypes for "Driver behaviour measures for vehicles"

D2.14 Small prototypes for "Mode shifting measures for vehicles"

1 INTRODUCTION

In this document we evaluate all noise mitigation measures related to traffic management studied in QCity.

1.1 BACKGROUND

QCity is a project in the EU's sixth framework programme. The aim is to develop an integrated technology infrastructure for efficient control of road and rail ambient noise by considering the attenuation of noise creation at source at both vehicle/infrastructure levels. The project supports the European noise policy to eliminate harmful effects of noise exposure and decrease levels of transport noise creation, especially in urban areas. A major objective is to provide municipalities with tools to establish noise maps and action plans (Directive 2002/49/EC) and to provide them with a broad range of validated technical solutions for the specific hot-spot problems they encounter in their specific city.

1.2 TASK DESCRIPTION

The objective in WP 2.3 is to study measures related to traffic management. In this report we aim to rank these measures in terms of performance/cost, general applicability and general acceptance. Studied measures include the concepts of traffic control, mode shift, car ownership, car type choice and traffic calming. Scenarios analysed are as follows:

Traffic control

Closing off through traffic on a specific road

Reduced speed limit on a specific road

Restrictions on noisy vehicles to enter or leave an area

Mode shift

Increased frequency of public transport services

Reduced ticket price in public transport

Area wide congestion-charging scheme

Car ownership and car type choice

Promoting low noise vehicles

Driver behaviour

Make people drive less aggressive by increased supervision or ISA-systems

As shown, studied measures are applied either on specific roads/sites or work area wide. This aspect has to be considered when measures are compared and evaluated.

2 METHODS USED

When studying the selected measures different types of traffic models and noise calculation methods were applied. For traffic control and mode shift policies a traffic forecasting system together with the noise mapping software CadnaA was used. The method is further described in paragraph 2.1. Car ownership car type choice effects were studied using models developed for the Swedish Rail and Road Administrations. To analyse driver behaviour impacts on noise levels a microscopic traffic simulation model was applied together with a simple noise calculation method based on noise level corrections due to acceleration and deceleration, see paragraph 2.3.

2.1 METHOD APPLIED FOR TRAFFIC CONTROL AND MODE SHIFT MEASURES

Studies were made using the transport forecasting system Sampers (Beser and Algers 2002) modelling travel demand and the transport system in Stockholm County. The most detailed results are vehicle flows per link for different time periods and transit loads for the same periods. Changes in flows and speed that occur for different traffic control strategies were used as input to create related noise maps. Noise calculations were made using the noise mapping software CadnaA (Datakustik GmbH, Munich). To handle differences in geographic representation and traffic data aggregation between the two modules an interface was developed and applied. (We have only studied traffic and noise levels for daytime conditions.) Two study areas were selected, Järva and Södermalm in Stockholm.

As traffic management policies not only have noise effects we additionally studied effects on travelled kilometres, person hours, change in travel pattern and in some cases other environmental effects. However, effects of a noise mitigation measure related to traffic management will always be network dependent and site specific. Here, we therefore present effects and cost less precise than for physical noise mitigation devices studied in QCity. In addition, it is important to understand that the relative changes presented are depending on the size of the modelled network.

2.2 CAR OWNERSHIP AND CAR TYPE CHOICE

Car ownership effects, i.e. effects related to the total number of cars, were studied by a model for car ownership developed for the Swedish Rail Administration. This model takes into account that the propensity to have a car is depending also on the utility of the increased accessibility given by the car in addition to other means of transport. If this increased accessibility is counteracted by the introduction of fees like congestion charging or noise fees, the propensity to have a car will decrease.

To model effects of noise fees on the share of low noise vehicles (electric hybrid cars are defined to be low noise vehicles) in the car stock, a car type choice model developed for the Swedish Road Administration was used. The share of low noise vehicles is depending on several factors. One factor is supply, i.e. there have to be cars on the market to buy. These cars also have to have characteristics that match those of other cars (size, price, performance, etc.). Another factor is demand, especially the inertia that is caused by brand loyalty. This makes the supply side even more important, because electric hybrid cars have to be supplied for those brands that already have a high market share in order to penetrate the market less slowly. The third factor is the rate of renewal in the car stock – it will take a long time before the new vehicles on the market have replaced the current ones.

We have modelled this mechanism by applying the choice model for choice of new car type, taking into account vehicle characteristics and differences in substitution elasticity between close alternatives and other alternatives. We have assumed a technical development where there is an increased supply of electric hybrid vehicles, according to the car industry. We have also modelled the development of the car stock over time, accounting for some time to put new vehicles on the market, and time to replace older vehicles by new ones. We have chosen a ten years perspective for the development of the car stock.

2.3 METHOD APPLIED TO STUDY DRIVER BEHAVIOUR IMPACTS ON NOISE LEVELS

For this measure we used a traffic simulation model, to model different types of car drivers and studied the impact of aggressive and less aggressive behaviour on noise levels. The changes in speed and acceleration/deceleration that occur for different scenarios were used as input to calculate effects on noise. In addition measures to make traffic run smoother may have an impact. Here we analysed an introduction of an Intelligent Speed Adaptation system, affecting individual acceleration and deceleration behaviour.

In the studies the microscopic simulation environment Aimsun NG (TSS, Spain) was used. It is a dynamic model where each vehicle is simulated individually. Road networks are built in detail and the concept of sections and intersections are used to describe roads and junctions. Each simulation step, every vehicle position and speed is updated using behavioural models such as “Car-following Model”, “Gap acceptance” and “Lane-Changing Model”. The algorithms use vehicle attributes like acceleration, deceleration, reaction times, minimum distance to the vehicle in front and speed acceptance to simulate the movements. Each simulation gives a range of simulation outputs such as average speed, queue lengths and density of a section.

In our studies we modelled a generalised stretch of road, a straight 2 km road with speed limit 70 km/h and traffic signals at the beginning and the end. The road was divided into three segments. For each segment and simulation step we collected simulation data in form of speed and acceleration for each vehicle passing.

Together with acousticians at Acoustic Control a generalised and quick method to calculate the influence of driver behaviour on the total road noise was developed. The method is based on the distribution of speed/acceleration behaviour on the road studied and noise level corrections due to acceleration and deceleration presented in the Harmonoise project.

3 SCENARIOS STUDIED – DESCRIPTION AND RESULTS

In this chapter the scenarios studied are briefly described and results of each measure presented. Below is a table illustrating a summary of all measures studied. Effects of a noise mitigation measure related to traffic management will always be network dependent and site specific. Here, we therefore present effects and costs less precise than for what is possible for physical noise mitigation devices, based on examples studied. It is important to understand that the relative changes presented in our examples are depending on the size of the modelled network, and serve here more as a reminder of the presence of such effects.

