

**Characteristics of vehicles producing excessive noise
and ground-borne vibration**

by R E Stait and M Clifton

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CHARACTERISTICS OF VEHICLES PRODUCING EXCESSIVE NOISE AND VIBRATION

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Executive summary

This programme of research addresses this issue of how to identify excessively noisy vehicles and examines the characteristics of such vehicles when they are in use. For larger vehicles, those generating excessive levels of vibration have also been examined. The research was commissioned by the Transport Research Foundation as part of the self-funded research programme. The first phase of the work, which was reported in PPR 202¹, developed a test methodology and a first series of experimental observations were undertaken to identify the characteristics of the excessively noisy vehicles. During the second phase of the work, which is reported here, the method was extended to a different highway environment.

Currently, the noise from a vehicle is only checked when the vehicle is new, and an example of the vehicle is taken through type approval. However, once a vehicle is in service the only noise check conducted is a subjective assessment during the vehicle's MOT test, and vehicles are often modified using after market products. Methods available for controlling in-service vehicle noise generally tackle noise from the traffic stream, focussing solely on low-noise surfaces and noise barriers. However, an additional, more targeted approach that could be adopted is to consider the noise caused by the noisiest vehicles, as noisy vehicles can have a very wide footprint that causes widespread disturbance.

Previous work has shown that across all vehicle classes the maximum pass-by noise for the noisiest of vehicles can be 6-8 dB(A) above the average for the sample. It is therefore useful to consider the characteristics of those vehicles that produce this excessive noise.

The aim of Phase 2 of this project was to collect noise data of cars, medium and heavy vehicles and then to identify the characteristics of those producing excessive noise. A further aim was to identify the characteristics of those heavy vehicles producing excessive levels of vibration.

Suitable measurement locations were identified on the A30 in Hampshire. This road carries a high volume of traffic and also contains a large proportion of heavy vehicles. The first site was on the westbound section of the A30 at Blackwater and the second site was on the eastbound section of the A30 at Blackbushe Airport.

At both sites, as each vehicle passed, the maximum noise level and speed was captured. Video cameras were set up to capture images of passing vehicles in order to identify possible noise sources. In addition, at Site 1 the maximum vertical and horizontal particle velocity in mm/s (a measure of vibration amplitude) was measured on the road surface.

The study has developed an efficient method for gathering information at the roadside on vehicles producing excessive noise and/or vibration. This may potentially provide a powerful addition to the control measures traditionally used to combat noise disturbance (e.g. noise barriers and low-noise road surfaces) which tend to reduce the average noise levels but fail to reduce the range of noise levels from individual vehicles.

The main conclusions that can be drawn from the study are:

- For light vehicles the majority of excessive noise events are caused by vehicles with modified exhausts. The majority of the remaining noisy events were caused by factors associated with large vehicles, such as large engines, large tyres or poor aerodynamics.
- The noise produced by trailers being towed by cars and vans was found to be excessive in a number of cases. This excessive noise was caused by both the trailer and the loads being carried on the trailer.
- Excessive noise produced by heavy vehicles was often caused by poorly secured loads.
- Car transporters have been found in this and the previous study to produce the highest levels of vibration. Refuse/waste vehicles, maintenance and skip lorries are also among the heavy

¹ **Watts G R and Stait R E (2006).** *Characteristics of vehicles producing excessive noise and ground borne vibration.* TRL Report PPR 202. TRL, Crowthorne, UK.

vehicles producing the highest levels of vibration. However, identifying the precise source of excessive vibration is far more complex than the identification of sources of excessive noise.

- It is recognised that while steps such as the securing of loads can easily be taken to reduce noise/vibration impact, the condition of the road surface plays an important part in the generation of noise and vibration. As such, any selection and identification of “noisy” vehicles for the purpose of taking remedial action would need to be undertaken with caution and in combination with measures to improve the quality of the road surfaces.

The method developed has the potential to be used for enforcement purposes that could either be used directly or as a means of identifying vehicles in a traffic stream that could then be taken for a further test.

Other areas identified during the research that could be investigated further are:

- Whether the relationship between noise level and the logarithm of vehicle speed still holds for the modern vehicle fleet.
- The possible development of a code of practice for the use of a trailer. This could include possible restrictions on the use of trailers, better design of trailers or annual inspections for trailers.
- Car transporters have been identified as causing excessive vibrations at low and high speeds. The causes of this could be investigated further.

1 Introduction

Noise nuisance is usually related to average noise levels, but can also be influenced by the numbers of events that stand out above the average level. These events are normally associated with individual vehicles that make excessive noise, and these can have a very wide footprint and can cause widespread annoyance. An example cited at a recent UN-ECE vehicle noise meeting was that a single motorcyclist riding an excessively noisy machine was alleged to have woken up an entire town in Sweden. Reducing maximum levels of noise in residential areas is likely to reduce sleep disturbance (World Health Organisation, 2000).

Currently, the noise from a vehicle is only measured when the vehicle is new. This process involves an example of the vehicle passing a type approval noise test and is covered by ISO 362 (International Organisation for Standardisation, 1998). However, once a vehicle is in service there are very few accurate checks on the noise produced, and vehicles are often modified using after market products.

Methods available for controlling after-service vehicle noise generally tackle noise from the traffic stream, focussing solely on low noise surfaces and noise barriers. However, an additional, more targeted approach to noise control that could be adopted is to identify and tackle those few vehicles producing the highest noise levels. As an illustration, the maximum pass-by noise levels from some vehicles contained within a traffic stream can be as much as 6 to 8 dB(A) above the average level for all vehicle classes. In acoustic terms, this difference could be interpreted as substantial.

The aim of this programme of research was to address this issue by developing a methodology that could be used to identify noisy vehicles from a traffic stream. These vehicles would then be examined to determine their characteristics (e.g. age, size, load) and from this recommendations could be made to tackle these categories of vehicle.

In addition to measuring noise, ground borne vibration levels produced by passing heavy vehicles were also be recorded as this is known to cause significant annoyance in some circumstances. Unlike noise, once ground-borne vibration exceeds the perception level, serious disturbance often results as occupants fear that their property will be damaged. In addition, amplification often occurs on suspended wooden floors leading to higher levels being experienced in bedrooms.

The first phase of the work, which was reported by Watts and Stait, (2006), developed a methodology and included a first series of experimental observations to identify the characteristics of the excessively noisy vehicles.

This report describes the second phase of the work, in which the method was extended to a different highway environment. Data were collected at two sites on a busy single carriageway road (the A30) with a wide mixture of traffic.

2 Methodology

The methodology used to collect the survey data was the same as that used during Phase 1 of the project (Watts and Stait, 2006), as described below.

It was the intention to collect information on the noise and vibration produced by vehicles under normal operating conditions and not when the vehicle is being driven in an aggressive manner e.g. under harsh acceleration. The main reason for this is that it is the vehicle characteristics and not the manner in which the vehicle is being operated that is the main focus of the proposed research. There is a case for examining the way motor vehicles are driven, but the methodology that would be adopted would differ to some degree from the approach proposed here.

2.1 Noise measurements and associated visual imaging

The measurement methodology trialled and then adopted was to simultaneously quantify the noise (in terms of the one-third octave-band frequency spectra) and speed of individual vehicles in the traffic stream. The measurement microphone was positioned 7.5 m from the middle of the closest running lane at a height of 1.2 m, in accordance with ISO 11819:1 (International Organisation for Standardisation, 1997), which is the standard method for roadside vehicle noise measurements. The measurements were controlled manually in order to ensure that the measured noise level of each vehicle was not contaminated with the noise from any other vehicles. In addition to the overall noise level being measured, a continuous audio recording was also made to assist with any necessary post analysis.

Visual recordings were also undertaken to capture images of the passing vehicles in order to identify possible noise sources. One camera was mounted at a height of approximately 4 m to capture an overall view of the vehicle (especially of loads being carried on HGVs) and a lower camera at a height of 1 m was used to capture images of the rear of the vehicle to obtain information on the number plate, exhaust pipes and tyres.

2.2 Vibration measurements

For the measurement of ground-borne vibration, the maximum vertical particle velocity in mm/s (a measure of vibration amplitude) was measured using a transducer placed on the road surface. This was positioned at a distance of approximately 2.5 m from the centre of the lane containing the irregularity responsible for the vibration. The vibration monitoring equipment was configured to record the maximum level over a 15 second period, and was triggered automatically when a predetermined vibration level was reached.

Road surface conditions sufficient to generate ground-borne vibration were only encountered at one of the experimental sites.

2.3 Audio recordings

To demonstrate the excessive noise produced by some vehicles, high quality stereo audio recordings were also taken of the noise from passing vehicles. The equipment used consisted of a portable recording device and a set of headphones, with microphones inside the outer casing of the headphones. When worn, this captures almost exactly the same noise as heard by the wearer. These audio recordings were only taken at Site 2 so as not to include any influence from the uneven road found at Site 1.

2.4 Vehicle categories

For the Phase 1 survey the vehicles surveyed were classified into three groups. These categories were identical to those described in the Calculation of Road Traffic Noise (CRTN), which is the standard

methodology used for noise calculations in the UK (Department of Transport and Welsh Office, 1988):

- Category 1 - Light vehicles (i.e. cars).
- Category 2 - Medium heavy goods vehicles, buses and coaches. Vehicles with 2-axles and 4 wheels on the rear axle.
- Category 3 – Heavy vehicles. Those with 3 or more axles.

During Phase 2 it was decided to add an additional category of vans (called category 1b) as there are a high proportion of these vehicles using the road network. It was also decided to include cars or vans that were towing trailers within the sample.

2.5 Measurement locations

The measurements during Phase 1 of the project were undertaken on a busy dual carriageway. This enabled a large sample of vehicles to be surveyed and the measurement methodology to be validated on that type of highway. Although this site provided a large sample of heavy vehicles, light vehicles (i.e. cars) were less prevalent. For Phase 2, the aim was to undertake the surveys on a slightly lower speed road but where there was still a large selection and variety of vehicles.

A site visit was undertaken to review potential locations and two sites were selected on the A30 near to Blackwater, on the Surrey / Hampshire border.

2.5.1 Site 1

This was located on the westbound section of the A30 at Blackwater. The wearing course of the road surface was a rough surface dressing. At this site there were a significant number of irregular patches across the carriageway (i.e. patches where the surface had been repaired) at the measurement point and it was considered these were sufficient to induce significant ground-borne vibration and body rattle noise. The open nature of the site allowed freely moving vehicles to be selected from the traffic stream. A view of the site is given in Figure 2.1.



Figure 2.1: View of measurement set-up at Site 1

The cameras can be seen in the foreground and on top of the mobile laboratory (on the left of the photograph). The microphone stand was located just to the left of the nearest camera, but is not shown

in the photograph. A view of the transducer and the irregularity in the road that gave rise to significant ground-borne vibration that could be observed above background levels is shown in Figure 2.2.



Figure 2.2: PPV transducer placed on the road surface (underneath a sandbag to ensure constant contact with the ground)

2.5.2 Site 2

This was located on the eastbound section of the A30 at Blackbushe Airport. The road surface was a surface dressing, but in better condition than that at Site 1. The layout was similar to Site 1 although the mobile laboratory was located within the grounds of the airport to protect the operators. The site provided an unobstructed view of approaching vehicles, and is shown in Figure 2.3.



Figure 2.3: View of measurement set-up at Site 2

3 Results

In this chapter the results are presented separately for Site 1 and Site 2. The analysis at Site 1 addresses noise and image data for all vehicle categories, together with vibration data collected for the heavy vehicles. Vibration levels for light vehicles were not recorded as it was found these were producing insignificant levels of vibration. The analysis of the data from Site 2 is confined to just noise and image data.

The relationship between noise and speed is well documented (Harland, 1974), with the maximum noise level of a passing vehicle being correlated to the logarithm of the vehicle's speed (in km/h). This relationship has been used in this study to determine which vehicles to classify as excessively noisy. For each vehicle class at each site, the maximum noise level has been plotted against the logarithm of vehicle speed to show the relationship. Any vehicles that were above a given level were considered to be excessively noisy. The level that has been used for each vehicle class is + one standard deviation of the noise level about the best fit regression line for the data set. This level (i.e. one standard deviation) was chosen because, for most vehicle classes, the standard deviation was close to 3 dB(A) which is the noise level considered to be a noticeable change.

Once the noisy vehicles had been identified, more specific details of each were obtained from DVLA using the registration numbers captured on the video analysis. Such data included the age of the vehicle, engine capacity and maximum gross weight. However, a match between the registration plates supplied and the DVLA data could not always be made. This was possibly due to unlicensed vehicles or errors during the interpretation of number plates during the analysis.

For the identification of those vehicles producing excessive vibration, a scatter plot of vibration level against speed was produced. A relationship between vibration and vehicle speed is less established than for noise. Therefore for the charts examining vibration levels, a horizontal line is drawn through the mean vibration level and then those vehicles that are a one standard deviation above the line are classified as producing high vibration.

3.1 Noise observations – Site 1

The survey at Site 1 was undertaken on the 23rd and 24th of May 2007. The weather conditions on both days was warm and sunny, with a very gentle breeze.

3.1.1 Light vehicles

Figure 3.1 shows the scatterplot of maximum A-weighted pass-by noise levels against the logarithm of speed together with the resulting linear regression line. The limit for defining 'noisy vehicles' is shown by the red line which is +1 standard deviation above the regression line.

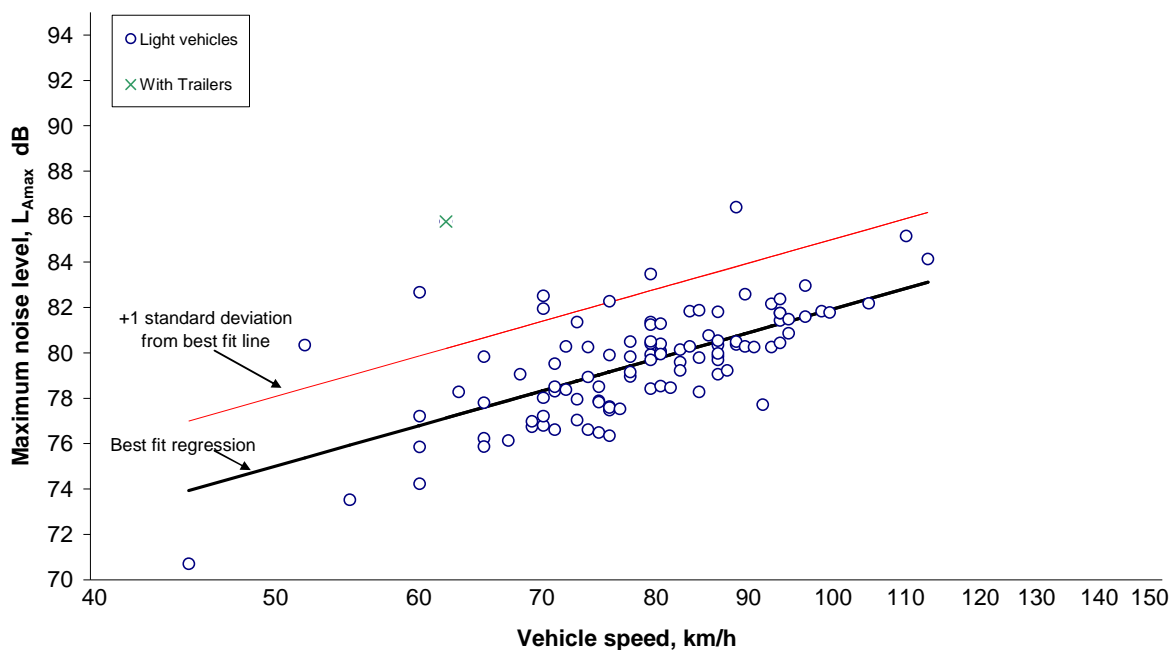


Figure 3.1: Noise levels and corresponding vehicle speeds measured for light vehicles at Site 1

It can be seen that eight vehicles were on or above the red line, including one vehicle (shown as a cross) that was towing a trailer.

