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Work Order T0218 Roadside Vehicle Noise Measurement – Phase 3 Part A

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Executive summary

This report has been produced by the Atkins Jacobs Joint Venture (AJJV) as a deliverable under the T0218 Roadside Vehicle Noise Measurement – Phase 3 project. The report describes the work undertaken for Part A of the project, which is to:

- Investigate the advantages and disadvantages of using a single noise threshold or a set of noise thresholds for a range of vehicle types
- To investigate the effect of exhaust and silencer modifications on vehicle noise emissions and how these may acoustically characterise excessively noisy vehicles
- To provide noise threshold recommendations, with associated tolerances, to be applied in real world driving environments that could be used by an automated system or a handheld device such as a sound level meter

Vehicle noise is a significant cause of noise pollution, particularly in urban environments. Excessively noisy vehicles lead to annoyance and complaints and this project seeks to address this issue. The police and local authorities have powers to take action against excessively noisy vehicles, however, it is difficult to collect sufficient evidence for meaningful enforcement action. The current approach does not sufficiently discourage vehicle modification.

To achieve the aims of Part A, a series of vehicle noise tests have been undertaken in controlled conditions at the UTAC Millbrook test facility. These tests have been undertaken with vehicles in standard condition and then with aftermarket products designed to increase noise. The noise tests undertaken were the full type approval test and cruise by tests at additional speeds. In addition to the noise testing, a series of subjective tests were undertaken to determine whether a vehicle was considered to be excessively noisy.

The results from the type approval noise tests undertaken at UTAC Millbrook has shown that on average a standard vehicle in service is within around 2 dB of the level at which it was type approved. Vehicles with aftermarket products showed noise levels up to 15 dB higher than the standard condition.

The subjective tests undertaken have shown that a vehicle would generally need to have a measured noise level above 90 dB(A) to be classed as noisy, and a measured level higher than this to be considered as excessively noisy.

Adverse weather conditions can cause higher than normal noise levels to be generated by a passing vehicle. This could cause a vehicle in normal condition to be deemed as producing excessive noise by an automated system. Given the amount of rainfall in the UK and the difficulty in categorising a wet road, it is recommended that the noise camera captures data in such conditions and the weather is considered within the evidence pack that would be produced to inform whether action is taken against the vehicle user.

A noise threshold of 95 dB L_{AFmax} is proposed to take forward for dummy enforcement in trials with a roadside noise camera. This threshold is proposed for both cars and motorcycles, for day and night, and for roads of all speed limits. A single figure is considered appropriate as it does not distinguish between a particular motorist group (e.g. cars, motorcycles) and is aligned with emerging best practice where noise cameras are already in use. The frequency component in terms of one-third octave bands has been examined to determine whether this can also be used to categorise an excessively noisy vehicle and be used as an additional trigger to the overall noise level.

It is recommended that should the project proceed to roadside trials a lower level of 85 dB L_{AFmax} should be used as the noise camera trigger in order to gather a large dataset to permit refinement of the proposed enforcement threshold.

1. Introduction

1.1. Background

Noise pollution is one of the top environmental risks affecting physical and mental health and wellbeing [1]. Vehicle noise is a significant cause of noise pollution, particularly in urban environments. Excessively noisy road vehicles, which have often been modified, also lead to significant annoyance and complaints from members of the public throughout the UK. The police and local authorities have powers to take action against excessively noisy road vehicles however it is difficult to collect sufficient evidence for meaningful enforcement action.

The Department for Transport (DfT) is seeking to address this issue and has commissioned a number of research studies over the years investigating excessively noisy vehicles and ways of reducing the problem. The most recent study was Phases 1 and 2 of DfT's Roadside Vehicle Noise Measurement project, which identified automated noise cameras as a potential technological solution to the problem [2, 3]. A prototype noise camera comprising a microphone, video camera, speed radar and Automatic Number Plate Reader was developed and tested during 2019 to establish proof of concept. The prototype noise camera was trialled in a real-world environment and delivered promising results, however, further development was recommended to improve components of the system and to distinguish individual vehicles passing the device close together as this resulted in sound from individual vehicles "blending" together. Further testing was also recommended to ensure that noise camera systems can operate effectively in a high noise environment.

Lessons from the UK and abroad during the development and proliferation of speed and red light cameras over the past two decades can be used to fast-track the design of acoustic detection so that it is compliant with existing legislation and the requirements of the criminal justice system.

The Atkins Jacobs Joint Venture (AJJV) has been commissioned by the DfT through the National Highways SPaTS2 framework to undertake research into excessively noisy vehicles and technologies that could be used to improve enforcement against them. The contract was awarded to the AJJV during December 2021.

1.2. Project Definition

The primary aim of this project is to improve enforcement against excessively noisy vehicles and in doing so, reduce disturbance from such vehicles in affected areas. Improvements to enforcement through the provision of enforcement technologies able to detect and identify excessively noisy vehicles would collect a robust evidential trail to support the police, local authorities and other stakeholders in successfully taking enforcement action against offenders (such as fines, vehicle defect rectification notices). Visible and publicised enforcement action could improve public awareness of the issue and simultaneously deter drivers from generating excessive noise through certain driving styles or vehicle modifications.

Phase 3 of the project comprises three distinct tranches of work with the following objectives.

- Part A – Defining excessive noise
    - To investigate the advantages and disadvantages of using a single noise threshold or a set of noise thresholds for a range of vehicle types,
    - To investigate the effect of exhaust and silencer modifications on vehicle noise emissions and how these may acoustically characterise excessively noisy vehicles, and
    - To provide noise threshold recommendations, with associated tolerances, to be applied in real world driving environments that could be used by an automated system or a handheld device such as a sound level meter.

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- Part B – Identifying, testing and recommending appropriate technology
    - To identify and review the latest available noise camera products to determine their suitability for UK roads and as an enforcement tool,
    - To test the performance of suitable noise camera products in controlled conditions, and
    - To develop a universal and technology neutral installation and deployment guide for any noise camera product that could be used by the police and local authorities.
- Part C – Roadside trials
    - To further test the performance of suitable noise camera products in real world driving environments, particularly in urban environments,
    - To verify and adjust if necessary the proposed noise threshold level, and
    - To finalise the universal installation and deployment guide developed in Part B based experience from the roadside trials.

Parts A and B have been undertaken in parallel to each other, but are reported separately.

This report discusses the research undertaken from the Part A scope of work and is focused on the acoustic characterisation of excessively noisy vehicles and potential noise thresholds that could be used for enforcement. The structure of the report is as follows:

- Chapter 2 – Methodology
- Chapter 3 – Review of Noise Threshold Approaches
- Chapter 4 – Initial Noise Thresholds
- Chapter 5 – Noise Trial in Controlled Environment
- Chapter 6 – Discussion
- Chapter 7 – Conclusion and Recommendations
- Chapter 8 – References

2. Methodology

The approach to achieving the objectives of Part A has been undertaken in seven stages. These are provided in Table 2-1.

Table 2-1 Part A Methodology stages

Stage	Details	Report Chapter
1	Review of options for establishing noise threshold(s) for excessively noisy vehicles following Phase 2 of the Roadside Vehicle Noise Measurement project [3].	3
2	Review of approach to setting noise thresholds by authorities and camera manufacturers.	3
3	Setting of initial noise threshold(s) based on the reviews outlined above.	4
4	Testing, in a controlled environment, the suitability of the initial noise thresholds and gathering trial data to inform selection of final recommended noise threshold.	5
5	Using data captured in stage 4 to characterise an excessively noisy vehicle. This will also examine whether the frequency component of a vehicle could be an effective means of setting a noise threshold.	6
6	Discussion of threshold and examination of potential tolerances (e.g. due to weather) that may be required when setting a noise threshold.	6
7	Present the final recommended noise threshold to be taken forward to Part C of the study (roadside trials). Identify and data gaps and make recommendations.	7

3. Review of Noise Threshold Approaches and Available Data

3.1. Phase 2 Options

This Chapter provides a summary of the pertinent findings and recommendations from the Phase 2 Final Report [3] related to the setting of noise thresholds for excessively noisy vehicles. The Chapter also reviews the approach to setting excessively noisy vehicle noise thresholds by authorities and trigger thresholds by noise camera manufacturers.

The Phase 2 Final Report [3] presents a summary of the review that was undertaken into the appropriateness of fixed noise thresholds for enforcement of excessively noisy vehicles (Table 8.2). The review made the following key statements:

- A bespoke noise threshold (i.e. one that dynamically adjusts to the vehicle under investigation) while being the most accurate approach identified, would come with a number of limitations such as uncertainty from public in what the 'noise limit' is, potentially difficult for police officers to enforce and more complex post-processing of data.
- A statistical noise threshold (i.e. one based on, for example, a statistical parameter such as 99th percentile) would allow for variation in local conditions to be more easily incorporated but would mean the 'noise limit' would different between different locations and may require a change in the law to all ow it to be implemented.
- A fixed noise threshold (i.e. a single threshold for all vehicles, or all vehicles in a subcategory) would be easier for public awareness campaigns and enforcement but would potentially require post-processing of data to account for camera position, would need to be sufficiently high to not incorrectly identify older (exempt) vehicles, and may require a change in the law to allow it to be implemented.

The first and third of these are considered further within Part A of this project. The second suggestion from the Phase 2 work has not been developed further as it is considered this is incompatible with using the regulations within the Road Vehicle (Construction and Use) Regulations [4] as an enforcement measure. A statistical noise threshold is considered to not have any relevance to excessively noisy vehicles and could penalise drivers whose vehicles just happen to be within a certain percentage band but are not excessively noisy. In addition, this approach is likely to require an individual percentage threshold for different road situations and to determine this would require a vast amount of data gathering which would not be obtained during Part A of the project.

The Phase 2 study also considered the frequency composition of the noise from the vehicles measured during the test work. The data available at Phase 2 suggested that a car without any aftermarket products may display elevated noise levels in the low to mid-frequency range (approximately 63, 100 Hz and 1 kHz). A car with aftermarket products fitted may display elevated noise levels between approximately 40 and 80 Hz.

3.2. Review of approach taken by authorities and camera manufacturers

A review of the approach to setting noise thresholds for enforcement purposes and trigger thresholds on noise cameras has been undertaken and is presented in Table 3-1.

Table 3-1 Review of noise thresholds and triggers values used by Authorities / Manufacturers

Authority or manufacturer	Approach and review
Royal Borough of Kensington and Chelsea (RBKC)	RBKC use varying noise thresholds for enforcement purposes (between 83 and 86 dB L_{AFmax}) that vary by location. It should however be noted that the local authority prosecutes the drivers of excessively noisy vehicles through the use of Public Spaces Protection Orders (PSPO) [5], rather than through the Construction and Use Regulations. RBKC use a noise camera made in England by 24 Acoustics. The noise threshold level is considered an appropriate noise level to capture likely offences while not gathering a lot of data that would subsequently be excluded. Although a review of enforcement approach is outside of the scope of Part A, enforcement through the PSPO currently requires post processing (manual review of evidence) which it is understood takes on average 12 minutes per vehicle. This may cause resourcing issues should noise cameras be used on a nationwide scale.
NEMO noise camera (Netherlands)	The NEMO project (part of EU Horizon 2020 research) currently suggest that excessively noisy vehicles are the 1% noisiest vehicles, which are 12 dB L_{AFmax} above normal vehicles/traffic. It is unknown what noise threshold is used or proposed for any enforcement. Information on this approach is patchy, however the percentage approach is not considered appropriate as reported earlier.
Acoem, Bruitparif and MicrodB (France)	Trials of noise camera technologies has been undertaken in France where manufacturers Acoem, Bruitparif and MicrodB have tested their products in controlled and roadside scenarios. Trigger noise threshold levels of between 83 and 85 dB L_{AFmax} have been used, with 90 dB L_{AFmax} recommended by one of the noise camera suppliers as an enforcement threshold level when using their product based on iterative testing (‘trial and error’). No final recommendations for enforcement thresholds have been publicly reported following the completion of the trials.