3.1 SUMMARY OF SCENARIOS STUDIED

Scenario number	Location	Action	Noise reduction at site [dB(A)]	Cost [€]	Level of acceptance	Site specific limitation
1	Link specific road traffic noise	Close off road for car through traffic	Can give substantial noise reduction of 3-14 dB(A) (L_{DAY})	Low implementation cost	High for people living close to the road. Low for citizens exposed to higher levels due to redistribution effects and for people with decreased accessibility.	Extent of traffic diversion effects
2	Link specific road traffic noise	Decrease speed limit	Can give noise a reduction of 3 - 4 dB(A) (L_{DAY})	Low implementation cost	High for people living close to the road. Low for citizens exposed to higher levels due to redistribution effects and for people with decreased accessibility. Traffic safety gains may increase the acceptance.	Extent of traffic diversion effects
3	Area wide road traffic noise	Create quiet areas by restricting noisy vehicles by charges or road barriers	Has a potential to give substantial noise reduction of 3 - 14 dB(A) (L_{DAY})	High implementation cost	Possibly high for people living inside the area. Low for citizens exposed to higher levels due to redistribution effects and for people with decreased accessibility.	Extent of traffic diversion effects, supply of low noise vehicles and adjacent parking

4	Area wide road traffic noise	Increased frequency of public transport services	Generally small noise reductions	High implementation cost	High for people with increased accessibility. Low for people with higher noise exposure.	Other effects than noise impacts needs to be considered.
5	Area wide road traffic noise	Decreased ticket price for public transport	Generally small noise reductions	High revenue loss	High	Other effects than noise impacts needs to be considered.
6	Area wide road traffic noise	Area wide congestion charging schemes	Generally small noise reductions of 1 - 2 dB(A)	High implementation cost (should be exceeded by revenues)	Generally low for people living outside the area, higher for people living inside the area.	Other effects than noise impacts needs to be considered.
7	Road traffic noise	Make people drive less aggressive	About 1 dB(A)	Situation specific	Relatively high, (lower for men and professional drivers), (Transek 2006 and Vägverket 2002).	Increased supervision or ISA-systems is necessary.
8	Area wide road traffic noise	Noise fees to increase low noise vehicle ownership	Very long term effect About 1 dB(A) in a 10 year perspective	System costs, fee revenues	Depending on zone size and fee level	Supply of electric hybrid vehicles

3.2 Scenarios Studied

Scenario 1	***Closing off through traffic***
Problem	Link specific road traffic noise.
Expected noise reduction	Can give substantial noise reduction, 3 - 14 dB(A).
Detailed description/objectives	Close a road and reallocate the noise source.
Examples	See below
Cost	Low implementation cost
Interactions – Limitations	Extent of traffic diversion effects.
Further information	See deliverable D2.11

Figure 1 illustrates a noise map over the study area Järva, north west of Stockholm. In a modelled scenario the main road marked by an arrow in Figure 2 was closed for through traffic. The difference in noise levels (L_{DAY}) compared to the base scenario is illustrated in the same picture.

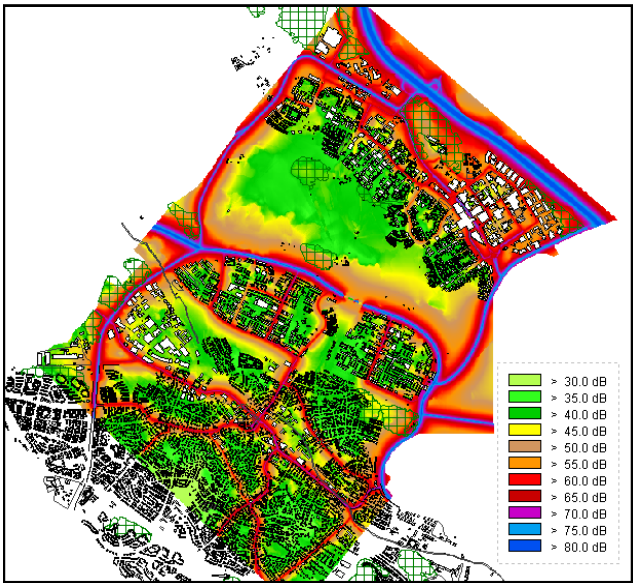

Figure 1: Noise map of the study area Järva, Stockolm. Base scenario, L_{DAY}.

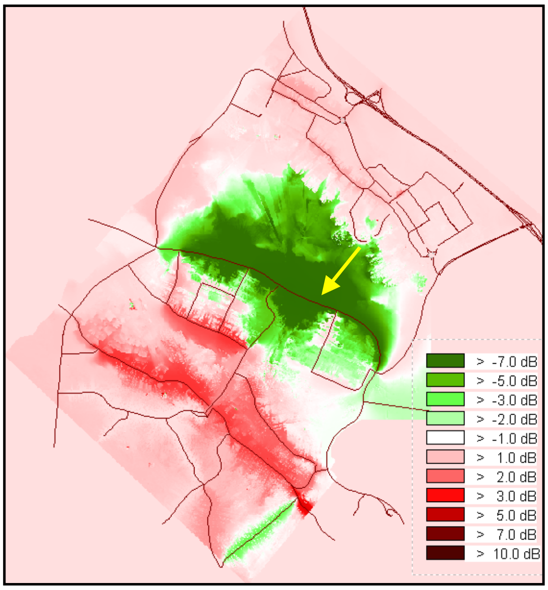

Figure 2: Difference in noise level when closing marked road for through traffic.

The difference plot shows large noise reductions near the closed connection, in some areas up till –14 dB(A). Due to rerouting, increased levels are obtained on alternative roads, approximately 4 dB(A) at maximum. These effects need to be considered when such a measure is applied. Below is a diagram illustrating the share of exposed inhabitants in 5 dB intervals. There is a clear reduction of exposure in levels around 55 dB(A). The measure shows low impacts on accessibility in terms of travel time and person hours travelled. These results are however relative to the total network, locally the effects can be much larger.

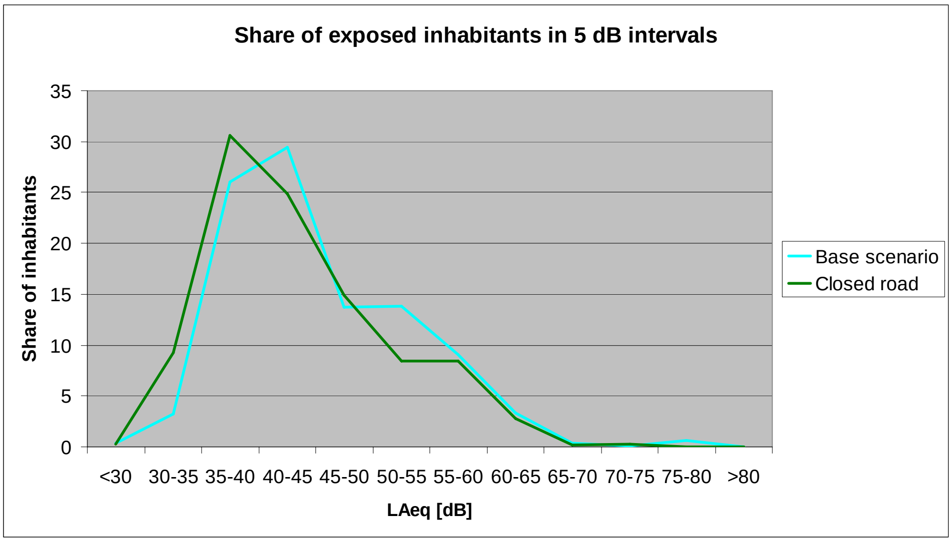

Figure 3: Share of exposed inhabitants in 5 dB intervals.

