DELIVERABLE 2.5

CONTRACT N° TIP4-CT-2005-516420

PROJECT N° FP6-516420

ACRONYM QCITY

TITLE Quiet City Transport

Subproject 2 Perception of vehicle noise sources

Work Package 2.3 Evaluate noise mitigation measures

Sub Work Package 2.3.4 Car Ownership measures for vehicles: Basic concepts

Written by Staffan Algers KTH

Date of issue of this report 2006-02-13

PROJECT CO-ORDINATOR
PARTNERS

Acoustic Control	ACL	SE
Accon	ACC	DE
Akron	AKR	BE
Amec Spie Rail	AMEC	FR
Alfa Products & Technologies	APT	BE
Banverket	BAN	SE
Composite Damping Material	CDM	BE
Havenbedrijf Oostende	HOOS	BE
Frateur de Pourcq	FDP	BE
Goodyear	GOOD	LU
Head Acoustics	HAC	SE
Heijmans Infra	HEIJ	BE
Royal Institute of Technology	KTH	SE
Vlaamse Vervoersmaatschappij DE LIJN	LIJN	BE
Lucchini Sidermeccanica	LUC	IT
NCC Roads	NCC	SE
Stockholm Environmental & Health Administration	SEA	SE
Société des Transports Intercommunaux de Bruxelles	STIB	BE
Netherlands Organisation for Applied Scientific Research	TNO	NL
Trafikkontoret Göteborg	TRAF	SE
Tram SA	TRAM	GR
TT&E Consultants	TTE	GR
University of Cambridge	UCAM	UK
University of Thessaly	UTH	GR
Voestalpine Schienen	VAS	AU
Zbloc Norden	ZBN	SE
Union of European Railway Industries	UNIFE	BE

PROJECT START DATE February 1, 2005

DURATION 48 months

Project funded by the European Community under the SIXTH FRAMEWORK PROGRAMME
PRIORITY 6
Sustainable development, global change & ecosystems

This deliverable has been quality checked and approved by QCITY Coordinator ***Nils-Åke Nilsson***

TABLE OF CONTENTS

0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

The objective of deliverable 2.5 is to describe the basic concepts of the methods used when studying car ownership effects on noise levels. It sets out the methodology that will be used when calculating these effects, and describes what types of scenarios that will be used.

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

In this task, effects related to car ownership polices will be analysed. This means that the level of car ownership as well as the car stock composition is of interest. In the EU project TREMOVE, a policy assessment model (also called TREMOVE) has been developed to study the effects of different transport and environment policies on the emissions of the transport sector (TREMOVE 2.30 Final Report 2005). The model estimates the transport demand, the modal shifts, the vehicle stock renewal, the emissions of air pollutants and the welfare level for different policies (for instance, road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc.) TREMOVE models both passenger and freight transport in the EU15 plus 6 extra countries, and covers the period 1995-2020. The TREMOVE model is quite aggregate, and is less well suited for application at the level of an urban area. Therefore, we have decided to use models that are more specific to the area under study, and that allow more detail for the issues at hand. However, concepts used in TREMOVE, like discrete choice theory, are also used in the models applied in QCITY.

In the QCITY project, the Sampers forecasting system together with a car ownership model developed on behalf of the Swedish Rail Administration and a car stock model developed on behalf of the Swedish Road Administration will be used in this task.

0.3 BACKGROUND INFO AVAILABLE AND THE INNOVATIVE ELEMENTS WHICH WERE DEVELOPED

This task involves two types of innovative elements – one is to relate car ownership and car stock effects to traffic noise effects, and the other one is to relate policies to promote less noisy vehicles to other types of noise mitigation measures.

0.4 PROBLEMS ENCOUNTERED

During the model and interface development we have not encountered any major problems that have made us reconsider the overall approach of the studies. However, the proposed methodology relies on model development outside the QCITY project, which has been subject to some delay due to delays in data collection. The work with this task has therefore not been advanced as much as was anticipated from the beginning. The necessary data have now been collected, and it is foreseen that the delay not will affect the time schedule for completion of the task.

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

Partners involved in WP 2.3.3 have been the Royal Institute of Technology (KTH). The contribution so far is the elaboration of the modeling concept.