Table 3.1 shows the descriptions of these eight vehicles, including their vehicle speed and maximum noise level. This also summarises the possible sources which resulted in the maximum noise level. For this category, a noisy vehicle was considered to be one where the maximum noise level was 3.1 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured was 86.4 dB(A), which was 5.6 dB(A) above the average for a vehicle of the same speed. This vehicle, a 3-litre estate car, was also the fastest of the vehicles selected.

Table 3.1: Description of “noisy” light vehicles at Site 1

Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Estate car (3 litre)	<1 yr	89	Aerodynamic noise, tyres	86.4
Pick up car with trailer laden with unsecured wood (3 litre)	<1 yr	62	Trailer load	85.8
Unknown saloon car	-	80	Exhaust	83.5
Sports hatchback (3 litre)	4 yr	60	Exhaust	82.7
Hatchback, 5 door (1.6 litre)	9 yr	70	Exhaust	82.5
Unknown classic car	-	76	Exhaust	82.3
Unknown 4x4	-	70	Exhaust	81.9
Convertible sports car (2.2 litre)	10 yr	52	Unknown	80.3

Figure 3.2 shows the one-third octave band frequency spectra captured at the maximum A-weighted level for each of the eight vehicles. For comparison, each graph also includes the *average level* in each one-third octave band across all sampled light vehicles. Generally the peak in noise level for traffic noise is around 1,000 Hz (or 1 kHz), which is essentially associated with tyre noise. Lower frequencies tend to be associated with exhaust noise and higher frequencies tend to be associated with such instances as a whine from a roof rack.

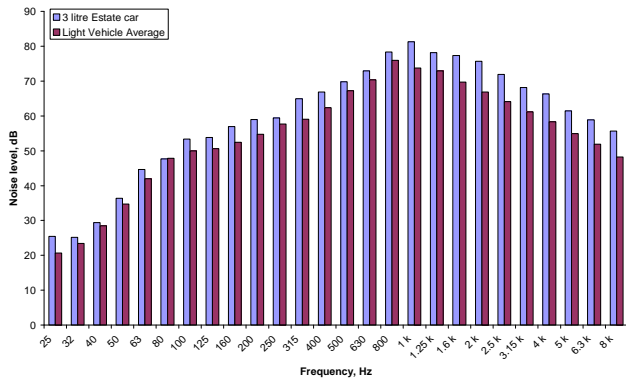
The spectrum for the large estate car shown in Figure 3.2(a) indicates no particular dominant frequency, just a general overall rise in each frequency band compared with the average. It is considered that this could be a result of tyre type, engine noise or aerodynamic noise from open windows.

Figure 3.2(b) shows the frequency spectrum from a pick-up towing a trailer part laden with wood. It can be seen that there is excessive noise at the frequencies 1.6 kHz and above. This broad (i.e. not dominant at one frequency) increase in noise level is consistent what would be expected from the rattle of a trailer.

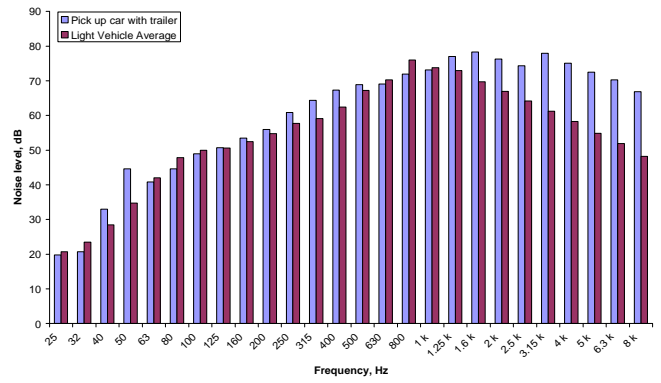
In Figure 3.2 (c-g) it can be seen that the frequency spectrum for each vehicle is dominated by low frequency noise associated with exhaust noise. The harmonics associated with exhaust noise are particularly obvious in Figure 3.2(c), where peaks at 100 Hz and then 200 Hz can clearly be seen.

The frequency spectrum for the convertible sports car, shown in Figure 3.2(h), does not show any obvious peaks at any frequency. However, with the vehicle travelling at a relatively low speed, it is producing a noise level that would normally be associated with a vehicle travelling faster, and is therefore shown as a ‘noisy vehicle’. It is not obvious from the spectrum what could have caused this excessive noise.

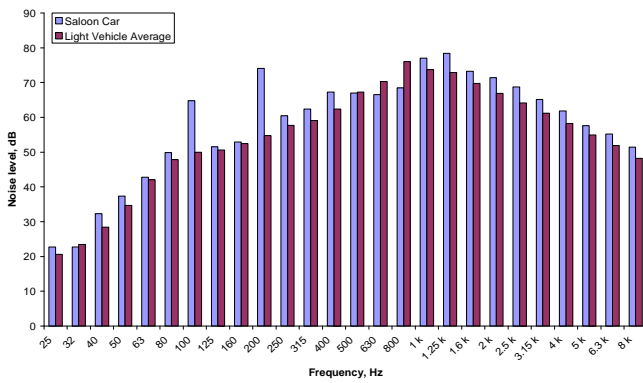
(a) Estate car (3 litre)



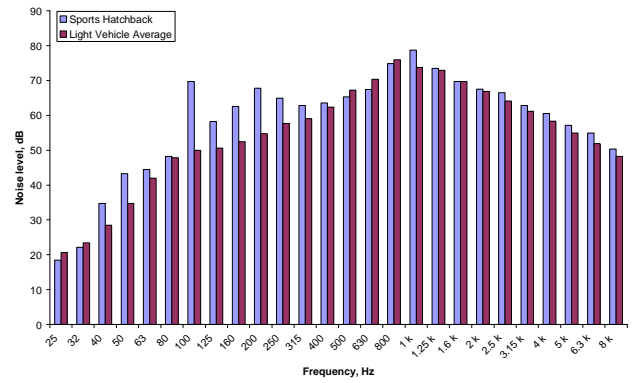
(b) Pick up car with trailer (3 litre)



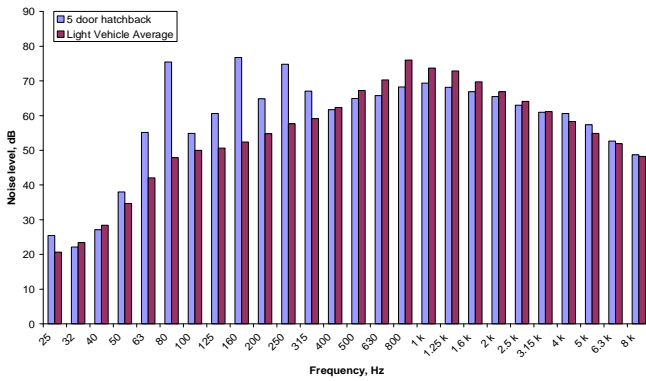
(c) Unknown Saloon car



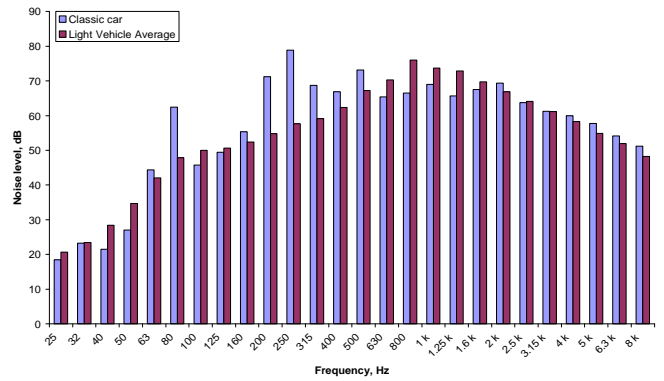
(d) Sports hatchback (3 litre)



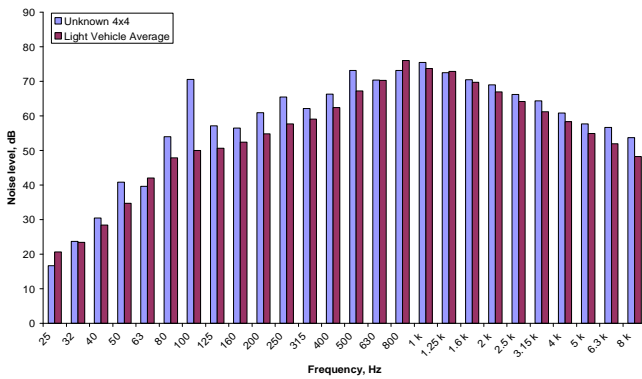
(e) Hatchback, 5 door (1.6 litre)



(f) Unknown classic car



(g) Unknown 4x4



(h) Convertible sports car (2.2 litre)

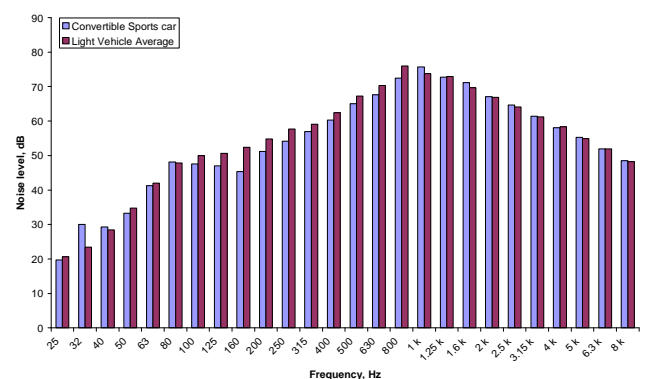


Figure 3.2: A-weighted one-third octave band spectra for “noisy” light vehicles at Site 1

3.1.2 Vans

Figure 3.3 shows the scatterplot of maximum A-weighted pass-by noise levels against the logarithm of speed together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. It can be seen that five vehicles lie either on or above the limit line; four of these vehicles were towing a trailer.

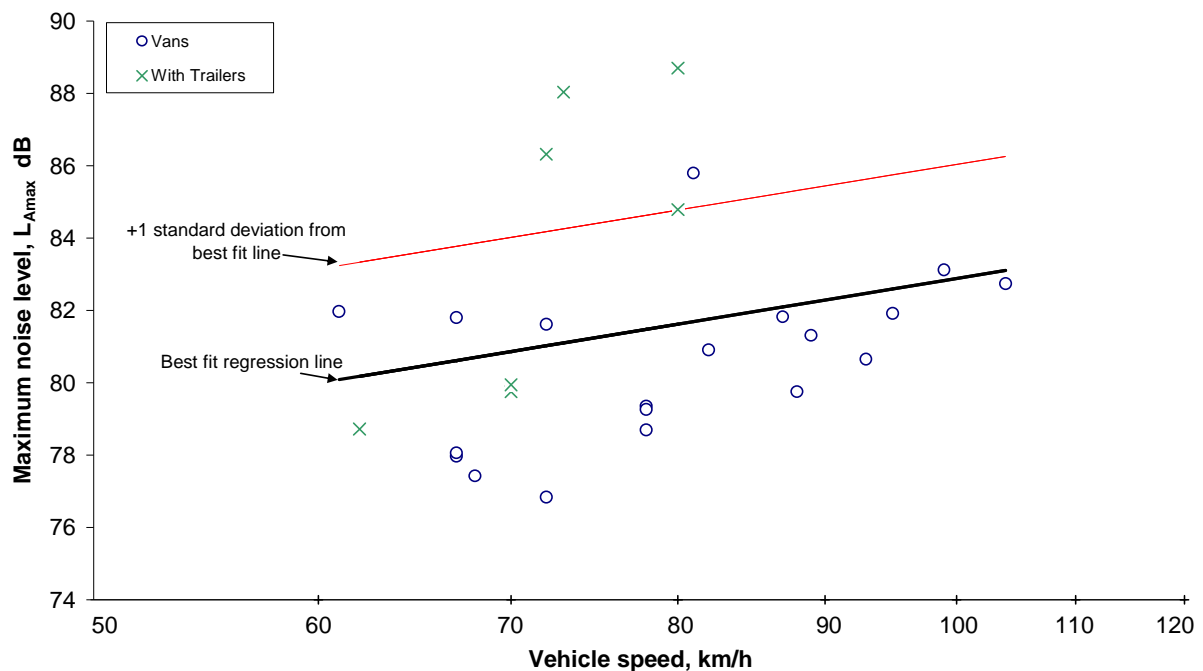


Figure 3.3: Noise levels and corresponding vehicle speeds measured for vans at Site 1

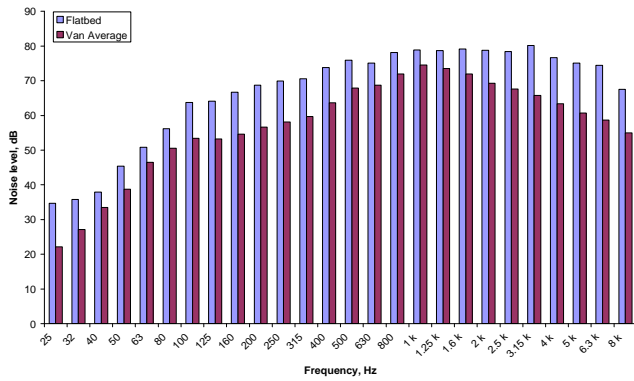
Table 3.2 gives the descriptions of these relatively “noisy” vehicles. This also summarises the possible sources which resulted in the maximum noise level. For this category, a noisy vehicle was considered to be one where the maximum noise level was 3.1 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured was 88.7 dB(A), which was 7.1 dB(A) above the average for a vehicle travelling at the same speed.

