Technical Note

Note: Technical notes are aimed at promoting discussion. The views expressed are not necessarily those of the editors or the Australian Acoustical Society. Contributions are not formally peer-reviewed.

ACOUSTICAL IMPACTS OF FUTURE GENERATION ROAD VEHICLES

Matthew Stead, Adrian White and Deb James
Resonate Acoustics, Australia
matthew.stead@resonateacoustics.com

Future generation transportation has inherently lower noise emissions which are driven by changes to regulation, improved technology and because of consumer expectations. Lower noise emissions will have an impact on infrastructure projects in terms of reduced capital costs and also improved amenity for the communities surrounding the infrastructure. It has been found that hybrid and electric vehicles will have the greatest impact on lower speed roads (80 km/hr or less) and only marginal impact for 100 km/r roads because tyre noise is the dominant source rather than propulsion noise at this speed. Results of these findings for major road infrastructure routes are presented for consideration by authorities, designers and contractors.

INTRODUCTION

With a resource constrained future, the viability of hybrid and electric vehicles is likely to increase. Hybrid vehicles combine a combustion engine with an electric motor. Propulsion is a mix of combustion and electric motor dependent on vehicle speed and load. Electric propulsion is inherently quieter than combustion propulsion vehicles as observed in current hybrid vehicles when in electric mode. There is even concern that electric vehicles are so quiet at low speeds that they pose a safety hazard to pedestrians and in particular blind pedestrians, as demonstrated by U.S. federal legislation which recently required an assessment of minimum noise levels [1].

Current traffic noise mitigation design for infrastructure projects is either based on noise models which have been calibrated to the current vehicle fleet and mix or on noise models based on historical vehicle noise emissions. There is an inherent assumption that the future vehicle fleet will have similar noise emissions to the existing or past fleet.

The allocation of capital on infrastructure is scrutinised and there is hence benefit in questioning the predicted future noise emissions from vehicles which is the basis for noise models. Anecdotal evidence from projects such as Eastlink in Victoria suggest that a 1 dB(A) increase in noise source level is approximately equal to 0.8 m higher noise walls. At current budgets for concrete noise walls this could equal up to $2 million for noise walls on both sides of Eastlink. This is a significant proportion of an infrastructure budget and hence it is critical that the accuracy of future traffic noise models be assessed.

This article reviews the sources of noise from road vehicles and makes an informed prediction of future road vehicle noise emissions.

SOURCES OF ROAD VEHICLE NOISE AND NOISE EMISIONS

The sources of road vehicle noise have been studied in numerous technical publications [2, 3]. The primary sources of noise can be categorised as:

- Road / tyre interaction
- Propulsion
- Aerodynamic
- Other miscellaneous sources such as brakes, suspension, rattle, etc.

At different speeds and under vehicle acceleration or deceleration modes the relative contribution of the sources change. In some cases the propulsion is the main source (generally low speed or under acceleration) and in other cases the road/tyre interaction is the dominant noise source (generally at higher speeds). The study by Lelong [2] found that for passenger cars at lower speeds (<60 km/hr) the propulsion system was the dominant noise source and at higher speed (>=60 km/hr) the tyre/road interaction noise was the dominant noise source. This suggests that hybrid or electric vehicles may have similar noise emissions to traditional propulsion vehicles at higher speeds.

A previous study [4] measured vehicle noise emissions on a rural Australian highway. The different vehicle noise emissions (for class Austroads Vehicle Classifications) were then compared with the standardised Traffic Noise Model (TNM) [5] and Calculation of Road Traffic Noise (CORTN) [6] noise models. The findings of the study are repeated in Figure 1. This study showed that the current fleet of Australian vehicles does not have the same emissions characteristics as the TNM or CORTN models. The result of this study is used as the basis for predicting overall noise emissions for Australia in this study.