Scenario 2	*Decrease speed limit*
Problem	Link specific road traffic noise
Expected noise reduction	Can give noise reductions of 3 - 4 dB(A).
Detailed description/objectives	Decrease the speed limit and consequently reduce noise levels.
Examples	See below
Cost	Low implementation cost
Interactions – Limitations	Extent of traffic diversion effects
Further information	See deliverable D2.11

In the base scenario presented previously the main road marked by a black line in Figure 4 is modelled as a 70 km/h road. In a scenario it was changed to model a 50 km/h road. Note that since the model captures speed reductions due to congestion this does not mean that we study noise effects when speed is reduced from 70 km/h to 50 km/h. The selected road is heavy loaded and the road speed is approximately 60 km/h in the base scenario. In peak hour traffic though, the speed is approximately 40 km/h (inbound direction, i.e. towards the city centre). The difference in noise levels (L_{DAY}) caused by this measure is also shown in Figure 4.

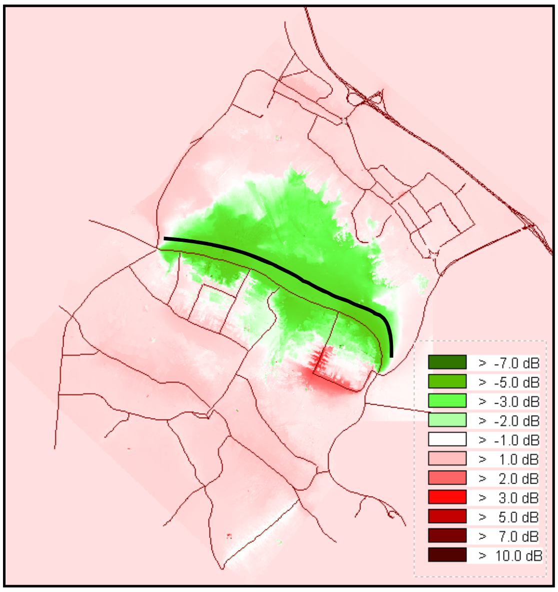

Figure 4: Absolute difference in noise levels due to reduced speed, L_{DAY}.

The plot shows a noise reduction of approximately 4 dB(A) near the road with reduced speed. Due to rerouting there is an average increase of 2 dB(A) on alternative routes. Below is a diagram illustrating the share of exposed inhabitants in 5 dB intervals. There is a reduction of exposure in levels around 55 dB(A), as expected not as large as when the road was closed for through traffic. But the reduction is still significant.

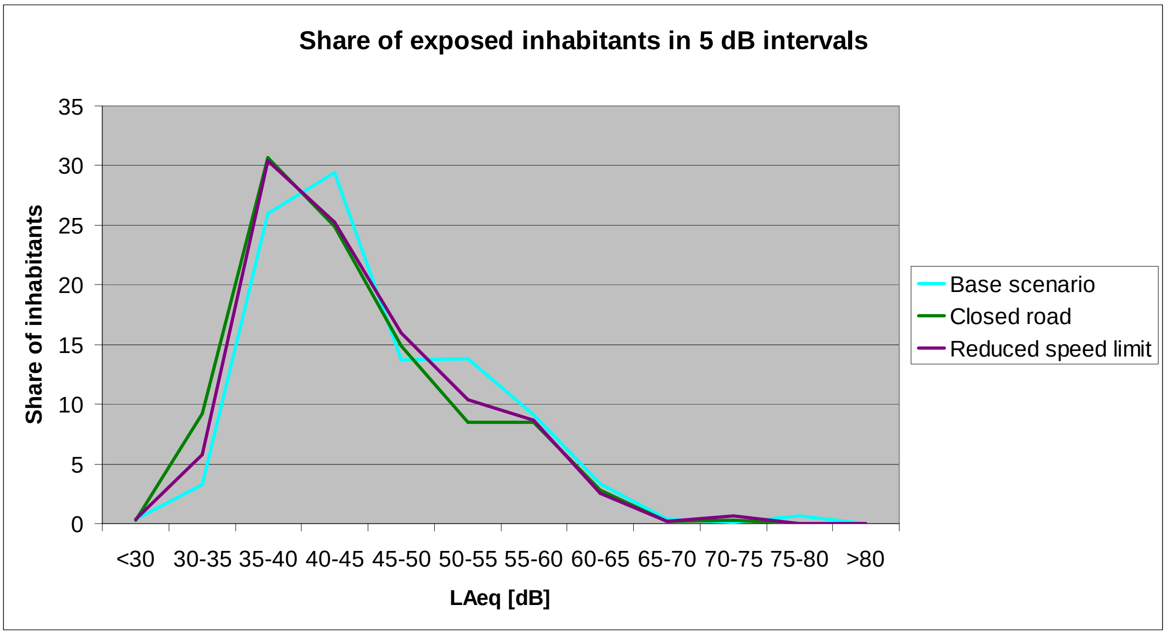

Figure 5: Share of exposed inhabitants for different scenarios.

Scenario 3	**Restrict noisy vehicles by charges or road barriers**
Problem	Area wide road traffic noise
Expected noise reduction	Has a potential to give substantial noise reduction, 3 to 14 dB(A).
Detailed description/objectives	Create a quiet area by restricting noisy vehicles by charges or road barriers.
Examples	See below
Cost	High implementation cost
Interactions – Limitations	Extent of traffic diversion effects, supply of low noise vehicles and adjacent parking.
Further information	See deliverable D2.11

A way to create quiet areas is to apply restrictions on noisy vehicles to enter a zone. The feasibility of such a measure depends however on the provision of adjacent parking space and low noise vehicles. Scenarios were modelled where noisy vehicles were restricted by road barriers or had to pay a charge. The restricted area, illustrated in Figure 6, was a generalised street network placed in the district Södermalm. The size of the zone is approximately 2 km^2.

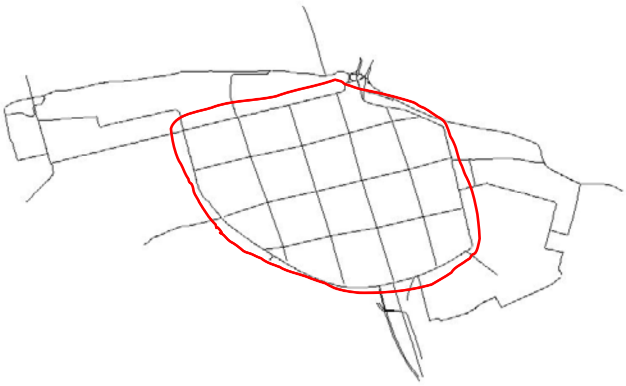

Figure 6: Södermalm with restricted area encircled in red.

In the model owners of noisy vehicles have to choose between different alternatives, namely pay the charge, park outside and walk in to the area, change route, change travel mode to e.g. public transport or change destination. Using forecasted traffic data from the transport model noise maps were created. Low noise vehicles were modelled to have a tyre/road noise 5 dB lower and an engine noise 10 dB lower than noisy vehicles. Building blocks were calculated with reflecting façade material. For more information about these values and calculations see deliverable D2.11.

A base scenario was modelled assuming a 5 % share of low noise vehicles for all car owners in the Stockholm County. When road barriers were applied the low noise vehicle share was assumed to be 5% outside the restricted zone and 100% for people living inside the restricted zone. Figure 7 illustrates the difference in noise levels for this scenario relative to the base scenario. Inside the area the noise reduction on car roads is large, in average 10 dB(A) and at maximum 14 dB(A). On pedestrian streets the reductions is approximately 3-4 dB(A). The boundary roads get higher noise levels due to rerouting, in average 2-3 dB(A) and 6 dB(A) at maximum. There are small leakage effects near the boundary on pedestrian streets but no leakage close to the barriers.

