Noise reduction by electric vehicles in the Netherlands

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As an alternative for vehicles with gasoline or diesel engines, electric and hybrid motor vehicles have received increasing interest in the past years. Large scale application of electrical and hybrid vehicles in urban environments may have favorable effects on both noise and air quality. This paper explores the effects on urban noise exposure, in case of a large scale transition in transportation means towards the use of electrical and hybrid road traffic vehicles. The first results indicate that in urban areas, reduction of engine noise by large scale use of E-vehicles will cause a significant reduction of traffic noise emissions, particularly if combined with the introduction of silent tires or silent pavings.

1 INTRODUCTION

Electric and hybrid motor vehicles are relatively silent, particularly at low speeds. These cars are also increasingly popular, see Figure 1. In the Netherlands, as in many other countries, the government gives tax credits for low emission cars (e.g. hybrid and electric) and subsidizes charging stations. At the current rate of increasing market share it is estimated[1] that for passenger cars by 2030-2035 an almost full scale transition towards a hybrid or electric car fleet may be realized.

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After 2030-2035 only classic (old timer) cars and, presumably, heavy trucks for the major part, are expected to still use diesel or gasoline engines. In a preliminary report[1], the authors gave an outlook into the effects of electric and hybrid passenger cars on traffic noise emission in urban areas. Based on measured data, certain estimated parameters, and calculations for a medium-sized city, an average noise reduction of 3-4 dB was estimated. In the present work package of TASTE, further measurement data is gathered and analyzed. In this paper a more refined analysis of measurement results is given regarding the potential noise reduction effects in of electric or hybrid vehicles in urban situations.

2 COMPARISON OF NOISE EMISSIONS

As the noise emission of road vehicles contains both engine noise and tire-road noise, it is necessary to separate these components in order to predict noise reductions from a hybrid or electric car fleet. To this aim one can rely on speed dependent models for noise emission from engine and tires or try to measure both components directly during driving. Both techniques are investigated in TASTE a research project currently running at RIVM, which aims to explore options for a sustainable urban noise quality. This chapter contains a comparison of measurement data on noise emissions from electric/hybrid and conventional passenger cars. The results are used to estimate the potential noise emission reduction of a future car fleet, in normal urban traffic situations.

2.1 Mid-size class: hybrid versus conventional passenger cars in urban traffic

Hybrid cars generally run in E-mode up to speeds of about 20 km/h. At higher speeds the fuel engine starts up, charging the battery. This means in practice that hybrid cars effectively do not produce engine noise below 20 km/h. In the mid speed range, from 20 to 35 km/h, where engine is still not dominated by tire-road noise, significant noise reduction can be expected compared to non-electric cars. For higher speeds the noise advantage will become negligible. In 2008, measurements were conducted by DGMR on a hybrid car (Toyota Prius) in the city of The Hague[2]. The purpose was to determine the propulsion noise as a function of speed under various urban driving conditions (built-up areas, traffic lights, congestion). A microphone under the hood measured the engine noise continuously, while a GPS-device monitored the position and driving speed. The Sound Pressure Level (SPL) was averaged within speed classes of 5 km/h. This type of measurement was repeated in the city of Utrecht by RIVM in March 2012 using a conventional diesel car (Volkswagen-Passat). Though the latter measurement was in a different city, the average speed over the route in the city centers was 22 km/h in both cases. The total length of each route was about 50 km. Fig. 2 shows the difference in SPL under the hood for both vehicles.

During idling, the difference in propulsion noise is about 15 dB. Between 15 and 50 km/h there is an approximately constant difference of 5 to 6 dB. At higher speeds the difference vanishes. This difference can used to estimate the propulsion noise power $L_{W,prop}$ of hybrid cars as a function of the speed in urban traffic. The average propulsion noise of conventional cars is for example given by the CNOSSOS-EU project[3]. For simplicity, here it is assumed that all hybrid car types have similar propulsion noise characteristics as the Toyota Prius. (In reality, a great variety of hybrid engine designs exist, but they share the aim to save fuel and emissions. Mostly this means that the combustion engines in hybrid cars can be kept small, and will therefore also be more silent.) Fig. 3 shows the CNOSSOS-EU rolling and propulsion noise curves for conventional cars, together with the constructed hybrid propulsion curve. The black dots ($L_{W,prop,hybrid}$) are calculated by subtracting the measured difference between the Volkswagen-Passat and Toyota Prius (see Fig. 2) from the CNOSSOS prediction of propulsion noise for diesel or gasoline powered passenger cars. The black 'generalized' line consists of four linear fits. The average emissions of propulsion noise, as shown in Figure 3, were used to calculate the urban noise reduction between a conventional car fleet and a hybrid car fleet. The results are discussed in Chapter 3.

