DELIVERABLE 2.13

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Small prototypes for "Driver behaviour measures for vehicles"

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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

The objective of deliverable D2.13 was to study how driver behaviour impacts the road traffic noise and evaluate noise mitigation measures related to less aggressive behaviour.

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

Our method was to use a dynamic 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 (ISA) 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.

0.3 BACKGROUND INFO AVAILABLE AND THE INNOVATIVE ELEMENTS WHICH WERE DEVELOPED

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

In deliverable D2.6 'Driver behaviour measures for vehicles: Basic concepts' we described the work of building a traffic model of a selected study area in Stockholm. This model turned out to be too complex to apply for these prototype studies. Therefore we chose to study a more generalised street network and driving situation. However, the large model might be used in further studies.

0.5 Partners involved and their contribution

Partners involved in WP 2.3.3 were the Royal Institute of Technology (KTH) and Acoustic Control (ACL). Traffic simulations were made by KTH and together with ACL a method to calculate noise impacts were discussed and developed.

0.6 Conclusions

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 studies give an indication of the expected noise effect if an ISA system is implemented or if speed limit supervision is increased. The scenarios modelled are network specific, but we believe they represent a road where aggressive drivers have the possibility to live out their full behaviour. Therefore the impact of a traffic calming measure would be higher for this type of road than if the road was single lane or curved with limited sight. However we have only studied passenger cars. If heavy vehicles, mopeds and motorcycles were added the noise impact might be higher.

The noise calculation method developed and used is simple and quick, although it has limitations. Noise corrections are only applied to the engine noise, though the tyre/road noise may also be affected by acceleration and deceleration behaviour. Moreover, the correction matrix used includes extrapolated values and the validity of these values can be discussed. Also the step of 10 km/h and 0,5 m/s^2 between each relation may be too coarse. However, in the work of developing a TrafficNoiseSynthesizer in SP5 a dynamic road traffic noise model developed in the Rotranomo project will be used. It would be interesting to compare the results of our simple method with results of this more detailed and complex model. If applying a dynamic model we may analyse the noise effect on both equivalent levels and maximum levels.

Our scenarios modelled show ideal conditions when the ISA system is applied. In reality it would be a long process to get a car fleet where all cars are equipped with this type of system. Also if speed limit supervision is increased, it is still plausible that not all drivers would adapt to the speed limit. Speed cameras still have an effect, and an evaluation of speed cameras made by the Swedish National Road Administration showed that the introduction of speed cameras on a 70 km/h road gave a speed reduction of 8 percent, and that the share of speed limit violations decreased by 40 percent

(Presented by Berg and Larsson at the transport conference “Transportforum”, Linköping 2007, session 49). Less aggressive behaviour also goes hand in hand with traffic safety. This would possibly increase the acceptance of any type of traffic calming measure applied.

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.

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

Selected outputs of our simulation model will be used as input to the TrafficNoiseSynthesizer developed in SP5.

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

1 INTRODUCTION

This document describes small prototype studies made in work package 2.3.3 to analyse driver behaviour impacts on noise levels. The concept is to apply a microscopic dynamic traffic model and analyse different driver behaviour scenarios with respect to noise impacts. Noise calculation methods have been discussed and developed together with Acoustic Control.

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 will support 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 sub work package 2.3.3 is to evaluate noise mitigation measures related to driver behaviour. Our method is to use a microscopic traffic simulation model, to model different types of car drivers and study the noise impact of aggressive and less aggressive behaviour. The changes in speed and acceleration/deceleration behaviour that occur for different scenarios are used as input to calculate related noise level effects. In addition measures to make traffic run smoother may have an impact. Here we analyse an introduction of Intelligent Speed Adaptation (ISA) systems, affecting individual speed keeping, acceleration and deceleration behaviour.

A generalised street network was built, describing a 2 km straight road with traffic signals at the beginning and at the end. Driver behaviour is analysed at different segments of the road to capture the traffic dynamics in different parts of the network.

2 METHOD

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." Each model has its own strengths and weaknesses, and in the QCity project therefore different types of traffic models are used in different applications. In each case, the practical situation in terms of data and model availability has been taken into account.

This chapter introduces the basic concept of traffic forecasting and describes the traffic model environment and noise calculation methods used in this task.