3.2.1. Royal Borough of Kensington and Chelsea Data Review

The RBKC have provided the project team with data collected at five locations within the borough. This data was collected using a noise camera supplied by 24 Acoustics. The five locations are:

- Sloane Street;
- Pont Street;
- Holland Park Avenue;
- Norland Square; and
- Lower Sloane Street.

The data gathered at Sloane Street is the most extensive and is presented in Table 3-2. This shows the number of potentially excessively noisy vehicles investigated over approximately a 20-month period and the number (and percentage) of those that were issued with fines under the local authority’s PSPO powers. A PSPO prohibits certain activities that, in the opinion of an enforcement officer, cause excessive nuisance. A PSPO in a certain area can last for up to three years.

Table 3-2 Number of occurances examined by RBKC and number of fines issued at the Sloane Street location

Noise level measured (L_{AFmax} dB)	Number examined	Number excluded	Number fined	% fined
80-85	689*	676	13	2%
85-90	2,565	2,466	99	4%
90-95	2,561	2,324	237	9%
95-100	1,372	1,156	216	16%
100-105	479	364	115	24%
105+	157	115	42	27%
Total	**7,823**		**722**	**9%**

* The trigger level for the camera is higher now than it was when first installed. After a review of the first noise events captured, it was decided that the camera was being triggered by events that were not breaches of the PSPO and not noisy events. The trigger level was subsequently increased, meaning fewer cases between 80-85 dB have been examined than between 85-90 dB.

Table 3-2 shows that most of the potentially excessively noisy vehicle cases examined at the Sloane Street location were in response to maximum measured noise levels of between 85 and 95 dB(A) (66% of the total number of cases examined), followed by 95 to 100 dB(A) (18%). As would be expected, the proportion of cases examined that resulted in fines being issued increased as the maximum measured noise levels increase, from 2% for noise levels of 80 to 85 dB(A), up to 27% for noise levels in excess of 105 dB(A).

Those excluded from the examination were due to numerous reasons, such as vehicle number plates being unrecognisable or not traceable, not meeting the PSPO requirements and the inability to identify which vehicle was generating the noise. The vehicle being from the emergency services is also a reason for exclusion, and this generally accounts for the low percentage of those above 100 dB(A) that were fined.

4. Consideration of Initial Noise Thresholds

Using knowledge from Phase 2 and any further research obtained from a review of current noise camera systems in use, an initial proposed noise threshold was determined. This was then evaluated as Part A and B work progressed.

Consideration was initially given to the advantages and disadvantages of using a single noise threshold or a set of noise thresholds for a range of vehicle types or conditions (similar to the bespoke noise thresholds discussed in Chapter 3). This is presented in Table 4-1.

Table 4-1 Advantages and disadvantages of single and multiple noise thresholds

	Advantages	Disadvantages
Single threshold	Likely to be easier to enforce.	No consideration of difference between noise level of vehicles when type approved.
	Likely to be easy for the public to understand what noise thresholds apply and how they are enforced.	May need to be high so as to be reasonable when applied to vehicles with the highest type approval noise levels.
	Changes to a fixed noise threshold (e.g. as may be required with technological developments) would be easier to make.	
	Groups of motorists (i.e. car drivers and motorcyclists) are not perceived to being singled out.	
Multiple thresholds	Potentially more accurate and would mean the difference between the noise threshold and noise level the vehicle was approved at remains broadly consistent between all vehicles.	More intensive post-processing of data collected by camera and microphone.
	May be viewed as fairer by motoring groups (i.e. car drivers and motorcyclists).	Likely to be more difficult for police to enforce.
		More difficult to communicate the noise thresholds to the public and may lead to confusion/ uncertainty for drivers.
		All vehicle types (models and specification) would need to be assigned to a noise threshold category based on their type approval noise level. this may cause difficulties with imported vehicles or those not subject to type approval.

Following the review presented in Chapter 3 and Table 4-1, two initial noise thresholds were proposed, one for passenger cars and light goods vehicles (LGV) and one for motorcycles[1]. The noise thresholds were set at:

[1] Applies to two- and three-wheeled vehicles and quadricycles.

- 85 dB L_{AFmax} for cars and LGVs, which equates to the maximum type approval test noise level [6]+10 dB for cars and +11 dB for LGV.
- 90 dB L_{AFmax} for motorcycles (including mopeds and scooters), which equates to the maximum type approval test noise level [7] +10 dB.

These were chosen based on the maximum type approval value for the respective categories (see Appendix B), plus a factor that could account for excessive noise. An increase of about 8 − 10 dB is required before the sound subjectively appears to be significantly louder [8]. Although this change generally relates to environmental noise, the upper end of this range was considered as a starting point for determining a level that could be classed as excessively noisy.

These initial noise thresholds relate to the type approval position of a microphone, which is at a height of 1.2 m and a horizontal distance of 7.5 m from the centre line of the vehicle under test.

A bespoke noise threshold approach (i.e. a threshold for different vehicle categories or different vehicles) would be difficult to implement for these reasons;

- The camera would capture a large amount of data because the noise trigger would need to be set for the lowest possible threshold. This would require significant post processing of data or real-time review of ANPR data in the camera to dynamically alter the threshold. It is considered that flexible noise thresholds would introduce additional technical challenges.

- It is considered that the differences in individual vehicle type approval categories would be relatively small compared to the threshold noise level for excessive noise. This makes the dynamic and more complex approach to defining noise thresholds unnecessary.

5. Noise Trial in Controlled Environment

5.1. Trial Methodology

The trial involved measuring noise emissions from the vehicles on test during two types of test. The first has been called a full type-approval equivalent test (FTA) and the second a partial type approval (PTA) test. Testing was undertaken on a range of vehicles, with some of these being modified by adding aftermarket products to increase the noise generated.

The testing took place at the UTAC Millbrook Proving Ground test facility in Bedfordshire over twelve days in April 2022. It was decided to undertake the test work in controlled conditions provided at UTAC Millbrook for the following reasons:

- The ability to use professional test drivers, which increased the accuracy of the data collected as the test conditions were repeatable and reproducible.
- If necessary, aftermarket products could be tested that were not road legal.
- A low risk of causing noise disturbance during the test work.
- The test setup at UTAC Millbrook is designed for type approval testing.
- Testing could take place on a road surface that is certified for type approval testing.

5.1.1. Test methodology and data collected

The trial methodology for the FTA test on the vehicles is consistent with that detailed within the relevant International Standards [6] [9] [10] [11]. The PTA test approach is a modified version of the FTA that was intended to provide a larger dataset of real-world driving conditions (namely a variety of vehicle speeds).

The trial was undertaken on the pass-by external noise track at UTAC Millbrook, which is typically used for noise measurements of vehicles to international standards. The asphalt surface of the test track meets ISO 10844 [12] test track specifications for measuring noise emitted road vehicles and their tyres.

The UTAC Millbrook test microphones (located either side of the test track) were present and in use throughout the trial, as was a separate sound level meter supplied by AJJV, which was positioned at a similar distance from the vehicles on test as the Millbrook microphones. The AJJV equipment conformed to Class 1 of BS EN 61672 [13], and was field calibrated during the trials with a calibrator of Class 1 of BS EN 60942 [14].

The initial noise thresholds (set out in section 4) were not used during the Part A or B site trials when capturing data from the noise cameras. It was instead decided that the trigger within the noise cameras would be set low enough to ensure that all data would be collected during the site trials. This approach ensured all data was captured and was available during review/analysis of the measured noise levels. The post processing of the data collected during the trial allowed for the initial noise thresholds to be tested against the pass-by noise levels for those vehicles on test that were considered to be excessively noise.

Meteorological data was recorded throughout the trial using the weather station provided by UTAC Millbrook at the test track. The data collected included air pressure, humidity, air temperature, road surface temperature, wind speed and direction.

5.1.1.1. Full Type Approval Test Summary

The FTA test was undertaken in accordance with the relevant ISO test methods at a constant speed of 50 km/h (31 mph) and full throttle acceleration. However, where applicable, older iterations of the test method (i.e. UNECE Reg 51.02) were also used for cars on test as these older iterations were in place at the time of testing for that model and age of vehicle (see Table 5-3).

5.1.1.2. Partial Type Approval Test Summary

The PTA test was a modified version of the FTA that allowed for vehicles to be recorded at varying speeds (namely 30, 40 and 50 mph). The gears selected for each pass-by test were selected by the driver/rider as being most appropriate for the speeds. Two tests were performed at each speed, with a tolerance of ± 3 mph of the target speed.

5.1.1.3. Adverse Weather

FTA testing cannot be undertaken during adverse weather conditions (i.e. a wet test surface or wind speed above 5 m/s). As such, all Part A tests (including the PTA tests) were paused during such conditions and recommenced when wind speeds were below 5 m/s and the track test surface was dry.

5.1.1.4. Data Collected

The data collected during the test trials included all of that which would normally be collected during FTA testing. This included the broadband noise levels measured at the Millbrook microphones and 1/3 octave band data (both as L_{AFmax}), along with vehicle speeds and acceleration. The AJJV equipment was set up to also record broadband sound and 1/3 octave band data (both L_{AFmax} and L_{Aeq} sound levels).

5.1.2. Test vehicles and aftermarket products

The vehicles presented in Table 5-1 were included in the Part A test work.

Table 5-1 Test vehicles

Vehicle	Model	Year of manufacture	Type approval level of vehicle when new (Sound Level Drive By), L_{AFmax}
A	Yamaha NMAX 125cc motorcycle	2016	*
B	BMW F700GS motorcycle (700cc)	2016	79 dB
C	BMW K1200S motorcycle (1200cc)	2007	80 dB
D	Honda Civic Type R 2.0L	2017	72 dB**
E	Ford Focus ST 2.5L	2006	74 dB
F	BMW M3	2002	*

Notes:
* Sound level pass-by was not available for this vehicle.
** The Honda Civic Type-R that was used during the trials was an American import and hasn't been registered. The UTAC engineers stated that it is almost identical to the European model. The pass by sound level quoted is that of a European specification Honda Civic Type R of the same age.

The test vehicles included in the trial covered a range of engine powers and sizes. All of the vehicles A to E were owned by UTAC Millbrook and were regularly serviced and maintained. Vehicle F was an additional vehicle available during the trial that was fitted with a sports exhaust.

For representation of motorcycle power and sizes the motorcycles chosen ranged from small (vehicle A) to large (vehicle C). Vehicles D and E were chosen as a representative high-performance sports cars. Vehicle E was a common vehicle to be fitted with aftermarket products and was therefore considered to provide a good representation of the noise levels that may be generated by modified cars in a roadside environment.