Table 3.2: Description of “noisy” vans at Site 1

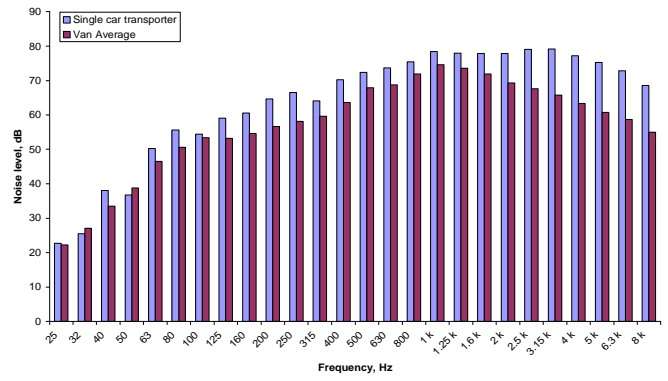
Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Flatbed van with laden trailer (2.4 litre) NB. The contents were unsecured	7 yr	80	Trailer, unsecured tools	88.7
Single car transporter with trailer (2.5 litre)	6 yr	73	Trailer, body rattle	88.0
4x4 with unladen 2 axle trailer	-	72	Trailer	86.3
Box style removal van	-	81	Exhaust	85.8
Transit tipper van with laden trailer (2.4 litre)	3 yr	80	Trailer	84.8

The following are the third octave spectra captured at the maximum A-weighted level. For comparison, each graph also includes the average levels across all sampled vans.

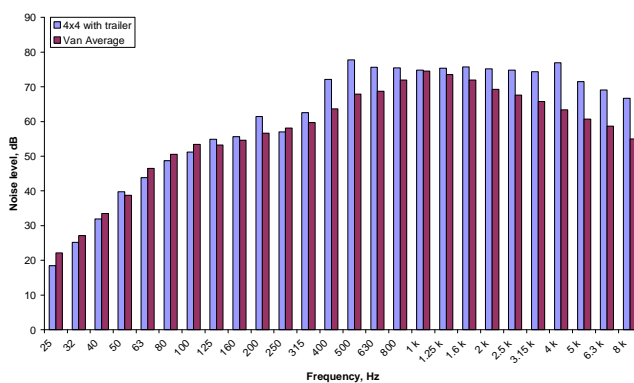
(a) Flatbed with laden trailer (2.4 litre)



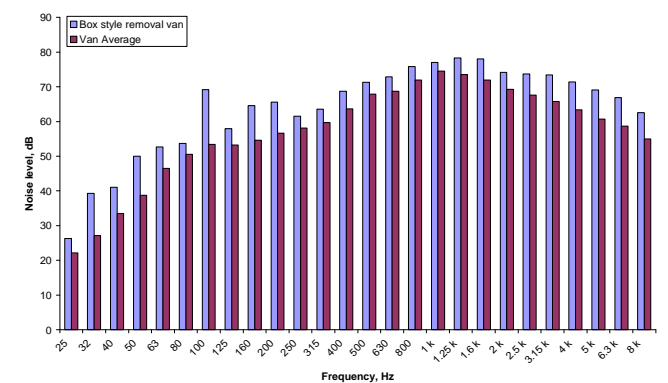
(b) Single car transporter with trailer (2.5 litre)



(c) 4x4 with unladen trailer



(d) Box style removal van



(e) Transit tipper van with laden trailer (2.4 litre)

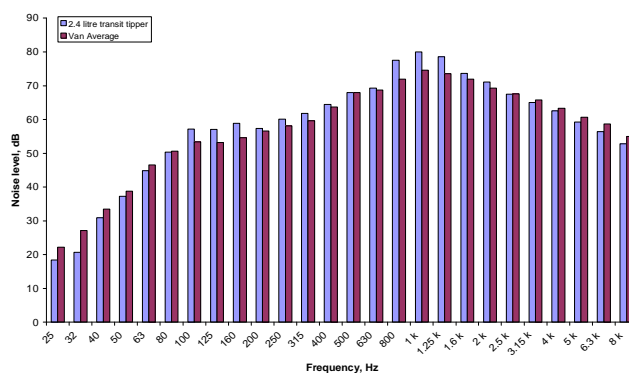


Figure 3.4: A-weighted one-third octave band spectra for “noisy” vans at Site 1

Figure 3.4(a) shows that the flatbed van towing a laden trailer produced higher than average noise levels over all the whole frequency range, with the noise levels in each one-third octave band being 5-10 dB(A) higher. With no dominant frequency, it is considered that the excessive noise is likely to be produced by the trailer and its unsecured contents.

It can be seen in Figure 3.4(b) that the noise produced by the small car transporter towing a trailer increases across most frequencies. The largest increases are at the higher frequencies, and are probably due to body rattle noise from the unladen trailer.

For the 4x4 towing an unladen trailer (Figure 3.4c) there is a general increase in noise level for all frequencies above 400 Hz. This is considered likely to be caused by noise from the unladen trailer.

Figure 3.4(d) shows that the removal vehicle produced high levels of exhaust noise (at 100 Hz) as well as being generally noisy over all the other frequencies.

In Figure 3.4(e), where a transit van was towing a laden trailer, there were only slightly higher noise levels between 800 Hz and 1.25 kHz.

3.1.3 Medium heavy vehicles

Figure 3.5 shows the scatterplot of maximum A-weighted pass-by noise levels for medium heavy vehicles against the logarithm of speed together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. From the chart it can be seen that 12 vehicles produced excessive noise levels.

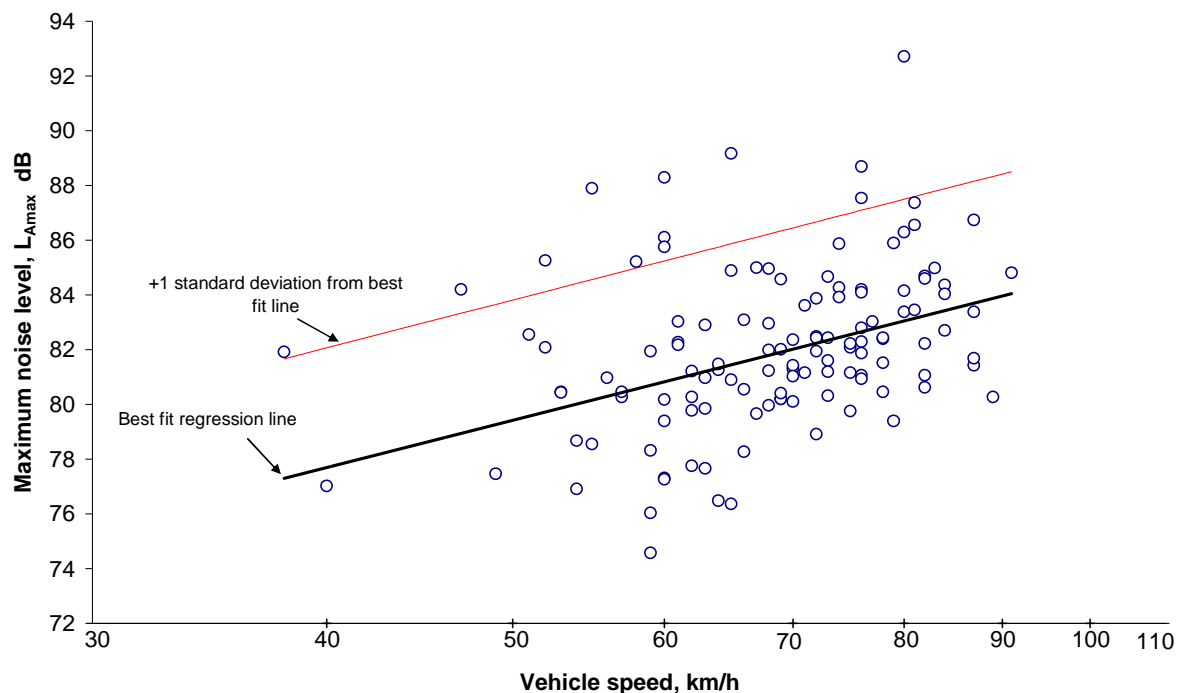


Figure 3.5: Noise levels and corresponding vehicle speeds measured for medium heavy vehicles at Site 1

Table 3.3 gives the descriptions of these “relatively noisy” vehicles. This also summarises the possible sources which resulted in the maximum noise level. For this category, a noisy vehicle was considered to be one where the maximum noise level was 4.4 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured, which was from an 18 year old car transporter, was 92.3 dB(A). This was 9.6 dB(A) above the average for a vehicle travelling at the same speed.

Table 3.3: Descriptions of “noisy” medium heavy vehicles at Site 1

Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Single car transporter (2.4 litre), unladen	4 yr	76	Body rattle	88.7
Box van	7 yr	65	Curtain ties flapping	89.2
Single car transporter (2 litre), laden	18 yr	80	Body rattle, age	92.3
Flatbed lorry (3 litre), unladen	8 yr	60	Metal fence at rear of cab	88.3
Goods vehicle (6.2 litre), unladen	13 yr	55	Custom body	87.9
Skip lorry (6.4 litre), laden	3 yr	76	Chain and body rattle	87.5
Dropside lorry, unladen with attachments	4 yr	60	Exhaust/body rattle	85.8
Refuse disposal truck	10 yr	60	Rattles from wheelie bins locked in position at rear of vehicle	86.1
Drop-side lorry (6.4 litre), laden with unsecured buildings materials	2 yr	58	Cargo rattles	85.2
Breakdown truck (4.1 litre), unladen	4 yr	52	Body rattle, exhaust	85.3
Skip lorry (6.4 litre), unladen	4 yr	47	Chain rattle/exhaust	84.2
Unknown tractor unit with unladen trailer	-	38	Exhaust/engine	81.9

The third octave band spectra of these vehicles are given in Figure 3.6. The single car transporter shown in Figure 3.6(a) is excessively noisy across the medium to higher frequencies of the spectrum. This is likely to be caused by body rattle from the unladen deck of the vehicle, including the access ramp.

A flapping canvas on the box van is considered to probably be responsible for the elevated levels of the higher frequencies shown in Figure 3.6(b).

General broadband body rattle can also be identified for the single car transporter (Figure 3.6c), the flatbed lorry (Figure 3.6d), the skip lorry (Figure 3.6f), the drop-sided lorries (Figure 3.6g and Figure 3.6i) and the breakdown truck (Figure 3.6j).

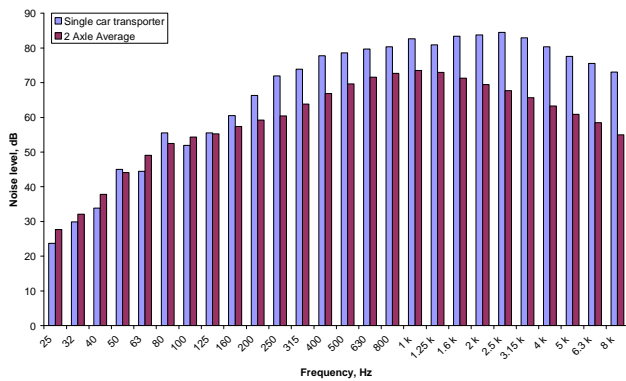
The drop-sided lorry (Figure 3.6(g)) and breakdown truck (Figure 3.6(j)) are also observed to produce excessive noise at 40 Hz and 50 Hz respectively, most likely corresponding to exhaust noise.

Two peaks are clearly above the average noise level for the flatbed goods vehicle shown in Figure 3.6(e). This particular vehicle had a non standard flat bed deck that was particularly raised. The peak at 63 Hz is likely to be due to excessive exhaust noise and that at 630 Hz may be caused by something relating to the modified vehicle.

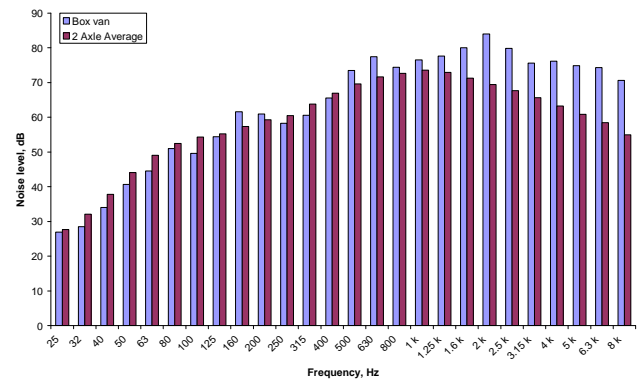
The refuse disposal lorry displayed in Figure 3.6(h) shows large peaks in noise level at 315 and 400 Hz. These peaks may have been caused by wheelie bins that were locked into place at the rear of the vehicle.

For the skip lorry shown in Figure 3.6(k), the peak in noise level at 100 Hz is likely to be caused by exhaust noise. For the tractor unit with an unladen trailer shown in Figure 3.6(l) the increase in level over most of the lower frequencies is probably caused by a combination of exhaust and engine noise as the vehicle was travelling at a low speed and appeared to be in a low gear.

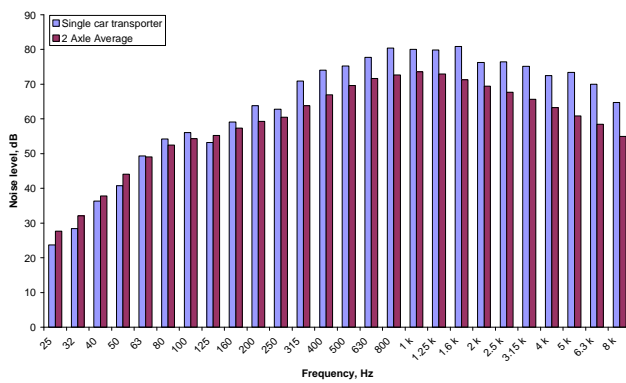
(a) Single car transporter (2.4 litre), unladen



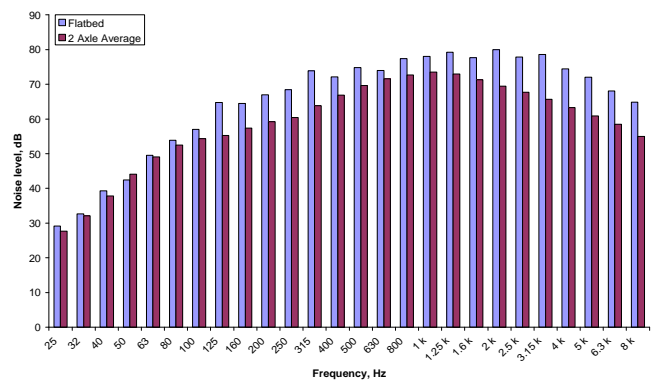
(b) Box van



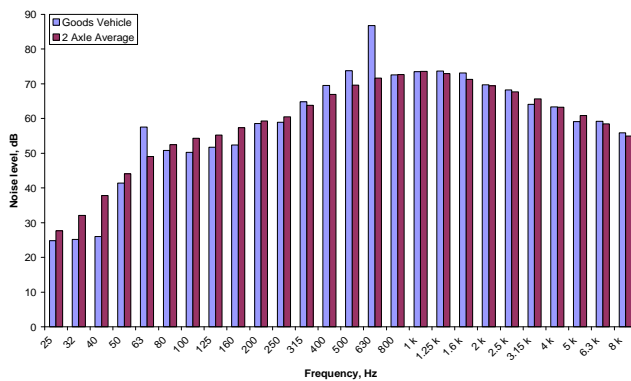
(c) Single car transporter (2 litre), laden