0.6 CONCLUSIONS

A method for describing effects of car ownership policies on traffic noise has been elaborated. The method enables calculation of noise effects of restrictions to use certain types of vehicles, as well as noise effects of promotion of low noise vehicles. Noise calculations will be based on multilayer noise sources (like in the case of driver behaviour), and the same type of interface between the forecasting software and the noise mapping software as is described in Deliverable 2.4 will be used.

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

The noise mitigation measures developed in this sub work package will be analyzed in WP 2.3.6 where all measures studied in WP 2.3 will be ranked considering performance/cost, general applicability and general acceptance.

The method and model setup will also be used in SP5, for the Stockholm test site.

1 INTRODUCTION

1.1 BACKGROUND

Noise effects from cars are depending on the size and composition of the car stock. The car stock is in its turn depending on economic growth, land use changes, technical developments in car manufacturing, car taxation policies, alternative transportation modes and traffic policy in general.

In the QCITY project it will be demonstrated to what extent the size and composition of the car fleet can be affected by policy measures of different kinds, and how this will affect noise levels. This will be achieved by explicitly modelling car ownership levels (to get the size of the vehicle fleet) and car purchase behaviour (to get the car fleet composition), in addition to the procedures used in the Traffic Control task.

1.2 TASK DESCRIPTION

The task is to describe effects of different policy measures directed towards reducing the car fleet and promoting the use of quieter vehicles. This requires of a number of steps to be carried out in the Stockholm case:

Modelling the fleet size

Modelling the car composition

Feeding the results into the Sampers forecasting system

Feeding forecasts into the noise calculation software

Reporting of the results

2 METHOD

In this task, effects related to car ownership polices will be analysed. This means that the level of car ownership as well as the car stock composition is of interest. In the EU project TREMOVE, a policy assessment model (also called TREMOVE) has been developed to study the effects of different transport and environment policies on the emissions of the transport sector (TREMOVE 2.30 Final Report 2005). The model estimates the transport demand, the modal shifts, the vehicle stock renewal, the emissions of air pollutants and the welfare level for different policies (for instance, road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc.) TREMOVE models both passenger and freight transport in the EU15 plus 6 extra countries, and covers the period 1995-2020. The TREMOVE model is quite aggregate, and is less well suited for application at the level of an urban area. Therefore, we have decided to use models that are more specific to the area under study, and that allow more detail for the issues at hand. However, concepts used in TREMOVE, like discrete choice theory, are also used in the models applied in QCITY.