Following the FTA and PTA tests, two vehicles were fitted with aftermarket products by UTAC Millbrook. The changes were as follows:

- Exhaust – vehicle C had a slip-on carbon fibre finish aftermarket product branded as a sports exhaust fitted and vehicle E had a cat back system (non-resonator) sports exhaust fitted. The exhaust system on vehicle C came supplied with an internal baffle (or 'bung') that restricts airflow and noise emission. The UTAC Millbrook technicians were able to remove the bung, thereby increasing noise levels in those tests where the bung was removed, and replicating how these type of aftermarket exhausts could be modified after purchase.

- Engine Remapping – vehicle E had performance engine remapping which allowed for the following three setting to be selected: standard (unaltered), de-cat tuned, and de-cat tuned with 'pops and bangs'. The phrase 'pops and bangs' relates to the effect where noise is generated on the vehicle overrun. Normally fuel is stopped when letting off the accelerator, but the remapping changes this to continue to inject fuel and change the ignition timing. This results in timing being retarded to a point when it sparks the mixture very late in the engine combustion cycle and the igniting of the fuel happens in the exhaust rather than the engine.

Vehicle F was only tested in the format with the aftermarket products. These were a sports exhaust, high-flow air filter in standard air filter housing, a higher differential gear ratio, performance engine remapping (without 'pops and bangs') and wide tyres with race specification compound.

5.1.3. Subjective testing

During the track trial, testing was undertaken to better understand the correlation between the perception of vehicle noise emission and the corresponding noise levels. The subjective testing was carried out on the same area of the UTAC Millbrook test track as the Part A noise tests. Six participants were present, comprising a member of the client project team and five police officers. The participants witnessed several examples of real-life traffic scenarios and driver behaviour, with noise measurements undertaken simultaneously at the same locations as the FTA and PTA testing.

For each test the observers were requested to score the noise from the test vehicle using the following scale:

1. Normal for that type of vehicle
2. Loud but not disturbing
3. Noisy
4. Excessively noisy

Table 5-2 shows the different driving tests undertaken for the subjective testing. Each test was conducted twice, once in each direction of travel along the test track, with the microphone the same distance from the vehicle for each test. The observers stood in the safe observation zone which was behind the measurement microphone but far enough away to avoid influencing the sound measurements. The vehicle tests were designed to provide a range of noise levels using vehicle C and vehicle E in different levels of modification. Vehicle C was demonstrated with the sports exhaust fitted and the internal exhaust bung removed. Vehicle E was demonstrated with a sports exhaust fitted and a performance engine remap. The performance engine remap was shown in two different states, standard condition and performance with additional 'pops and bangs'.

Table 5-2 Subjective test details

Vehicle	Test name	Description
E (Car)	C1	Slow moving before hard acceleration ('pops and bangs' occurred during both run 1 and 2)
	C2	Drive by at 40 mph

Vehicle	Test name	Description
	C3	Full acceleration up to monitoring site then shut off to allow engine braking ('pops and bangs' occurred during run no.1)
	C4	Drive by at 20 mph with higher gear
	C5	Same as C4 but in standard engine remap condition
	C6	In lower gear and hard acceleration
C (Motorcycle)	M1	Slow moving before hard acceleration
	M2	Drive by at 40 mph
	M3	Full acceleration up to monitoring site then shut off to allow engine braking
	M4	Drive by at 20 mph with higher gear
	M5	In lower gear and hard acceleration

5.2. Results

The results of the FTA and PTA noise level measurements are presented below in Table 5-3 and Table 5-4.

5.2.1. Full type approval testing

Table 5-3 shows the measured FTA noise levels for each test vehicle with results shown for wide open throttle (WOT) tests and cruise by (CRS) tests. Those vehicles where aftermarket products had been fitted were tested in both conditions (i.e. standard and with the aftermarket products). Vehicles D and E were tested to the current test method and also the old test method (UNECE Reg 51.02) that would have been applicable when the model of vehicle was type approved. The UNECE Reg 51.02 test was still a WOT test but the requirements in terms of vehicle test site entry conditions were such that higher noise levels were generated.

Table 5-3 Full type approval test results

Vehicle	Aftermarket product	Test condition	dB L_{AFmax}
A	None	WOT	79.7
		CRS	71.0
B	None	WOT	77.3
		CRS	70.8
C	None	WOT	78.8
	Sports exhaust with bung	WOT	84.9
	Sports exhaust without bung	WOT	93.4
D	None	WOT	74.2
		CRS	73.0
		Reg 5102	78.2
E	None	WOT	73.2
		CRS	68.0
		Reg 5102	75.6
	Sports exhaust	WOT	77.2

Vehicle	Aftermarket product	Test condition	dB L_{AFmax}
		CRS	67.9
		Reg 5102	96.0
	Sports exhaust with engine remap	WOT	76.7
		CRS	67.7
		Reg 5102	97.3
F	Sports exhaust	WOT	78.9

Notes:
WOT – Wide open throttle acceleration test at 50 km/h
CRS – cruise by test at 50 km/h
Reg 5102 - UNECE regulation 51.02 (previous version of current FTA test for cars)

The FTA results in Table 5-3, when compared to the level at which the vehicles were type approved (in Table 5-1), are shown below:

- Vehicle B - measured at 77 dB(A) (2 dB lower than the level at which it was type approved)
- Vehicle C (standard condition) - measured at 79 dB(A) (1 dB lower than the level at which it was type approved)
- Vehicle D - measured at 74 dB(A) (2 dB higher than the level at which it was type approved)
- Vehicle E (standard condition) - measured at 76 dB(A) (2 dB higher than the level at which it was type approved)

All measurements were within 2 dB of type approval levels, reasons for variation from type approval level could be, for example, due to variation in production of vehicles or in-service wear and tear.

A comparison cannot be made for vehicle A as the initial type approval for this motorcycle is unknown. In addition, vehicle F was not tested without the aftermarket products and so a comparison cannot be made.

5.2.2. Partial type approval testing

Table 5-4 shows the measured PTA noise levels for each test vehicle. Those vehicles where aftermarket products were fitted were tested in both conditions (i.e. standard and with aftermarket products). Not all vehicles were tested at all speeds due to time constraints or the capability of the vehicle. Where time was limited, what were considered as the most important speeds (namely higher speeds as noise emissions are typically higher) were targeted.

Table 5-4 Partial type approval test results

Vehicle	Aftermarket product	Speed (mph)	L_{AFmax} (dB)	L_{AFmax} change from previous speed (dB)	L_{AFmax} change vs. unmodified at same speed (dB)
A	None	20	66.9	-	-
		30	70.7	+3.8	-
		40	75.5	+4.8	-
B	None	20	65.2	-	-
		30	69.6	+4.4	-
		40	73.8	+4.2	-
		50	76.6	+2.8	-
C	None	20	69.7	-	-

Vehicle	Aftermarket product	Speed (mph)	L_{AFmax} (dB)	L_{AFmax} change from previous speed (dB)	L_{AFmax} change vs. unmodified at same speed (dB)
		30	71.6	+1.9	-
		40	73.9	+2.3	-
		50	75.8	+1.9	-
	Exhaust with bung	20	71.6	-	+1.9
		30	72.7	+1.1	+1.1
		40	75.4	+2.7	1.5
		50	78.3	+2.9	2.5
	Exhaust without bung	20	81.2	-	9.6
		30	82.5	+1.3	9.8
		40	82.6	+0.1	7.2
		50	82.7	+0.1	4.4
		60	86.0	+3.3	-
D	None	20	66.4	-	
		30	71.9	+5.5	
		40	75.8	+3.9	
		50	78.1	+2.3	
E	None	20	62.0	-	
		30	70.9	+8.9	
		40	71.5	+0.6	
		50	74.8	+3.3	
	Sports exhaust	20	62.7	-	0.7
		30	67.8	+5.1	-3.1
		40	70.4	+2.6	-1.1
		50	74.5	+4.1	-0.3
	Engine remap to generate 'pops and bangs'	30	67.8	-	-3.1
		40	70.8	+3.0	-0.7
	Engine remap for additional performance	20	61.0	-	-1.0
		30	66.9	+5.9	-4.0
		40	70.1	+3.2	-1.4
	Sports exhaust with engine remap to generate 'pops and bangs'	20	63.9	-	1.9
		30	68.0	+4.1	-2.9
		40	71.2	+3.2	-0.3
		50	75.5	+4.3	0.7
		60	85.0	+9.5	-
F	Sports exhaust	20	67.2	-	-
		30	72.4	+5.2	-
		40	76.0	+3.6	-
		50	79.0	+3.0	-

It should be noted that these tests were a cruise by with steady throttle position. This was not the style of driving that produces the 'pops and bangs' from vehicle E and therefore none of these were evident in PTA tests. In addition, a change of gearing may have influenced the changes in noise between speeds.

The PTA test results in Table 5-4 show that:

- The highest pass-by noise level at 50 mph for any vehicle in standard condition was 78 dB(A) for vehicle D.
- For vehicles C and E where it was possible to reach 60 mph, the measured noise levels at this speed were consistent around 85 dB(A).
- The smallest change in noise level with increased speed was observed for vehicle C with the aftermarket exhaust without the bung. This vehicle showed increases in measured noise levels of 1.3, 0.1 and 0.1 dB from 20 to 30, 30 to 40 and 40 to 50 mph, respectively. This indicates that the noise from a motorcycle with an aftermarket exhaust may be less dependent on vehicle speed than noise from a car.
- Vehicle C with the aftermarket exhaust without the bung generated the highest noise levels during the test trial, 86 dB(A) at 60 mph.
- Vehicle E in standard condition at 30 mph was measured at 71 dB(A), which is 3 to 4 dB higher than the noise level measured for the vehicle when fitted with aftermarket products, which may be due to variation in noise at different frequency bands. The noise levels measured at the maximum speed during testing (50 mph) were broadly comparable.
- The varied changes in noise as speed increases may have been a reflection of the gear selected for the test, as the test engineer selected the gear appropriate for that speed.

Figures 5-1 to 5-6 show the measured broadband noise levels measured during the FTA and PTA tests for all vehicles on test.