2.1 TRAFFIC FORECASTING

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

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

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

2.1.1 Micro simulation models – Aimsun NG

To be able to model driver behaviour impacts on noise levels in a credible way we must use a microscopic model. In Qcity the microscopic simulation environment in Aimsun NG (TSS, Spain) is used. It is a relatively new product though the simulation models included are well documented and used in their previously released simulation packages. In order to describe how we use the program environment, the next paragraphs gives a more detailed description of micro simulation models and Aimsun NG in particular related to traffic supply, traffic demand, simulation and results.

2.1.1.1 Traffic supply

In a micro simulation model the concept of sections and intersections are used to describe actual roads and junctions. Sections are associated to a road type and are modelled with attributes like number of lanes, capacity per lane and maximum speed. Allowed turnings and traffic controls define intersections. The network is visualised very close to reality showing e.g. the number of lanes and side lanes. By working with layers it is possible to show traffic on roads of different height levels. In Aimsun NG it is also doable to model the altitudes of a section, which will have effects on a vehicle's breaking and acceleration behaviour. Ortho photos and dxf-files can be used as background to make it easier to build a network of a study area. An example is illustrated in Figure 1.

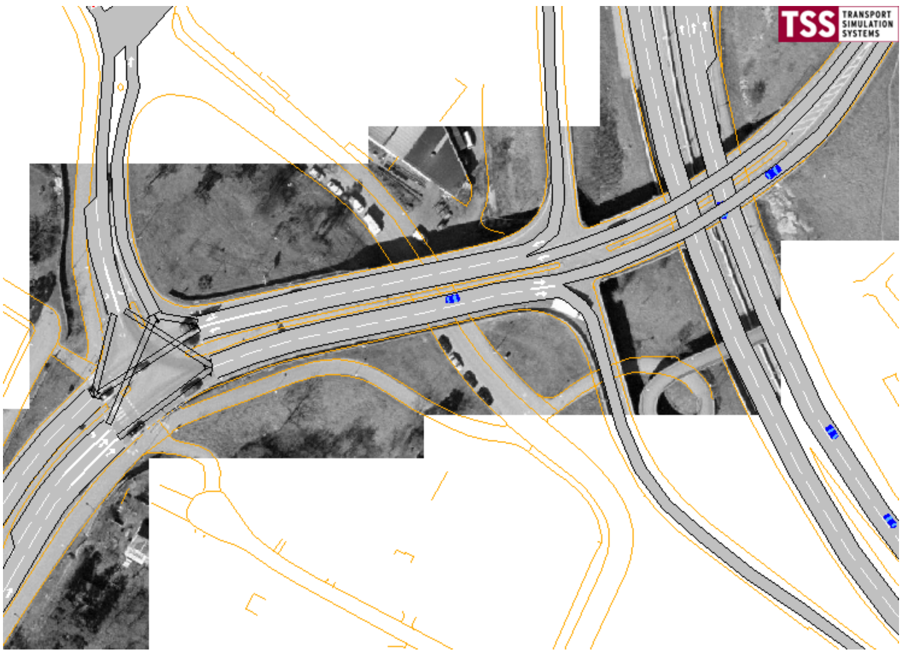

Figure 1: Example of a micro simulation network.

Since a micro simulation model models each vehicle individually and simulates the interactions between the vehicles, one of the inputs needed is traffic control. Turnings are specified for each junction and can be controlled by traffic signals or yield and/or stop signs. It is also possible to add solid line lane separators.

Moreover in Aimsun NG bus lines and trains can be modelled. Each transit line has a route and timetable. A timetable is defined by a departure schedule, type of vehicle and stop times (mean and deviation) for each stop. Buss stops are added to the network and the user can reserve lanes for public transport.

2.1.2.1 Traffic Demand

Traffic demand in Aimsun NG is related to vehicles and there are two options to model traffic demand. One is based on input flows and turning percentages and the other is based on OD-matrices and route paths. Data input needed might be a result of a survey or a calculation made in a macroscopic traffic forecasting system, possibly adjusted with data collected from traffic detectors.