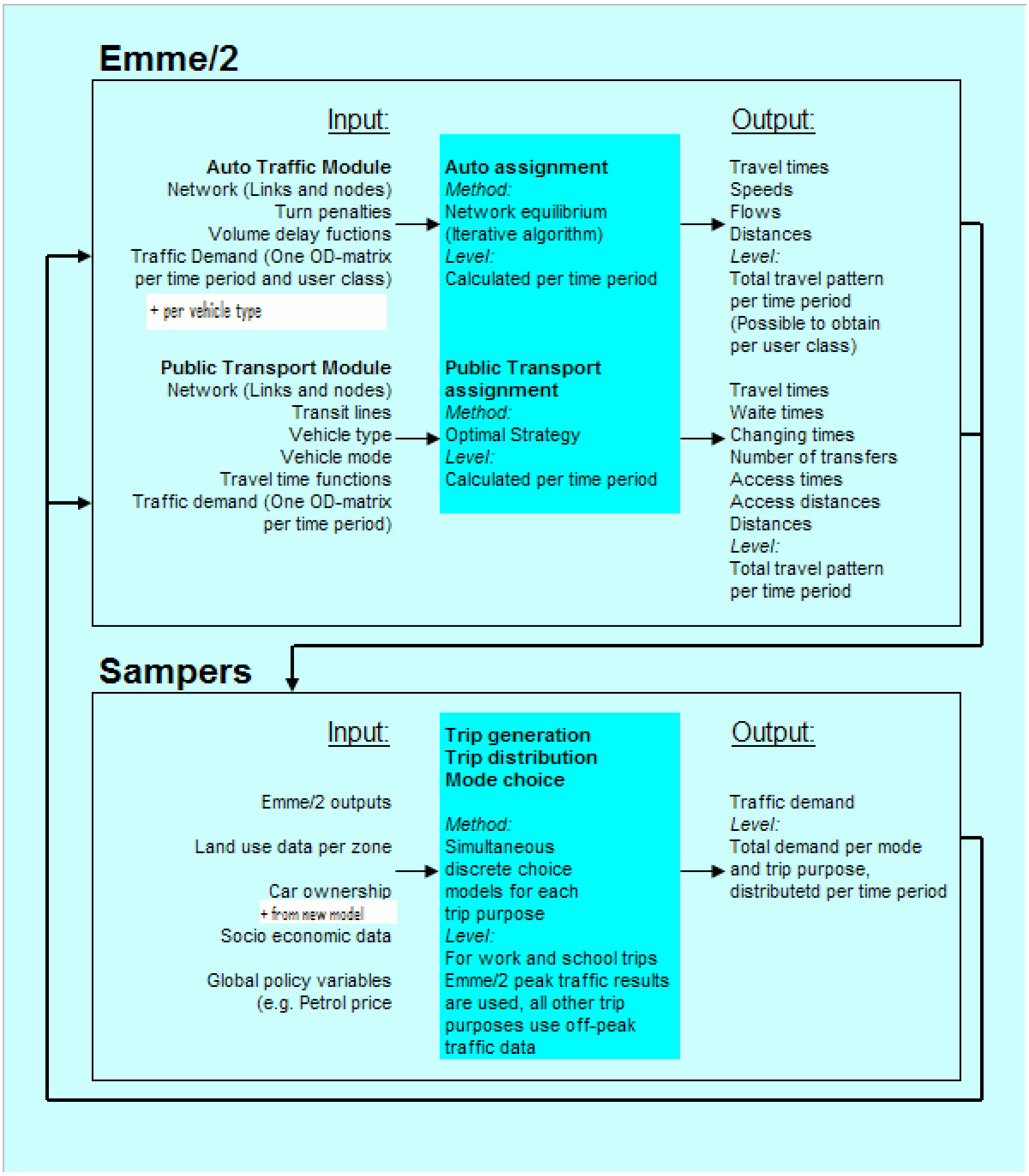
In the QCITY project, the Sampers forecasting system together with a car ownership model developed on behalf of the Swedish Rail Administration and a car stock model developed on behalf of the Swedish Road Administration will be used in this task.

2.1 THE SAMPERS FORECASTING SYSTEM

The Sampers forecasting system contains a module for car ownership. This module includes socioeconomic variables and a variable for petrol price. The car ownership levels are not sensitive to public transport measures or to policies constraining car use (such as the congestion charging system currently in use). There is also no regard to the types of cars that are used for personal traffic. In order to make it possible to analyse effects of car ownership and car stock effects, the Sampers system needs to be enhanced by models that can do these tasks.

Such an enhancement is out of scope for the QCITY project, but fortunately such enhancements are being provided by other actors. A new car ownership model has been developed, commissioned by the Swedish Rail Administration (Transek and the Royal Institute of Technology, 2005). A model for car stock composition is also under development, commissioned by the Swedish Road Administration. The new models are not fully integrated in the Sampers system, and the interface between the models needs to be manually handled in the QCITY project. The models are described in further detail below.

The Sampers model system can be summarised in the graph below:



The places where the information from the additional car ownership and car fleet composition models is fed into the model are shown in the graph (with a + in white).

2.2 A POLICY SENSITIVE MODEL FOR CAR OWNERSHIP

Many model systems are based on discrete choice models, like the models in the Sampers forecasting system. These models comprise models for mode- and destination choice. The models are of the logit type, and are based on assumptions of utility maximisation. An individual is assumed to choose the alternative that gives him/her the most benefit (highest utility). As we cannot know the full utility function of all individuals, we define the utility as a stochastic variable (i.e. a variable that contains a stochastic part) and calculate the probabilities for an alternative to be chosen rather than actual choices. Working with stochastic utilities means that we use the concept of expected maximum utility in stead of an actual maximum utility.

Given a discrete choice model of the logit type (Ben-Akiva and Lerman, 1985), the expected maximum utility can be described by the so called logsum variable. Thus, the expected maximum utility over all mode and destination alternatives can be calculated. The variables associated with mode and destination alternatives are related to the transport system as well as to the land use pattern. This variable is some times also called accessibility.

