DEVELOPING A NEW SOURCE MODEL FOR ROAD TRAFFIC VEHICLE NOISE

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1 INTRODUCTION

1.1 Background

The Calculation of Road Traffic Noise (CRTN) methodology[1], used in the United Kingdom (UK), was last revised in 1988 and was published prior to commercial noise modelling software. Whilst it remains capable of meeting the original purpose of assessing road traffic noise levels under a variety of commonly encountered conditions, it is relatively inflexible in terms of modelling certain parameters such as variations in meteorological conditions, modern vehicle classifications and vehicle acceleration.

As such, development of a new calculation methodology has been discussed within the British Standards EH/1/2 Committee on transportation noise. A scoping panel was created to look into what would be required of a new calculation method. This panel produced a number of scoping documents outlining the key stakeholders, user requirements and a suggested format for a new method covering both road and rail noise sources, and their propagation[2,3].

The approach outlined in the scoping documents consists of treating road and rail vehicles as equivalent moving sound power levels with a common propagation element. This is the approach taken in many modern European calculation methods, including the CNOSSOS-EU methodology described in Directive 2015/996[4] and subsequently updated in Delegated Directive 2021/1226[5]. However, as the CNOSSOS-EU methodology has been designed and validated only for strategic scale national mapping, it is not appropriate to adopt it as a national standard which must be capable of modelling localised effects.

Feedback from the acoustics community indicated that using the IMAGINE model as a foundation for the road noise source terms within the new calculation methodology was the preferred approach. The IMAGINE model follows the overarching approach adopted by CNOSSOS-EU but is more flexible, making it more applicable to local scale traffic noise calculations. However, the IMAGINE model was developed from measurement programmes completed in mainland Europe between 2000 and 2005[6,7] and therefore requires validation with respect to the modern vehicle fleet and road surfaces in the UK. This paper describes work undertaken for National Highways to perform this validation of the road noise source terms.

1.2 Scope of work

The validation exercise for the road traffic source noise terms was broken down into the following tasks:

- Review existing information on vehicle noise emission data.
- Undertake a suite of roadside noise measurements to obtain relevant data for use within the proposed new road calculation methodology.
- Derive revised coefficients for core elements of the IMAGINE method, applicable to the UK and draft the road source noise section of the proposed calculation methodology.

2 EXISTING INFORMATION

2.1 IMAGINE

The Environmental Noise Directive 2002/49/EC (END)[8] was supported by pan-European research into the modelling of road, rail and aircraft noise. This research led to the creation of a noise emission model for European road traffic[9]. This model was initially developed under a research programme called Harmonoise and subsequently finalised under another research programme called IMAGINE. Here we call this emission model the IMAGINE model.

This model groups the vehicle fleet into several vehicle classes and provides formulae for the sound power levels of vehicles in that class, across the 1/3rd octave spectra, at a reference speed of 70 km/h and on a defined reference surface. Correction factors are then provided to account for a variety of parameters that could influence the sound power level including different vehicle speeds, road surfaces, tyre widths, fleet composition and road gradient.

This is the framework used by the proposed new calculation methodology.

2.2 CRTN lockdown study

As part of a study for National Highways to understand the impact the COVID-19 lockdowns had on road traffic noise, in addition to noise exposure surveys both during and after the lockdown period, nine Statistical Pass-By (SPB) surveys were undertaken, covering six different road surface types found on the Strategic Road Network (SRN). Data from these surveys informed the validation exercise undertaken as part of this work.

2.3 Other data sources

Other research studies were investigated to understand how they could be used to help inform the validation exercise. These included a research study for National Highways, Eurobitume UK and the Mineral Products Association to investigate techniques for the manufacture of durable low noise surfacing products with improved skid resistance[10] and work for the Department for Transport (DfT) trialing roadside noise cameras to detect excessively noisy road vehicles[11,12].

Much of the data collected as part of the DfT study either concerned excessively loud vehicles, which would not represent the vehicle class average suitable for the calculation method, or was collected remotely from noise camera systems with no associated information on vehicle speed that would be required for the accurate validation of the calculation method. Part of the study did however collect detailed information on motorbikes, including sound levels and speeds, and these data could potentially be used to inform future work on validating the sound power coefficients for powered two wheelers.

3 DATA COLLECTION

3.1 Methodology

One-third octave band frequency data relating to the A-weighted maximum noise level from vehicle pass-bys were captured using a sound level meter. The speed of the vehicle was also captured using a handheld speed gun. The methodology for these surveys closely followed the SPB procedure described in ISO 11819-1[13]. This methodology is used for the Highways Authority Product Approval Scheme (HAPAS) to calculate the acoustic performance of road surfaces in terms of the Road Surface Influence (RSI)[14].

A total of 17 vehicle sub-categories were used for this study to allow for a detailed analysis of the noise level of different vehicle groups. This information was used to help determine whether some vehicle categories warranted their own distinct set of coefficients in the new calculation methodology. This expands upon the standard SPB vehicle categories of L for light vehicles, H1 for 2-axle heavy vehicles greater than 3.5 tonnes and H2 for heavy vehicles greater than 3.5 tonnes with more than 2-axles. The vehicle sub-categories used are shown in Table 1.