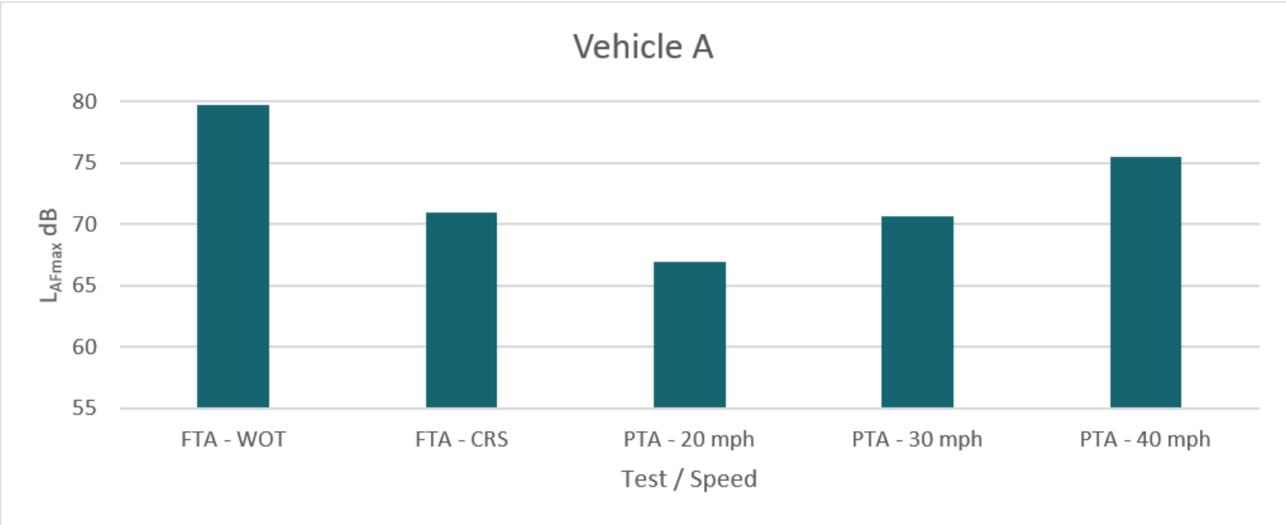

Figure 5-1 Measured broadband L_{AFmax} noise levels for vehicle A, 125cc motorcycle

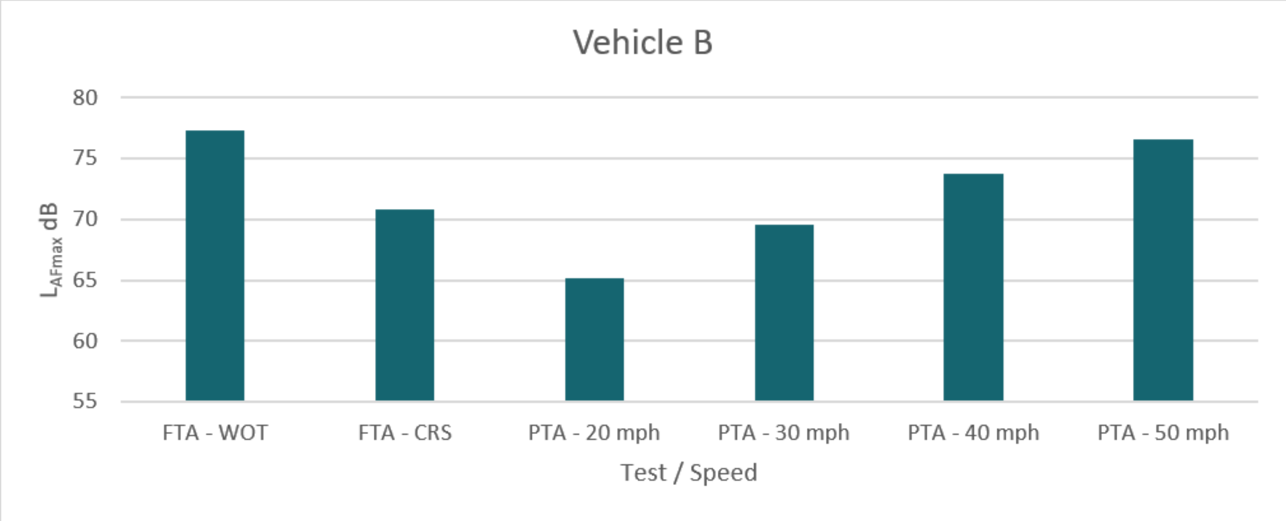

Figure 5-2 Measured broadband L_{AFmax} noise levels for vehicle B, 700cc motorcycle

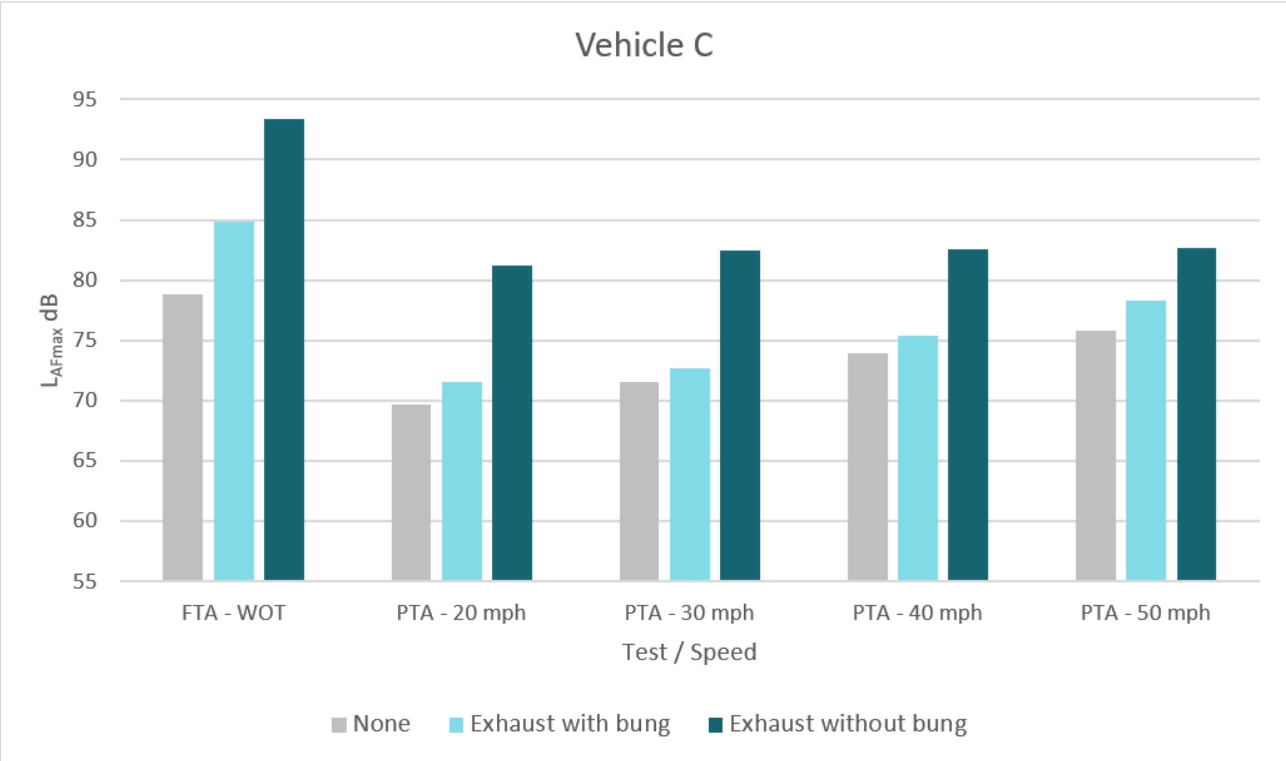

Figure 5-3 Measured broadband L_{AFmax} noise levels for vehicle C, 1200cc motorcycle

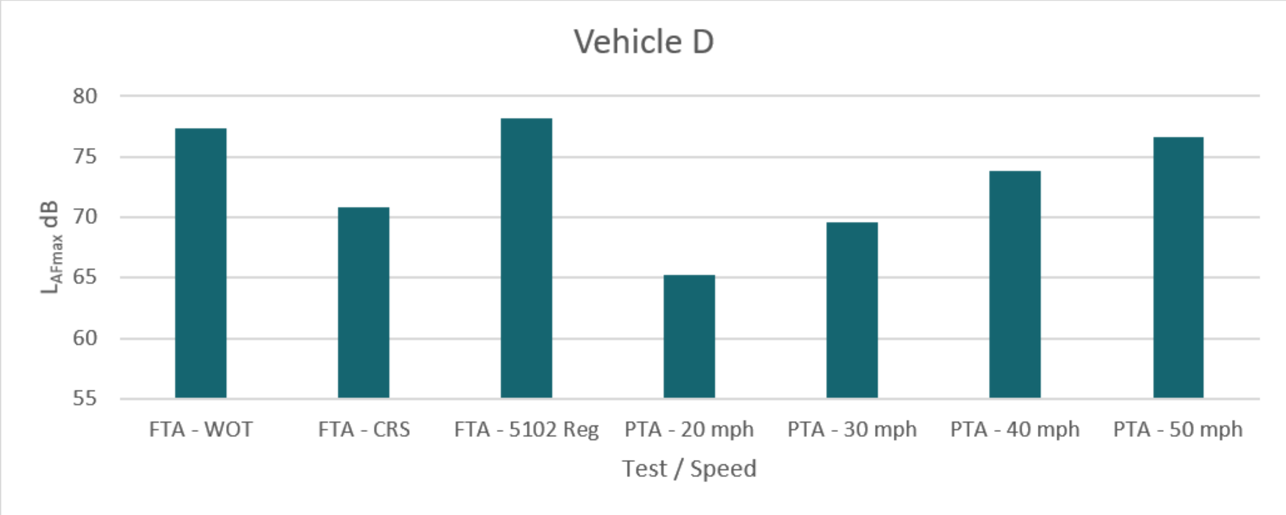

Figure 5-4 Measured broadband L_{AFmax} noise levels for vehicle D, Honda Civic Type-R

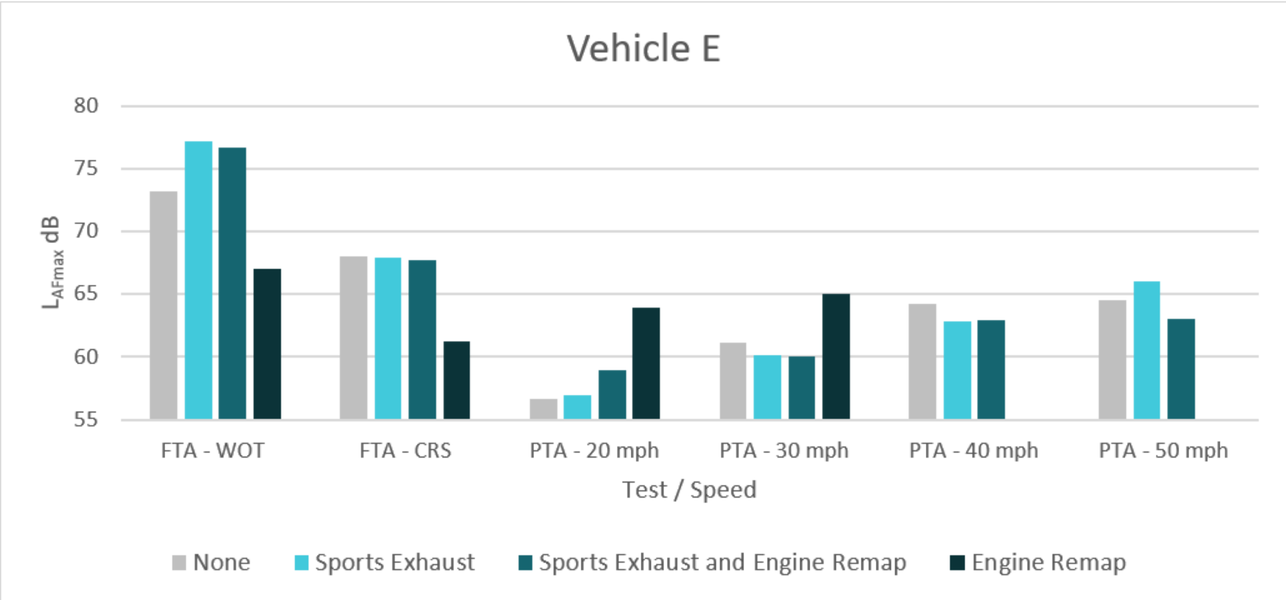

Figure 5-5 Measured broadband L_{AFmax} noise levels for vehicle E, Ford Focus ST