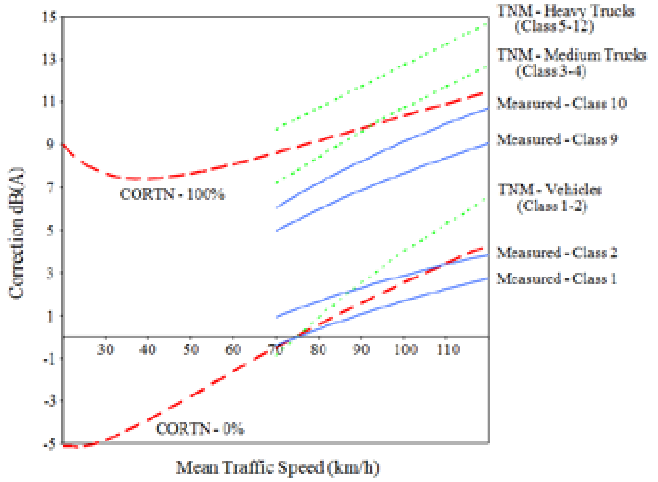

Figure 1. Correction to traffic noise emissions levels using TNM, CORTN and measured by Jurevicius et al. [7] with varying percentage commercial vehicles (normalised to 75 km/hr and 0% commercial vehicles)

HISTORICAL ROAD VEHICLE NOISE EMISSION REDUCTIONS

The regulations associated with vehicle noise emissions have gradually been reducing the noise emission limits over the past 45 years [7]. The development of overall vehicle noise emission limits in the EU, Japan and USA from [7] is shown in Figure 2. The effect of noise emission regulations on received noise levels at residences vary significantly depending on the study being assessed in Sandberg 2001. The overall conclusion of the [7] study was that regulations have not been effective and only small reduction in noise levels at residences have been achieved over the studied 30 year time period. This primarily is related to the regulation of propulsion noise the when the dominant tyre/road interface noise has not been regulated to the same degree.

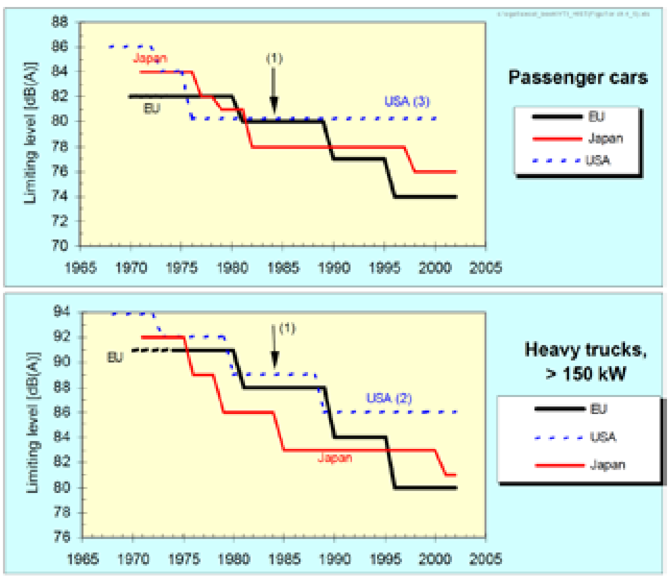

Figure 2. Examples of the development of individual vehicle noise emission limits over the years including some projected limits [7]

PROJECTED FUTURE FLEET MIX

Projections on the future vehicle fleet mix are difficult to make. There is a trend towards more hybrid vehicles as demonstrated by the number of models available. The current percentage of hybrid vehicles being sold in the USA is around 3% [8]. This is expected to increase but at an unknown rate.

In this article, a low (<10%), medium (50%) and high (90%) mix of passenger hybrid / electric vehicles has been assumed. Commercial vehicles are likely to have a slower adoption of hybrid vehicle technology due to the additional range and loads they carry. As such it is assumed that the noise emission for commercial vehicles is likely to remain similar to existing levels given the restricted choice of hybrid commercial vehicles.

ASSESSMENT OF ELECTRIC/HYBRID AND COMBUSTION VEHICLE PASS-BY NOISE EMISSION

To assist in the analysis of noise from hybrid/electric vehicles compared with a combustion engine vehicle, a back-to-back test was carried out with a hybrid and a manual 4 cylinder combustion engine passenger vehicle. A Toyota Camry was selected for the testing and two vehicles with similar tyre wear and the same model chassis were sourced. The test vehicles both had the same tyre make and model (Dunlop Supersport 300E) and similar wear. This model vehicle was selected as it is a mid-size vehicle and currently in production as both a hybrid and non-hybrid version.