A property of the logsum variable is that it increases if travel costs and travel times are shortened (and reverse). It also increases if another mode is added to the set of available alternatives (e.g. by acquisition of a car), or if more activities are added (like more workplaces). Specifically, the effect on the logsum variable (accessibility) of adding a mode is depending on its utility relative to other modes. If the other modes have longer travel times, the impact will be larger. This means that the utility of having a car is depending on the performance of other alternatives, as well as on the car performance. In other words, improvements of other modes will affect (decrease) the utility gain from acquiring a car, and restrictions on car use will affect (decrease) the utility gain from acquiring a car (and reverse of course). This means that we have a device for describing the utility of holding a car, which could be used in a discrete choice model for the number of cars in a household.

As car holding is a household choice rather than an individual choice, it is needed to take into account the effects for all household members. This can be done by summing up the utilities for all household members. Another issue is how to describe utility effects of having more than one car in the household. This can be done by using a measure of car competition, often expressed as the ratio between the number of driving licenses in the household and the number of cars.

The development of a model based on the above mentioned concepts was commissioned by the Swedish Rail administration, and was completed in 2005. The model can formally be described by the following formula:

$$P(i) = \frac{\exp(\sum_k \beta_k x_{ki})}{\sum_{j \in C} \exp(\sum_k \beta_k x_{kj})}$$, where

P(i) = probability to choose alternative i

β_k = coefficient for variable k

x_{ki} = variable k for alternative i

C = the choice set (all available alternatives)

The coefficients in the model are reported in the table below. In the table, for each variable the alternative to which it belongs (0 1 or 2+ cars), the coefficient value and the t-value are reported:

Variable	Alt.	Coefficient	t-value
Constant for one car alternative	1	-2.79	-23.9
Constant for 2+ cars alternative	2+	-7.03	-44.5
Logsum difference other purpose	1	0.36	10.2
Logsum difference work purpose	1	0.42	8.2
Logsum difference other purpose	2+	0.67	13.0
Logsum difference work purpose	2+	0.60	9.8
One person household, age 25-44	0	-0.70	-11.5
One person household, age 45-64	0	-0.69	-10.9
One person household, age 65 -	0	0.02	0.4
One person hh with child, youngest age 0-6	0	-0.51	-5.0
One person hh with child, youngest age 7-18	0	-0.81	-9.2
One person hh without children	0	-0.86	-9.6
Couple without children, age 15-24	0	0.99	2.5
Couple without children, age 25-44	0	0.67	1.7
Couple without children, age 45-64	0	-0.19	-0.5
Couple without children, age 65-	0	0.00	0.0
Couple with 1 child, age 0-6	0	0.42	1.1
Couple with 1 child, age 7-18	0	-0.10	-0.2
Couple with 2+ children, youngest age 0-6	0	0.12	0.3
Couple with 2+ children, youngest age 7-18	0	-0.06	-0.2
One person household, worker	1	0.30	3.8
Couple, none working	1	2.04	5.3
Couple, 1 person working	1	2.13	5.4
Couple, 2 persons working	1	2.62	6.6
One person household, worker	2+	0.88	6.7
Couple, none working	2+	2.67	6.7
Couple, 1 person working	2+	3.87	9.4

Couple, 2 persons working	2+	4.77	11.6
Lives in own house	1	1.25	34.1
Lives in own house	2+	2.30	46.1
Houshold income (1000 SEK) – low income hh	1	0.00764	17.0
Houshold income (1000 SEK) – high income hh	1	0.00011	0.4
Houshold income (1000 SEK) – low income hh	2+	0.00686	14.6
Houshold income (1000 SEK) – high income hh	2+	0.00136	4.2

The model is implemented in a special version of the Sampers forecasting system. The logsums used in the car ownership model come from the models for mode and destination choice used in the Sampers system. Therefore, effects of various policies on car ownership can be analysed with the model.

In the QCITY project, it is intended to model effects of car restraints – specifically congestion charging - as well as public transport improvements. The noise effects will be calculated in the same way as is described in Deliverable 2.4.

2.3 A MODEL FOR CAR STOCK COMPOSITION

The car stock composition is a result of people's decisions to acquire new cars and to scrap old ones, accumulated over time. A model for the car stock composition should therefore reflect this process. This can be done by a model for choice of car type, given the decision to by a new car, and a model for scrapping cars. This is similar to the TREMOVE concept. The number of new car purchases is given by the result of the car ownership model (giving the change in the total stock) and scrapping. Other concepts are conceivable, but this concept is chosen for simplicity. Formally, the model for the car stock year t can be written like:

$$\text{stock}_{\text{year t}} = \text{stock}_{\text{year t-1}} - \text{scrapping}_{\text{year t}} + \text{new purchase}_{\text{year t}}$$

where stock is a matrix of car models by year (vintage), scrapping is a matrix of scrapped models and new purchase is a vector of new models.

