Final report for project 2011-01805 Low noise HD truck for night time distribution

Project within Transport Efficiency

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Content

FFI in short

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1. Executive summary

The aim of the project was to find an acoustic understanding of the questions around a “last mile” distribution corridor used outside ordinary working hours. The purpose was also to create a methodology for specifying such a vehicle acoustically. The project has delivered significant knowledge and a good understanding for the prerequisite of this type of corridor and vehicle.
Chalmers has created a calculation methodology for future work with acoustical optimization of vehicles in transport corridors. The acoustic work has resulted in a better understanding of acoustical demands related to upcoming changes in the transportation system. The acoustic work also indicates there are several solutions for distribution corridors for use outside ordinary working hours and depends on the context and implies cooperation between all involved actors. Chalmers work has also shown the need for a better knowledge of noise perception to secure an adjustment of distribution to outside ordinary working hours.

2. Background

The density of vehicles in cities of today has increased to a level making it necessary for changes in the transportation system. One possible solution is goods deliverance outside ordinary working hours, but such a solution needs an acoustical acceptance from society.

3. Objective

The main objective was to acoustically understand the prerequisites for the last part of a transport corridor through city centre used outside ordinary working hours. The second objective was to define a methodology for acoustically specify such a vehicle. The methodology should include models for calculating indoor noise levels and noise levels at the façade when a vehicle passes by outside. The models should also be possible to use backwards, estimate how a vehicle should be specified out of a specific indoor noise.

4. Project realization

The project has been organized into 5 work packages:

WP1, Noise demands from a society perspective
WP2, Necessary structural changes in society
WP3, Decreased noise radiation from delivery vehicles
WP4, New technology for noise absorbers
WP5, Demonstrator

The disposal of report will be as follow:

- Preparation work
- Noise analysis: Noise demands from a society perspective (WP1), Decreased noise radiation from delivery vehicles (WP3 + 5)
- Necessary structural changes in society (WP2)
- New technology for noise absorbers (WP4)

Preparation work

During project preparation two “state of the art” reports were created by Chalmers. One analyzing the issue from a sound quality aspect, and concluding the sound pressure dBA measure used today may need to be supplemented for defining the prerequisites for transports outside ordinary working hours. It also concludes that the knowledge is defective regarding influence on sleep quality, annoyance and restoration from traffic noise [1]. The second report analyzes existing vehicle noise source models for traffic noise used in Sweden and models planned for use in Europe. It also includes an introduction to how existing noise source models are used [2]. Chalmers did also analyze a lot of existing noise data to be able to organize the analysis work within project.

Noise analysis

To be able to perform the analysis of interaction between indoor sound perception and vehicle specification as a sound source, the work was divided into four parts: Modelling of noise source and noise transfer, Noise abatement measures on the vehicle, Sound synthesis, and Sound Quality evaluation.

Modelling of noise source and noise transfer

One purpose with a noise transfer path model for vehicle noise was to be able to calculate the indoor noise in an apartment when a vehicle is passing by on the street.

The other purpose was to use the same model backwards to specify a vehicle acoustics from an indoor noise perspective. To be able to carry out this we divided the modelling work in four steps.
The first step was to model the noises source at a good enough level, but not so complex as it would be hard to use. In the second step the sound propagation in the street canyon was modelled and in the third step the filtering through the house façades was modelled. In the last step the room characteristics were modelled.
To secure the quality of the models, each step was verified by Sound Quality evaluation.
With the developed models it is possible to calculate the resulting noise on a house façade or inside a room in an apartment for the analyzed street canyon based on source strength measurements performed at Volvos Noise and Vibration Laboratory. It is also possible to use the model backwards using a specified indoor noise.
Following conclusions were made from our noise analysis:

- The low frequency noise content from vehicle has large impact on calculated indoor noise level
- A vehicle noise specification used for “last mile” distribution corridor transport is related to the design of street canyon, noise characteristics of façades , road surface attributes (I.E. Belgian pave or asphalt) and drivers behaviour
- For the case “open window” there is today no possibilities to fulfil the noise demands from the National Board of Health and Welfare (Socialstyrelsen) (the case “open window” is also not included in the demands)

The importance of the low frequency content initiated a work at Chalmers to create reference cases for façades/windows/ventilation noise data. A set of typical full range frequency filters were created representing the most common façade combinations in Sweden. The work resulted in a reference document that Chalmers is going to use in the education [3].