To use OD-matrices centroids must be added to the network. A centroid represents a zone that generates and/or attracts trips and can e.g. be a dwelling area or a working site. An OD-matrix defines for each origin to every destination the number of vehicles that want to travel between each origin and destination pair. During a simulation vehicles are randomly added to the system from the matrix following an arrival distribution (e.g. exponential distribution). When a vehicle is generated at an origin centroid it will be assigned to one of the available routes connecting the origin centroid to the vehicle's destination. The vehicle will follow the path except if it is allowed to change its route when a better route exists from its current position to its destination.

There are several alternatives to model the path selection using Shortest Path algorithms and Route Choice models. The underlying theory is that a driver wants to use the route with lowest cost for example defined as shortest travel time.

When traffic is defined by traffic flows and turnings vehicles are generated to the network via input sections and distributed randomly in accordance with the turning percentages defined for each junction. Thus when a vehicle enters the system is does not have a route to follow, it only "knows" its next turning movement.

2.1.3.1 Driver Behaviour Parameters

In Aimsun NG it is possible to model different vehicle types. Traffic demand is defined for each kind. A vehicle type can be a car, truck, police-car, sports car etc. Each vehicle type has physical characteristics and driver attributes like length, speed acceptance, acceleration and deceleration. These parameters are set with mean, minimum, maximum and deviation values and the characteristics are sampled from a truncated normal distribution. Thus in a simulation all vehicles in a vehicle type do not necessarily behave in the same way.

The idea to study driver behaviour impacts on noise levels is to define vehicle types with different characteristics of driver behaviour and evaluate influences on traffic statistics and consequently noise levels. An example is to model Intelligent Speed Adaptation (ISA), affecting individual acceleration and deceleration behaviour by changing the speed acceptance parameter. A hypothesis is that ISA will make traffic flow smoother and decrease the mean speed of a section and as a consequence decrease the noise level.

Bellow is a list of descriptions of important driver behaviour parameters that are possible to vary and examples of parameter influences on simulation outputs (taken from the Aimsun 5.1 Microsimulator User's Manual).

Maximum desired speed:

Mean, deviation, maximum and minimum values.

The maximum speed this type of vehicle can travel at any point in the network.

Influence: Speed, flow, travel times, etc.

Maximum acceleration:

Mean, deviation, maximum and minimum values.

The maximum acceleration in m/s^2 a vehicle can achieve. The parameter is used in the car-following model.

Influence: Speed, flow, queue discharge, etc.

Normal deceleration:

Mean, deviation, maximum and minimum values.

The maximum deceleration in m/s^2 a vehicle can achieve under normal conditions. The parameter is used in the car-following model.

Influence: Speed, flow, density, etc.

Maximum deceleration:

Mean, deviation, maximum and minimum values.

The most severe braking in m/s^2 a vehicle can apply under special circumstances,, such as emergency braking.

Influence: Speed, flow, density, etc.

Speed acceptance:

Mean, deviation, maximum and minimum values.

The degree of acceptance of speed limits. A value greater than 1 means that the vehicle will take as maximum speed for a section a value greater than the speed limit, while a value less than 1 means that the vehicle will use a lower speed limit.

Influence: Speed, flow, queue discharge, etc.

Minimum distance between vehicles:

Mean, deviation, maximum and minimum values.

The distance in meters a vehicle keeps between itself and the preceding vehicle when stopped.

Influence: Flow, queue lengths.

Maximum give-way time:

Mean, deviation, maximum and minimum values.

This parameter is used when modelling gap-acceptance and describes the time a vehicle will wait at a give-way situation e.g. a Yield sign in a junction or an on-ramp at a freeway before it becomes more aggressive and reduces the acceptance margins in order to make a cross or merge. It is also used in Lane-Changing models as the time a vehicle accepts being at a standstill while waiting for a gap to be created in the desired turning lane before giving up and continuing ahead.

Influence: Yield and On-Ramp capacity, lane changing blockages and consequently flow.

Driver's reaction time:

The time it takes for a moving vehicle to react to speed changes of the preceding vehicle. It is used in the car-following model and can either be fixed for all vehicle types or variable. In case of variable, a discrete probability function for each vehicle type is defined.

Influence: Flow, speed, etc.

Reaction times at stop:

The time it takes for a stopped vehicle to react to the acceleration of a vehicle in front, or to a traffic light changing to green. Like Reaction Time it can be fixed or variable.

Influence: Queue measures, flow.