(d) Flatbed lorry (3 litre), unladen



(e) Goods vehicle (6.2 litre), unladen



(f) Skip lorry (6.4 litre), laden

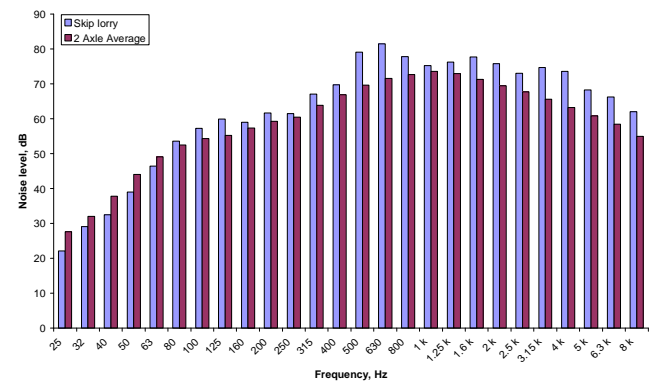
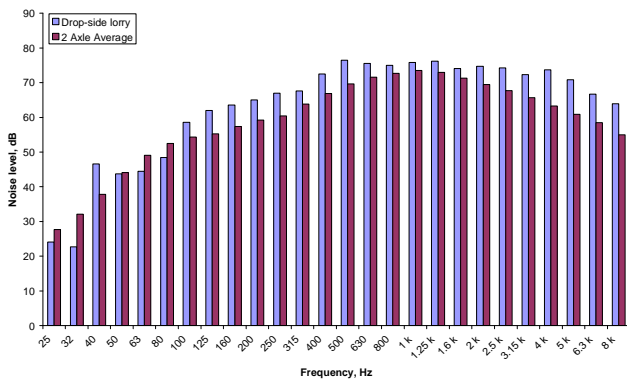
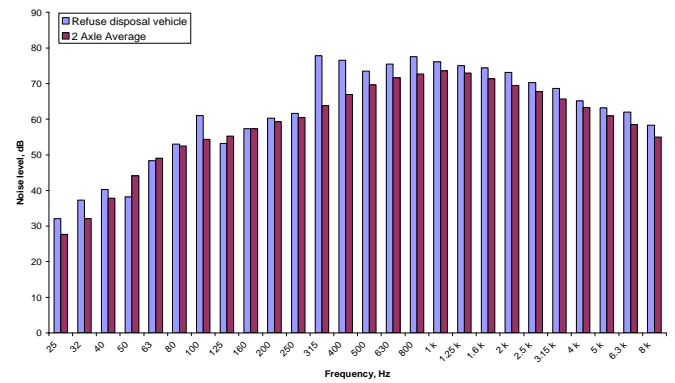


Figure 3.6: A-weighted one-third octave band spectra for “noisy” medium heavy vehicles at Site 1

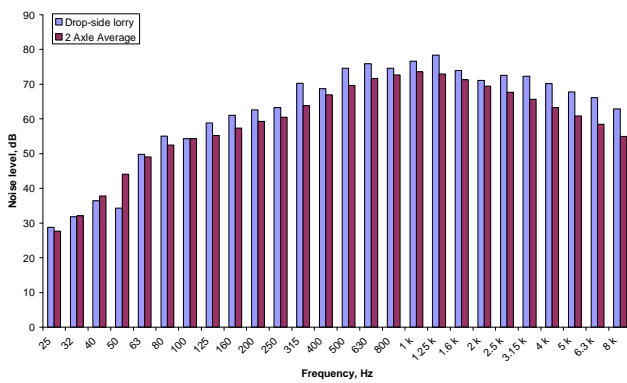
(g) Drop-side lorry with attached device



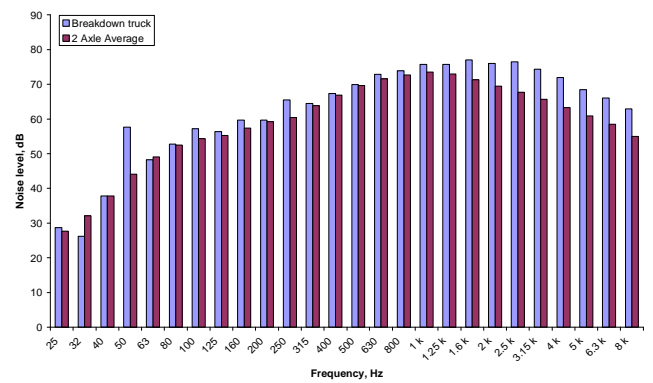
(h) Refuse disposal truck



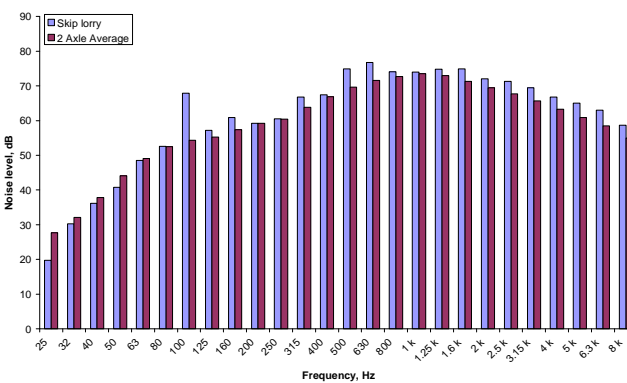
(i) Drop-side lorry (6.4 litre), laden



(j) Breakdown truck (4.1 litre), unladen



(k) Skip lorry (6.4 litre), unladen



(l) Unknown tractor unit with unladen trailer

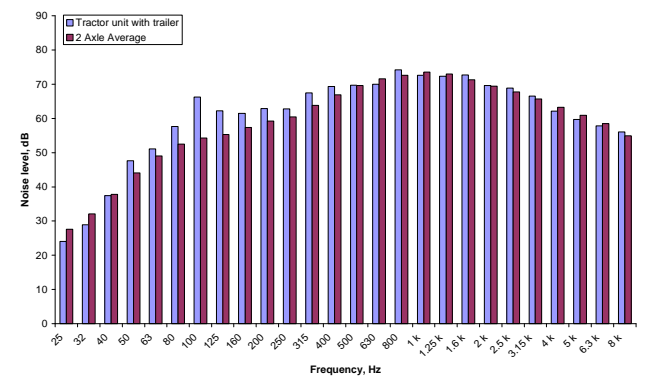


Figure 3.6: A-weighted one-third octave band spectra for “noisy” medium heavy vehicles at Site 1 (continued...)

3.1.4 Heavy vehicles

Figure 3.7 shows the scatterplot of maximum A-weighted pass-by noise levels for the heavy vehicles against the logarithm of speed, together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. It can be seen that there are three vehicles above the red line.

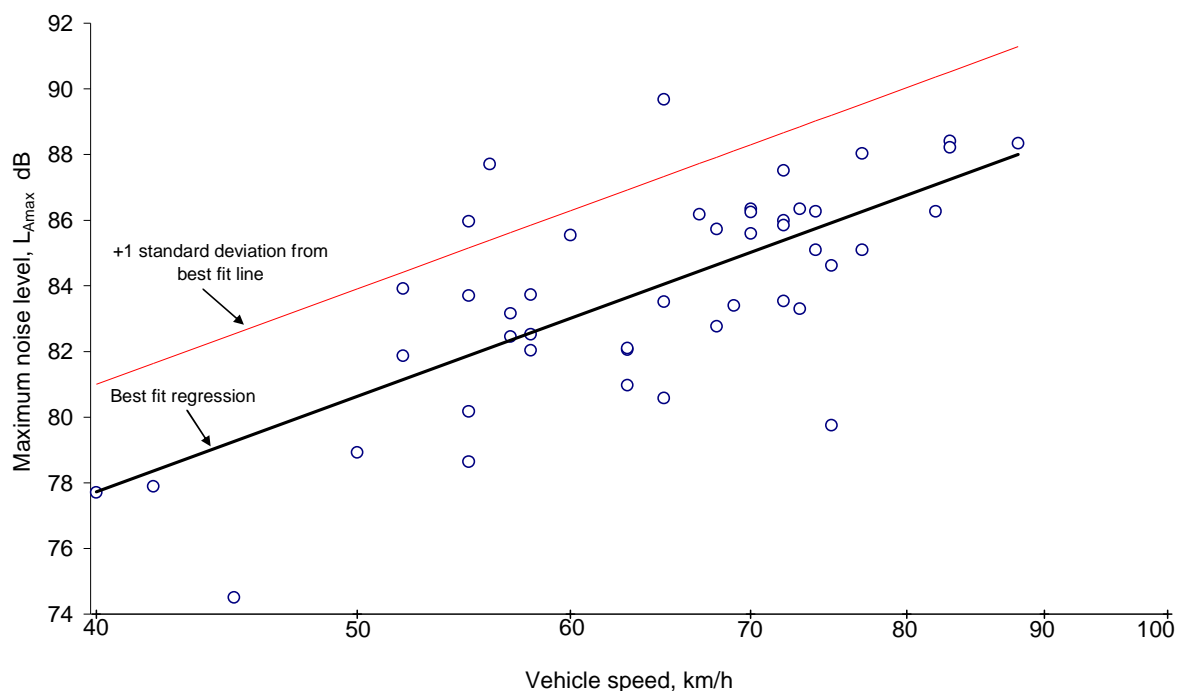


Figure 3.7: Noise levels and corresponding vehicle speeds measured for heavy vehicles at Site 1

Table 3.4 lists the characteristics of these vehicles. Two of the three vehicles classified as noisy were car transporters. For this category, a noisy vehicle was considered to be one where the maximum noise level was 3.3 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured, which was from a 5 axle open-top container, was 89.7 dB(A). This was 5.6 dB(A) above the average for a vehicle travelling at the same speed.

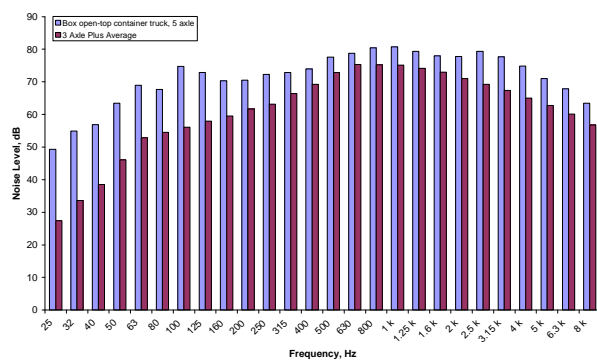
Table 3.4: Description of “noisy” heavy vehicles at Site 1

Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Open-top container (5 axle), unladen	7 yr	65	Body rattle, exhaust, engine	89.7
Car transporter (5 axle, 12.2 litre), unladen	2 yr	55	Slack metal safety fencing on sides of transporter decks, aerodynamic noise	86.0
Car transporter (5 axle, 12.2 litre), laden	2 yr	56	Bottom rack at rear is empty (one missing car) producing body rattle	87.7

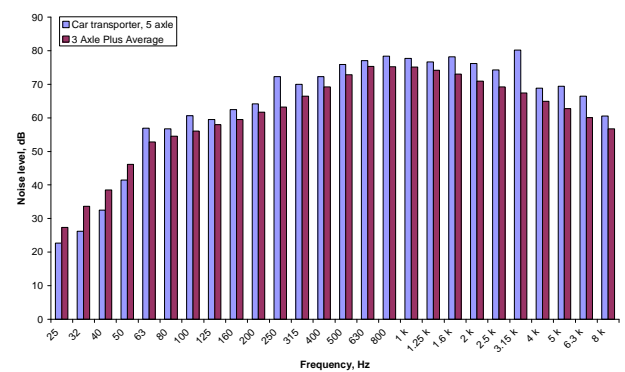
The third octave band spectra of these vehicles are given in Figure 3.8. It can be seen in Figure 3.8(a) that the open-top container truck with 5 axles is noisy at low, mid and high frequencies. This is probably due to engine and exhaust noise while at high frequencies body rattle is considered to be the most likely noise source.

The other two vehicles (Figure 3.8(b) and Figure 3.8(c)) are car transporters, one laden and one unladen. Loose chains, safety fences around load beds and ramps are all likely to be sources of body rattle on these vehicles. The high peak at 3.15 kHz in Figure 3.6(b) is likely to be caused by aerodynamic noise.

(a) Open-top container truck (5 axle, unladen)



(b) Car transporter (5 axle, 12.2 litre), unladen



(c) Car transporter (5 axle, 12.2 litre), laden

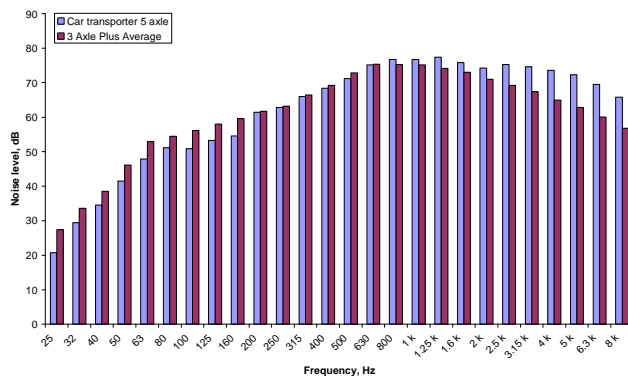


Figure 3.8: A-weighted one-third octave band spectra for “noisy” heavy vehicles at Site 1

3.2 Noise observations – Site 2

The survey at Site 2 was undertaken on the 31st May and 1st June 2007. On the 31st May the weather was slightly breezy and dull. Measurements were suspended due to a brief period of rain during the day, but were started again when the surface was dry. The weather conditions on the 1st June were dull with a light breeze.

3.2.1 Light vehicles

Figure 3.9 shows the scatterplot of maximum A-weighted pass-by noise levels against the logarithm of speed, together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. It can be seen that eight vehicles gave a noise level that is on or above the red line.