2.2 Subcompact class: electric versus conventional passenger cars in drive-by tests

In 2010 pass-by measurements were carried out by RIVM on two subcompact class cars, one being electric (a Nordic 'Th!nk City') and the other one with diesel engine (VW Polo). The cars passed by in normal gear at speeds of 10, 30 and 50 km/h, respectively. The road type was DAC. The microphone was at 3 m from the road axis and 1,5 m above the road surface. The noise reductions (electric minus non-electric car) are plotted in blue in Fig. 4. Also a least squares fit is shown.

The diesel car in the drive-by test is a rather heavy subcompact car, while the electric car is a rather light one (nominal engine power: 74 kW versus 34 kW). This may overestimate the noise reduction effect of electric cars. Nevertheless these data confirm the assumption that the propulsion noise of electric cars can be neglected completely in assessment of the urban noise reduction of an electric car fleet.

3 ESTIMATION OF NOISE REDUCTION IN URBAN TRAFFIC

3.1 Scenarios for average noise reduction

Average traffic noise reductions are assessed for four future fleet composition scenarios. It is assumed that about 5% of the cars will not reduce in noise emission (classic cars and other vehicles that are excluded from future noise emission regulations). Furthermore, most future mid-weight and heavy trucks in city centers in future will probably still have diesel engines[4]. Therefore the share of conventional passenger cars for the future scenarios is predicted at 10% (i.e. an intended overestimation by 5% to account for conventional trucks).

The scenarios describe the effect of a transition to 90% hybrid and 90% electric fleet, respectively. Two secondary scenarios include the effect of silent tires on the hybrid and electric vehicles. Silent tires are here assumed to reduce tire-road noise by 3 dB, regardless of speed. (Note that a scenario with 3 dB more silent road pavements will lead to the same conclusions as a scenario with these silent tires.) Fig. 5 gives the noise reduction as a function of speed, based on the results given in Chapter 2.

The speed log of two urban test routes with passenger cars has been used to estimate the overall effect in urban traffic. The first trip was made with a Ford Escort (petrol engine) and the second with a VW Passat (diesel). A distribution of speeds is given in Fig. 6 and the overall effects are given for various scenarios in Table 1. The noise emission reduction that can be achieved ranges from about 3 dB to 6 dB. The effect of silent tires, by itself, on vehicles with silent propulsion systems is about 1.5 to 2 dB. This is larger than the effect of silent tires on conventional cars under urban conditions, which can be evaluated at about 0.8 dB (not shown in the table). In other words, silent tires are more effective if the engines are less noisy.

3.2 Estimating the effect on the population

Table 1 gives the average noise reductions. Actual reductions will show spatial variation and will not be equally distributed throughout the urban environment. At junctions and at roads with fairly low average speeds, the noise reduction will probably be larger than average, while elsewhere it will be less. This is illustrated in Fig. 7, where the potential noise reduction of the conventional test car (VW Passat) is calculated along the city trip. Here, the potential noise reduction refers to replacing its diesel engine by an electric one, while keeping the same conventional tires. Wherever the car is accelerating from idling, the potential noise reduction will be highest. The highest potential reductions are found at junctions and at roads with fairly low average speeds. It is here that highest effects regarding reduced annoyance and sleep disturbance of the population can be expected. It must be mentioned that this also brings about consequences for safety of pedestrians, because it is also here that the latter are most vulnerable, particularly regarding the safety of disabled people or playing children[1]. This is definitely a point to be considered and may need additional precautionary measures in a future traffic transition towards E/H vehicles. In case the noise reduction of all traffic would be evaluated, the local differences will be spread out geographically. If the effects of the noise reduction in terms of noise exposure on the population are to be assessed, the values given in Table 1 might be used as a starting point. In the TASTE project, it is envisaged to carry out additional measurements and assessments of effects on the population. These could improve insights in spatial spreading and representative average effects for the complete car fleet.