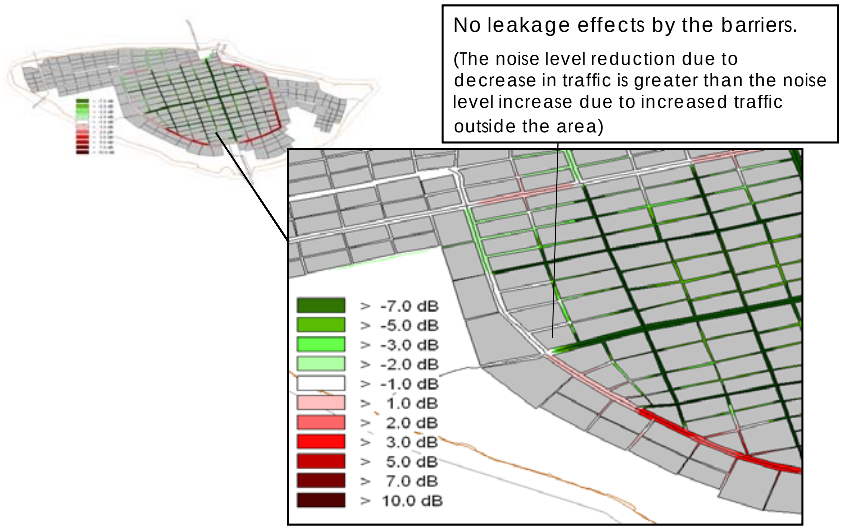

Figure 7: Difference in noise levels due to road barriers for noisy vehicles, L_{DAY}, building blocks in gray.

Figure 8 illustrates a difference plot where owners of noisy vehicles need to pay a charge of 2 euro to enter or leave the restricted area. In this scenario the car ownership of low noise vehicles is assumed to be 20% inside the area and 5% outside. Again there are large noise reductions inside the area in average 7 dB(A) and at maximum 11dB(A). Pedestrian streets get a reduction of approximately 2 dB(A) and we get small leakage effects by the boundary. The increase in noise levels on the ring road is approximately 2-3 dB(A) and at maximum around 6 dB(A).

Figure 8: Difference in noise levels due to charging of noisy vehicles, L_{DAY}.

Our noise calculations are generalized and we are modelling ideal conditions (e.g. high share of low noise vehicles, no limitation of parking space and heavy vehicles need to follow the restrictions). Nonetheless our analyses show that this concept has a large noise reduction potential. However an implementation would be expensive. Additional parking space outside the area must probably be supplied and a system to register passing vehicles must be developed and applied. On the other hand a well-designed charging system will in the long run give revenues.

Further investigation is needed and before a measure of this type could be applied a thorough cost-benefit analysis must be undertaken. One ought to consider both environmental effects and effects on commerce and accessibility. We may also face a new traffic safety issue, accidents caused by people not noticing the low noise vehicles.

Scenario 4	***Increased frequency of public transport services***
Problem	Area wide road traffic noise
Expected noise reduction	As a single measure it generally gives small noise reductions.
Detailed description/objectives	By improved public transport people travelling by car shift to public transport.
Examples	See below
Cost	High implementation cost
Interactions – Limitations	Other effects than noise impacts need to be considered.
Further information	See deliverable D2.14

If the frequency of public transport services is increased, the attractivity of the mode is increased. As a consequence people will to a higher extent choose to travel by bus, subway or train. A scenario was created where the frequency of all public transport lines including buses and commuter trains was increased by 25 % relative to the base scenario.

The result on peak hour traffic volumes relative to the base scenario is illustrated in Figure 9. It shows the effect on flows in absolute numbers where green is a decrease and red an increase. Although this is a very large improvement of the public transport system, the impact on traffic flows is small. The relative change in flows is on most links a decrease below 10% and often close to zero. Effects on speed are small. Off-peak hour results show the same pattern. Thus this policy will give small but area wide noise effects. However, the increased numbers of buses and trains may offset the decrease in car traffic.

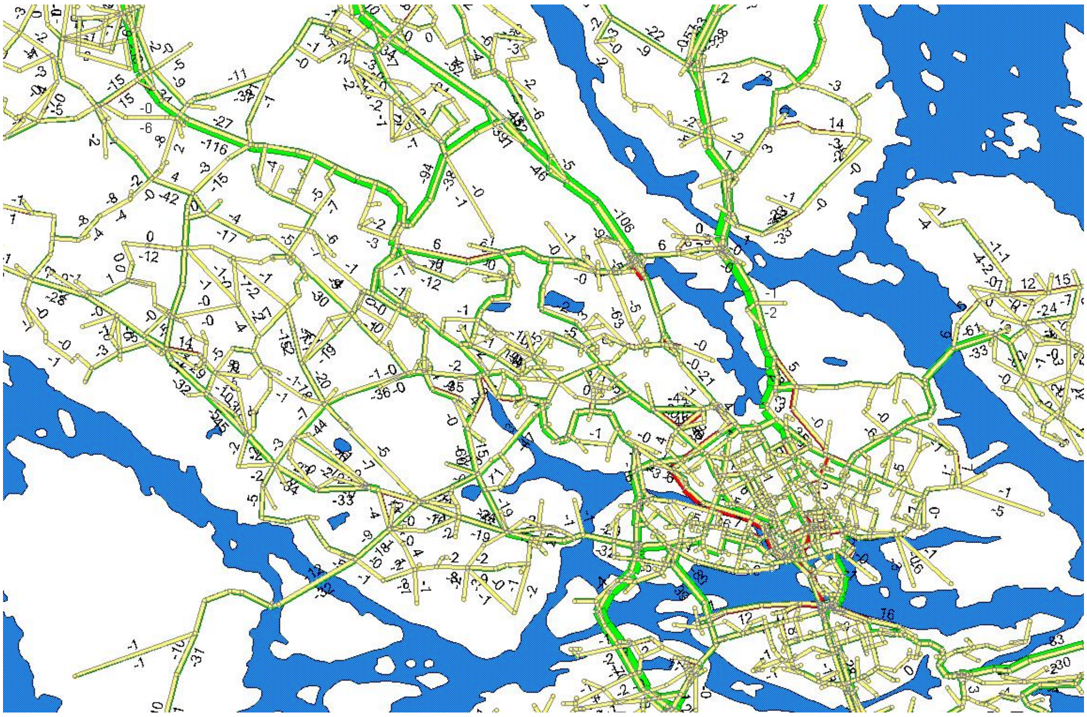

Figure 9: Absolute difference in car traffic due to increased frequency in public transport. Green shows decrease, red increase, (Peak hour traffic).

The total effect on travel pattern is illustrated in Figure 10. The increase in use of public transport is a result of less car driving but also less use of bicycle and walk. Other effects at a total network level are described in Table 1.