2.1.4.1 Simulation

Before starting a simulation the user sets the simulation time, e.g. a morning peak period. When running a simulation the time is divided into small time intervals, simulation steps. For each simulation step every vehicle position and speed is updated using behavioural models such as "Car-following Model", "Lane-Changing Model", and "Gap acceptance". These models describe how vehicles interact in the system. E.g. how a driver reacts to movements of the vehicle in front, how a vehicle acts when it desires to change lane to make its next turning manoeuvre or how vehicles behave in non-signalised crossings.

The algorithms use vehicle attributes like acceleration, deceleration, minimum distance to the vehicle in front and speed acceptance to simulate the movements. The speed acceptance parameter describes a driver's degree of desire to follow speed limits. A value greater than 1 implies that at free flow the driver exceeds the speed limits of a section. Thus behavioural models also depend on section parameters. Important section parameters used are distance parameters, these parameters describe the distance in time to the next junction and are e.g. used when a vehicle must change lane to be able to make a turn.

Micro simulation models include a lot of stochastic models and stochastic data, e.g. vehicles' arrival distribution, vehicle parameters, or the random distribution of vehicles at turns when using flows and turning percentages as traffic demand. Thus to get credible results of an experiment a number of replications must be simulated. After simulating, an average of all replications can be calculated. The number of replications to use is an issue to handle when calibrating and validating the model. For a more in depth description of traffic simulation, see for example Kitamura and Kuwahara (2005).

2.1.5.1 Simulation Results and Outputs

Statistics of a simulation in microscopic models can be collected at different levels of output e.g. system, section, or OD-matrix level. Statistics can be calculated for each vehicle type or aggregated to a vehicle level. Presented in the list bellow is a selection of the statistic outputs provided by Aimsun NG at the section level (taken from the Aimsun 5.1 Microsimulator User's Manual). It is possible to get results of each replication but most important are the average results of the replications of an experiment.

Section Statistics

- *Mean flow*: average number of vehicles per hour that have crossed the section during the simulation period.
- *Density*: average number of vehicles per kilometre in section.
- *Mean speed*: average speed for all vehicles that have traversed the section. This is calculated using the mean speed for the section journey for each vehicle.
- *Travel time*: average travel time a vehicle needs to cross the section. This is the mean of all the single travel times of every vehicle that has left the section.
- *Delay time*: average delay time per vehicle. This is the difference between the expected travel time (time it would take to traverse the section under ideal conditions) and the travel time. It is calculated as the average of all vehicles.
- *Stop time*: average time at a standstill per vehicle while travelling in the section.
- *Number of Stops*: average number of stops per vehicle while travelling in the section.
- *Mean Queue Length*: average length of queue in that section, expressed as number of vehicles per lane.
- *Maximum Queue Length*: maximum length of the queue in this section, expressed as number of vehicles per lane.

In addition to these statistics it is possible to place detectors in the network and gather supplementary data. A detector can be placed anywhere at a section and includes measuring capabilities as vehicle count, speed and headway between vehicles crossing the detector. The user may also collect additional data by extending the functions of the Aimsun NG environment by programmning an Aimsun API module.

Finally, to build a credible traffic simulation model it is important to follow a structure when input data parameters and driver behaviour models are chosen and calibrated. Figure 2 illustrates the different steps when making a simulation study (Law and Kelton 1991).

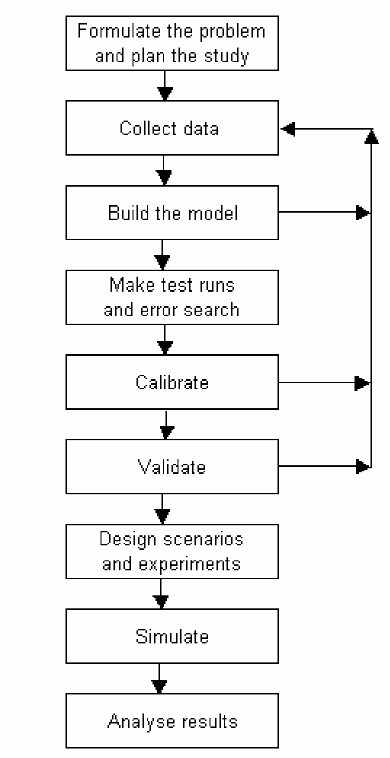

Figure 2: Procedure when making a simulation study.