4 CONCLUSIONS

- If the conventional car fleet is replaced by cars with hybrid or fully electric propulsion systems, the noise emission in urban environment would be reduced by about 3 to 4 dB. These figures confirm results that were reported earlier by RIVM.
- If also silent tires (or silent pavements) are applied, an additional reduction of 1.5 to 2 dB is achieved. These results are partly based on *in situ* measurements of one conventional diesel car and one hybrid car under urban traffic circumstances. By combining the data with known fleet averages for propulsion noise and tire-road noise, it appeared possible to generalize them as to represent a future car fleet.
- Further measurements on different types of cars can improve insights into representative fleet averages. These could also be used to predict local differences in noise reduction, for example at junctions (with accelerating and decelerating cars) and at roads with much more steady driving speeds.
- Preservation of safety for pedestrian at junctions is requires attention and may need additional precautionary measures in a future traffic transition towards E/H vehicles.

5 REFERENCES

1. E. Verheijen and J. Jabben, Effect of electric cars on traffic noise and safety, RIVM report 680300009/2010, http://www.rivm.nl/bibliotheek/rapporten/680300009.pdf

2. A. Kok, Onderzoek geluidsemissie hybride voertuigen, DGMR report V.2008.0726.00.R001, 27 October 2008.

3. Draft JRC Reference Report on CNOSSOS-EU, Version 2d, 28 May 2010, http://sicaweb.cedex.es/docs/documentos/CNOSSOS-JRCdraft.pdf

4. Elektrisch autorijden – Evaluatie van transities op basis van systeemopties, Netherlands Environmental Assessment Agency (PBL), report 500083010, D. Nagelhout, J.P.M. Ros, January 2009.

TABLES

Table 1 –Average urban noise reduction in dB(A) for four car fleet composition scenarios.

	Route 1 (FE)		Route 2 (VW)	
Tires	Standard	Silent	Standard	Silent
90% hybrid fleet	-3.0 dB	-4.6	-2.8 dB	-4.5
90% electric fleet	-4.0	-6.1	-3.7	-5.8

FIGURES

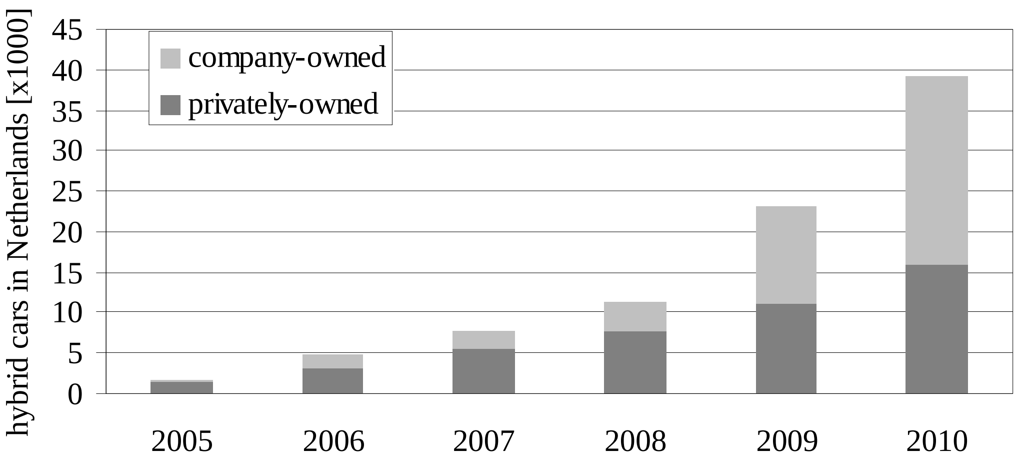

Fig. 1 - Number of hybrid cars registered in the Netherlands. Source: Central Bureau of Statistics.