Table 1 Vehicle sub-categories

Vehicle code	Description
L1	Small / standard car
L1_V	Car derived van
L1_E	Small / standard car – electric
L1_V_E	Car derived van – electric
L2	Large family car
L2_V	Medium sized van (e.g. Ford Transit)
L2_E	Large family car – electric
L2_V_E	Medium sized van – electric
L3	Sports car
H1	2 axle lorry
H1_V	Box van
H1_C	Coach
H1_B1	Single decker bus
H1_B1_E	Single decker bus – electric
H1_B2	Double decker bus
H1_B2_E	Double decker bus – electric
H2_N	>= 3 axle lorry (N number of axles)

3.2 Results

A breakdown of the survey sites in terms of the road surface type, age of the surface and the speed limit of the road is presented in Table 2. The shorthand code adopted for this study was chosen to match that used for Round 4 Environmental Noise Mapping using the CNOSSOS-EU method[8,4,5].

Table 2 Site survey information

Description	Code	Total Sites	Surface age (years)	Speed limit (mph)
Surface dressing	C02	1	26	70
Concrete (brushed)	C03	2	33 & 42	70
TSCS[1] 6 mm	C04	1	1	70
TSCS 10 mm	C05	6	1, 6 & 8	70
TSCS 14 mm	C06	10	3,7,9 & 10	60 & 70
TSCS unknown chip size	C07	8	9,11 & 15	50, 60 & 70
Stone mastic asphalt 10 mm	C09	5	1-2* ,2 ,2-5* & 5	30, 40, 60 & 70
Stone mastic asphalt 14 mm	C10	12	1, 1-2*, 2-5*, 3, >5*, 6 & 8	20, 30, 40, 50, 60 & 70
Hot rolled asphalt 20 mm	C13	4	4, 5 & 7	60 & 70

Description	Code	Total Sites	Surface age (years)	Speed limit (mph)
Hot rolled asphalt 14mm	C13.2[2]	5	1-2*, >5*	20, 30 & 40

[1]TSCS stands for Thin Surface Course System and is defined in National Highways Design Manual for Roads and Bridges[15]. The associated number refers to the primary aggregate size in the asphalt mixture

[2]Surface type code created for this study

*Sites with this symbol have had both the surface type and age estimated using site photographs of the surface rather than National Highways data

The total number of vehicles measured during the data collection process, the range of vehicle speeds measured and the range of the acoustic performance of the road surfaces is given in Table 3.

Table 3 Summary of vehicles measured and surface performance

Number of vehicles measured[1]			Speed range (km/h)	RSC[2] dB(A)
L	H1	H2		
5769	610	1080	21 to 148	-7.6 to +3.5

[1] L, H1 and H2 are the totals of all vehicle sub-categories in Table 1 starting L, H1 and H2 respectively
[2] While the acoustic performance was derived in terms of the RSI metric, it is termed RSC (for Road Surface Correction) in acknowledgement of the fact that the sites did not necessarily comply with all the requirements stipulated in the SPB methodology

4 DATA ANALYSIS

4.1 IMAGINE methodology

The purpose of the roadside noise surveys was to collect data that would support the adjustment of the IMAGINE methodology to suit the vehicle fleet and road surfaces in the UK. These adjustments are made to the speed dependent rolling and propulsion sound power levels of the vehicles themselves, in 1/3rd octave bands. The full structure of the method is presented in the IMAGINE documentation[9]. A brief overview of the basic framework of the methodology is provided below.

The IMAGINE methodology treats each individual vehicle as an equivalent moving point source with a sound power level split into rolling noise and propulsion noise components. The sound power associated with the rolling noise for each vehicle category is given by:

$$L_{WR} = A_R + B_R log_{10}\left(\frac{v}{v_{ref}}\right) \quad (1)$$

where A_R and B_R are constants in each 1/3rd octave band for each vehicle class, v is the speed of the vehicle in km/h and v_{ref} = 70 km/h. The sound power associated with the propulsion noise for each vehicle category is given by:

$$L_{WP} = A_P + B_P\left(\frac{v - v_{ref}}{v_{ref}}\right) \quad (2)$$

where A_P and B_P are constants in each 1/3rd octave band for each vehicle class. These equations describe the sound power levels of a vehicle class over the speed range 20 km/h to 130 km/h with respect to a series of reference conditions. When local conditions vary from these reference conditions, corrections to these levels are applied, many of which have their own associated coefficients. As such, the constants A_R, B_R, A_P and B_P are what are referred to as the 'core coefficients' and any other parameters that are altered as part of the validation process are termed 'correction coefficients'.