A section of test road (Boundary Road, Truganina, Victoria, Australia) was selected which had a surface equivalent to dense graded asphalt, was flat, straight and in a rural setting without other traffic. The road was a single lane and there were no significant reflecting surfaces or road imperfections where the measurements were taken. The test road was used for vehicle pass by noise measurements. The surrounding area was grassed and flat. The tests consisted of a number of pass-bys with varying constant speed and engine load. At the time of the testing the conditions were minimal wind, 10 deg C, clear skies and 86 % relative humidity.

A calibrated Class 1 Bruel and Kjaer 2250 hand-held analyser and sound level meter with audio recording was used to take measurements of the vehicle pass by. The sound level meter was located 7.0 m from the centre line of the vehicle and was mounted on a tripod 1.2 m above the ground level. The overall averaged results of the testing is summarised in Table 1.

The coasting noise levels at 100 km/hr per hour were 0.4 dB(A) lower for the 4 cylinder vehicle and 1.2 dB(A) lower for the hybrid vehicle with constant speed and engine load. At lower speeds the propulsion noise was more significant compared to tyre/road interface noise. The difference between the engine loaded and unloaded noise levels show the engine / motor is not the dominant noise source at 100 km/hr and there was a greater difference with the hybrid vehicle.

Table 1. Vehicle maximum pass-by relative noise levels

Test Condition	Average individual vehicle maximum pass-by noise level		Difference between 4 Cylinder and Hybrid Camry maximum pass-by noise level (positive number where 4 cylinder has a higher noise level)
	Hybrid Camry	4 Cylinder Combustion Camry	
60 km/hr constant speed and engine load	70.6 dB(A)	72.9 dB(A)	2.3 dB(A)
80 km/hr constant speed and engine load	75.0 dB(A)	78.3 dB(A)	3.3 dB(A)
100 km/hr constant speed and engine load	79.4 dB(A)	80.1 dB(A)	0.7 dB(A)
100 km/hr coasting (engine unloaded)	78.2 dB(A)	79.7 dB(A)	1.5 dB(A)

Table 2. Predicted change on overall noise emissions

Percentage Commercial Vehicle Low (5%) Medium (10%) High (20%)	Hybrid Vehicle Fleet Percentage		
Speed	Low (10%)	Medium (50%)	High (90%)
60 km/hr			
Low CV%	0.2 dB(A)	1.1 dB(A)	1.7 dB(A)
Medium CV%	0.2 dB(A)	0.9 dB(A)	1.4 dB(A)
High CV%	0.2 dB(A)	0.7 dB(A)	1.0 dB(A)
80 km/hr			
Low CV%	0.4 dB(A)	1.6 dB(A)	2.4 dB(A)
Medium CV%	0.3 dB(A)	1.3 dB(A)	2.0 dB(A)
High CV%	0.2 dB(A)	0.9 dB(A)	1.4 dB(A)
100 km/hr			
Low CV%	0.1 dB(A)	0.3 dB(A)	0.5 dB(A)
Medium CV%	0 dB(A)	0.2 dB(A)	0.4 dB(A)
High CV%	0 dB(A)	0.2 dB(A)	0.3 dB(A)

ASSESSMENT OF ROAD/TYRE INTERACTION NOISE EMISSION

The noise emissions from the road / tyre interaction could reduce with future advances in tyre and road technology with between 4 and 6 dB(A) theoretically possible with current reported technologies [9]. The current Australian Design Rule for passenger car tyres [10] however does not provide noise limits and hence without a regulatory driver there is unlikely to be significant change in Australia. While tyres may be imported from Europe (where there are noise limits) the impact on reducing noise on Australian road noise emission is questionable in the absence of a regulatory driver. For the purposes of this paper it is hence assumed that there will be no significant reduction in tyre noise emission levels in Australia.