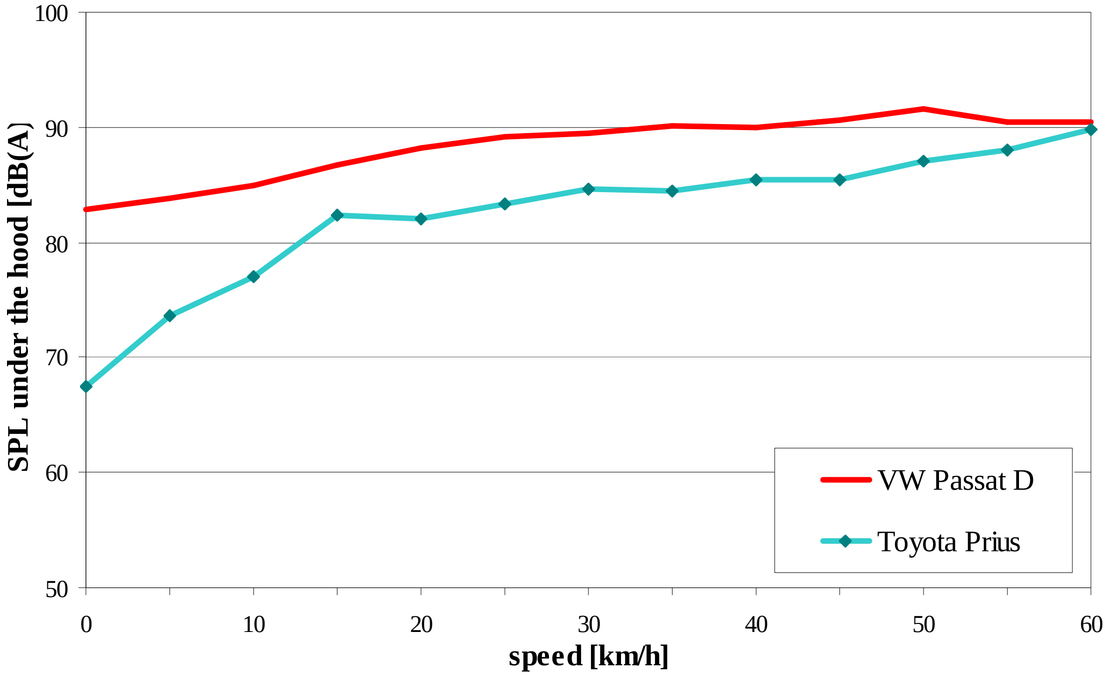

Fig. 2 - Average propulsion noise (SPL) in urban traffic, measured under the hood. The cars drove different urban routes of about 50 km each. In both cases, the average speed in the city centers was 22 km/h.

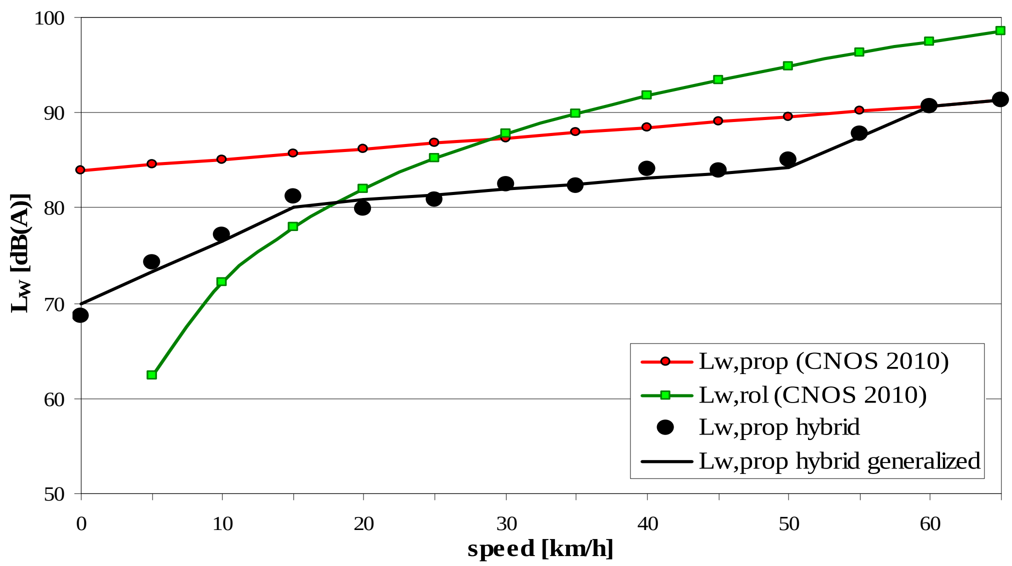

Fig. 3 - The sound power level of propulsion and tire-road noise of conventional passenger cars as given by the CNOSSOS draft method[3]. Also the propulsion sound power level of hybrid cars is derived.