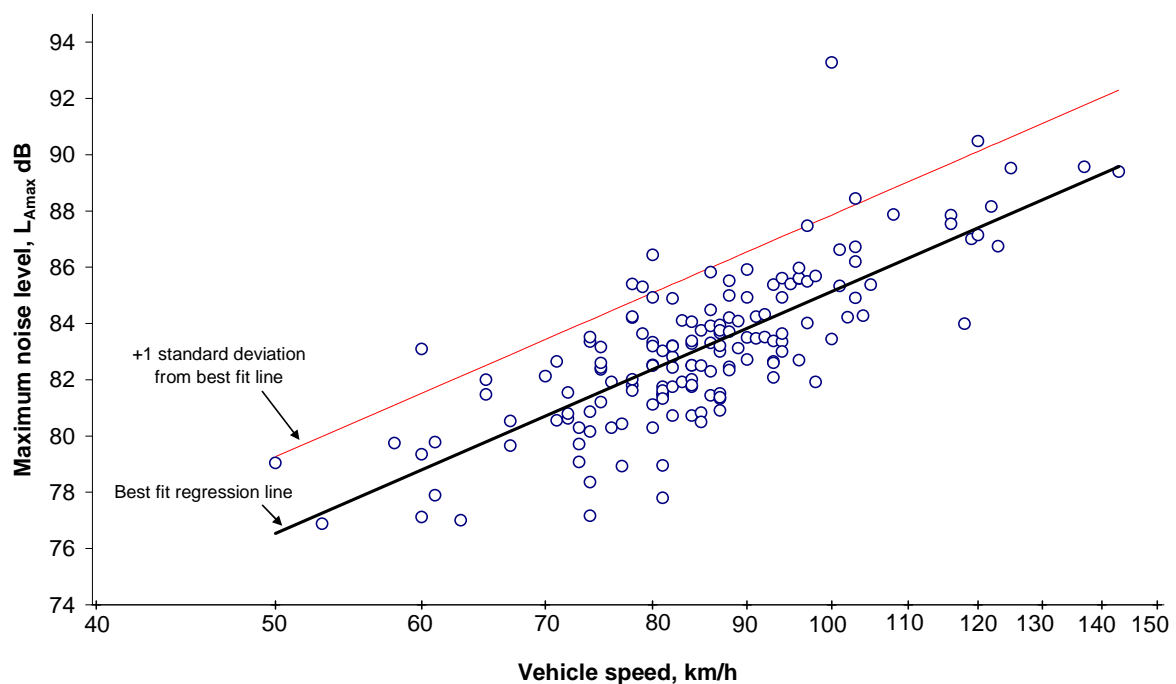


Figure 3.9: Noise levels and corresponding vehicle speeds measured for light vehicles at Site 2

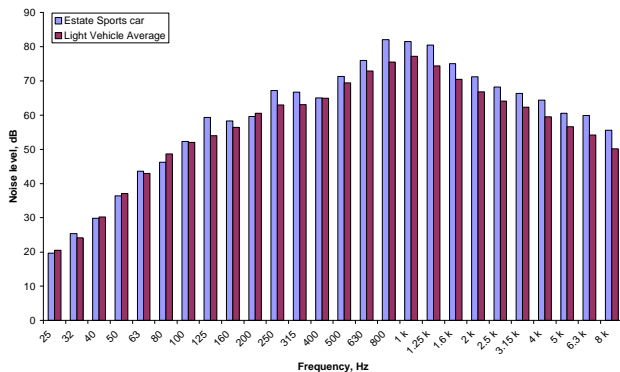
Table 3.5 gives the descriptions of these eight vehicles, including the vehicle speed and maximum noise level. For this category, a noisy vehicle was considered to be one where the maximum noise level was 2.7 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured, which was from a 2.6 litre coupe, was 93.3 dB(A). This was 8.2 dB(A) above the average for a vehicle travelling at the same speed.

Table 3.5: Description of “noisy” light vehicles at Site 2

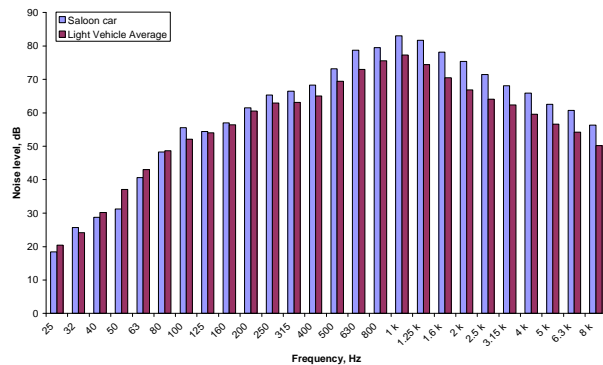
Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Estate Sports car (3 litre)	<1 yr	97	Aerodynamic noise, tyres	87.5
Saloon car, four door (2 litre)	3 yr	103	Aerodynamic noise, tyres	88.4
Saloon car, four door (2 litre, automatic transmission)	3 yr	120	Aerodynamic noise, tyres, speed	90.5
Saloon car, two door (2 litre)	13 yr	80	Exhaust	86.4
Coupe (2.6 litre)	3 yr	100	Aerodynamic noise, tyres, gear selection	93.3
Coupe (2 litre)	7 yr	78	Exhaust	85.4
Sports car (5 litre)	12 yr	79	Exhaust	85.3
Hatchback (1.4 litre)	6 yr	60	Exhaust	83.1

The third octave band spectra for these eight vehicles are given in Figure 3.10.

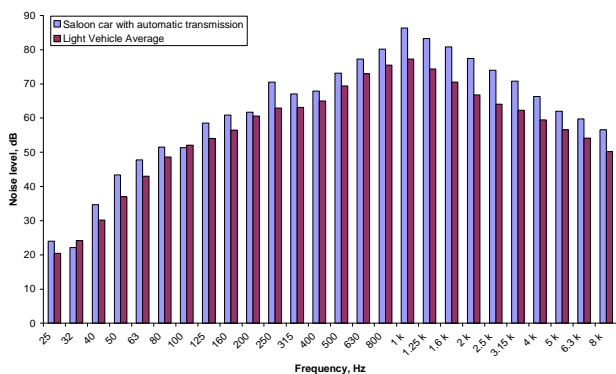
(a) Estate Sports car (3 litre)



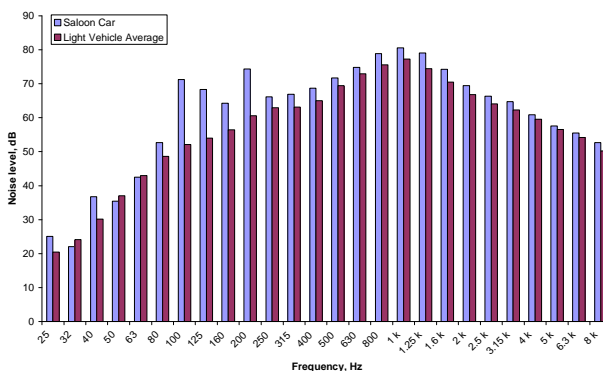
(b) Saloon car (2 litre)



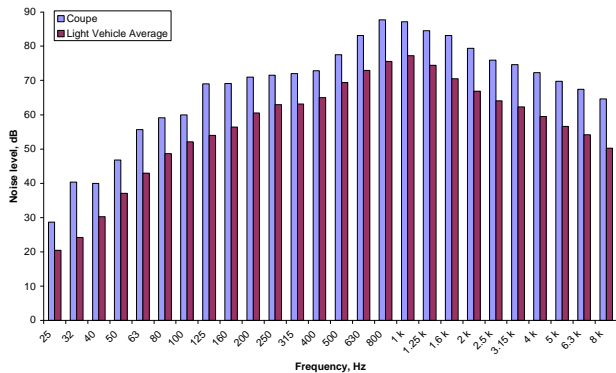
(c) Saloon car (2 litre, automatic transmission)



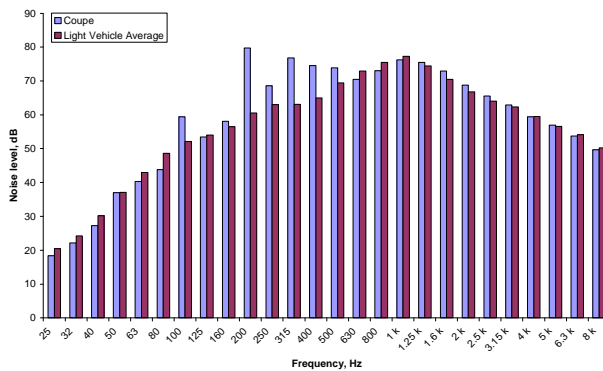
(d) Saloon car, two door (2 litre)



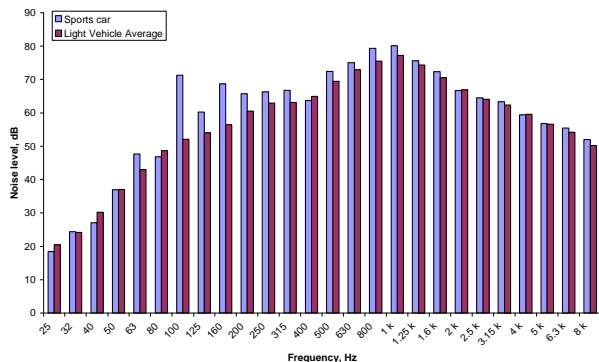
(e) Coupe (2.6 litre)



(f) Coupe (2 litre)



(g) Sports car (5 litre)



(h) Hatchback (1.4 litre)

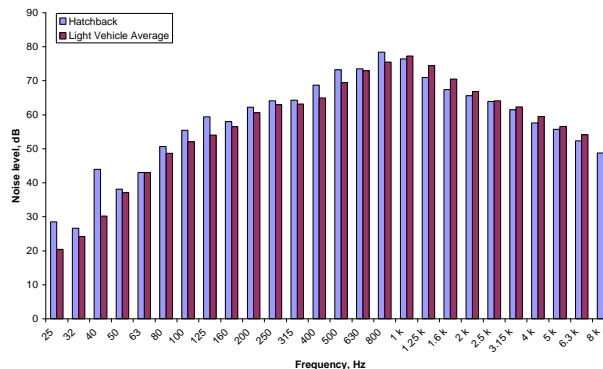


Figure 3.10: A-weighted one-third octave band spectra for “noisy” light vehicles at Site 2

For the vehicles shown in Figure 3.10(a), Figure 3.10(b) and Figure 3.10(c) there is a slight increase in noise level over all frequency bands. A similar spectra is shown in Figure 3.10(e), but for this vehicle there is large increase over all frequencies. This vehicle, a 2.6 litre coupe, produced by far the highest noise level of all selected light vehicles.

The remaining spectra presented in Figure 3.10(d), Figure 3.10(f), Figure 3.10 (g) and Figure 3.10 (h) show peaks over the lower frequencies, indicating engine and exhaust noise. For vehicles 'd', 'f' and 'g', that were all travelling at similar speeds, there are clear harmonics associated with exhaust noise at 100 and 200 Hz. Vehicle 'h' was travelling at a lower speed than the other three vehicles and therefore has a peak in the spectra at 40 Hz.

During the data collection at Site 1, observations were made with regard to the noise levels of very large light vehicles (including 4x4's; see Section 3.1.1). It was found that these vehicles were not often subjectively judged to be excessively noisy but often produced noise levels that were higher than average.

Therefore, for the survey at Site 2, vehicles in this (subjective) category were specifically sampled along with other light vehicles. Analysis of the data showed that of the 12 large vehicles sampled at Site 2, 10 vehicles produced noise levels which were above the average level defined by the linear regression line and two were just below the line; none of these vehicle were observed to be excessively noisy (all the levels were below the limit defined by the +1 standard deviation above the linear regression line). By sampling this particular type of large light vehicle, it gave some explanation as to why some light vehicles (for example vehicles 'a', 'b', and 'c' above) which were subjectively identified as 'noisy' during the on-site observations but analysis of the spectrum showed they did not have any noticeable excessive noise sources (i.e. the noise levels are marginally higher than average across the full one-third octave band spectrum). Such noise sources may be tyre size and vehicle dimensions and shape.

3.2.2 Vans

Figure 3.11 shows the scatterplot of maximum A-weighted pass-by noise levels against the logarithm of speed, together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. It can be seen that one vehicle gave a noise level that is above the red line.

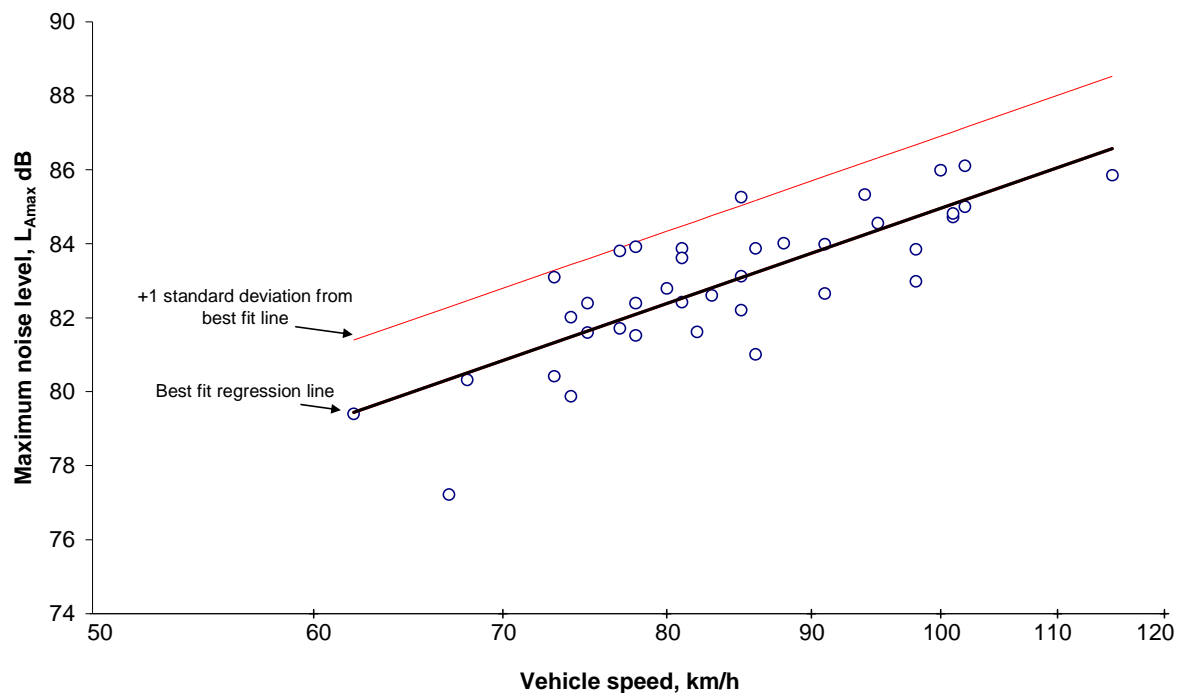


Figure 3.11: Noise levels and corresponding vehicle speeds measured for vans at Site 2

Table 3.6 gives the description of the one van that was above the one standard deviation threshold, including the vehicle speed and maximum noise level. For this category, a noisy vehicle was considered to be one where the maximum noise level was 2.0 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured was 85.3 dB(A), which was 2.6 dB(A) above the average for a vehicle travelling at the same speed.

Table 3.6: Description of “noisy” vans at Site 2

Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Transit van (2.5 litre)	9 yr	85	Exhaust	85.3

The third octave band spectra for this vehicle is shown in Figure 3.12 where it is compared with the average spectra obtained for all vans at this site. It can be seen that the van produced higher than average noise levels at all the lower frequencies, especially at 63 Hz, which would indicate excessive engine and exhaust noise.