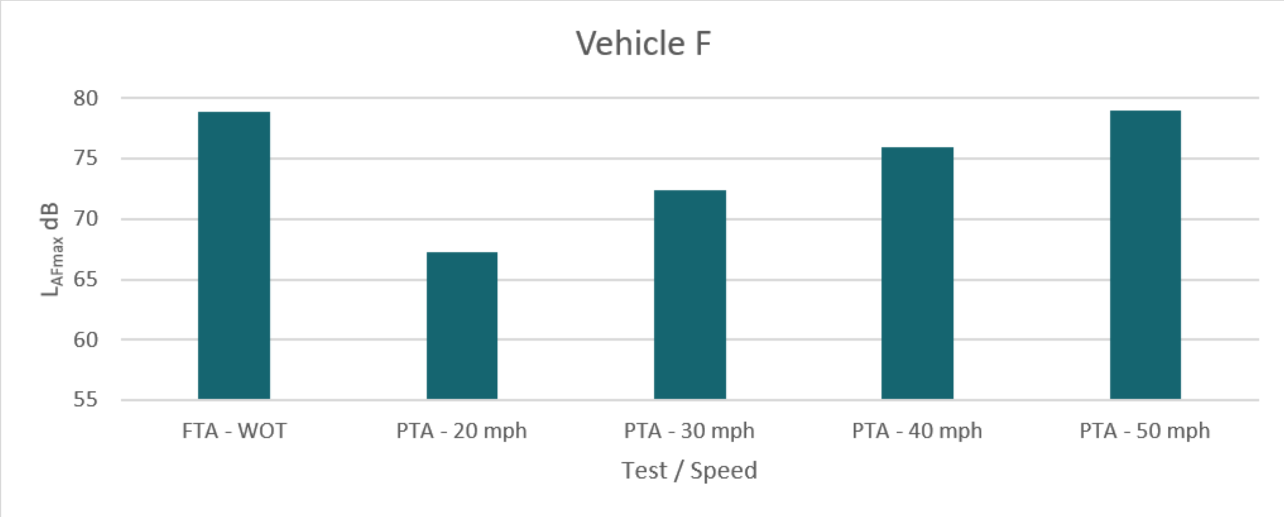

Figure 5-6 Measured broadband L_{AFmax} noise levels for vehicle F, BMW

5.2.3. Frequency component

Figure 5-7 and Figure 5-8 presents the L_{AFmax} noise spectra for the vehicles fitted with aftermarket exhausts during the wide-open throttle FTA tests. The measured noise levels in Figure 5-7 (vehicles C and F) show spikes in noise levels between approximately 63 and 160 Hz, however the highest noise level contributions tended to be between approximately 63 Hz and 1 kHz (low-mid frequencies). The variation in the spikes that are evident at low frequencies, in Figure 5-7, are similar to those identified for the vehicles exhibiting the highest noise levels from the Phase 2 work. The measured noise levels in Figure 5-8 (vehicle C) show spikes in noise levels between approximately 125 and 400 Hz.

It is worth noting that the number of vehicles with aftermarket exhausts shown in Figure 5-7 and Figure 5-8 is low, at just three, and as such any conclusions drawn from the data should be treated with caution. It should be noted that these tests were the WOT type approval test, and so the style of driving was not that which produces the 'pops and bangs' from vehicle E.

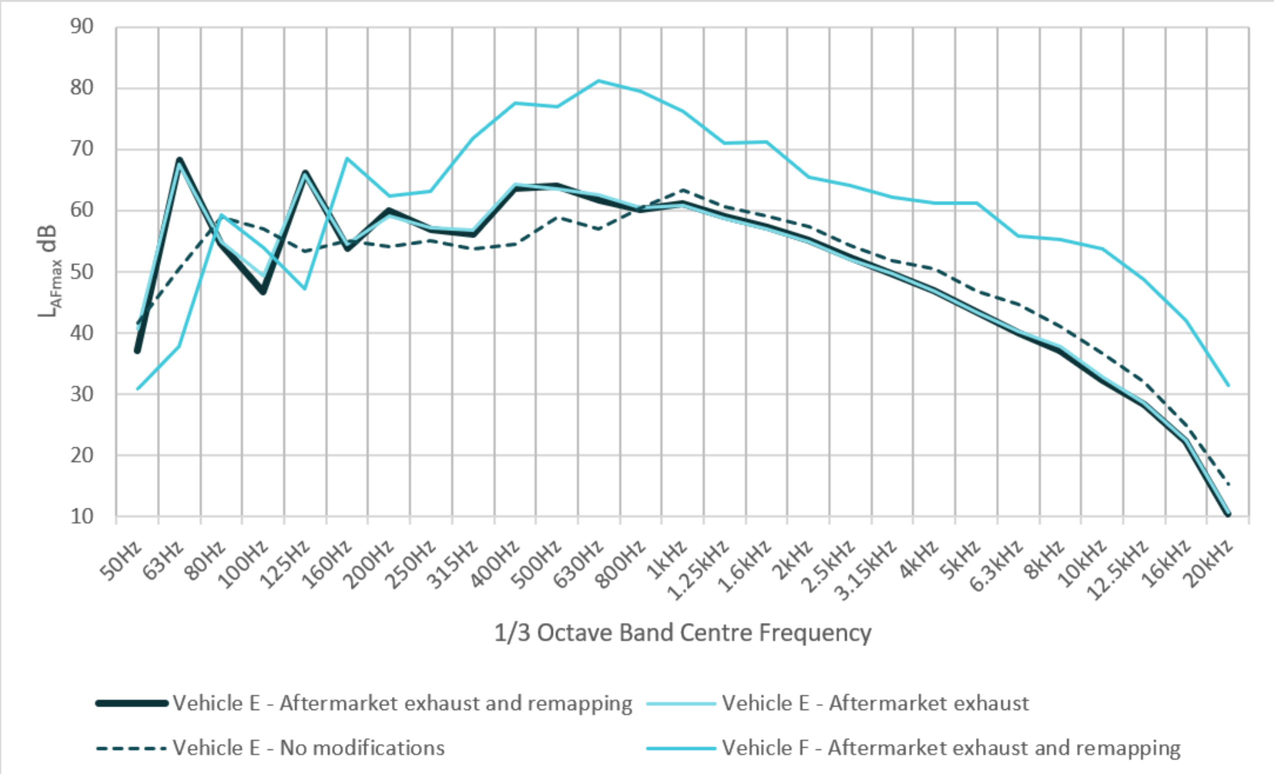

Figure 5-7 Noise spectrum for cars with and without aftermarket products

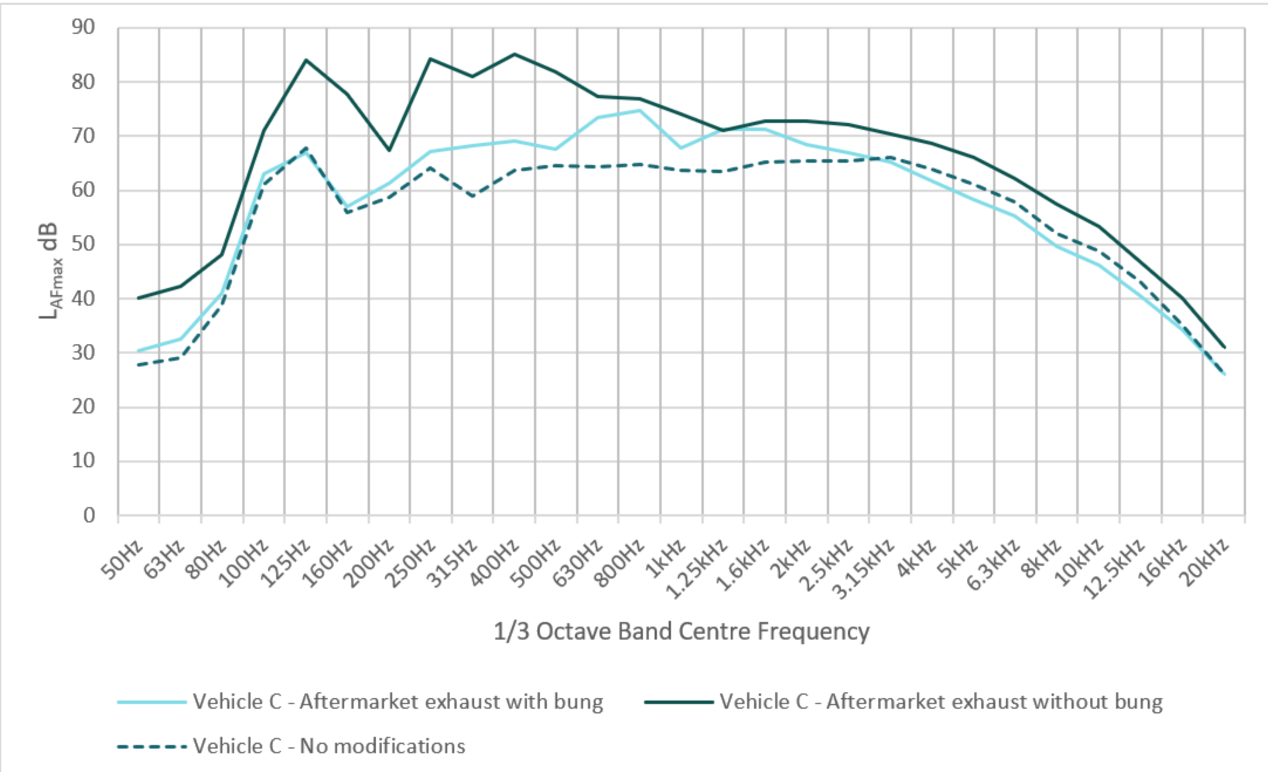

Figure 5-8 Noise spectrum for motorbike with and without aftermarket products

5.2.4. Subjective testing

The full results of the subjective tests are presented below in Table 5-5. The average score shown is the average response from all six subjects.

Table 5-5 Subjective test results

Vehicle and modifications	Test	Run	Maximum Sound Level (dB L_{AFmax})	Average score
E (Car) Aftermarket exhaust and engine mapping	Slow moving before hard acceleration	1	105	Excessively noisy
		2	105	Excessively noisy
	Drive by at 40 mph	1	97	Loud but not disturbing
		2	72	Normal for that type of vehicle
	Full acceleration up to monitoring site then shut off to allow engine braking	1	107	Excessively noisy
		2	82	Loud but not disturbing
	Drive by at 20 mph with higher gear	1	87	Loud but not disturbing
		2	78	Loud but not disturbing
	Same as C4 but in standard engine remap condition	1	87	Loud but not disturbing
		2	75	Normal for that type of vehicle
	In lower gear and hard acceleration	1	101	Noisy
		2	95	Noisy
C (Motorcycle) Aftermarket exhaust with bung removed	Slow moving before hard acceleration	1	90	Loud but not disturbing
		2	91	Loud but not disturbing
	Drive by at 40 mph	1	85	Loud but not disturbing
		2	82	Normal for that type of vehicle
	Full acceleration up to monitoring site then shut off to allow engine braking	1	98	Noisy
		2	98	Noisy
	Drive by at 20 mph with higher gear	1	97	Noisy
		2	94	Loud but not disturbing
	In lower gear and hard acceleration	1	96	Noisy
		2	97	Noisy

The results of the subjective test show that of the six tests with the car with the aftermarket products (vehicle E), two of the tests were considered to be 'excessively noisy' by those observing. These tests were when the 'pops and bangs' occurred, and the noise level was of 105 and 107 dB L_{AFmax}.