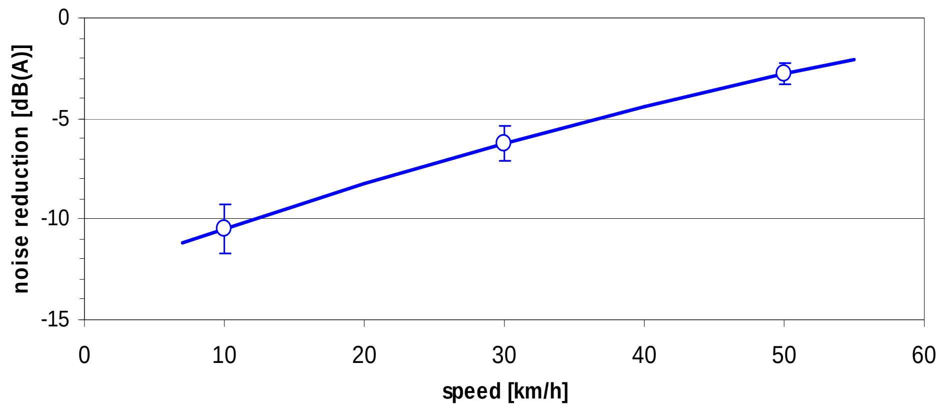

Fig. 4 - Difference in total noise emitted by electric and conventional subcompact cars (Th!nk City and VW Polo) during drive-by in normal gear. Measured at 3 m distance, 1.5 m above the ground surface. Averaged across 5 drive-bys per speed.

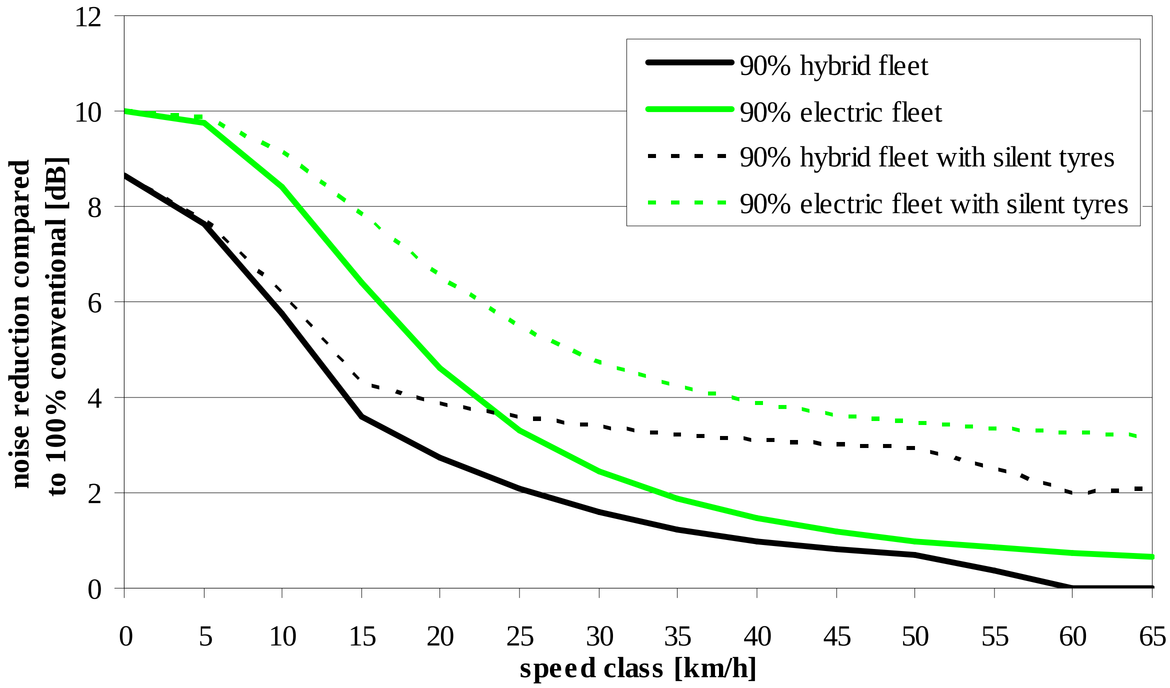

Fig. 5 -Noise reduction as a function of driving speed for different car fleet composition scenarios. The reference scenario is that of a 100% conventional fleet with present-day tires. Silent tires are assumed to produce 3 dB less tire-road noise independent of speed.