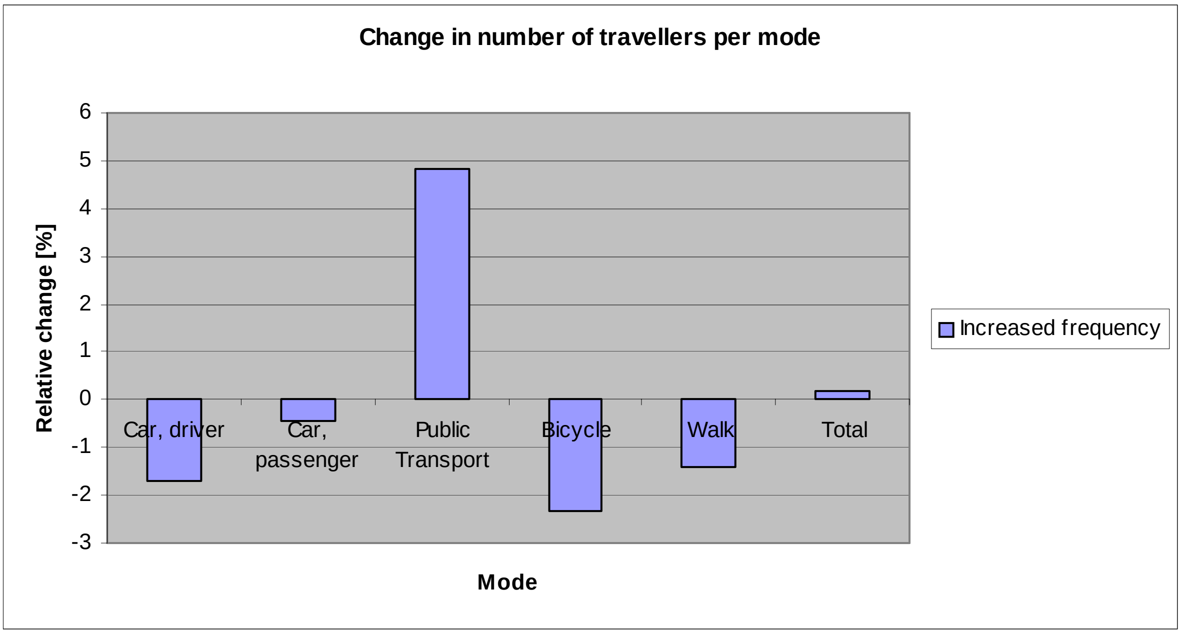

Figure 10: Change in number of travellers per mode relative to base scenario (total network level).

Total vehicle kilometres	- 1%
Person hours in car	- 3%
Person hours all modes in total*	+ 4%
Total emissions in tons**	- 1%
Accidents	- 1%

* Car driver, car passenger and public transport
** CO_2- equivalents, NO_x, HC, SO_2 and particles

Table 1: Effects at total network level relative to base scenario.

Scenario 5	***Decreased ticket price for public transport***
Problem	Area wide road traffic noise
Expected noise reduction	As a single measure it gives small noise reductions.
Detailed description/objectives	By improved public transport people travelling by car shift to public transport.
Examples	See below
Cost	High revenue loss.
Interactions – Limitations	Other effects than noise impact needs to be considered.
Further information	See deliverable D2.14

A way to reduce car traffic is to reduce the fare for public transport and thus make this mode more attractive. In a scenario the ticket price was reduced by 50% on both single tickets and season tickets. The effect on peak hour traffic volumes is illustrated in Figure 11. It shows the changes in volumes in absolute numbers (green is a decrease and red is an increase). The relative decrease is generally lower than 5 %, which gives small noise reductions. In addition, on some roads the traffic volumes is increased due to rerouting. The increases are however not large. Off-peak hour results show the same pattern.

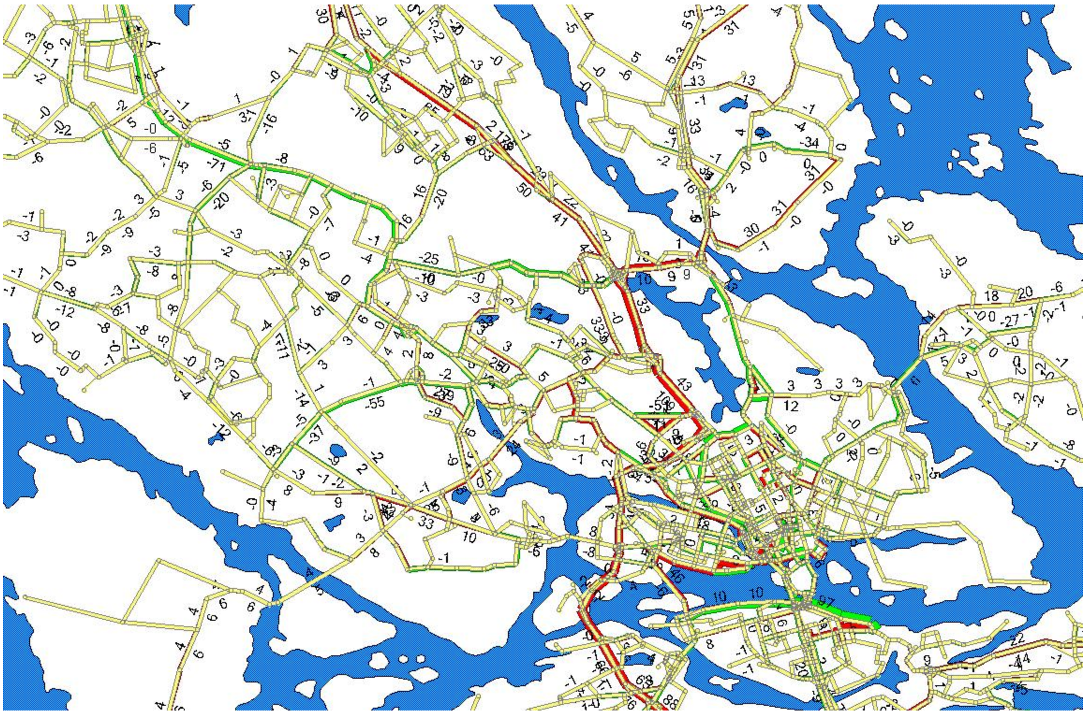

Figure 11: Absolute difference in traffic flow due to lowered ticket price for public transport (morning peak hour traffic), green decrease, red increase.

The total effect on travel pattern is illustrated in Figure 12. The increase in use of public transport is a result of less car driving but also less use of bicycle and walk as travel mode. Other effects at a total network level are described in Table 2.

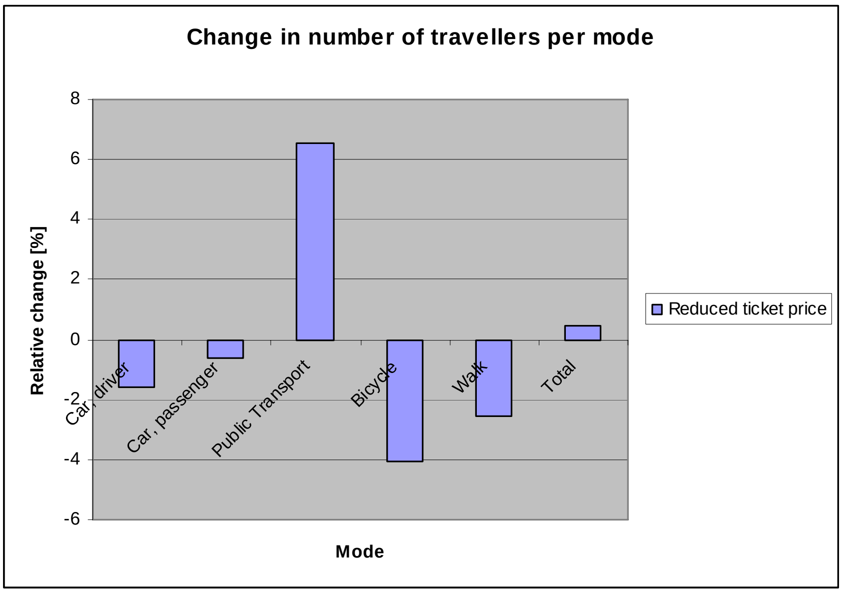

Figure 12: Change in number of travellers per mode relative to base scenario (total network level).