Noise abatement measures on vehicle

Three different vehicles were used in order to make the variation of the basic data for the noise analyses and modelling work large enough: one standard Volvo FM 6*2 Rigid, one modified FM 6*2 Rigid with handmade drive train encapsulation on five sides, extra muffler and limitations for drive train behavior, one standard Mercedes Benz Sprint van. The Volvo vehicles have been analyzed several times in Volvos Noise and Vibration Laboratory Semi-Eco free room. They were also analyzed at one of the field test exercises at Landsvägsgatan in Gothenburg. In the other field test the MB Sprint van was analyzed together with the standard Volvo vehicle. Analyses of the Volvo vehicles gave that the handmade extensive encapsulation resulted in 5 dB lover sound pressure levels compared to standard vehicle.
One possibility for lowering the traffic noise is to limit the vehicle speed. This can be done voluntarily or by speed forced limitation control. One way to control the speed is to use Geofencing. A short analysis was performed to see the prerequisites for using existing techniques.

Figure 1, Room interior at second field test analysis at Landsvägsgatan.

Figure 2, Street canyon view at second field test at Landsvägsgatan.

Figure 3, Project truck in the Semi-Eco free room at Volvo Noise and Vibration Laboratory.

Sound synthesis

To be able to perform sound quality analysis of indoor noise and to evaluate and verify the different steps in the modelling work, Chalmers applied a method for synthesizing noise from Heavy Duty vehicles. This synthesis work was not part of the project from the beginning, but showed up to be essential for shaping different noise files needed within the project. With this technique it was possible to generate the different variants of sound files used in the sound quality evaluation work. This part of the work also resulted in a conference paper [4].
The work with acoustic understanding of the issue and sound synthesis also became a base for the parallel project SENDSMART, work package 3, “Silent refuse collection”. The common conclusions from SENDSMART WP3 are animated and auralized in a film using the same synthesis method. The film is called “Silent refuse collection” (“Tyst avfallshantering”) and compares two refuse collection concepts. The film can be viewed via the home page for project SENDSMART [5] (for the right sound of the low frequency content loud speakers are needed or high performance head phones).

Sound Quality evaluation

While there have been several purposes behind the Sound Quality evaluations, the main goal have been to build up a deeper understanding and more knowledge about human perception of indoor noise caused by vehicles. The evaluations have also been

used for verifying the different parts in the modelling work to secure the acoustic behavior in each step. This was done in order to get the overall model as accurate as possible.
Within the area of Sound Quality the sounds can be represented by two dimensions, Aurosal (perceived level of activation) and Valence (perceived level of pleasantness). By using these two dimensions it is possible to get a deeper understanding of human perception of sound. In the Sound Quality evaluation work done by Chalmers, the findings are as follow:

- Mitigation of the high frequency content in sound is positive for perceptual response of Valence
- A decrease in low frequency content will decrease the Aurosal response
- During night time it is of most importance to reduce the Aurosal response, but during evenings, when people are awake, both dimensions are to be considered
- The hardware modifications applied on the modified Volvo truck decreased the indoor Aurosal response significantly for bad façades (low damping of noise) and for the case “open window”
- No significant difference of the indoor Aurosal response was noticed between modified and unmodified Volvo trucks for good facades with closed windows