None of the five motorcycle tests were considered to be excessively noisy. The highest noise level from any of the tests with vehicle C was 98 dB L_{AFmax}.

A summary of the results from the tests is presented in Table 5-6. These are presented as the arithmetic average of all the noise levels from the tests scored in each category.

Table 5-6 Summary of results from the subjective testing

	Normal for that type of vehicle, dB L_{AFmax}	Loud but not disturbing, dB L_{AFmax}	Noisy, dB L_{AFmax}	Excessively noisy, dB L_{AFmax}
Vehicle E (car)	74	86	98	106
Vehicle C (motorcycle)	82	90	97	-
Combined	77	88	98	106

The results from the subjective tests show that as the noise increases, so does the subjective response. For the car (vehicle E) and the motorcycle (vehicle C), the incremental increase in noise level is very consistent across the scoring categories. This is then reflected in the combined score.

It should be noted that the tests were undertaken in the controlled conditions of the UTAC Millbrook test track where there were no other vehicles present during the test and the background noise level is low. If other vehicles were passing during the test, then it is possible that the noise from the test vehicle may have been more in context with perhaps a more normal expected noise level from other vehicles. This lack of perspective and perhaps the not-real-world test situation with a known noisy vehicle may have influenced the scoring. The low background noise at the UTAC Millbrook test track could also have influenced the scoring, with the test vehicles appearing to increase the background noise level by a large amount. These factors may have influenced some individual's scoring more than others. However, given the consistency in the scoring the results from the subjective testing, these results show that the noise level where the test vehicle was considered noisy is higher than the initial proposed enforcement value for excessively noisy vehicles.

6. Discussion

6.1. Noise threshold level – single value or bespoke

Chapter 4 of this report contains an initial review of the advantages and disadvantages of a single noise threshold or a set of noise thresholds for a range of vehicle types. It was concluded that while a bespoke noise threshold approach (i.e. a threshold for different vehicle categories or different vehicles) may be the most accurate, it would be difficult to implement. Following this initial suggestion, the test work at UTAC Millbrook has been reviewed to determine whether there is any evidence that this suggestion should be changed. This has focussed on whether there is any difference between the results from the cars and motorcycles.

The results from the FTA tests have shown that the standard motorcycles and cars do show a difference in noise, with the noise level from the motorcycles being around 4 dB above the cars. This is not unsurprising given the higher type approval noise level for motorcycles. Overall, the noise levels were all below 80 dB L_{AFmax}, which from the subjective tests would on average be classed as ‘normal for that type of vehicle’.

The results from the tests with the vehicles fitted with aftermarket products have shown a similar difference in noise level of around 4 dB in the FTA test (97 dB L_{AFmax} for the motorcycle to 93 dB L_{AFmax} for the car). These noise levels would be classed as between ‘loud but not disturbing’ and ‘noisy’.

During the PTA tests with the vehicles fitted with aftermarket products there was just 1 dB difference at 60 mph between the motorcycle and the car, with the motorcycle being the higher (86 dB L_{AFmax} to 85 dB L_{AFmax}). The subjective testing would class this noise level around ‘loud but not disturbing’.

The results from the subjective test work at UTAC Millbrook (see Chapter 5) have shown that the motorcycle was never classed as excessively noisy. However, the highest noise levels were generated by the car and it was only these that were classed as ‘excessively noisy’. Reviewing the highest category where comparable data is available (i.e. ‘noisy’), the results between the car and motorcycle are only 1 dB different. Given these small differences between cars and motorcycles it is not considered that there is justification for a different noise threshold between cars and motorcycles and that a single figure noise threshold is therefore now considered as the most appropriate.

6.2. Acoustic characterisation of noisy vehicles

The fitting of aftermarket exhaust products has changed the characteristics of the vehicles tested. Considering the vehicles that were tested with their standard exhaust systems and then an aftermarket product, the following can be considered:

For the PTA test at 50 mph with vehicle C (motorcycle), the noise level increased from 76 dB L_{AFmax} to 83 dB L_{AFmax} following the fitting of the aftermarket exhaust. For vehicle E (car), the noise level remained at 75 dB L_{AFmax} following the fitting of only the aftermarket exhaust (i.e. no engine mapping).

For the FTA WOT test with vehicle C (motorcycle) the noise level increased from 79 dB L_{AFmax} to 93 dB L_{AFmax} following the fitting of the of aftermarket exhaust. For vehicle E (car), the noise level increased from 73 dB L_{AFmax} to 77 dB L_{AFmax} following the fitting of only the aftermarket exhaust (i.e. no engine mapping).

Both these comparisons show that the increase in noise is far more evident on the motorcycle than the car with the fitting of an aftermarket exhaust product. The effects of the engine mapping on vehicle E (i.e. the ’pops and bangs’) were not evident in the FTA or PTA due to the nature of tests.

The characteristics can also be considered by examining the frequency component of these two vehicles with and without the aftermarket exhausts. These are presented in Figure 6-1 for the 50 mph (80 km/h) PTA test and in Figure 6-2 for the FTA test at 50 km/h.

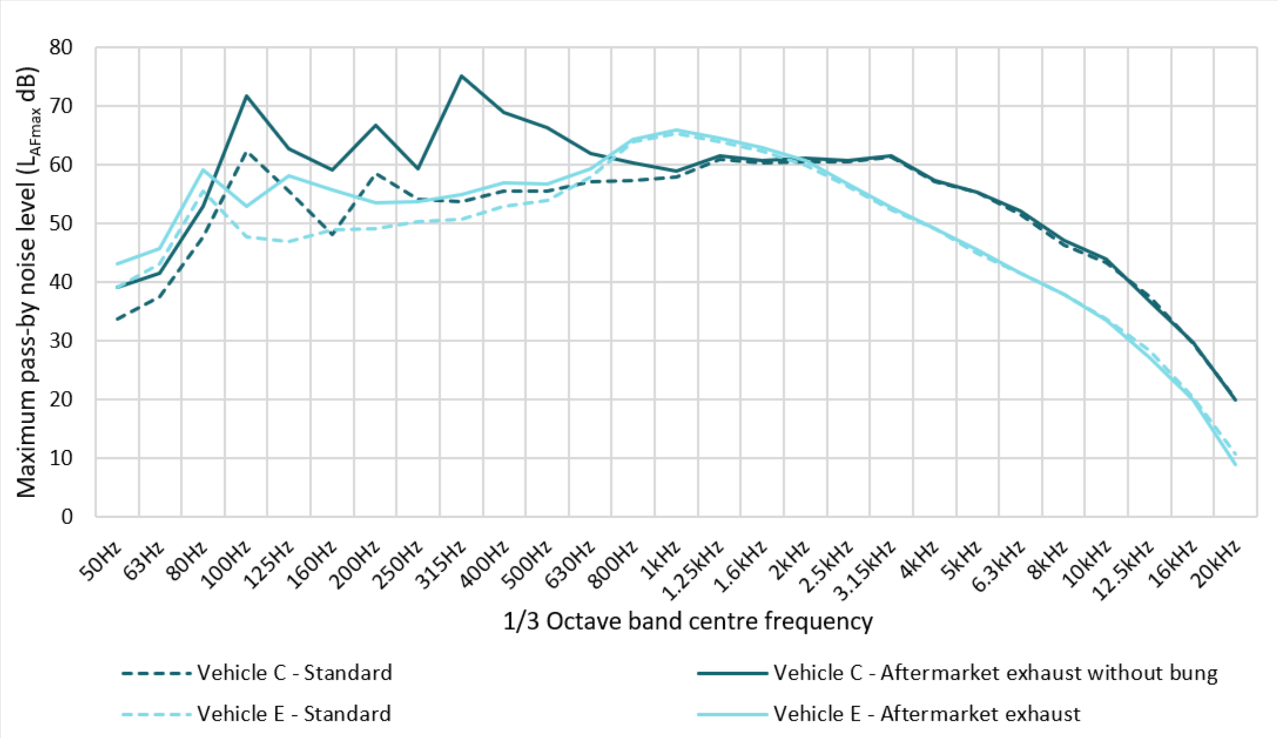

Figure 6-1 80 km/h PTA frequency characteristics of standard condition and fitted with aftermarket exhausts

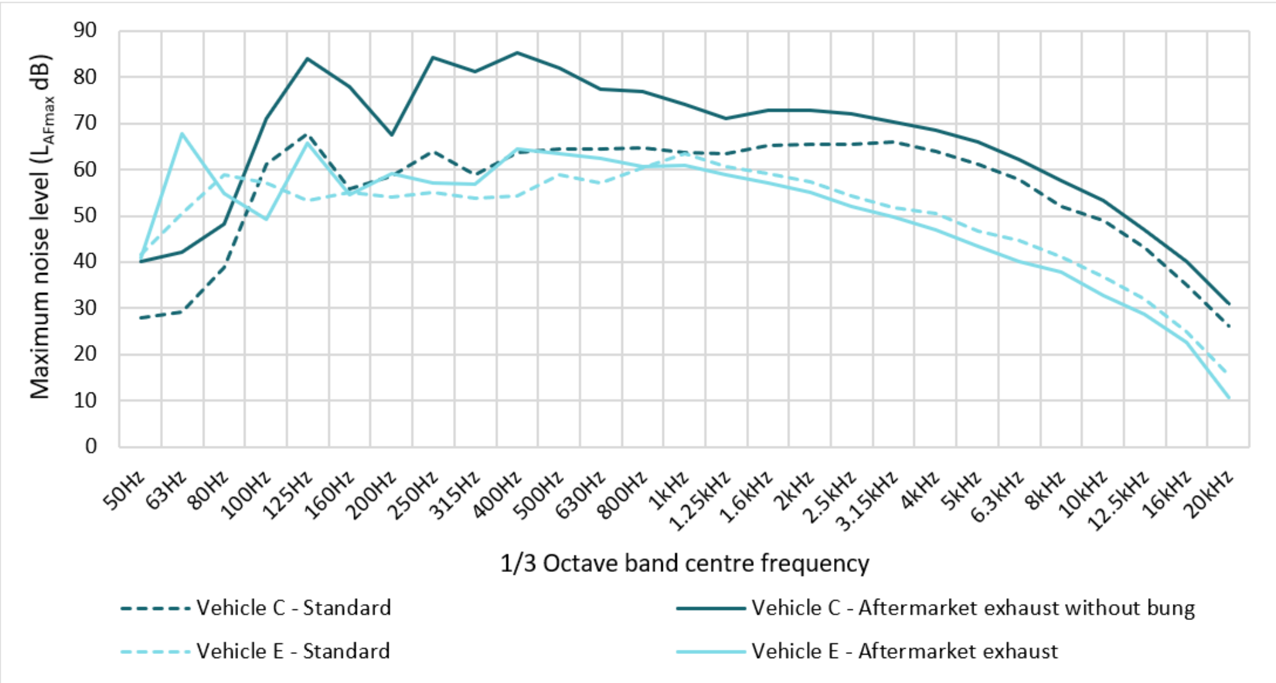

Figure 6-2 50 km/h FTA frequency characteristics of standard condition and fitted with aftermarket exhausts

Both figures show a more pronounced difference for vehicle C (motorcycle) between the standard and aftermarket exhaust conditions. The differences in the frequency bands for the standard and the vehicle fitted with the aftermarket exhaust for both vehicles are greater at the lower frequencies, with vehicle C showing the greatest differences. Vehicle C also exhibited a higher noise level at all frequencies with the aftermarket exhaust, whereas vehicle E this was not always the case with the FTA test (Figure 6-2). During the PTA test (Figure 6-1), both vehicles produced very similar noise levels from 1 kHz upwards. For both vehicles in both tests the aftermarket exhausts demonstrate a greater change between frequency bands below 1 kHz, which is a clear characteristic of a noisy vehicle, with the aftermarket product exaggerating certain frequencies. Other aftermarket exhaust products are expected to have similar characteristics but could exhibit higher levels in different frequency bands.