Total vehicle kilometres	- 0.4 %
Person hours in car	- 3 %
Person hours all modes in total*	+ 3 %
Total emissions in tons**	- 0.3 %
Accidents	- 0.4 %

*Car driver, car passenger and public transport
** CO_2- equivalents, NO_x, HC, SO_2 and particles

Table 2: Effects at total network level relative to base scenario.

Scenario 6	***Area wide congestion charging schemes***
Problem	Area wide road traffic noise
Expected noise reduction	As a single measure it gives small noise reductions, 1-2 dB(A).
Detailed description/objectives	Area wide congestion charging schemes for people travelling by car.
Examples	See below
Cost	Should be less than revenues.
Interactions – Limitations	Other effects than noise impacts need to be considered.
Further information	See deliverable D2.14 and www.stockholmsforsoket.se

A possible way to reduce traffic volumes is to introduce a charge for car travellers entering an area e.g. the city centre. A scenario was implemented with toll charges corresponding to the Stockholm trial. The fee in peak hours was 20 SEK, in off peak hours 10 SEK and the maximum fee per day 60 SEK (1 SEK is approximately 0.1 euro). The charging area is illustrated in Figure 13.

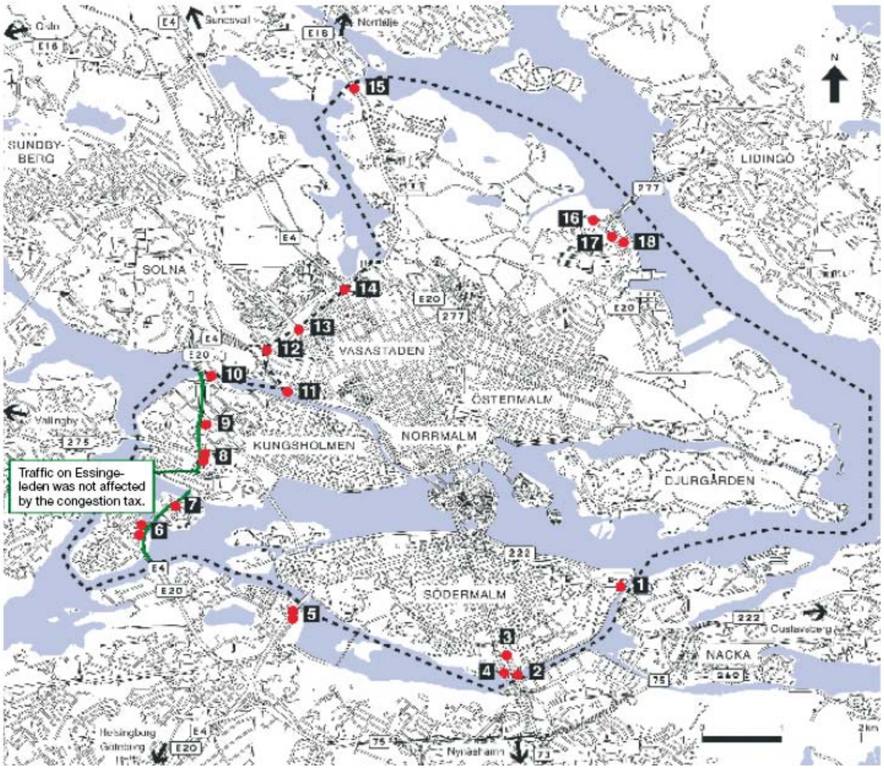

Figure 13: Charging area in the Stockholm Trial.

Traffic volume results in peak hour for the modelled scenario are shown in Figure 14 and Figure 15 where green is a decrease and red an increase (off-peak hour results show the same pattern). They illustrate that the impact on traffic volumes are relatively large close to the city centre, however not large enough to give large noise level impacts. Experience from the Stockholm Trial, where both congestion charges and improved public transport were adapted, showed overall no or little effect on noise levels. The effects where approximately changes of 1 dB(A) up to 2 dB(A). Though the effects are not audible studies showed that a part of the population felt that the noise had decreased due to reduced congestion and traffic.

Figure 14: Difference in traffic flow in peak hour due to area wide congestion charging scheme. North part of the charging area.

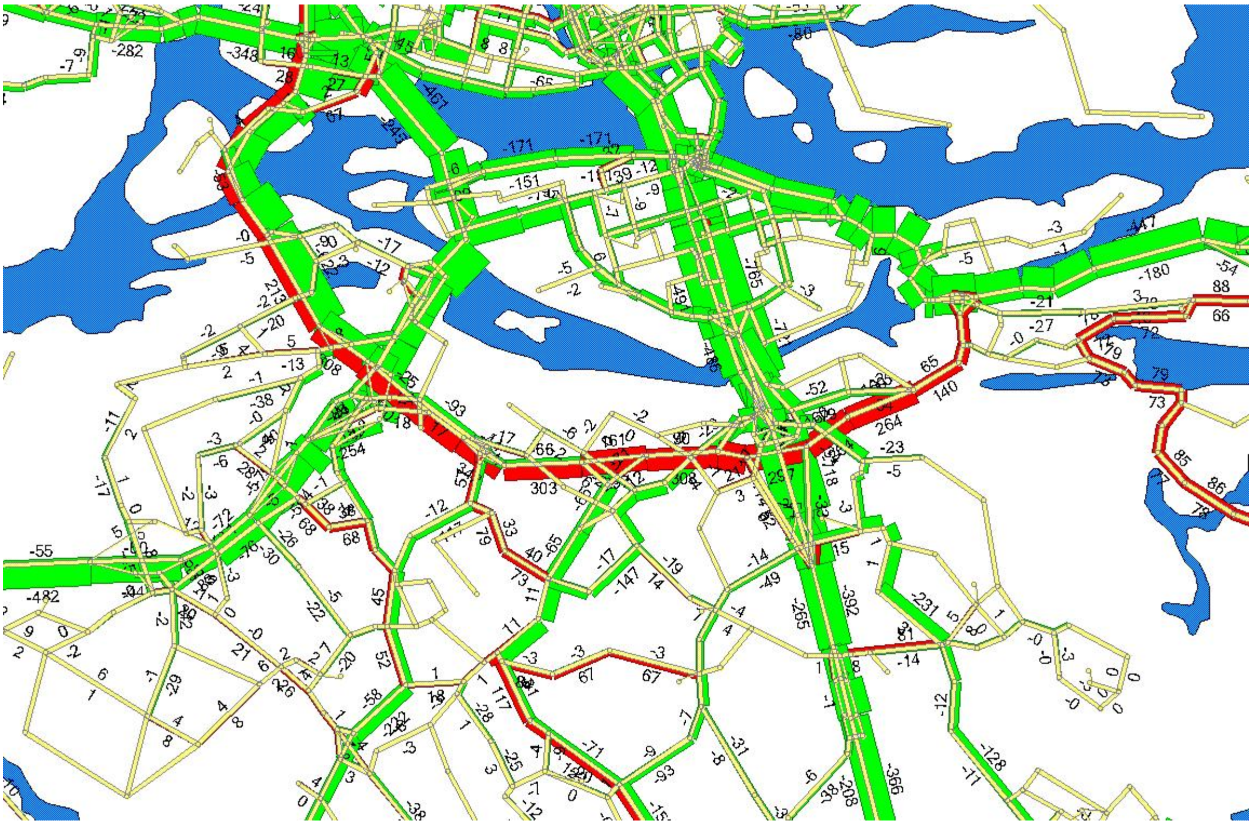

Figure 15: Difference in traffic flow in peak hour due to area wide congestion charging scheme. South part of the charging area.