2.2 METHOD TO CALCULATE NOISE IMPACTS

To study noise impacts due to different driver behaviour acceleration and deceleration need to be considered. This can be made using dynamic noise calculation models like the one developed in the Rotranomo project (see www.rotranomo.com). Though in this work package, KTH together with Acoustic Control have developed a simpler method which is relatively easy to apply and with low calculation time. The Rotranomo model is however considered for use in WP 5.12 (Development of a perception tool for traffic noise).

The concept is to collect driver behaviour data from the traffic simulation model by applying an API module extension. For each simulation time step speed and acceleration/deceleration data of all vehicles travelling on a section is stored. After a simulation matrices are created illustrating the speed and acceleration/deceleration distribution of each section, see an example in Table 1.

Table 1: Distribution of speed and acceleration/deceleration behaviour [%].

Acceleration m/s2 / Vehicle speed km/h	-4	-3,5	-3	-2,5	-2	-1,5	-1	-0,5	0	0,5	1	1,5	2	2,5	3	3,5	4
0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,00
20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,02	0,05	0,05	1,46	0,05	0,34	0,00	0,00
30	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,11	0,11	3,38	0,05	0,18	0,03	0,00
40	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,00	0,02	0,06	0,20	1,52	3,49	0,03	0,00	0,46	0,00
50	0,00	0,00	0,00	0,00	0,00	0,02	0,21	0,08	0,02	0,02	1,81	3,25	1,60	0,02	0,00	0,44	0,00
60	0,00	0,02	0,00	0,00	0,02	0,02	0,00	0,00	0,00	4,22	4,50	2,44	0,00	0,00	0,53	0,06	0,00
70	0,00	0,00	0,02	0,00	0,02	0,00	0,00	0,00	20,01	8,25	3,61	0,03	0,06	0,53	0,09	0,00	0,00
80	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,08	22,82	3,98	0,02	0,43	0,76	0,12	0,00	0,00	0,00
90	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,26	0,41	0,56	1,04	0,66	0,00	0,00	0,00	0,00	0,00
100	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,06	3,72	1,46	0,00	0,00	0,00	0,00	0,00	0,00	0,00

With these distributions the total road traffic noise per section is calculated using a method based on a noise level correction ΔL_{acc} due to acceleration/deceleration. Normal pass-by noise at different constant speed for a passenger car is illustrated in Table 2 (provided by Acoustic Control).

Table 2: Pass-by noise for different constant speed in dB(A).

Speed	Engine noise	Tyre/road noise	Total noise
0	60	0	60,0
10	65	59	66,0
20	65	61	66,5
30	65	63	67,1
40	65	67	69,1
50	65	70	71,2
60	65	72	72,8
70	65	74	74,5
80	65	75	75,4
90	65	77	77,3
100	65	79	79,2

The noise level correction, according to what has been presented in public documents from the Harmonoise project (Harmonoise, 2004), is defined according to the equation below and should be applied only to the drive line noise (i.e. not the noise emission from the tyre/road system):

$$\Delta L_{acc} = a \cdot C, \quad -2ms^{-2} \leq a \geq 2ms^{-2}$$

Where

a is the acceleration in m/s² and

C is a coefficient that for light vehicles is set to C=4.4.

Since the correction applies only on the drive line noise the influence from driver behaviour is small at higher velocities. The reason for this is that the tyre/road noise will be the dominating noise source at higher velocities. In the table below the total noise correction in dB, for different velocities and deceleration/acceleration, is presented. The Harmonoise correction is based on measurements primarily around 30 km/h, thus the table includes extrapolated values ranging from 10 to 100 km/h and –4 to 4 m/s².

Table 3: Noise level correction in dB.