In terms of what may be considered as being excessively noisy, the only vehicle to be classed as 'excessively noisy' by the subjective testing was the car with the engine mapping. This was during a test when the measured noise level was up to 107 dB L_{AFmax} due to the 'pops and bangs'. The characteristics of the noise that caused this to classed as excessively noisy was the overall noise level and the sudden and unexpected noise.

6.3. Tolerances (Uncertainty in measurement)

To be an accurate and reliable representation of the actual noise level, a measured noise level is dependent upon several factors. These factors have been considered to determine whether a tolerance (correction for uncertainty in measurement) needs to be applied to the noise threshold level being used.

6.3.1. Road speed

An increase in vehicle noise generally occurs with an increase in vehicle speed [15]. It is therefore possible that different noise thresholds could be used for roads with different speed limits.

The maximum noise level measured during the PTA test at 50 mph for any vehicle in standard condition was 78 dB L_{AFmax} (vehicle D). The tests at 60 mph for vehicles C and E with aftermarket products gave pass by levels of, respectively, 86 and 85 dB L_{AFmax}. These noise levels are still 10 dB below the noise level that was deemed as 'noisy' from the subjective testing, and it is therefore considered that no adjustment is required to account for the speed limit of the road.

There were no tests undertaken at speeds up to 70 mph as this speed was not possible on the testing area used at UTAC. It is considered that should a noise camera be used on roads with a speed limit of 70 mph then the proposed noise threshold level would still be appropriate.

6.3.2. Road surface

The road surface type is a factor than can influence the generation of noise, mainly through the interaction of the surface and the vehicles' tyres and when vehicle speeds are above 75 km/h (~50 mph). Below this speed the engine noise is assumed to be the dominant factor in the generation of noise [16]. The influence the surface has on noise generated from motorcycles is less prevalent due to less contact space and generally narrower tyres.

A vehicle travelling along a concrete road surface generally generates the highest levels of noise compared with other surfaces. Noise can be in excess of 5 dB(A) above Hot Rolled Asphalt [17]. A concrete road surface could therefore become a factor that may require a tolerance where a noise camera is installed alongside a concrete road. This is because the noise generated, especially by cars, could cause a vehicle to be classed as excessively noisy on roads where the tyre / road noise is dominant.

Before a tolerance is considered, the situations where this may arise are examined. Concrete has mostly been used on high-speed roads that carry large volumes of traffic. Concrete on high-speed roads is now becoming less common, and the government has a priority to phase out remaining sections [18]. It is initially recommended that noise cameras are not deployed alongside roads with concrete surface with speed limits of 50 mph or greater. The use of cameras in areas with a concrete road surface and speed limits less than 50 mph are expected to be minimal.

6.3.3. Night-time noise

The influence of time of day on the listeners response to a potentially excessively noisy vehicle has not been observed in this study. It is common for the night-time period (typically defined at 23:00 to 07:00) to be identified as more sensitive and assigned lower permissible noise thresholds as a result. For example, the following assessment guidance all identify night-time periods as more sensitive and subject to lower noise thresholds:

- BS 5228-1 [19]. Night-time noise threshold for construction is 20 dB lower than daytime threshold.
- World Health Organisation [20] [21] recommends lower noise thresholds for night-time periods.
- Institute of Environmental Management and Assessment [22] suggests the night-time period is more sensitive as ‘people are generally trying to fall asleep, are asleep or trying to fall back to sleep’, and that ‘noise can disturb these activities’.

However, within The Road Vehicles (Construction and Use) Regulations [4] when defining excessively noise, there is no reference made to day or night. Without questioning a large sample of enforcement officers, it is not known whether the time of day is consciously or subconsciously taken into consideration when determining whether a vehicle is deemed to be excessively noisy.

This could be through either a consideration of the background noise level or a view that excessive noise should be more controlled at night. Due of this lack of evidence, it is considered that the same suggested noise enforcement level should initially be used for day and night periods.

6.3.4. Weather

The main weather factors that can influence a measured noise level of a vehicle are wind (direction and speed) and rain, which creates a wet surface on the road that can generate additional tyre spray noise. Changes in road surface temperature can also affect the generation of road/tyre noise.

6.3.4.1. Wind

The wind direction can influence a measured noise by either increasing (downwind) or decreasing (upwind) the noise level. However, at such short distances that a noise camera would be in relation to the vehicle under measurement, this influence would be negligible and a tolerance would not be required [23].

A similar conclusion is likely for wind speed unless in extreme conditions where buffeting of the microphone could distort an audio measurement. It is considered that this situation is best dealt with as part of an evidence pack as opposed to adding a tolerance for wind speed, since this may be difficult to measure in some situations (e.g. an urban environment with tall buildings).

6.3.4.2. Rain

A wet road surface can influence the generation of tyre/road noise, with the presence of water generating higher levels of noise. The wet track caused an increase of up to 10 dB L_{AFmax} for Vehicle E due to the larger total contact area between the tyres and surface. The increase in noise is due to high frequency (>1000 Hz) noise caused by the interaction of the tyres with the road surface, as shown in Figure 6-3 and Figure 6-4 The lower frequency noise (50Hz – 1000Hz) remained relatively unchanged for both vehicle types (vehicles C and E) as this component of the frequency spectra is dominated by noise from the vehicle exhaust and engine.

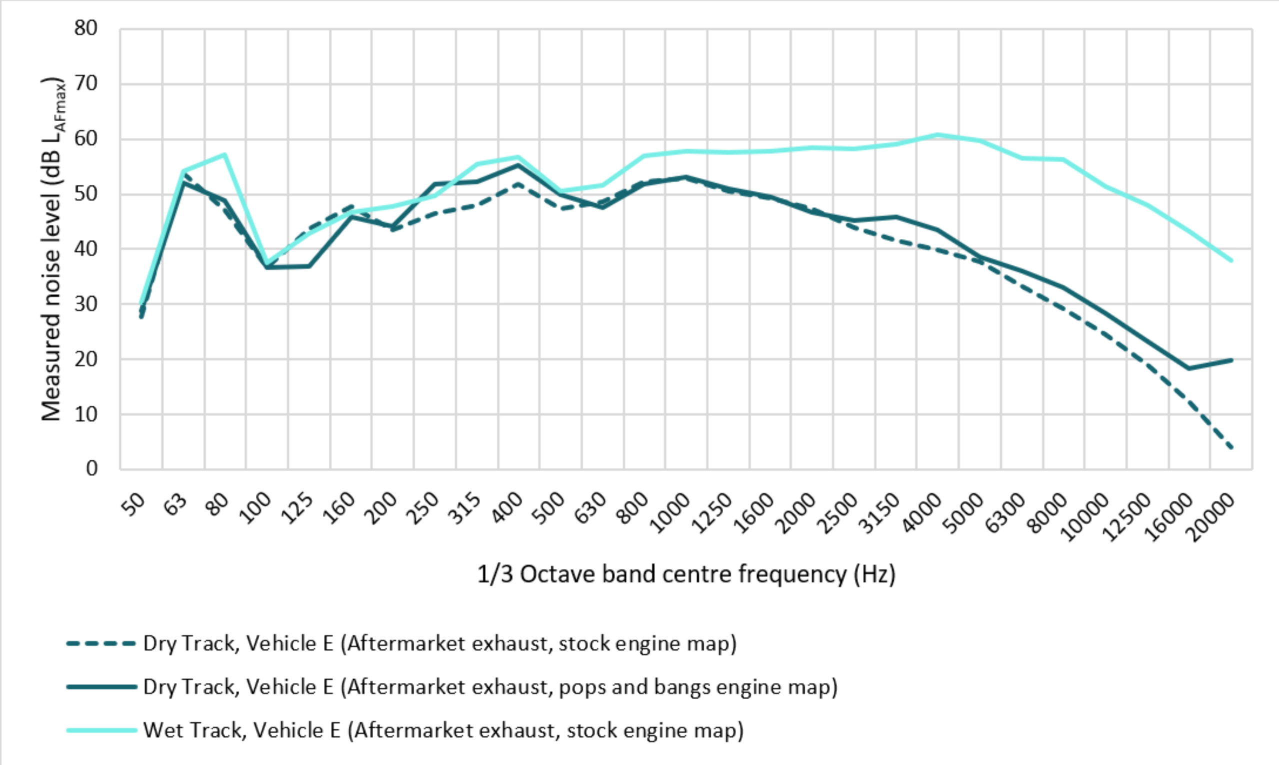

Figure 6-3 Single vehicle pass-by noise levels at 20mph during different track conditions

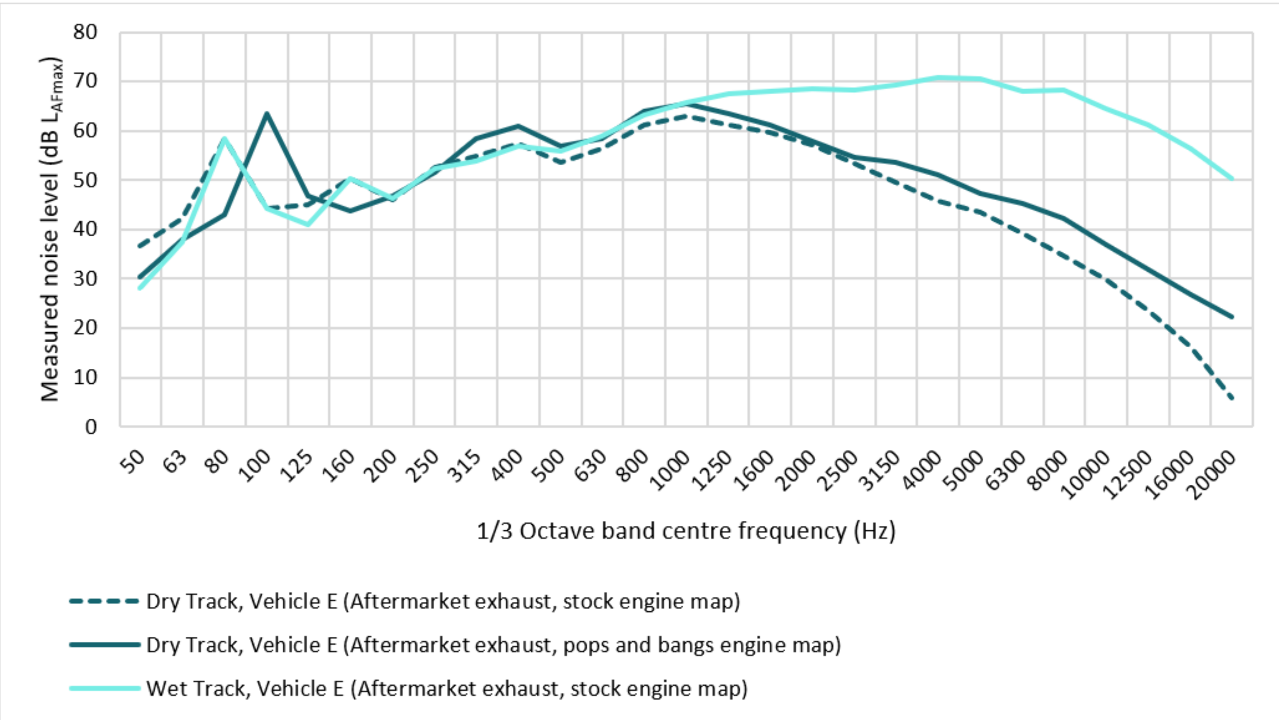

Figure 6-4 Single vehicle pass-by noise levels at 40mph during different track conditions

The tests at UTAC Millbrook have shown that noise levels can be up to 10 dB higher between a dry and very wet road. The addition of 10 dB to the noise from a vehicle that may be noisy (but not excessively so) cause it to trigger the threshold being used by an automated system. Therefore, a tolerance could be considered for wet roads. However, given that the UK often experiences wet weather it is considered that many instances of excessively noisy vehicles would be lost if enforcement is only undertaken when the road surface is dry. In addition, a classification of 'wetness' of the road and its subsequent influence on measured noise levels at a noise camera would need to be determined. This classification of 'wetness' would then need to be measured in the location of the noise camera deployment.

