Noise from electric vehicles – 'state-of-the-art' literature survey

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ABSTRACT

As a part of the COMPETT project about electric vehicles and the promotion of the use of these, an international 'state of the art' literature survey on noise has been done. It investigated how much is already known about the noise from electric vehicles and discovered where more research is needed. The findings in the literature survey show that there is a potential for noise reduction by replacement of ICE vehicles with electric vehicles, but the findings also show that there is a great deal of uncertainty about how large this potential is. The reductions of noise found in the references differ greatly and seem to depend very much on how the comparison between noise from ICE vehicles and electric vehicles is done. Most references do however find that it is only at low speeds that a noise reduction can be expected.

This report is concluded with recommendations for how future measurements of noise from electric vehicles could be performed and what aspects of this noise need further investigations.

In the next step in the noise investigations in the COMPETT project measurements of the noise from electric vehicles will be carried out.

1. INTRODUCTION

The project COMPETT (Competitive Electric Town Transport) [1] is financed by national funds which have been pooled together within ERA-NET-TRANSPORT.

In January 2011 ERA-NET-TRANSPORT initiated a range of projects about electric vehicles under the theme ELEKTROMOBILITY+ [2] concerning topics from the development of battery and charging technology to sociological investigations of the use of electric vehicles.

20 European project consortia have now been initiated including the COMPETT project. COMPETT is a co-operation between The Institute of Transport Economics in Norway, The Austrian Energy Agency, The University College Buskerud in Norway, Kongsberg Innovation in Norway and the Danish Road Directorate (DRD). The objective of COMPETT is to investigate how the use of electric vehicles can be increased, particularly with focus on private passenger cars. The main question to answer in the project is "How can e-vehicles come in to use to a greater degree?"

The literature survey "Noise from electric vehicles – a literature survey" [1] was the first deliverable of work package 3 "Silent urban driving" in the COMPETT project. This survey was started in order to investigate how much is already known about noise from electric vehicles in urban areas and to discover where more research is needed.

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2. WHAT'S KNOWN ABOUT NOISE AND ELECTRIC VEHICLES?

Through a search of relevant literature twenty-two references were found to be of interest to the COMPETT project. These references were found in the TRID database [3], in proceedings from relevant conferences and handed in form other members of the COMPETT project consortium. This paper will summon the points of the literature survey [4] which are most important to the COMPETT project.

2.1 Passenger cars

Several of the references contained information on noise emission from passenger cars of different kind (electric, hybrid or combustion) driven at different speed and patterns. The noise from vehicles comes mainly from the propulsion and the contact between the tires and the road. The tire/road noise increases more than the propulsion noise with the increasing speed. This is illustrated in Figure 1 by showing the propulsion noise, the tire/road noise and the total noise from a passenger car as a function of speed calculated with the Nord2000 model [5].