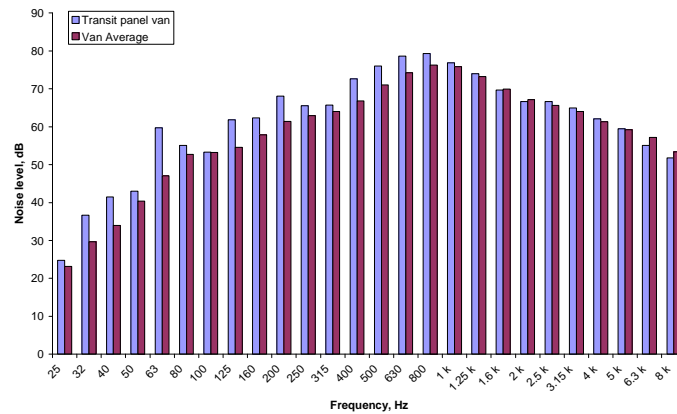


Figure 3.12: A-weighted one-third octave band spectra for the “noisy” van at Site 2

3.2.3 Medium heavy vehicles

Figure 3.13 shows the scatterplot of maximum A-weighted pass-by noise levels against the logarithm of speed, together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. It can be seen that three vehicles were above the red line. Of these three vehicles, the same double-decker bus was sampled twice due to it passing the measurement position on two occasions.

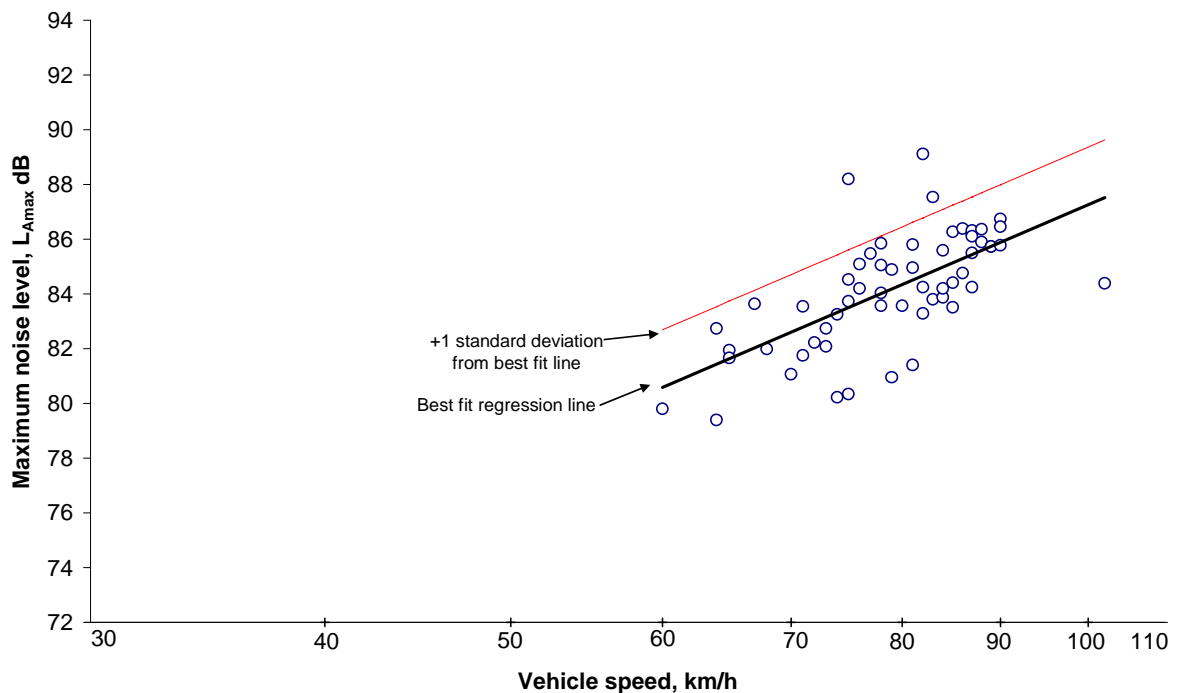


Figure 3.13: Noise levels and corresponding vehicle speeds measured for medium heavy vehicles at Site 2

Table 3.7 gives the descriptions of these three vehicles, including the vehicle speed and maximum noise level. For this category, a noisy vehicle was considered to be one where the maximum noise level was 2.1 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured, which was from a double decker bus, was 89.1 dB(A). This was 4.4 dB(A) above the average for a vehicle travelling at the same speed.

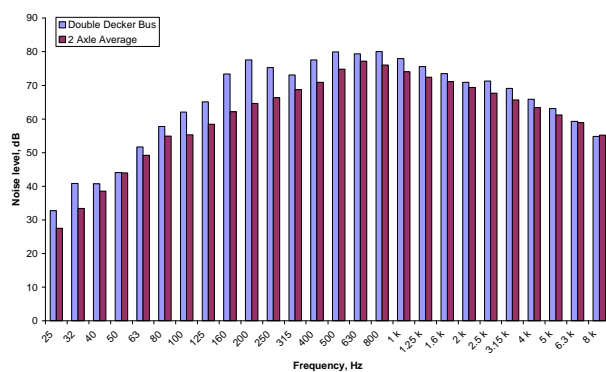
Table 3.7: Description of “noisy” medium heavy vehicles at Site 2

Description	Age	Speed (km/h)	Possible source of noise	Noise level L_{Amax} dB
Double Decker Bus	12 yr	75	Engine & aerodynamic noise	88.2
		82		89.1
Skip lorry (12 litre), laden	4 yr	83	Engine noise	87.5

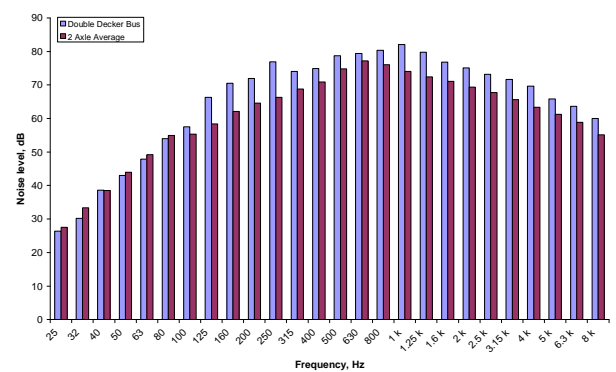
The third octave band spectra for these vehicles are given in Figure 3.14. For the double decker bus travelling at 75 km/h there is an increase in the noise level at the lower frequencies, especially in the range 100 to 200 Hz, most likely to be due to engine noise. The same double-decker bus travelling at 82 km/h also showed high noise levels in this range, again due to engine noise. However, on this pass-by the bus also had higher than average noise levels for the higher frequencies. This could possibly be caused by aerodynamic noise from the shape of the bus.

It is likely that engine or exhaust noise is responsible for the peak at 100 Hz for the skip lorry shown in Figure 3.14(c).

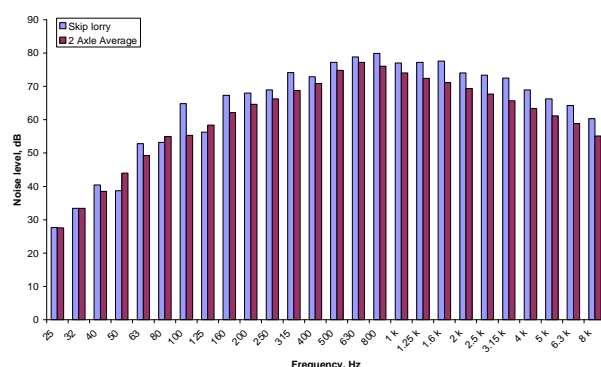
(a) Double Decker Bus (75 km/h)



(b) Double Decker Bus (82 km/h)



(c) Skip lorry (12 litre), laden

**Figure 3.14: A-weighted one-third octave band spectra for “noisy” medium heavy vehicles at Site 2**

3.2.4 Heavy vehicles

Figure 3.15 shows the scatterplot of maximum A-weighted pass-by noise levels against the logarithm of speed, together with the regression line and the line at one standard deviation above the regression line denoting the limit for “noisy vehicles”. It can be seen that three vehicles were above the red line, and that two vehicles that were very close to the line.

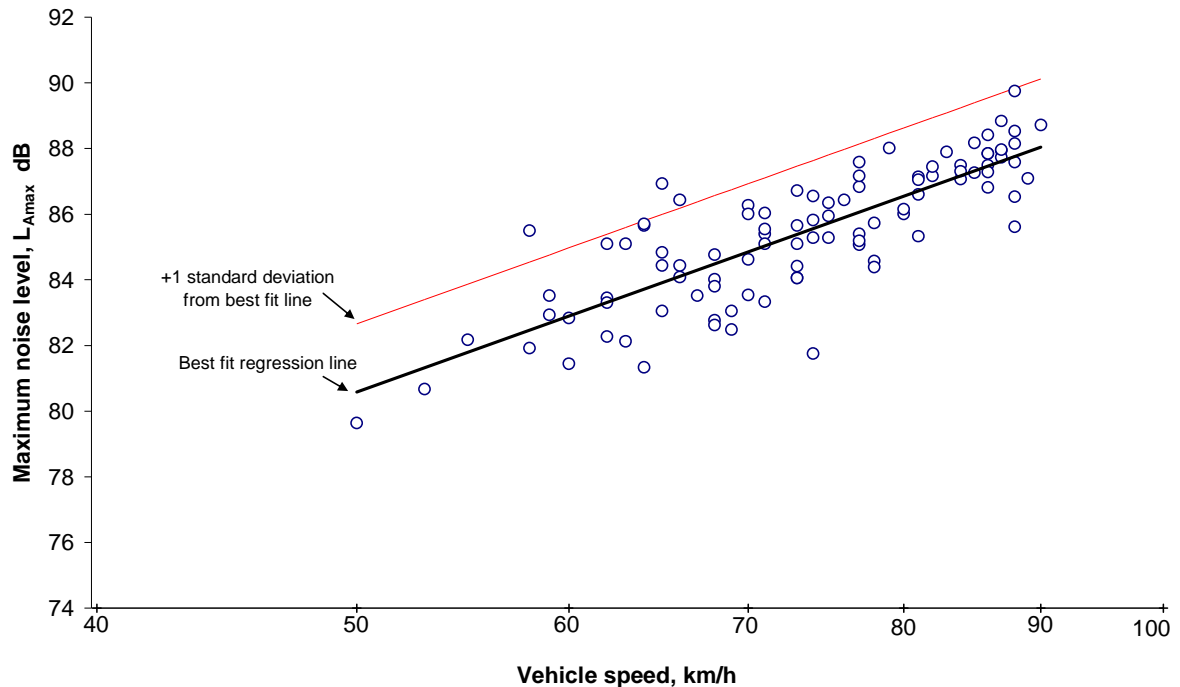


Figure 3.15: Noise levels and corresponding vehicle speeds measured for heavy vehicles at Site 2

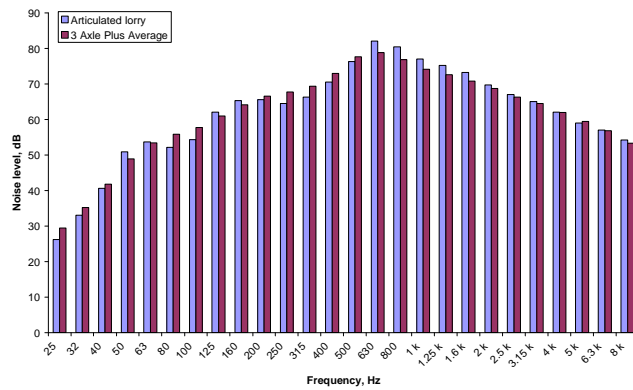
Table 3.8 gives the descriptions and details of the five vehicles selected. For this category, a noisy vehicle was considered to be one where the maximum noise level was 2.1 dB(A) above the average for a vehicle travelling at a similar speed. The highest level measured was 89.8 dB(A) produced by the 5 axle tipper truck, which was 2.1 dB(A) above the average for a vehicle travelling at the same speed. However, the vehicle which is furthest from the plus one standard deviation line was measured at 86.7 dB(A) and was 2.8 dB(A) above the best fit line for a vehicle travelling at the same speed.

Table 3.8: Description of “noisy” heavy vehicles at Site 2

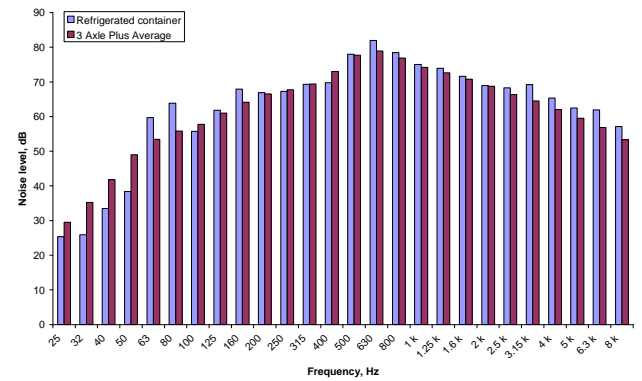
Description	Age	Speed (km/h)	Possible source of noise	Noise level L _{Amax} dB
Articulated container lorry (5 axle, 10.8 litre)	<1 yr	65	Exhaust	86.7
Refrigerated container (6 axle, 12.7 litre)	<1 yr	66	Exhaust / gear change	86.4
Tipper truck (5 axle, 11.7 litre)	4 yr	88	Loose covers, exhaust	89.8
Tipper truck (4 axle, 12.1 litre)	5 yr	58	Exhaust	85.5
Skip lorry (4 axle)	5 yr	64	Exhaust	85.7

The third octave band spectra for all these vehicles are given in Figure 3.16. In all cases there are not any significant increased levels above 630 Hz; however slight increases above this frequency were due to flapping covers as shown in Figure 3.16(c). In cases (b), (c), (d) and (e) significant increases in noise level are observed at lower frequencies indicating high levels of exhaust or engine noise. In one case (skip lorry (e)) there is a strong tonal component at 250 Hz.