Necessary structural changes in society

There can be many positive impacts on the citizens, if the city heavy duty traffic can be decreased during ordinary working hours. Together with increased traffic safety and better environment, the total fuel cost for distribution companies will decrease due to reduction of total amount of idling in traffic jams and queues. Many ordinary distribution routes are between 30 and 100 km and thus 30 min less idling will give less fuel consumption calculated in percent.
To be able to calculate a profit for distribution outside ordinary working hours, the total distribution chain has to be taken into account. During field tests with distribution outside ordinary working hours in other European cities and in cities in US, the conclusion was that evening distribution can be 3 times more efficient compared to daytime distribution. However, if no retour load can be taken regardless of daytime or nighttime, then there will be a profit, but if distribution outside ordinary working hours results in an empty truck on the way back there is perhaps no obvious profit.
Other important factors taking into account are working hours and rules for working hours, both for driver and for people receiving the goods. With night time distribution there has to be someone in charge taking care of the deliverance, or if it is possible to solve it in another secure way.
For the project we decided to focus on the “last mile” of the transport corridor through densely populated city centers. The reason for this is the already proposed demands for loading and unloading of goods written by TNO in the Netherlands called PIEK [6]. In the PIEK-cycle loading and unloading noise are included both for truck and for bodywork. To be able to fulfill the PIEK demands there are already products on the market such as PIEK classified body works with damped floor, doors, cooling system, carriers etc. Another possibility to solve the loading/unloading problem is to use

loading docks or indoor delivery areas for silent handling of goods.
One way to lower the traffic noise is to lower the traffic flow by using some kind of speed limitation. This implies a speed limitation for a certain area, but also some kind of follow-up. For this Geofencing control of speed can be used or own responsibility, where the exemption is withdrawn if someone is complaining on the distribution company. In both cases the solution has to be based on interaction between different involved actors and the noise level is dependent not only on vehicle or distributor, but also on the local regulations, as is suggested in the guidelines for "off hour delivery" by Transport for London.
Corresponding conclusions have been drawn in the noise analysis work, the noise prerequisites for distribution outside ordinary working hours are not only depending on vehicle and distributor. The outdoor noise and noise level also depend on acoustic attributes for the street corridor. For the perception of indoor noise and noise levels you have to combine the outdoor results with the acoustic attributes for the façades. The indoor noise can also be amplified in a bad way by room resonances that coincide with low frequency noise from vehicles.
The focus for this project has been on drive train related noise, which dominates the vehicle noise at low speeds. But vehicles can also generate other noises at low speed, such as tire nose related to tread pattern and road surface (asphalt, Belgian pavé etc), structural noise/impact noise related to uneven road surface.
The following results were obtained from analysis of society influence:

- Exterior and indoor noise has to be specified separately
- The perceptual response to noise outdoors or indoors is an interaction between source (vehicle) and context (street canyon, type of buildings etc)
- Noise specification for vehicle is depending on the design of buildings along transport corridor
- Noise specification for vehicle is depending on the traffic flow and thus the speed and amount of vehicles allowed in the area for the corridor
- Noise specification for vehicle is depending on street surface (different asphalt qualities, Belgian pavé, concrete etc), causing impacts and structural noise from vehicle
- Noise specification for vehicle is depending on, if and how, the vehicle is controlled/supervised regarding speed in the corridor
- If Geofencing is used for supervision of speed, it is important that all actors have the same information and there has to be a co-ordination in map data handling
- If used, Geofencing has to be a part of the procurement for transport routes
- Existing building directives do not really take into account the low frequency noise generated by a diesel engine. The night time directive of 45 dBA for indoor noise has perhaps to be looked over.

New technology for noise absorbers

During the work with more fire safe surface materials for noise shields on vehicles YKI (SP Group) has performed a lot of different tests on different surface materials and different surface treating methods. The aim of the work was to lower the diesel absorption in the porous materials in noise shields. This material property will

increase in importance if the encapsulation around the drive trains has to be increase to manage new noise demands.