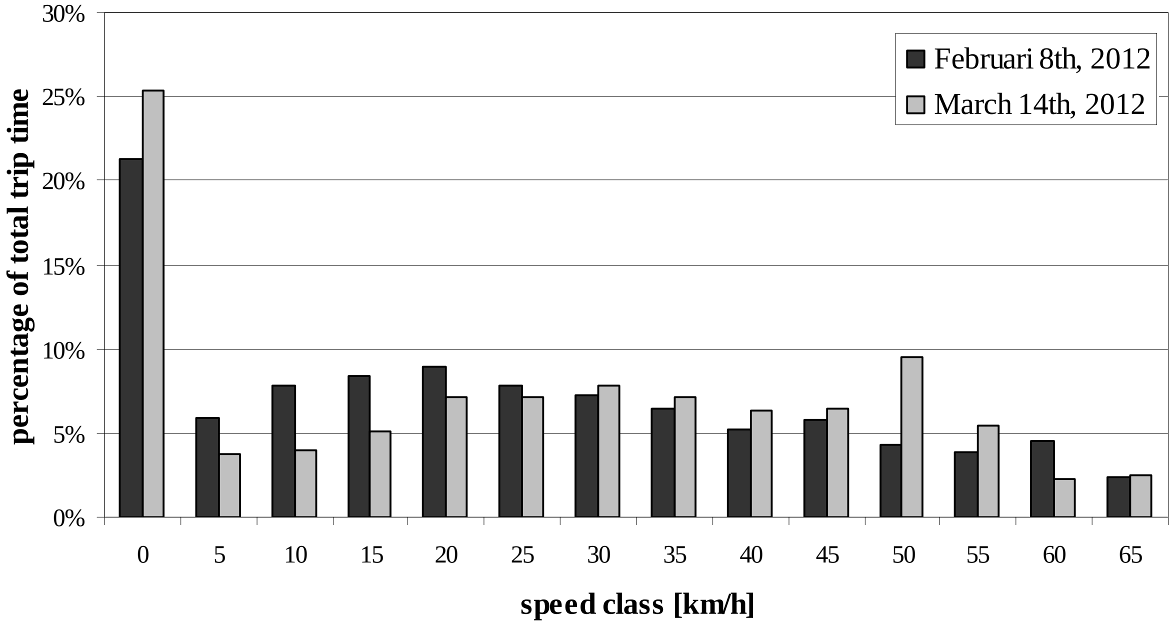

Fig. 6 - Speed distribution during two afternoon city trips in a passenger car, in the town of Utrecht. The trip on March 14th is the one used for measurements the under the hood.

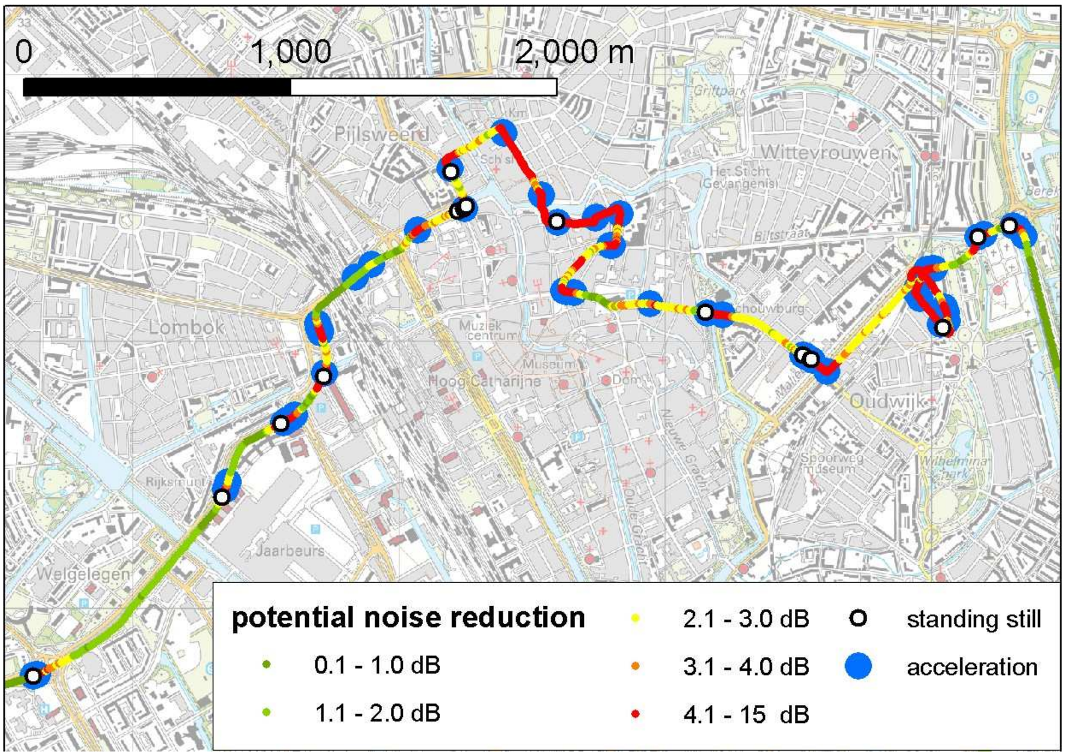

Fig. 7 - Potential noise reduction along the route by replacing the diesel engine by an electric one.