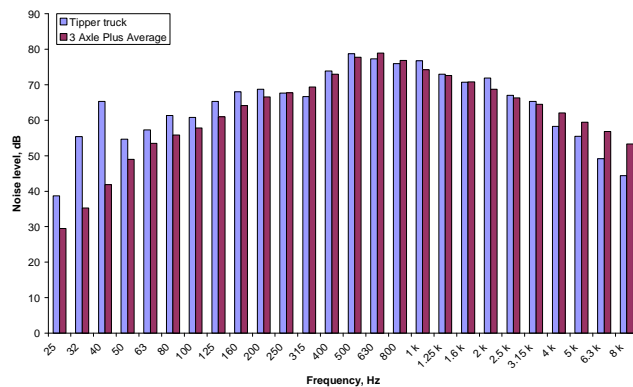
(a) Articulated lorry (5 axle, 10.8 litre)



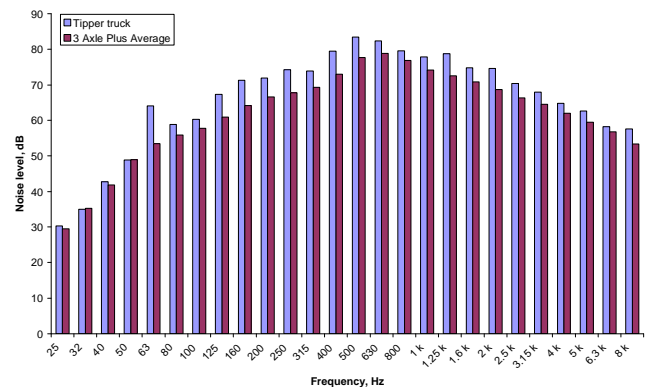
(b) Refrigerated container (6 axle, 12.7 litre)



(c) Tipper Truck (5 axle, 11.7 litre)



(d) Tipper Truck (4 axle, 12.1 litre)



(e) Skip lorry (4 axle)

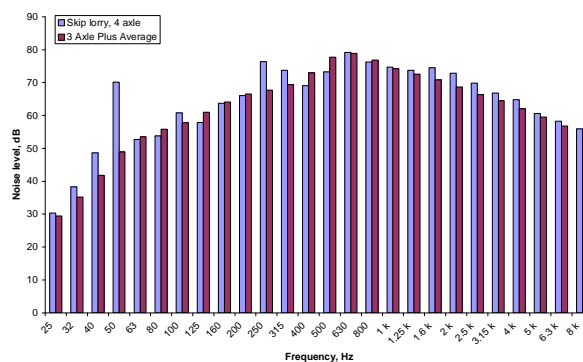


Figure 3.16: A-weighted one-third octave band spectra for “noisy” heavy vehicles at Site 2

3.3 Audio recordings – Site 2

Extra measurements using specialist audio equipment were undertaken on the 30th July. The aim of this was to record the actual sound of the passing vehicles to provide an aural comparison between vehicles. For these measurements the weather was very warm with a gentle breeze.

Three examples of light vehicles have been selected for a comparison of the noise produced by different vehicles. The audio files for each are available from the TRL website (www.trl.co.uk). The vehicles selected were all travelling at speeds between 101-105 km/h, with no other vehicles within close proximity. These three types are :

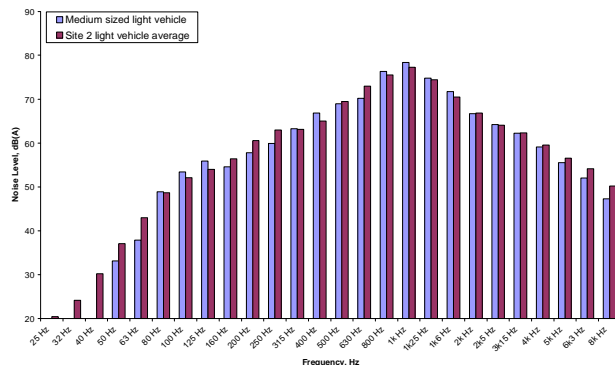
- A medium sized light vehicle;
- A large light vehicle;
- A light vehicle with noticeable exhaust noise.

The third octave band spectra for the three vehicles are given in Figure 3.17. It can be seen that the spectra for the medium sized light vehicle, Figure 3.17(a), is very similar to the average spectrum for light vehicles used for the main analysis in Section 3.2.1.

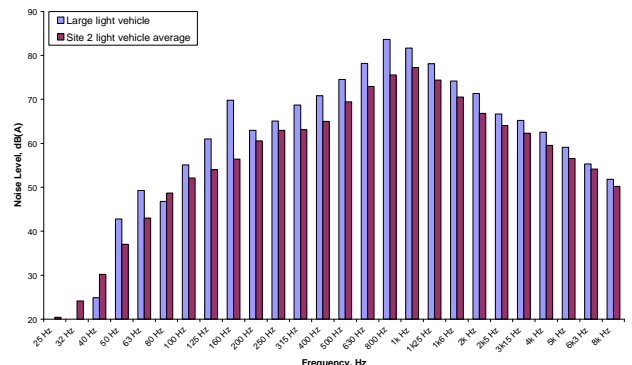
The spectra for the large light vehicle, Figure 3.17(b), shows an increase over all frequency bands, with the greatest increases being at the lower frequencies. These increases could be due to large tyres, a large engine or simply the non-aerodynamic shape of the vehicle.

The light vehicle shown in Figure 3.17(c) had a clearly audible exhaust note when measured. This is shown in the spectra by large peaks at 100 Hz, 125 Hz and 250 Hz. This was caused by either a non-standard or defective exhaust.

(a) Medium sized light vehicle



(b) Large light vehicle



(c) Light vehicle with exhaust noise

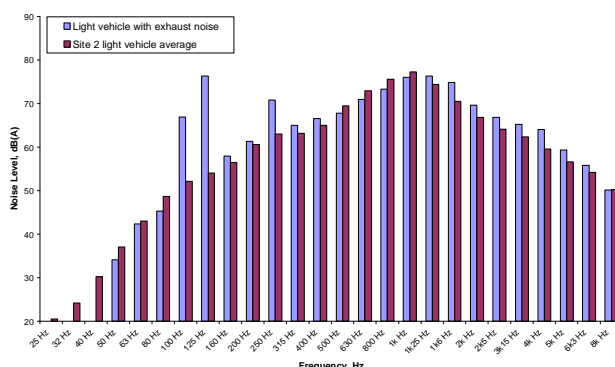


Figure 3.17: A-weighted one-third octave band spectra for light vehicles from audio recordings at Site 2

In addition to these three different vehicle types, four other recordings are given on the TRL website. These are recordings of light vehicles travelling at different speeds but which were not judged to be producing excessive noise. These audio files indicate the change in noise level as vehicle speed changes.

3.4 Vibration observations – Site 1

3.4.1 Medium heavy vehicles

Figure 3.18 shows the maximum component of vertical vibration plotted against vehicle speed. Since there is no general correlation between vehicle speed and the level of vibration, there is no regression line plotted through the dataset. The horizontal lines shown on the chart are the mean level and the mean level plus one standard deviation. This has been selected as a cut-off point to determine those vehicles to examine in detail. The number of vehicles on or above the line was 21, and the details for these are given in Table 3.9.

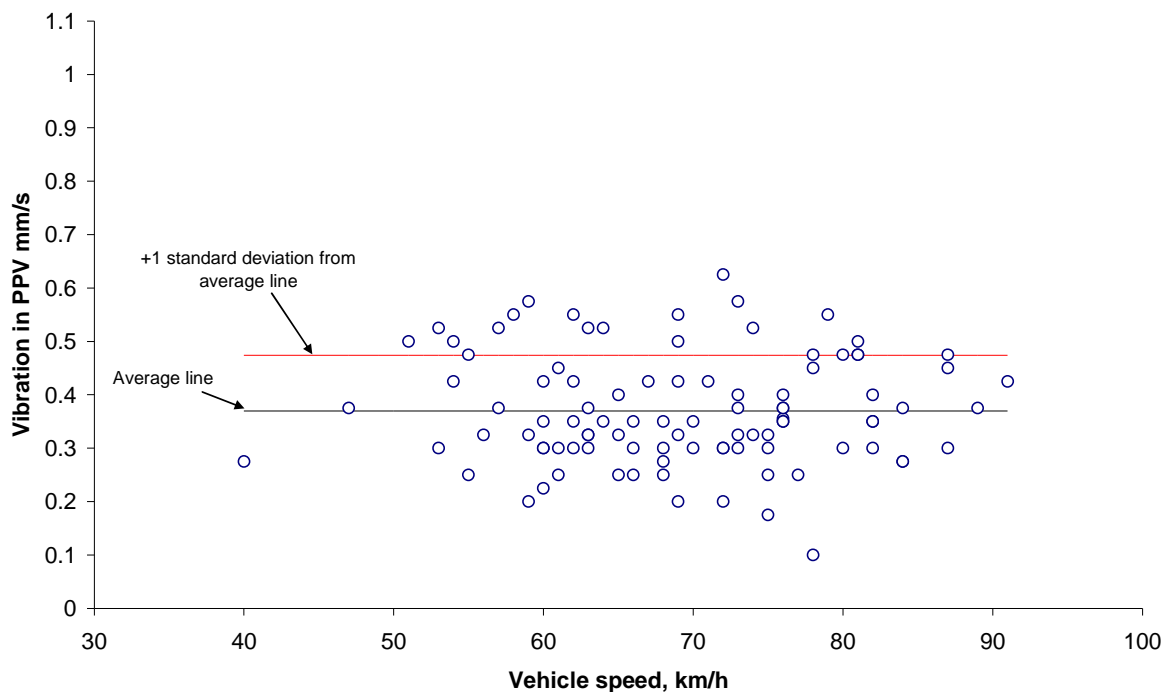


Figure 3.18: Maximum peak particle velocity for medium heavy vehicles at Site 1

Table 3.9 gives the details of those vehicles classified as producing high levels of vibration. It should be noted that these vehicles are not necessarily those that were classified as being “noisy” by the acoustic measurements. The highest maximum vibration level was produced by a maintenance vehicle travelling at 72 km/h.

Table 3.9: Description of medium heavy vehicles producing highest vibration levels at Site 1

Description	Age	Speed (km/h)	Max. PPV
Maintenance vehicle (5.9 litre) with unidentified attachments	3 yr	72	0.625
Flat bed lorry (5.9 litre) laden	8 yr	59	0.575
Flat bed (9.2 litre) carrying unidentified object*	2 yr	73	0.575
Box van (9 litre) with goods platform	4 yr	88	0.550
Skip lorry, laden*	11 yr	81	0.550
Drop-side lorry (6.4 litre) with unsecured building materials*	2 yr	58	0.550
Box van (5.9 litre)	3 yr	62	0.550
Curtain sided lorry (9.6 litre)	9 yr	69	0.550
Curtain sided lorry with goods platform (5.9 litre)	4 yr	52	0.525
Maintenance vehicle with metal cage*	-	53	0.525
Flammable liquid transporter (8.9 litre)*	<1 yr	63	0.525
Curtain sided lorry (9.2 litre) with goods platform	3 yr	64	0.525
Drop-side lorry (3.2 litre) carrying long lengths wood	7 yr	57	0.525
Skip lorry (6.4 litre) laden*	4 yr	81	0.500
Refrigerated van (6.4 litre) with goods platform*	4 yr	51	0.500
Unknown flat bed lorry laden with attached unidentified object*	-	62	0.475
Curtain sided lorry (7.3 litre) unladen*	7 yr	62	0.475
Flat bed lorry (6.2 litre) unladen*	13 yr	55	0.475
Skip lorry (3.4 litre) laden*	8 yr	81	0.475
Refrigerated lorry (6.4 litre)	4yr	80	0.475
Coach (12.6 litre)	<1 yr	78	0.475

* depicts vehicles that were also classified as noisy.

Figure 3.19 displays the average vibration level of a variety of vehicle types and the number of those vehicles sampled. It can be seen that the greatest average vertical vibration (0.475 mm/s) was produced by maintenance vehicles (e.g. council traffic management vehicles), while drop-side lorries produced the lowest average level of vibration of 0.330 mm/s.

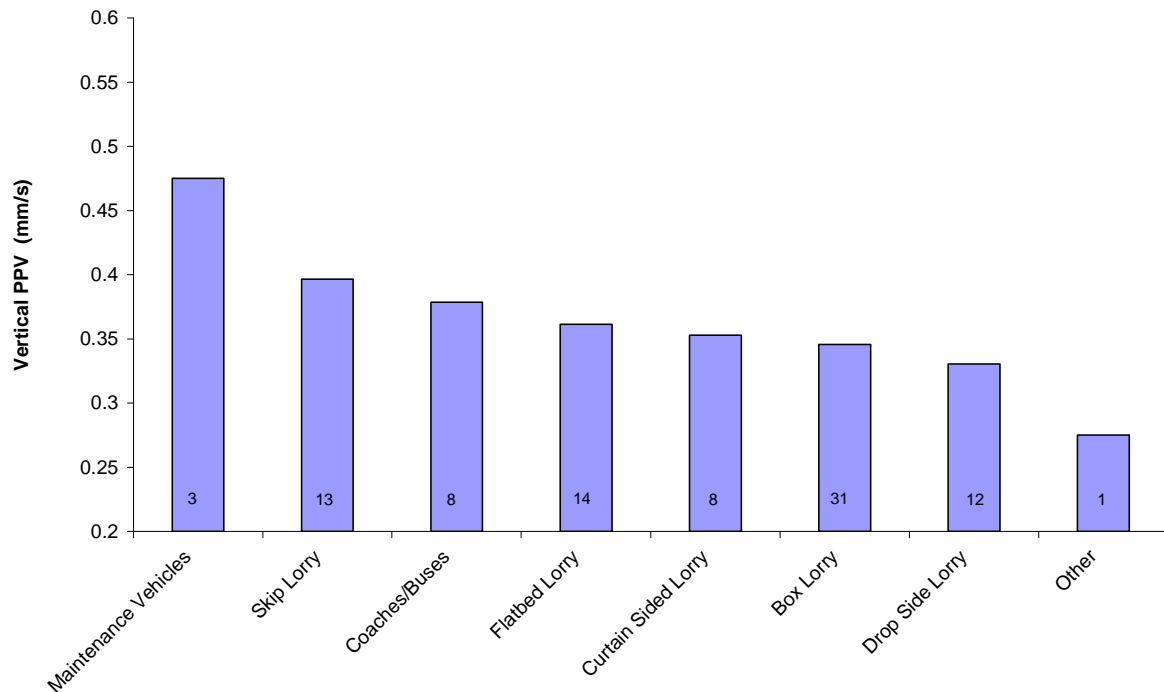


Figure 3.19: Average vibration levels of medium heavy vehicles at Site 1 by body type (number of each type assessed is shown on the bars)

3.4.2 Heavy vehicles

Figure 3.20 shows the maximum component of vertical vibration plotted against speed. Again it can be seen that there is very little variation with speed. The horizontal lines shown on the chart are the mean level and the mean level plus one standard deviation. This has been selected as a cut off point to determine those vehicles to examine in detail. There are six vehicles on or above the line, and details of these are given in Table 3.10.