4.2 Analysis procedure

The analysis of the survey data was conducted using a bespoke software tool based on the open-source point-to-point implementation of the Harmonoise method, produced under the 2014 project to develop and implement harmonised methods[16]. The analysis procedure for the validation exercise was broken down into the following steps:

- **Define a suitable distance at which comparisons between measured and calculated sound pressure levels should be made.** Due to the constraints of local site conditions, vehicle noise levels were measured at different distances from the road edge from site to site. For this study, the distance specified in the SPB methodology[13] was used for comparison purposes. As such, all measured sound pressure levels were first corrected, under the assumption of point source propagation, to a point 7.5 m from the centre of the trafficked lane.
- **Determine the vehicle categories to be used in the revised methodology.** As part of this work, all the vehicle sub-classes given in Table 1 were considered, including whether or not they warranted separate categorisation for the purpose of defining sound power levels.
- **Determine the reference surface to be used in the revised methodology.** The reference surface used in the existing national methodology in the UK (i.e. CRTN) is a virtual surface with an RSI of 0 and this was carried forward as the reference surface for the new methodology to aid continuity.
- **Consider local site conditions in selecting appropriate vehicles.** At some survey sites, particularly those adjacent to low-speed roads, soft verges exist between the road and the microphone, and this can result in a greater level of sound absorption and scattering, and therefore lower measured levels. Data from these sites is still informative and will be very useful in helping to validate elements of the propagation method, such as ground absorption and scattering models, but these results have not been used to determine RSC values.
- **Determine the corrections to the sound power levels required to account for common road surface types found in the UK.** Survey data is collated according to road surface type and this has, along with historical data[17], been used to determine 1/3rd octave band corrections for each class of road surface.
- **Consider the range of other factors that may influence the vehicle sound power levels including the impact of air and surface temperature.** There are a range of additional variables that can influence the source noise of motor vehicles and, whilst these factors could not be explicitly validated through the survey programme, their impact and how they may be modelled was considered.

4.3 Vehicle categories

The IMAGINE methodology splits vehicles into categories described as light motor vehicles, medium heavy vehicles, heavy vehicles, and powered two-wheelers. As part of this work, surveyed vehicles were categorised into a wider variety of classes to determine whether or not it would be worthwhile to derive separate core coefficients for these sub-classes.

The final set of vehicle categories for the revised method is given in Table 4, along with the corresponding UN ECE vehicle classification for each category. The only change from the IMAGINE method being the division of category 1 vehicle into three separate sub-classes.

Table 4 Vehicle categories in the revised method.

Category	Name	Description	UNECE Vehicle Class[1]
1	Light motor vehicles	1C – Passenger cars < 3.5 tons	M1
		1V – Delivery vans < 3.5 tons	N1
		1CE – Passenger cars < 3.5 tons when powered by an electric motor	M1
2	Medium heavy vehicles	Delivery vans, trucks and buses > 3.5 tons, with two axles	M2, M3 and N2, N3
3	Heavy vehicles	Heavy duty vehicle > 3.5 tons with more than two axles	M2 and N2 with trailer, M3 and N3
4	Powered two wheelers	4A – mopeds and quads up to 50cc	L1, L2, L6
		4B – motorbikes over 50cc	L3, L4, L5, L7

[1]As defined in ECE/TRANS/WP.29/78/Rev.7

4.4 Core coefficients

From an analysis of the 1/3rd octave data for vehicles that sit close to an RSI 0 curve, at high speed, core (A_R) coefficients for the rolling noise component were derived. The Hot Rolled Asphalt (HRA) surfaces were chosen for this analysis. The high-speed data for HRA typically indicated good agreement with the speed dependency of the RSI=0 curve, so only small adjustments were made to the default coefficients B_R from the IMAGINE model.

With the rolling noise coefficients fixed, the low-speed data was analysed to determine appropriate propulsion noise coefficients. Adjustments were made primarily to the A_P coefficients, with limited evidence to suggest that the propulsion noise variation with speed, determined by B_P, needed much adjustment.

4.5 Surface corrections

With the core coefficients in place, correction terms for each of the road surface types could be determined. Vehicles that are close to the corresponding expected performance of the road surface were analysed to determine appropriate correction factors. This included age dependent corrections and the speed dependency of the vehicle noise levels on each surface.

4.6 Other Factors

In addition to the vehicle category and road surface, there are a number of other factors that can influence the sound power levels of the vehicles, such as air temperature, vehicle acceleration, road gradient and surface wetness. While it was not within the scope of this work to fully validate these parameters, commentary was provided on how these factors are treated in the IMAGINE model and whether or not an initial version of the new UK calculation methodology should adopt the relevant coefficients in the IMAGINE model. Further research into these factors could potentially inform an update to the new calculation methodology post the initial release.

5 SUMMARY

This paper summarises work undertaken to validate the road vehicle sound powers used in the European IMAGINE model, developed in the early 2000s, with respect to the vehicle fleet and road surfaces in the UK in 2023/2024.

The validation exercise consisted of comparing results from a series of roadside vehicle noise measurements with results from a series of calculations using a short-range point-to-point implementation of the IMAGINE model. The intention is for the output of this work to form a core component of a revised national calculation methodology for road and rail noise.

It is anticipated that alongside the new national calculation methodology, guidance documents concerning use of the standard will need to be updated or created as required depending on the application of the method. Such guidance would likely include a discussion on the uncertainty inherent in the model, see for example[18], and appropriate traffic data requirements, see for example[19,20].

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