The total effect on travel pattern for the modelled scenario is illustrated in Figure 16. Other effects such as change in vehicle kilometres are described in Table 3.

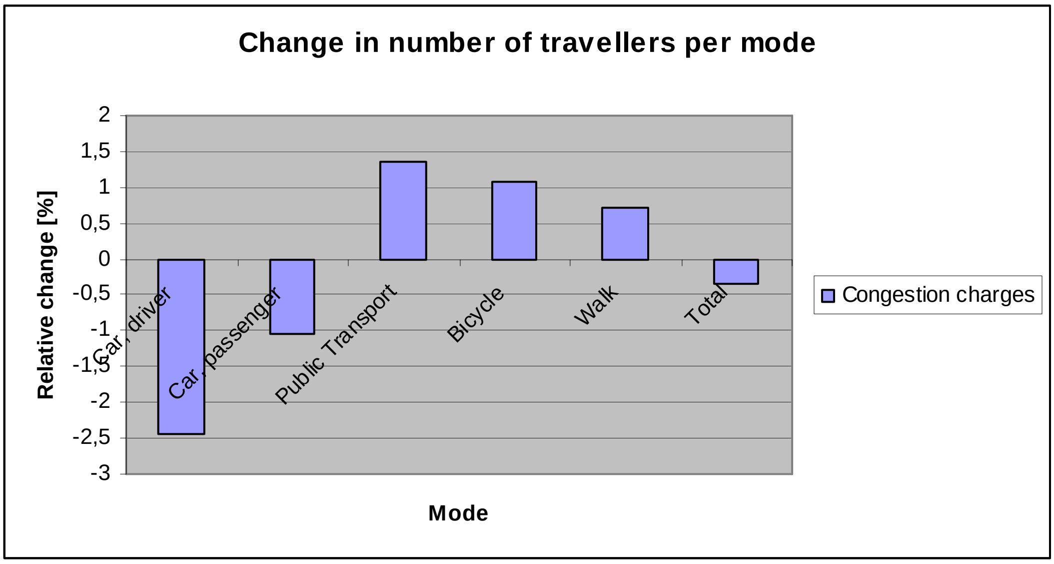

Figure 16: Change in number of travellers per mode relative to base scenario (total network level).

Total vehicle kilometres	- 3 %
Person hours in car	- 9 %
Person hours all modes in total	- 3 %
Total emissions in tons**	- 3 %
Accidents	- 3 %

* Car driver, car passenger and public transport.
** CO_2- equivalents, NO_x, HC, SO_2 and particles.

Table 3: Effects at total network level relative to base scenario

Scenario 7	***Decrease aggressive driver behaviour***
Problem	Traffic noise from road due to aggressive driver behaviour.
Expected noise reduction	About 1 dB(A)
Detailed description/objectives	Make people drive less aggressively.
Examples	See below
Cost	Situation specific
Interactions – Limitations	Increased supervision or ISA-systems is necessary.
Further information	See deliverable D2.13

In a study we modelled a generalised stretch of road, a straight 2 km road with speed limit 70 km/h and traffic signals at the beginning and the end. The road was divided into three segments. For each segment and simulation step we collected simulation data in form of speed and acceleration/deceleration for each vehicle passing. See a schematic picture of the road in Figure 17.

Figure 17: Segments of the study road.

Different driver behaviour was described by three driver categories "calm", "normal" and "aggressive". Each group was modelled by a set of fixed driver behaviour parameters, see Table 4. To simplify the study we only studied passenger cars.

Table 4: Driver behaviour parameters per driver type.

	Calm	Normal	Aggressive
Share [%]	30	50	20
Max desired speed [km/h]	70	80	100*
Max acceleration [m/s^2]	1.9	2.1	3.5
Normal Deceleration [m/s^2]	2	2	3
Max deceleration [m/s^2]	3.5	3.5	4.5
Speed Acceptance	1	1.15	1.43
Min Distance Vehicle [m]	2	1.5	1

*The speed where you in Sweden lose your drivers license if spotted travelling on a 70km/h road.

To analyse the noise impact of different driver behaviour and also the noise calculation method, several scenarios where modelled. Tables below show their characteristics. For all scenarios we made simulations with speed acceptance parameters according to Table 4 and to resemble an ISA system, we made simulations with the speed acceptance set to 1 for all driver types. In Table 5 and Table 6 noise impact due to the traffic calming measure is illustrated for the first and the second section. Results of the third section (the end section) are not presented. Our studies showed that these results very much depended on the circle time of the traffic signals and it is therefore not relevant to make scenario comparisons for this section.

Table 5: Results on the first section (after the traffic signal).

Length [m]	Total flow [vehicles/h]	Share of calm drivers [%]	Share of normal drivers [%]	Share of aggressive drivers [%]	Number of replications	Average speed [km/h]	Average speed with ISA [km/h]	Total noise level [dB(A)]	Difference in noise level due to ISA [dB(A)]
250	500	30	50	20	10	70	63	75,5	-1,0
125	500	30	50	20	10	65	59	75,2	-0,9
250	2000	30	50	20	3	62	59	74,1	-0,5
250	500	0	0	100	3	89	65	78,8	-3,4
125	500	0	0	100	3	81	63	78,9	-2,9

Table 6: Results on the second section (middle of the road).

Length [m]	Total flow [vehicles/h]	Share of calm drivers [%]	Share of normal drivers [%]	Share of aggressive drivers [%]	Number of replications	Average speed [km/h]	Average speed with ISA [km/h]	Noise level [dB(A)]	Difference in noise level due to ISA [dB(A)]
1500	500	30	50	20	10	79	70	75,7	-1,2
1750	500	30	50	20	10	79	70	75,6	-1,1
1500	2000	30	50	20	3	74	70	75,0	-0,5
1500	500	0	0	100	3	100	70	79,2	-4,7
1750	500	0	0	100	3	99	70	79,1	-4,6

Our prototype studies show that an ISA system applied to reduce aggressive driver behaviour is likely to give small noise impacts, around 1 dB(A) both after a signalised crossing and at a road section with relatively constant speed. The impact is larger if the degree of aggressive behaviour is high before an implementation. The impact is less if the traffic flow is high. The study only included passenger cars, if heavy vehicles and mopeds and motorcycles where added the noise impact might be higher.

Scenario 8	***Car ownership and car type choice***
Problem	Area wide road traffic noise
Expected noise reduction	About 1 dB(A) in specific areas in 10 years
Detailed description/objectives	To make people own low noise vehicles by applying noise fees for quiet areas
Examples	See below
Cost	Charging system costs, fee revenue
Interactions – Limitations	Effects develop slowly over time
Further information	See deliverable D2.12

In scenario 3, one way of creating a quiet zone was that car drivers had to pay a fee for entering the zone. The fee was set to 2€ per entry or exit, which substantially reduced car use and consequently road traffic noise in the quiet zone. Low noise cars were assumed to be exempt from the fee, and an assumption was that the share of low noise vehicles would become larger within the zone than outside, as almost all car trips originating from the inside would be subject to the noise fee. In scenario 8 we study the noise fee effect with respect to changes in car ownership only.