The development of such a model was commissioned by the Swedish Road Administration, and is now near completion.

The model for choice of new car to purchase is of course the one that is most responsve to car promotion policies. This model is also the one that is most elaborated. The modelling work is based on two major types of sources describing new purchase behaviour. The largest source is the Swedish Car Register, which contains data for the complete Swedish car stock. From this data source the stock, new purchases and scrappage was retrieved for a few years. The other data source is a Stated Choice survey directed to persons who bought a new car in the beginning of the autumn 2005.

The scope of the car stock model is to be able to model effects of different policies directed towards purchase of new cars, and thus influencing the car stock composistion. In order to do this, it is necessary to understand what influences car type choice. Therefore, in addition to the data on what cars are purchased, data describing attributes of the makes and models on the market are needed. In addition to the data sources already mentioned, data describing a number of attributes of different car makes and models was also collected.

Modelling car type choice on car register data has to be restricted to attributes already existing. Using only existing data can also be difficult from a statistical point of view, as there may be strong correlation between variables such as price, size, horsepower etc. These two reasons were the main reasons to conduct the stated choice study, in which attributes contained also in the larger data set could be varied in a statistically more efficient way, and where additional attributes such as fuel infrastructure and fuel type could be better analysed.

The final model will be based on a combination of the two data sets, using the strengths of both data sources.

At the current stage, some initial model results can be shown. For the actual purchase data from the car register, a simple logit type choice model with 163 alternatives (composed by brand and model) was estimated. As in the case of the car ownership model, this model for car type choice can formally be described by the following formula:

$$P(i) = \frac{\exp(\sum_k \beta_k x_{ki})}{\sum_{j \in C} \exp(\sum_k \beta_k x_{kj})}$$, where

P(i) = probability to choose alternative i

β_k = coefficient for variable k

x_{ki} = variable k for alternative i

C = the choice set (all available alternatives)

The parameters (the beta's) in the model were as follows:

Variable	**Parameter**	**t-value**
Fuel consumption l/ 10 mil	-0,18	(-28,7)
Purchase price, 1000 SEK	-0,0023	(-42,9)
Weight, kg	0,0012	(36,6)
Horsepower per 1000 kg	0,0059	(7,9)
England	-3,22	(-65,7)
France	-1,89	(-165,9)

Italy	-3,78	(-66,9)
Japan	-2,61	(-222,4)
Korea	-4,14	(-57,5)
Spain	-4,30	(-71,0)
Germany	-1,87	(-215,1)
Czech republic	-1,85	(-78,5)
USA	-3,54	(-98,1)

As can be seen from the table, higher fuel consumption and higher purchase price lead to lower purchase probability, whereas higher weight and more horsepower lead to higher purchase probability. In Sweden, all foreign brands have a lower purchase probability relative to Swedish cars (everything else being equal). The corresponding situation is likely to exist in other countries. This means that market penetration of more environment friendly cars will be slower if these cars are not supplied by domestic producers.

The model shown above is estimated with no regard to type of car owner. In Sweden, as in some other EU states, company cars that are provided to employees for more or less free use constitute a large share of new purchases. This means that not only the purchase price is important, but also the taxation rules for the benefit of enjoying a company car. Therefore separate models need to be developed for company cars and privately owned cars. Different policy variables would be used to affect new car purchase. Also, the model structure will be more elaborated in order to take into account the fact that elasticities may be different between and within brands, i.e that car owners are more inclined to switch to a model with the same brand than an equivalent model of another brand..

The Stated choice study comprised approximately 800 private and 500 company car acquisitions for 2004. Preliminary model results show that petrol/electric hybrids are valued about the same as normal petrol cars, although less than petrol/ethanol and petrol/gas vehicles.

2.4 NOISE EFFECTS OF CHANGED CAR STOCK COMPOSITION

Description of noise effects of changes in the car stock makes it necessary to identify one or more subgroups in the traffic flow. This can be done by attaching such a sub grouping to the car matrices, and assigning the subgroups simultaneously but separately, as is done by the multi user class assignment technique already used to reflect different values of time. Then separate flows for separate car type subgroups can be fed into the noise calculation software CadnaA.