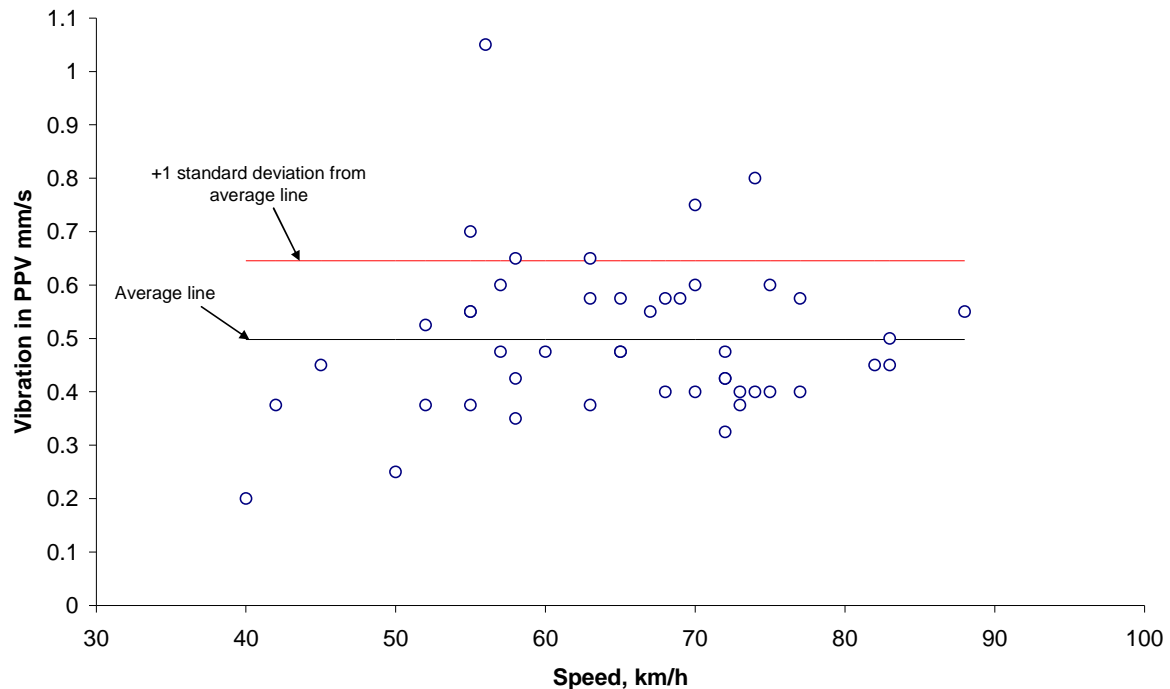


Figure 3.20: Maximum peak particle velocity for heavy vehicles at Site 1

Table 3.10: Description of heavy vehicles producing the highest vibration levels at Site 1

Description	Age	Speed (km/h)	Max. PPV
Car transporter (5 axle, 12.1 litre) unladen*	2 yr	56	1.050
Curtain sided lorry	-	74	0.800
Curtain sided lorry (3 axle, 7.3 litre)*	7 yr	70	0.750
Maintenance vehicle with crane (3 axle)*	3 yr	55	0.700
Waste recycling lorry	-	63	0.650
Waste lorry	-	58	0.650

* depicts vehicles that were also classified as noisy.

It can be seen that maximum levels are approaching twice that for two-axle trucks (see Table 3.10). The highest recorded level was from an unladen car transporter.

Figure 3.21 displays the average vibration level of a variety of vehicle types and the number of those vehicles sampled. It can be seen that the greatest average vertical vibrations (0.56 mm/s) were produced by the two car transporters, while cement mixers produced the lowest vibrations, 0.375 mm/s, although only one cement mixer was sampled.

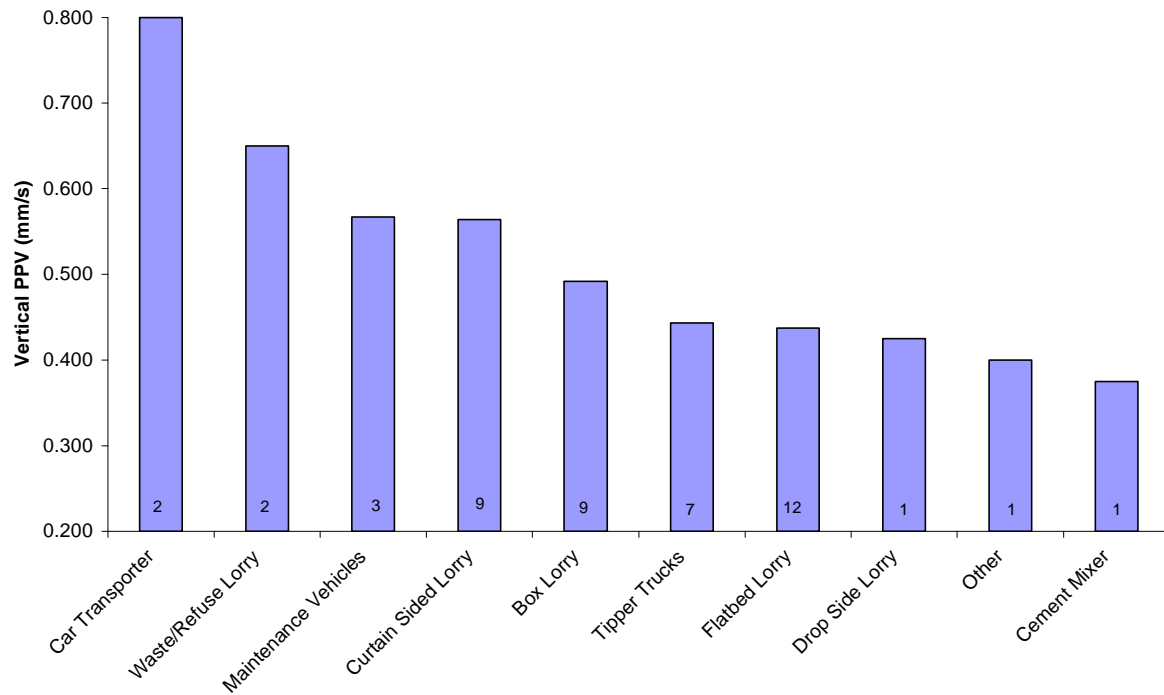


Figure 3.21: Average vibration levels of heavy vehicles at Site 1 by body type (number of each type assessed is shown on the bars)

4 Discussion of results

4.1 Noise observations

4.1.1 Light vehicles

The results from both Sites 1 and 2 have shown that the majority of those vehicles classed as “noisy” show increases in the lower end of the frequency range. This lower frequency range is where exhaust noise is dominant, and increases in noise here are likely to be an indication of a modified or defective silencer. From visual surveys it is more likely the cause is a modified exhaust since the vehicles tended to have other modifications that are normally associated with a modified vehicle (e.g. lowered suspension, extra bodywork).

Following exhaust noise, the next largest category (found mainly in those vehicles surveyed at Site 2) were vehicles where there was a general increase in noise level over all frequency bands, indicating that a number of factors may be influencing the overall noise level. These factors could include the shape of the vehicle, large tyres or large engines.

The relationship between noise and the logarithm of vehicle speed was developed over 30 years ago, and has formed the basis in this project for determining which vehicles are considered as “noisy” (i.e. those vehicles which are one standard deviation above a linear plot of noise against the logarithm of speed). As discussed above, some of the vehicles identified as “noisy” were generally noisy at all frequencies and showed no obvious indication of what was making the extra noise. It is possible that due to changes in vehicle trends (e.g. larger tyres, engines, general body shape) that the linear relationship no longer holds for the modern vehicle fleet. A different vehicle fleet may introduce more uncertainties, especially at higher vehicle speeds, in the relationship between noise and the logarithm of vehicle speed, or even cause the relationship to be non-linear.

At Site 2, a note was made if the sampled light vehicle was considered to be especially large. Of the twelve of these sampled, ten were above the best fit line through the data. Although only a small sample, this may indicate that not all groups of vehicle follow the standard relationship.

The irregularities in the road at Site 1 did not induce any excessive noise within cars, except for where the vehicle was towing a trailer. Noise from trailers is discussed in more detail below.

The noisiest light vehicles recorded were 5.6 dB(A) and 8.2 dB(A) above the average noise level for the same speeds for site 1 and site 2 respectively. These levels can be considered a significant increase in noise among the general traffic noise.

4.1.2 Vans

At Site 1, where there were irregularities in the road, the most common cause of excessive noise from this group of vehicles was associated with the van towing a trailer. The excessive noise measured was either generated from the load on the trailer or the trailer itself. The condition of the road will have a significant effect on the frequency and scale of noisy events.

A load on a trailer is relatively easy to secure to avoid excessive noise. All that is generally required is some form of padding, straps or rope to secure the load and time from the driver of the vehicle.

Noise from the trailer itself is less easy to control, and is often caused by a lack of maintenance or the general condition of the trailer, usually related to the age.

One noisy event at each measurement site was identified as being caused by a vehicle with an excessively noisy exhaust. With a van, excessive exhaust noise is more likely to be caused by a defective exhaust than a modified exhaust since this type of vehicle is less likely to be modified by the owner.

The noisiest vans recorded were 7.1 dB(A) and 2.6 dB(A) above the average noise level for the same speeds for site 1 and site 2 respectively. The level recorded for site 1 can be considered a very noticeable increase in noise among the general traffic noise, whilst site 2 can be considered as a just noticeable increase in noise.

4.1.3 Heavy vehicles

For both categories of heavy vehicles (those with 2 axles and 3+ axles), the majority of noisy events were caused by some form of body rattle or from a load being transported. The loads being carried varied, but were often not adequately secured. The condition of the road will have a significant effect on the frequency and scale of these noisy events.

The code of practice for body rattle noise (Department for Environment, Transport and the Regions, 2000) provides guidance on methods of preventing such noise. It is likely that there are particular challenges in reducing rattle noises for this type of vehicle because there are many loose metal components and more detailed investigations of the major sources and their elimination are required.

The noisiest 2 axle vehicles recorded were 9.6 dB(A) and 4.4 dB(A) above the average noise level for the same speeds for site 1 and site 2 respectively. These levels at site 1 can be considered a significant increase in noise among the general traffic noise, whilst at site 2 the increase in noise is noticeable.

The noisiest 3+ axle vehicles recorded were 5.6 dB(A) and 2.1 dB(A) above the average noise level for the same speeds for site 1 and site 2 respectively. These levels can be considered a noticeable difference in noise level among the general traffic noise.

4.2 Vibration observations

Unlike noise, where the source can often be heard, the cause of any high vibration levels is difficult to determine. It must be recognised that the condition of the road surface plays an important part in the generation of ground-borne vibration.

For heavy vehicles with 2 axles, the highest average levels were produced by maintenance vehicles and skip lorries. Due to the nature of the work and loads these vehicles carry it is not surprising that they produced the highest vibration levels since they are among the heaviest of the vehicles in the 2-axle category, where the vehicles can range from 3.5 to 17 tonnes.

For 3+ axle group, the highest levels were found among car transporters and refuse / waste vehicles. The results for car transporters are similar to those observed by Watts and Stait (2006), where this category of vehicle was found to produce the highest levels of vibration on a high speed road. As these vehicles have been shown to produce high levels of vibration on both high and low speed roads it would indicate that there is possibly something related to the design or load of the vehicle that is causing excessive vibration. This may be due to the general configuration of the vehicles, as these were noted as having different axle configurations to a standard large heavy vehicle. The layout of the axles was similar to that of a 'drawbar' vehicle that is standard in mainland Europe (i.e. a 2-axle rigid truck that is towing a trailer, normally of similar size). The distribution of load may be another reason for high levels of vibration.

Over both categories, the age of the vehicle may be a factor because suspension systems have changed over recent years. Today most trucks have air suspension while previously steel leaf spring systems were more common. The degree of damping will also affect the maximum force applied to the road. In the case of defective dampers the travel of the suspension may be excessive when the wheels travel over an irregularity. In such a case the suspension may reach its limits of travel and hit the bump stops producing extremely high dynamic forces and consequently vibration. Note that this can occur in both air and steel suspension systems. An old or poorly maintained vehicle is more likely to have a defective suspension system than a new, well maintained vehicle.

5 Conclusions

The study developed a new and efficient method for gathering information at the roadside and identifying vehicles producing excessive noise and/or vibration.

This may potentially provide a powerful addition to the control measures traditionally used to combat noise disturbance (e.g. noise barriers, low-noise road surfaces) which tend to reduce the average noise levels but fail to reduce the range of noise levels from individual vehicles.

Such a method could be used for the identification of a noisy vehicle in a traffic stream and the subsequent enforcement of noise levels. A logging device could be programmed to alert an operator if a passing vehicle exceeds a set noise level, either an overall level or a level at a given frequency. The noise level would first need to be set for a particular site, taking into account the existing road surface. If this measurement device and operator were upstream of an enforcement officer then the officer would be able to pull a vehicle over for a further more controlled test (possibly stationary) to determine whether it is in breach of any set limits. Such limits do not currently exist but the results from this study could form the base for the setting of such limits.

It is known to the authors that the Department for Transport are receiving an increasing number of complaints about vehicles producing excessive noise, so this could provide a suitable method for the identification of noisy vehicles if the Department pursues this further.

The application to the control of ground-borne vibration could be via similar method. Heavy goods vehicles are routinely stopped on the road network at Department for Transport weighbridge sites, normally to check the weight of the vehicle. The vibration produced by a vehicle could be used as an identification method of which vehicles to call in for checks, or a more advanced vibration test could be developed for any vehicle called in for routine tests.

For the approach to be most effective, it is considered that the combination of measurements and video recordings (and not simply number plate recognition) should always be used – in many of the cases, where noise sources are not related to either the engine or exhaust, video footage assists in the specific identification of the noise source.

The main conclusions that can be drawn from the study are:

- For light vehicles the majority of excessive noise events are caused by vehicles with modified exhausts. The majority of the remaining events were caused by factors associated with large vehicles, such as large engines and tyres and poor aerodynamics.
- The noise produced by trailers being towed by cars and vans was found to excessive in a number of cases. This excessive noise was caused by both trailer and also the loads being carried on the trailer.
- Excessive noise produced by heavy vehicles was often caused by poorly secured loads.
- Car transporters have been found in this and the previous study to produce the highest levels of vibration. Refuse/waste vehicles, maintenance and skip lorries are also among the heavy vehicles producing the highest levels of vibration. However, identifying the precise source of excessive vibration is far more complex than the identification of sources of excessive noise.
- It is recognised that while steps such as the securing of loads, etc can easily be taken to reduce noise/vibration impact, the condition of the road surface plays an important part in the generation of noise and vibration. As such, any selection and identification of “noisy” vehicles for the purpose of taking remedial action would need to be undertaken with caution and in combination with measures to improve the quality of the road surfaces.

If such a system for the identification of noisy vehicles was adopted it would have the potential to extend trade in a number of areas:

- The monitoring of noise and vibration from vehicles requires specialist knowledge and equipment. This could increase the need for trained acoustic staff in authorities responsible

for the monitoring and the need for specialist equipment. If remote unattended monitoring systems were to be used for monitoring then development of such systems would be required.

- A clampdown on noisy components, both on heavy good vehicles and from trailers, would increase the need for noise reducing systems or components. Such systems or components may also require development and testing before production and the sales.
- In addition, the potential exists for best practice guidance documents to be developed which could result in the need for fleet owners to employ specialists to ensure compliance with such guidance

6 Recommendations for use of method and for further work

The method developed for the identification of noisy vehicles has the potential to be used for enforcement purposes. This could be either directly or as a means of identifying vehicles in a traffic stream that could then be taken for a further test.

Other areas identified during the research that could be investigated further are:

- Whether the relationship between noise level and the logarithm of vehicle speed still holds for the modern vehicle fleet.
- The possible development of a code of practice for the use of a trailer. This could include possible restrictions on the use of trailers, better design of trailers or annual inspections for trailers.
- Car transporters have been identified as causing excessive vibrations at low and high speeds. The causes of this could be investigated further.

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