The share of low noise vehicles (electric hybrid cars are defined to be low noise vehicles) in the car stock is depending on several factors. One factor is supply, i.e. there have to be cars on the market to buy. These cars also have to have characteristics that match those of other cars (size, price, performance etc). Another factor is demand, especially the inertia that is caused by brand loyalty. This makes the supply side even more important, because electric hybrid cars have to be supplied for those brands that already have a high market share in order to penetrate the market less slowly. The third factor is the rate of renewal in the car stock – it will take a long time before the new vehicles on the market have replaced the current ones.

We have modelled this mechanism by applying a choice model for choice of new car type, taking into account vehicle characteristics and differences in substitution elasticity between close alternatives and other alternatives. We have assumed a technical development where there is an increased supply of electric hybrid vehicles, according to the car industry. We have also modelled the development of the car stock over time, accounting for time to put new vehicles on the market, and time to replace older vehicles by new ones. We have chosen a ten years perspective for the development of the car stock.

The results in this scenario shows that people frequently using their car to enter or exit areas subject to noise fees will adapt by increasing ownership of low noise cars. The model results are, given an increased supply of electric hybrid vehicles, that the share of electric hybrids for these people can approach 40 percent for new cars towards the year 2010. The share of electric hybrid cars in their car stock can be estimated to reach 15 percent in the year 2016. Possible effects of second hand car purchases, not handled by the model, may contribute to reaching this share earlier.

The immediate noise reduction due to the changes in the car stock is small, but develops over time as the share of electric hybrid cars increases. Another way to adapt to noise fees is to reduce car ownership, i.e. to decrease the number of cars owned. Based on a car ownership model, this effect can be estimated to about 5 percent for people living inside the area.

It should be recognised that the results are based on a fairly high fee, and that the results depend on the actual situation concerning car type market shares.

4 DISCUSSION AND CONCLUSION

The QCity project is mainly related to noise mitigation measures on vehicles or along the road, reducing noise but not affecting traffic itself. In this work package we in addition study measures affecting the noise source directly, i.e. traffic. The nature of such measures is different in two important ways. The first is that they impact not only noise, but also accessibility, other emissions and accidents, etc. The second is that traffic management measures, undertaken to obtain an effect at some desired site, also will have redistribution effects, i.e. diverted traffic will cause noise (and other) effects elsewhere. These effects need to be considered to avoid sub optimization. Thus **noise reduction** and **noise redistribution** are keywords when traffic management measures are analysed.

In addition, differences in speed due to traffic management measures are important, as it affects noise levels as well as travel times. Ability to forecast speed changes is therefore essential and should be considered if any measure related to traffic management measure is to be applied.

Effects of a noise mitigation measure related to traffic management will always be network dependent and site specific. Here, we therefore present effects and costs less precise than for what is possible for physical noise mitigation devices, based on examples studied.

In our study examples, the measures that show the largest potential of noise reduction are closing off trough traffic and restrictions on noisy vehicles to create quiet areas. The feasibility of the latter depends however also on the provision of adjacent parking space and low noise vehicles. Moreover they are both related to relatively large redistribution effects. Reduced speed limits give a relatively high noise reduction and redistribution effects are lower than for closing off through traffic.

Measures related to reducing car traffic in general, such as improved public transport or area wide congestion charging schemes, do not give enough traffic volume reductions to give more than small noise effects, generally less than 1 dB(A) or possibly 1 to 2 dB(A). However, these measures give area wide reductions in opposite to measures like reduced speed on a specific link.

Our prototype studies show that an Intelligent Speed Adaptation (ISA) system applied to reduce aggressive driver behaviour is likely to give small noise impacts, around 1 dB(A) both after a signalised crossing and at a road section with relatively constant speed. The impact is larger if the degree of aggressive behaviour is high before an implementation. The impact is less if the traffic flow is high. The study only included passenger cars, if heavy vehicles and mopeds and motorcycles where added the noise impact might be higher.

The costs to undertake a traffic management measure are difficult to present, as they consist of two parts. One part is related to the implementation of the measure in question, like the cost of changing the speed limit sign, and one part is related to the effects of the measure, like car running costs, values of travel time changes, emission costs and accident costs. As for noise effects, these costs are difficult to present, as they are situation specific. Also, different countries apply different economic values to these effects. However we believe it is important to make cost-benefit analyses when noise mitigation measures of this type are applied. Below we present general cost aspects of the measure studied.

The implementation cost of closing off a road for through traffic or decrease speed limits is relatively low and they are easy to put into practice. To create quiet areas by restricting noisy vehicles is a relatively expensive action to implement. If charges are applied revenues should be used to finance the system and possibly also to pay for measures to reduce negative noise boundary effects.

In a cost perspective the cost of an ISA system is high and implies installation of ISA devices on individual vehicles. Increased supervision is less expensive and can more easily be locally implemented. In both cases the value of traffic safety gains and noise reduction effects should be related to the costs.

Increased public transport service is a very expensive action, both to implement and to maintain whilst a well-designed congestion-charging system gives revenues. To reduce transit fares is also very costly, revenues are decreased and it may also be costly to meet the increase in demand. For congested cities, where there is scope for improving traffic conditions, congestion charging seems to be the most cost effective way of reducing car traffic (and consequently road traffic noise) among the mode shifting policies studied. Even if the effects of the policies studied will be site specific to some extent, we believe this is a general conclusion.

Because noise effects of mode shift policies are not large, the main objectives of such policies are generally not related primarily to noise. But because the small effects are widely spread, and because small effects from different policies can add to each other, we believe it is important not to forget about these effects but to ensure that such noise impacts are properly considered, for example by inclusion in cost-benefit analyses.

Measures related to reducing car ownership and increasing the share of low noise vehicles in the car fleet are not likely to have immediate effects on the car stock, because of the inertia of car stock changes. In addition, effects of locally decided measures that can affect the total car fleet size, like congestion charges, are estimated to be small. Measures taken to promote low noise vehicle purchase, like noise fees, will have an impact over time, but is depending on an increased supply of electric hybrid cars.

The acceptance of applying any of the measures studied is related to the number of people affected. We believe that reduced speed has higher acceptance than closing off trough traffic as it generally impacts the driver less and is also related to positive traffic safety effects. Swedish studies show that the acceptance of measures impacting driver behaviour in form of speed cameras or ISA-systems is relatively high, though the acceptance is lower for men and professional drivers (Transek 2006 and Vägverket 2002). Creation of quiet areas using restrictions on noisy vehicles will most likely have a low level of acceptance. But for people living inside the area and for owners of low noise vehicles the level of acceptance would possibly be much higher. Improvements in public transport generally have a high level of acceptance. The acceptance will be lower for people exposed to higher levels due to increased frequency of public transport services. In both London and Stockholm, where congestion-charging schemes have been implemented, more people had a positive opinion about the system after the implementation than prior. However the acceptance was higher inside the areas than outside.

The scenarios studied are of different character and are applied at specific roads/sites or work area wide. Therefore it is difficult to make a final ranking. Though, altogether the conclusion is that reduced speed limit is the measure of all studied that shows the largest potential. It gives relatively high noise reductions and low noise redistribution effects. It is an inexpensive and easy measure to implement. Moreover reduced speed also generally has a positive impact on traffic safety aspects and air quality. Together with noise reduction effects this would most likely lead to a relatively high level of acceptance. However, a large-scale application of speed reduction may face lower acceptance, if there are noticeable accessibility effects. The reduction of speed from 50 to 30 km/h in most residential streets in Stockholm was widely accepted (Trafikkontoret 2006). Reductions on longer stretches of arterial streets may face more resistance.

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