2.5 THE NOISE MAPPING SOFTWARE CADNAA

When creating noise maps CadnaA (developed by Datakustik GmbH, Munich) will be used. CadnaA is a commercial software, continually updated and improved with the latest prediction methods and calculation algorithms.

Calculations will be performed according to official Nordic prediction methods for respective source. For road traffic noise the Nordic prediction method for road traffic noise, rev. 1996, will be used.

The CadnaA software automatically manages the effects of ground absorption, screening, reflections etc. according to the official prediction method.

Calculations demand a 3 dimensional map (Data Terrain Model, DTM) as well as data for the different kinds of sources, e.g. the amount of traffic on a specific road or the sound spectrum for a specific source.

The terrain model is built with contour lines defining the height along the line. Locations of larger wooded areas, lakes shore lines, locations of buildings and screens as well as their height are then implemented to complete the digital terrain model (DTM).

The 24 hours representing the day is divided according to the EU directive 2002/49/EC;

- Day 06 - 18
- Evening 18 - 22
- Night 22 – 06

Traffic data needed to calculate noise levels is speed, flow and share of heavy vehicles of a road represented per time period. In addition it is possible to calculate noise levels of each period separately.

The roads as well as the railways are fitted to the DTM. The bridges and overpasses are taken into account by letting the road “float” at the defined height. No source are placed when roads or railway are in a tunnel.

When the sources are in place the calculations result in a grid showing the calculated sound pressure level. For the study are Järva in Stockholm the grid will have a receiver spacing of 10 by 10 meter and a receiver height of 4 meter.

2.6 ADAPTING TRAFFIC FORECASTS TO NOISE MAPPING SOFTWARE

The adaptation of traffic forecast data to the noise mapping software draws on the work described in Deliverable 2.4 to create an interface between Sampers and CadnaA. The same procedure will be used in this task, which means that the output from the traffic forecast will be transformed into shape files with associated data base files, using a key between the traffic network and the CadnaA road network. The difference will be that there will be more separate flows as a consequence of introducing vehicle subgroups (noisy and less noisy vehicles).

3 DESCRIPTION OF ANALYSED CAR OWNERSHIP SCENARIOS

3.1 NO POLICY CHANGE

The base case is the current situation, against which all other scenarios will be compared.

3.2 GENERAL CAR RESTRICTION POLICY

Different car restriction policies are to be analysed. We take the same policy scenarios that are being used in the other sub work packages, namely:

- congestion charges,
- traffic control,
- improved public transport supply

3.3 CAR TYPE DIFFERENTIATED RESTRICTION POLICY

Car type restriction policies are used in many situations. Often these policies are related to trucks versus private cars. Here, we will look into effects of restrictions related to different types of private cars, specifically silent cars.

3.4 CAR TYPE PROMOTION POLICY

Car type promotion policies are already in use in Sweden. These policies have so far taken the form of reducing company car benefit taxes for persons using alternatively fuelled cars (including electric hybrid cars). Cars using ethanol are given a 20 percent deduction, and cars using gas or are equipped with electric engines are given a 40 percent deduction. Different or increased subsidies can be conceived. Also, provision of fuel infrastructure is of interest. The following types of scenarios are foreseen:

- Doubling of the current company car deductions
- 30 per cent reduction of the price of ethanol
- 30 per cent reduction of the price of biogas
- Provision of 50 percent of all fuel stations with alternative fuel

4 CONCLUSIONS

A method for describing effects of car ownership policies on traffic noise has been elaborated. The method enables calculation of noise effects of restrictions to use certain types of vehicles, as well as noise effects of promotion of low noise vehicles. Noise calculations will be based on multilayer noise sources (like in the case of driver behaviour), and the same type of interface between the forecasting software and the noise mapping software as is described in Deliverable 2.4 will be used.

5 REFERENCES

Ben-Akiva, M.; Lerman, S.R. (1985) Discrete Choice Analysis: Theory and Application to Travel Demand, London

TREMOVE 2.30 Model and Baseline Description, FINAL REPORT, 18 February 2005 www.tremove.org

Transek and the Royal Institute of Technology (2005) A Car Ownership Model – development of a car ownership model including accessibility factors. (In Swedish)