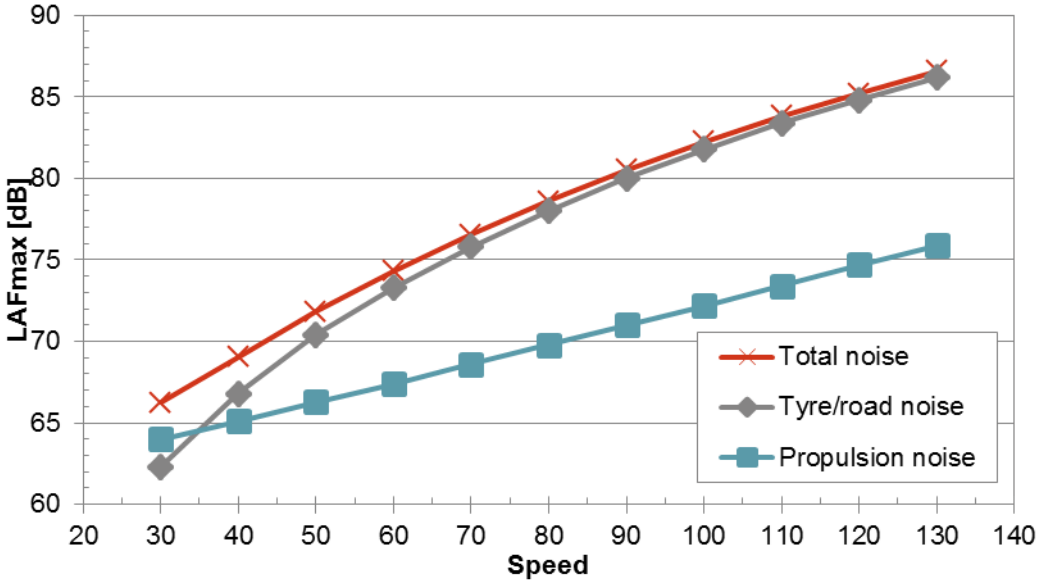

Figure 1 - The propulsion noise, the tyre/road noise and the total noise from a passenger car calculated with the Nord2000 noise prediction model [5].

The prediction model states that the propulsion noise is dominant at low speed, but at higher speed the tire/road noise is dominant. Thus an electric, hybrid and Internal combustion engine (ICE) vehicle of similar weight and shape and with the same type of tires will emit the same noise at high speed. Urban areas have low speed limits. Thus in urban driving conditions the propulsion noise will greater contribution to the total noise emission from the vehicle.

2.1.1 Comparing noise levels of ICE and electric vehicles

Several of the references in the literature survey handle the investigation of noise from vehicles very differently. The conditions of the measurements differ in type of vehicle, range of speed, distance to the microphone etc. Often the type of tires and pavement are not even mentioned in the studies. This is surly a serious lack of information since these are the components of tire/road noise. The conditions of the measurements are not clear for some of the references, thus it is not possible to compare the noise levels from the different references.

Table 1 is taken from the literature survey and it attempts to sum up the different results from the references. The only clear tendency is that there is a difference in noise from electric passenger cars and internal combustion engine passenger cars but only at low speeds. The speed where there is no longer a difference varies between 25 km/h and 50 km/h.

Table 1 – Reduction in noise when a electric passenger car is compared to an ICE passenger car. *Lowest measured speed, **Highest measured speed. [1]This reference compared 'twin' cars and the same is done here. This is for the Highlander (SUV) 'twins'. [2]This reference compared 'twin' cars and the same is done here.

This is for the Matrix/Prius (regular passenger car) 'twins'.

Reference	Max. reduction	Speed of no reduction	Distance to microphone, m
[6]	15 dB at 10 km/h*	50 km/h	7.5 m from centre, 1.2 m from ground
[7]	20 dB at idle*	30 km/h	2 m from centre
[8]	7 dB at 10 km/h*		2 m from centre, 1.2 m above the ground
[9]	12 dB at 8 km/h*	24 km/h (difference grows above 45 km/h to 2 dB at 70 km/h**)	
[10][1]	1 dB at 9,7 km/h*	32 km/h	3.7 m from centre, 1.5 m above ground
[10][2]	9 dB at 9,7 km/h*	32 km/h	3.7 m from centre, 1.5 m above ground
[11]	4 dB at 30 km/h*		
[12]	7 dB at 10 km/h*	40 km/h	7.5 m from centre
[13]	10,5 dB at 10 km/h*		3 m from centre, 1.5 m above ground

2.1.2 Comparing noise in different driving patterns

The speed in urban driving situations cannot in all driving situations be classified as constant; there will be accelerations and decelerations at intersections etc. Thus the difference of noise from electrical passenger cars and ICE passenger cars when accelerating and decelerating is important to investigate in order to predict the effects of introducing electrical passenger cars in urban areas. Only three of the relevant references found in the literature survey studied the noise from electrical and ICE passenger cars when decelerating and/or accelerating.

Reference [9] measures a difference of 7 dB at about 8 km/h with full acceleration and above 40 km/h there is none or little difference in noise level. In reference [10] the cars accelerated from 32 km/h 61 m from the microphone. The acceleration was constant but it is not stated what the constant was. The difference of noise level in this acceleration measurement is small or none, which compared to the results from the previous reference, is logical because of the high speed at the beginning of the measurement.