5. Results and deliverables

Chalmers has created a calculation methodology for future work with acoustical optimization of vehicles in transport corridors. The acoustical work has resulted in a better understanding of what is needed for upcoming changes in the transportation system. The acoustic work also indicates there are several solutions for distribution corridors for use outside ordinary working hours and a solution depends on context and implies cooperation between all involved actors.
Chalmers work has also shown a need for better knowledge of noise perception to secure an adjustment of distribution to outside ordinary working hours. Project results and conclusions are compiled in a technical report from Chalmers [7].

5.1 Delivery to FFI-goals

The project and its results are in line with the main goals for the program Transport Efficiency. If distribution outside ordinary working hours is possible to implement, the environmental load will decrease and it will contribute to the global climate work. A lowering in total fuel consumption per ton-km will not only result in a decrease in CO2 emissions, it will also decrease other emissions, increase traffic safety and increase the coefficient of efficiency for the transportation system.
Differentiations of the transport system will most likely lead to new business cases and generate demands for new business models.
It is a condition for the Swedish vehicle industry and transport companies to participate in the change of the transport system, to be able to keep their market position.
Last but not least the project and its results will contribute to increased competence within the area of transportation, both for industrial partners as for academic partners. It has also resulted in a deeper knowledge, a more equal view on the issue between academy and industry, and a deeper cooperation.

6. Dissemination and publications

6.1 Knowledge and results dissemination

There is today knowledge about traffic noise as a health problem, but also an understanding of the need for more research and more knowledge to really understand the connection between noise and health [1].
To lift this in the discussion and to make a more equal view on the question between different actors, will be a help to create sustainable solutions such as the one analysed in this project.

6.2 Publications

1, Traffic Noise – The effect on sleep quality, annoyance and restoration, P. Bergman
2, Ljud från tunga vägfordon – aktuella källmodeller och gränsvärden för exponering inomhus, J, Forssén
3, ISSN 1652-9162 2014:1, Suggested facade cases for study of sound insulation considering wall, window and air intake, J. Forssén
4, AIA DAGA 2013-681, Auralization of truck engine noise –preliminary results using a granular approach, J. Forssén et al
5, Film ”Tyst avfallshantering” visualisation/auralization of results from WP 3 in project SENDSMART using the noise synthesize method. Film can be found on page: http://closer.lindholmen.se/om-closer/sendsmart
6, PIEK demands proposed by TNO, the Netherlands, TNO report MON-RPT-2010-0046
7, Towards a low noise truck specification, P. Höstmad, P. Bergman, J. Forssén

7. Conclusions and future research

For the project as such we are very satisfied with results and outcomes and have a good view of acoustic demands for a “last mile” distribution corridor used outside ordinary working hours. For “**Modelling of noise source and noise transfer**” we are very pleased with the method Chalmers has created for analysis and calculation of acoustic numbers using indoor measurements performed at Noise and Vibration test laboratory. In part “**Noise abatement measures on vehicle**” performed measures on vehicle has generated changes in acoustic attributes needed for other parts in project. The work with “**Sound synthesis**” was not a part of project from the beginning but increased the quality of results and knowledge level in project results.
The verification of models with “**Sound Quality evaluation**” did work well and has secured the quality for the acoustic attributes for the complete model. The work has also generated knew knowledge and a better understanding of perceptual response to indoor noise from vehicles. We did not manage to find something better explaining indoor noise response of low frequency vehicle noise beside dBA. There is a lack of basic knowledge today in certain areas such as influences on sleep quality from noise.
For the question about “**Necessary structural changes in society**” we have managed to analyse it from different acoustic perspectives.
YKI (SP Group) has performed the work in chapter “**New technology for noise absorbers**” very well and has generated several conclusions and more knowledge regarding different possibilities for decreasing diesel absorption. However, it was much harder than expected to get a stable solution for a surface.
On the topic future research, we see a need for more knowledge and understanding of human perception of sounds. Of most importance are the areas related to sleep quality and restoration. We also see a need for more research within the area new materials, related to upcoming demands for increased sound absorption and decreased diesel absorption.

8. Participating parties and contact person

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