Vehicle speed km/h \ Acceleration m/s2	-4	-3,5	-3	-2,5	-2	-1,5	-1	-0,5	0	0,5	1	1,5	2	2,5	3	3,5	4
10	-6,7	-6,5	-6,2	-5,8	-5,1	-4,3	-3,1	-1,7	0,0	1,8	3,8	5,9	8,0	10,1	12,3	14,5	16,6
20	-5,3	-5,2	-5,0	-4,7	-4,2	-3,6	-2,6	-1,5	0,0	1,7	3,5	5,5	7,6	9,7	11,8	14,0	16,2
30	-4,0	-3,9	-3,8	-3,6	-3,3	-2,8	-2,2	-1,2	0,0	1,5	3,2	5,0	7,0	9,1	11,2	13,4	15,5
40	-2,1	-2,0	-2,0	-1,9	-1,8	-1,6	-1,2	-0,7	0,0	1,0	2,2	3,8	5,5	7,4	9,4	11,5	13,6
50	-1,2	-1,2	-1,1	-1,1	-1,0	-0,9	-0,7	-0,4	0,0	0,6	1,5	2,7	4,1	5,8	7,6	9,6	11,6
60	-0,8	-0,8	-0,7	-0,7	-0,7	-0,6	-0,5	-0,3	0,0	0,5	1,1	2,0	3,2	4,7	6,3	8,2	10,2
70	-0,5	-0,5	-0,5	-0,5	-0,4	-0,4	-0,3	-0,2	0,0	0,3	0,8	1,5	2,4	3,6	5,1	6,8	8,6
80	-0,4	-0,4	-0,4	-0,4	-0,4	-0,3	-0,3	-0,2	0,0	0,3	0,6	1,2	2,0	3,1	4,5	6,1	7,9
90	-0,3	-0,3	-0,3	-0,2	-0,2	-0,2	-0,2	-0,1	0,0	0,2	0,4	0,8	1,4	2,3	3,4	4,8	6,4
100	-0,2	-0,2	-0,2	-0,2	-0,1	-0,1	-0,1	-0,1	0,0	0,1	0,3	0,6	1,0	1,6	2,5	3,6	5,0

In the data presented above the vehicles are assumed not to use the engine break during deceleration. This is normally true for light vehicles. It has also been assumed that the tyre/road noise is not affected[1] by the driver behaviour.

Table 4 shows the total noise per speed and acceleration/deceleration behaviour with the corrections in Table 3 applied. When calculating the total road traffic noise due to different driver behaviour Table 4 and the related distribution matrix are used by adding the contribution to the total road noise of each share of speed/acceleration combination. Thus the noise level is calculated as if one car is driving a road section with a specific set of driver behaviour. Hence, the noise calculated somewhat resembles a pass-by noise. Influence of road traffic flow will be reflected in the distribution, e.g. if the flow is high the share of high speed and high acceleration will be decreased.

[1] For high deceleration and acceleration in a real situation a small incrase (1-3 dB(A)-units) could actually occur also for tyre/road noise primarily at higher frequencies above 800 Hz. This contribution is neglected here.

Table 4: Total noise with correction due to acceleration and deceleration in dB(A).

Acceleration m/s2 / Vehicle speed km/h	-4	-3,5	-3	-2,5	-2	-1,5	-1	-0,5	0	0,5	1	1,5	2	2,5	3	3,5	4
10	59,3	59,5	59,8	60,2	60,8	61,7	62,9	64,3	66,0	67,8	69,8	71,8	73,9	76,1	78,3	80,4	82,6
20	61,2	61,3	61,5	61,8	62,2	62,9	63,8	65,0	66,5	68,1	70,0	72,0	74,0	76,1	78,3	80,4	82,6
30	63,1	63,2	63,3	63,5	63,8	64,3	65,0	65,9	67,1	68,6	70,3	72,2	74,1	76,2	78,3	80,5	82,6
40	67,0	67,1	67,1	67,2	67,3	67,6	67,9	68,4	69,1	70,1	71,4	72,9	74,6	76,5	78,5	80,6	82,7
50	70,0	70,0	70,1	70,1	70,2	70,3	70,5	70,8	71,2	71,8	72,7	73,9	75,3	77,0	78,8	80,8	82,8
60	72,0	72,0	72,0	72,1	72,1	72,2	72,3	72,5	72,8	73,2	73,9	74,8	76,0	77,5	79,1	81,0	83,0
70	74,0	74,0	74,0	74,0	74,1	74,1	74,2	74,3	74,5	74,8	75,3	76,0	76,9	78,1	79,6	81,3	83,2
80	75,0	75,0	75,0	75,0	75,1	75,1	75,2	75,3	75,4	75,7	76,1	76,6	77,5	78,5	79,9	81,5	83,3
90	77,0	77,0	77,0	77,0	77,0	77,1	77,1	77,2	77,3	77,4	77,7	78,1	78,7	79,5	80,7	82,0	83,7
100	79,0	79,0	79,0	79,0	79,0	79,0	79,1	79,1	79,2	79,3	79,5	79,7	80,1	80,8	81,6	82,8	84,2

3 SCENARIOS STUDIED

This paragraph describes the study network built, parameter settings and scenarios studied. Our approach was to model general behaviour on a 70 km/h road and not to make the model site specific.