The study in reference [10] the deceleration was investigated by breaking from 32 km/h at a constant deceleration of $1 m/s^2$ 30 m from the microphone making the speed at the microphone 16 km/h. This was measured with two sets of similar cars one had the electrical passenger car noisiest with1.9 dB the other set had the ICE noisiest with 4.5 dB. It is difficult to conclude from these results.

2.2 Heavy vehicles

Even though the COMPETT project has the agenda to investigate the possibilities and effects of introducing electrical vehicles to personal transportation in urban areas, it is not to be underestimated that heavy vehicle also contribute to traffic noise in the cities. Thus noise from electrical versus ICE heavy vehicles is also investigated in the literature survey.

As for passenger cars the noise from heavy vehicles comes mainly from tire/road and propulsion noise. A study [14] compared 5 hybrid busses with 2 conventional busses with a diesel engine. This

study found the maximum reduction of the exterior noise from the hybrid bus driven in all electric mode to be 12 dB. Another study [15] compared noise emitted from electric and hybrid dual-axel trucks with the noise from an ICE truck. At 20 km/h the difference is almost 10 dB, whereas the difference above 50 km/h is only around 1 dB.

2.3 Subjective perception of noise from electric vehicles

The literature survey focuses on objective measurements of noise from electric vehicles, but a couple of references have been found where perceptions of the noise from electric vehicles are investigated. The studies retrieved in the literature survey took very different approaches to subjective perception. Reference [14] included a questionnaire survey, which showed that people tend to like to be a passenger in an electric bus better than an ICE bus.

Japanese researchers have in [16] carried out a questionnaire survey about the experiences with noise from electric and hybrid vehicles. This study indicated that the hybrid and electric vehicles are considered quiet and in some cases too quiet.

A German study [17] including tests with a listing panel of 240 participants in the age range of 5 to 95 years. The listing panel where including hearing and visually impaired as well. The subjects were standing on the side of a street and the cars then passed by one at a time with a constant speed of 30 km/h the test subjects then crossed the street and answered a questionnaire. This concluded that there is a very small difference in loudness. It should be noted that the two cars emitted sound levels which were measured to be close to each other.

2.4 Predictions about the noise reduction in cities by electric vehicles

The COMPETT project will attempt to predict the effects of introducing electric vehicles in urban areas instead of ICE vehicles. Thus the literature survey also included an investigation of predictions about the noise reduction in cities by electric vehicles.

In the Netherlands predictions [18] were preformed where 90% of passenger cars and 80% of the heavy trucks were substituted with electric vehicles. A noise reduction map was made of the entire city noise of Utrecht and the overall noise reduction was 3 dB. The same authors continued the studies in [11], this time with 95 % of the passenger cars and only very few heavy vehicles would be replaced. This study showed that electric cars could mean a significant reduction in the noise level on urban roads with speed below 30 km/h.

An American study [6] showed that replacement of all cars with electric cars would give very little effects at peak hours and noon. This lack of reduction is explained by the fact that at these hours more busses and trucks populate the streets and these types of vehicles are not expected to be replaced by electric vehicles.

3. CONCLUSIONS

The literature survey makes some conclusions on and recommendations on what the COMPETT project could and should investigate. It finds that there is a potential for noise reduction by replacement of ICE vehicles with electric vehicles, but there is a great deal of uncertainty about how large the potential is.

If it is desired to be able to predict a reduction in sound level in a city then it is necessary to know what types of pavement are present in the city. A noisier pavement can mean that the tire/road noise is dominant at lower speeds than it would be on low noise pavement and there can therefore be a difference in how great a noise reduction can be obtained. And the same problem can be obtained by the choice of tire. Thus more knowledge is needed about the tires used on electric cars. Do they have other dimensions or tread patterns? This would indicate whether the tire/road noise would be the same when driving electric or ICE vehicle or not. Thus it is relevant to examine what types of tires are generally used on electric cars.

The literature survey also recommends that measurements of different driving situations such as acceleration, braking and backing are needed. If the noise reduction in a city is to be predicted then a thorough investigation of the driving patterns is needed. Some of these subjects will be further investigated through the COMPETT project.

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