ANALYSIS

Changes to future vehicle emission levels have been calculated for the low (<10%), medium (50%) and high (90%) mix of passenger hybrid / electric vehicles using measured results from Table 1 and vehicle emission levels from Figure 1. The percentage of commercial vehicles is assumed to be low (5%), medium (10%) and high (20%) with no change in commercial vehicle noise emissions and no change due to tyre/road interaction noise levels.

From Table 2 it can be seen that significant noise reduction (> 0.5 dB(A)) is only achieved at lower speeds (less than 80 km/hr) and with medium to high hybrid vehicle fleet mix. In limited cases the difference is greater than 1 dB(A). Hybrid vehicles are not likely to have a significant impact for freeway / expressway infrastructure projects operating at 100 km/hr.

CONCLUSIONS

The simplistic assumption that hybrid or electric vehicles will significantly reduce the scale of noise walls on urban freeways is not shown by the research in this paper. While over time the propulsions noise levels have reduced, the overall noise levels have not significantly reduced mainly to the slower improvements in tyre technology. While this is not likely to change rapidly in the future because of a lack of regulation around tyre noise in Australia, there is still the potential for reductions in vehicle noise emissions with hybrid or electric vehicles. Should there be a change to tyre noise regulations the reductions could be much more significant. Pressure should be placed on the reduction of tyre noise emissions. The impact on the reduction in noise is greatest at low speeds and with greater than 50% of the vehicle fleet being hybrid or electric. The results from this research have found that for a low percentage of hybrid vehicles there is unlikely to be any significant changes to vehicle noise emissions.

REFERENCES

[1] United States Federal Congress, *Bill S. 841 (111th) Pedestrian Safety Enhancement Act of 2010*, http://www.govtrack.us/congress/bills/111/s841 (last accessed November 2012)

[2] J. Lelong, "Vehicle noise emission; Evaluation of tyre/road and motor noise contributions," *Proceedings of InterNoise 99*, Florida, USA, 6-8 December 1999

[3] C. Hansen and D. Bies, *Engineering noise control, Theory and practice*, 4th edition, London, New York, Spon Press, 2009

[4] D. Jurevicius, P. Agnew and M. Stead, "Correlation of rural highway road traffic noise with vehicle speed and commercial vehicle percentage for the day and night time periods", *Proceedings of the 14th International Congress of Sound and Vibration*, Cairns, Australia, 9-12 July 2007

[5] G.G. Fleming, A.S. Rapoza and C.S.Y. Lee. *Development of National Reference Energy Mean Emission Levels for FHWA Traffic Noise Model (FHWA TNM®)*, Version 1.0, Report No. FHWA-PD-96-008/DOT-VNTSC-FHWA-96-2, U.S. Department of Transportation, Research and Special Programs Administration, November 1995

[6] UK Department of Transport, Welsh Office, *Calculation of Road Traffic Noise*, 1998, http://www.noiseni.co.uk/calculation_of_road_traffic_noise.pdf

[7] U. Sandberg, "Noise emissions of road vehicles, Effect of regulations", Final Report 01-1, *International Institute of Noise Control Engineering*, 2001

[8] Hybrid Cars, April 2012 Dashboard, http://www.hybridcars.com/news/april-2012-dashboard-45388.html (last accessed November 2012)

[9] Forum of European National Highway Research Laboratories (FEHRL), Study S12.408210 *Tyre/Road Noise*, Volume 1, Final Report, 2006

[10] Vehicle Standard, Australian Design Rule 23/02 *Passenger Car Tyres*, Federal Register of Legislative Instruments F2007C00769, Australian Government, 2007

Update Your Records

The AAS will be increasing the use of the on-line records with an update of the web page in the near future. The decision has been made on the model layout for this new improved website which will greatly increase the navigation and value for the website.

It is important that the records held in the membership base are up to date. It is the responsibility of each member to log on, check the current listing and update your company, address, preferred email, etc. So please check out your records now. If you have forgotten your username and/or password, you can retrieve them with the forgot username / forgot password options and then you can check and amend your AAS records.