3.1 THE STUDY NETWORK

To make the study as generalised as possible we built a simple study network. It is a 2 km straight road with a speed limit of 70 km/h. The road was modelled to be 2-lane, thus aggressive drivers can change lane and overtake calmer drivers. The road studied begins and ends with traffic signals. The cycle times were set to 60 seconds and equal length of red-time and green-time (27 seconds). Figure 3 shows a part of the road and the first traffic signal. The road was set to be flat with no gradient.

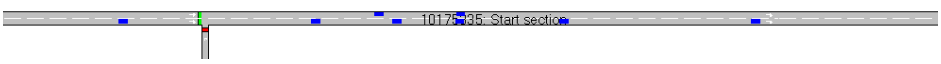

Figure 3: A part of the study road and the first traffic signal.

In order to study different driver behaviour occurring on the road, it was divided into three segments, see a schematic picture in Figure 4. In the first section we study acceleration behaviour after a traffic signal, in the second section free flow behaviour and at the third section deceleration behaviour in front of a traffic signal.

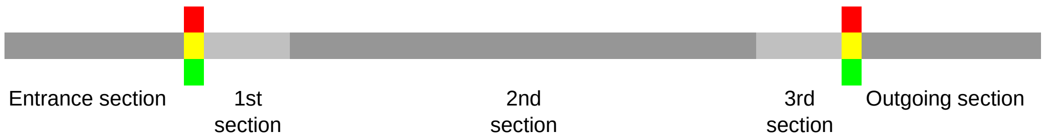

Figure 4: Segments of the study road.

Traffic demand is modelled by specifying a traffic flow and a uniform arrival distribution. Cars enter at the entrance section and continue straightforward, passing the two traffic signals and leave the system through the outgoing section. Note that driver behaviour is only studied at the segments between the two traffic signals.

3.2 DRIVER PARAMETERS

In our study we describe driver behaviour by three different driver categories "calm", "normal" and "aggressive". We chose to set the driver behaviour parameters to fixed values, thus all drivers within a group have the same behaviour characteristics. To simplify the study we only study passenger cars.

In 2004 Vägverket Konsult made a study of speed and speed limit violation on national roads in Sweden (Vägvärket Konsult, 2004). Their measurements showed that on 70 km/h roads in the Stockholm region, the share of travelled kilometres exceeding the speed limit was approximately 70% for passenger cars without trailer. In average this 70% exceed the speed limit by 10 km/h. All travelled kilometres included, the average speed on a 70 km/h was approximately 76 km/h. Moreover, in a publication from the Swedish road administration (Vägverket, 2004) standard levels for deceleration and normal acceleration behaviour for Swedish road conditions are given. E.g. in normal traffic situations the average acceleration between 0-50 km/h is 2.1 m/s^2 for passenger cars. Braking from 50-0 km/h is in normal situations 0-2.0 m/s^2 whereas relatively hard braking is 2.0-3.5 m/s^2 and hard braking 4.5 m/s^2. With these data as a reference to current road conditions and the assumption that both normal drivers and aggressive drivers exceed the speed limit, we set the shares of driver types and behaviour parameters per driver type according to Table 5.

Table 5: 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 70 km/h road.

The reaction time/simulation time was set to 1.0 second and reaction time at stop to 1.35 seconds for all driver categories (default values).

3.3 SCENARIOS STUDIED

To analyse the noise impact of different driver behaviour and also the noise calculation method, several scenarios were modelled. Table 6 shows their characteristics. For all scenarios we made simulations with speed acceptance parameters according to Table 5 and to resemble an ISA system, we made simulations with the speed acceptance set to 1 for all driver types.

As the calculated noise levels depend on where along the road the data is collected, the division of the study road was varied, thus the section lengths were varied but not the total length of the road.

Moreover, driver behaviour is dependent of the number of vehicles interacting on the road. A relatively low input flow was applied (500 vehicles per hour) where drivers are not very limited by other drivers in their behaviour to travel fast. In addition we run a scenario where the input flow was set to 2 000 vehicles per hour, a flow where the interaction is high but no queues are built up because of the circle time of the second traffic signal.

In yet another scenario we studied noise impacts of an ISA system assuming all drivers being aggressive. Also for this scenario we applied different road section divisions.

Table 6: Scenarios studied.

Length of 1st section [m]	Length of 2nd section [m]	Length of 3rd section [m]	Total flow [vehicles/h]	Share of calm drivers [%]	Share of normal drivers [%]	Share of aggressive drivers [%]
250	1500	250	500	30	50	20
125	1750	125	500	30	50	20
250	1500	250	2000	30	50	20
250	1500	250	500	0	0	100
125	1750	125	500	0	0	100

4 RESULTS

For every scenario described several replications were simulated. For each replication the total noise level per study section was calculated using the method described in 2.2. Finally for each section the average noise level of all replications was calculated using logarithmic addition. At first ten replications were used but analyses showed that three replications could be considered enough as the variation between the replications was small.

Results of the scenarios are illustrated in the tables below. Table 7 and Table 8 show the results for the first and the second section respectively. 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.

The first and the second scenario in Table 7 and Table 8 show that the noise level impact due to an ISA system is small, around 1 dB(A), both on the middle section with relatively constant flow and at the entrance section with acceleration behaviour. For these scenarios the difference between analysing the noise impact of applying different section lengths is small (0.1 dB(A)).

The noise impacts of an ISA system would be larger if the driver behaviour is very aggressive before the measure is applied. In our scenarios with 100% aggressive drivers the reduction is around 3 dB at the first section and 5 dB at the middle section. Though these figures must be treated with caution since they are based on high acceleration behaviour where the accuracy of the noise corrections can be discussed. In this scenario the influence of the length of the first section is higher than for the previous example. This is because the ISA system has a high impact on aggressive drivers and has larger effect at the end of the first section where more drivers have reached their desired speed.

Moreover, as expected the noise impact due to less aggressive behaviour is smaller when the traffic flow is high. For the scenario with 2 000 vehicles instead of 500 the noise impact is approximately –0.5 dB(A) compared to –1 dB(A). For higher flows, the impact can be expected to be even smaller.

Table 7: 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 8: 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

5 DISCUSSION AND CONCLUSIONS

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 studies give an indication of the expected noise effect if an ISA system is implemented or if speed limit supervision is increased. The scenarios modelled are network specific, but we believe they represent a road where aggressive drivers have the possibility to live out their full behaviour. Therefore the impact of a traffic calming measure would be higher for this type of road than if the road was single lane or curved with limited sight. However we have only studied passenger cars. If heavy vehicles and mopeds and motorcycles where added the noise impact might be higher.

The noise calculation method developed and used is simple and quick, although it has limitations. Noise corrections are only applied to the engine noise, though the tyre/road noise may also be affected by acceleration and deceleration behaviour. Moreover, the correction matrix used includes extrapolated values and the validity of these values can be discussed. Also the step of 10 km/h and 0,5 m/s^2 between each relation may be too coarse. However, in the work of developing a TrafficNoiseSynthesizer in SP5 a dynamic road traffic noise model developed in the Rotranomo project will be used. It would be interesting to compare the results of our simple method with results of this more detailed and complex model. If applying a dynamic model we may analyse the noise effect on both equivalent levels and maximum levels.

Our scenarios modelled show ideal conditions when the ISA system is applied. In reality it would be a long process to get a car fleet where all cars are equipped with this type of system. Also if speed limit supervision is increased, it is still plausible that not all drivers would adapt to the speed limit. Speed cameras still have an effect, and an evaluation of speed cameras made by the Swedish National Road Administration showed that the introduction of speed cameras on a 70 km/h road gave a speed reduction of 8 percent, and that the share of speed limit violations decreased by 40 percent (Presented by Berg and Larsson at the transport conference "Transportforum", Linköping 2007, session 49). Less aggressive behaviour also goes hand in hand with traffic safety. This would possibly increase the acceptance of any type of traffic calming measure applied.

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.

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