For noise cameras that collect frequency data, an approach for reducing any wet weather false positives could be to focus the data collection on noise emissions below 1250 Hz, as these frequencies (for the vehicle speeds considered in the study) were shown to be unaffected by wet road surfaces and are often the frequency components most associated with excessively noisy vehicles. However, this approach is only viable if there are no sources of excessive vehicle noise in the higher frequencies that should be enforced against.

Given the potential difficulties it is considered that a tolerance should not be applied for wet road and that an enforcement officer should easily be able to distinguish between noise from a vehicle travelling on a wet road to that of an excessively noisy vehicle.

6.3.4.3. Road temperature

The temperature of the road surface can influence the generation of tyre/road noise [24]. However, given the aim of the project is to capture those vehicles generating an excessive amount of noise, any influence from the temperature of the road surface is considered negligible and no tolerance is required.

6.3.5. Sound level meter

The quality of the device used for measuring the noise and the accompanying microphone is one essential part of the measured level being an accurate representation of a passing vehicle. Sound level meters are classed as either Class 1 or Class 2 in BS EN 61672, with Class 1 being more accurate. The differences between the two types are larger when examining some aspects of the frequency component of a measured level. Given that an excessively noisy vehicle could exhibit high levels of noise in either low frequency (generally exhaust noise) or mid-high frequency (engine) bands, it is possible that a tolerance could be applied for the class of sound level meter being used.

Around 800 to 1,250 Hz, which is generally the dominant frequency range for a vehicle, a Class 1 calibrated sound level meter has an accuracy performance of ± 1 dB, whereas for a Class 2 sound level meter this is ± 1.5 dB [13]. At a lower frequency of 63 Hz, where it is not uncommon to see a peak from a vehicle with an aftermarket exhaust (see Figure 5-7 and Figure 5-8), the performance is still ± 1dB for Class 1 sound level meter but ± 2 dB for a Class 2 sound level meter. At a higher frequency of 4,000 Hz the accuracy performance is ± 1 dB for Class 1 sound level meter but ± 3 dB for a Class 2 sound level meter.

Given the differences in accuracy performance of the two Classes of sound level meter are small in decibel terms relative to the overall noise level identified in Section 5 of this report as being 'excessively noise' or even 'noisy', it is not considered that a tolerance is required for the class of sound level meter being used.

6.3.6. Equipment Location

Whilst the tests undertaken have been kept simple, it is considered that the location of the camera may be an influential aspect in determining whether a tolerance needs to be applied. For example, noise levels may be higher in urban situations where noise is reflected from buildings and other structures. Insufficient data is available to quantify if such a tolerance is needed or suggest a magnitude if needed. It is noted that constraints on where noise cameras can or cannot be used have potential to reduce the need for this type of tolerance.

7. Conclusion and Recommendations

The recommended noise threshold level is presented below, together with remaining knowledge gaps and further recommendations should the project proceed to Part C (roadside trials).

7.1. Recommended noise threshold level

Based on the findings presented in this report it is proposed that a single figure noise threshold for enforcement of **95 dB** L_{AFmax} be adopted for the trials with a roadside camera. This threshold level is higher than the provisional threshold proposed at the start of Part A, and has been adjusted following review of the findings of the Part A study. The proposed noise threshold is based on the findings of this study and set high enough so as to be unlikely to be reached by an unmodified well-maintained vehicle driven in a normal manner. At the start of the project, it was envisaged that the prosecution route would be via Construction and Use Regulations, where there is a need to prove a vehicle is 'excessively noisy'. The subjective trials undertaken at UTAC showed that a much higher noise level is required for a vehicle to be considered as excessively noisy, which would indicate that the initial threshold may have been set too low. Although using a different enforcement route, the experiences of RBKC showed that this level of 95 dB(A) is regularly exceeded and fines being issued.

It is proposed that this threshold would apply to both cars and motorcycles, for day and night periods and would be appropriate at all speed limits. Discussion on these aspects has been contained in Chapter 6.

A single figure noise threshold is considered most appropriate as it does not distinguish between motorist groups (e.g. cars, motorcycles) and is aligned with emerging best practice where noise cameras are already in use. A single figure noise threshold would also likely be easier to enforce and easier in relation to public awareness / understanding.

The frequency component in terms of one-third octave bands has been examined to determine whether this can also be used to categorise an excessively noisy vehicle and be used as an additional trigger to the overall noise level. With the relatively small dataset obtained from the track trials, categorising an excessively noisy vehicle based on frequency content has proved inconclusive. Furthermore, not all of the noise cameras examined during the study currently have the capability to measure and report one-third octave band levels.

There are no recommended tolerances applied to the proposed noise threshold for weather conditions (including filtering out noise levels measured at frequencies above 1250 Hz), road surface, road speed, time of day or sound level meter measurement accuracy. If the work undertaken in Part C suggests that weather conditions cannot be adequately considered as part of an evidence pack then a tolerance may be required.

7.2. Knowledge gaps to fill in future research

The Part A testing is robust and has enabled a noise threshold to be set. During the Part A work some issues have arisen that may require further examination, these are listed below.

Whether the time of day, namely if the noise event occurs during the sensitive night-time period (typically defined as 23:00 to 07:00), influences the listeners response to a potentially excessively noisy vehicle and if this response either consciously or subconsciously considered when determining whether a vehicle is deemed to be excessively noisy. If it is felt, following further research, that the time of day has a material effect on the assessment outcome, then it may be appropriate for separate day and night noise thresholds to be explored. It is considered that knowledge can only be obtained through extensive subjective trials, which are beyond the scope of this project.

If future research was undertaken, a wider sample of aftermarket products could be tested to investigate whether a frequency component can be added to the recommended noise threshold level. A wider sample of aftermarket products would be needed in order to investigate this possibility further.

The only vehicle to be classed as ‘excessively noisy’ by the subjective testing was the car when fitted with the aftermarket exhaust and the engine mapping. This was during a test when the measured noise level was around 105 dB L_{AFmax}. The highest noise level measured from the motorcycle during the subjective testing was 98 dB L_{AFmax}, which was classed as ‘noisy’. It is unknown whether if the motorcycle (vehicle C) produced noise levels similar to that of the car it would have been classed as ‘excessively noisy’. The characteristics of the car when producing the highest noise levels (i.e. the ‘pops and bangs’ associated with the engine remapping) was a sudden increase in noise and quite distinctive to general traffic noise. It is unknown if such a sudden noise were to be produced by the motorcycle whether it too would be classed as ‘excessively noisy’.

7.3. Recommendations for Part C

The proposed noise threshold of 95 dB L_{AFmax} is untested in the roadside environment. However, it is recommended that a noise camera trigger level of 85 dB L_{AFmax} is set in order for all data above 85 dB L_{AFmax} to be recorded for research purposes. If, during the analysis of the data gathered during Part C, it is considered that the 95 dB L_{AFmax} threshold is too high, then the data captured below this level can be examined and a refinement made to the noise threshold. Should the recommended noise threshold be lowered, then the implications of separate values for different speed limits may need to be considered.

Should the chosen camera(s) for the Part C roadside trials be capable of obtaining one-third octave frequency data, it is recommended that this be examined to determine whether a frequency component could be added to the recommended noise threshold level. This could also potentially be used to identify excessively noisy driving styles.

8. References

[1] World Health Organisation, “Environmental Noise Guidelines for the European Region,” WHO, Copenhagen, 2018.

[2] Atkins Jacobs Joint Venture, “Roadside Vehicle Noise Measurement: Phase 1 Study Report and Technology Recommendations,” Department for Transport, London, 2019.

[3] Atkins Jacobs Joint Venture, “Roadside Vehicle Noise Measurement: Phase 2 Final Report,” 2020. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1007868/roadside-vehicle-noise-measurement-phase-2-final-report.pdf. [Accessed 29 11 2023].

[4] Her Majesty's Stationery Office, “Road Vehicle (Construction and Use) Regulations,” HMSO, London, 1986.

[5] Her Majesty's Stationery Office, “Anti-social Behaviour, Crime and Policing Act 2014; Chapter 2 Public spaces protection orders,” HMSO, London, 2014.

[6] Economic Commission for Europe of the United Nations, “Regulation No 51: Uniform provision concerning the approval of motor vehicles having at least four wheels with regard to their sound emissions [2018/798],” UNECE, 2018.

[7] European Union, “Regulation 168/2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles,” EU, 2013.

[8] “Environmental Noise,” Brüel & Kjær Sound & Vibration Measurement A/S, 2001.

[9] Economic Commission for Europe of the United Nations, “Regulation No 41 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of motor cycles with regard to noise,” UNECE, 2012.

[10] International Organization for Standardization, “ISO 362:2009 Measurement of sound pressure level emitted by accelerating road vehicles - Engineering method - Part 2: L category,” ISO, Geneva, 2009.

[11] International Organization for Standardization, “ISO 362:2015 Measurement of noise emitted by accelerating road vehicles - Engineering method - Part 1: M and N categories,” ISO, Geneva, 2015.

[12] International Organization for Standardization, “ISO 10844:2014 Acoustics - Specification of test tracks for measuring noise emitted by road vehicles and their tyres,” ISO, Geneva, 2014.

[13] British Standards Institution, “BS EN 61672-1 Electroacoustics. Sound level meters, Specification,” BSI, London, 2013.

[14] British Standards Institution, “BS EN 60942. Electroacoustics - Sound Calibrators,” BSI, London, 2018.

[15] Department of Transport and the Welsh Office, “Calculation of Road Traffic Noise,” HMSO, 1988.

[16] TRL, “Extension of CRTN road surface correction to lower speeds (PR SE/707/03 3/323 F-R0015),” Transport Research Laboratory, 2005.

[17] Highways Agency, “Noise assessment of concrete trunk roads opened since June 1988,” 2002.

[18] Department for Transport, “Roads Investment Strategy 2: 2020-2025,” London, 2020.

[19] British Standards Institution, “BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites - Part 1: Noise,” BSI, London, 2014.

[20] World Health Organisation, “Night Noise Guidelines for Europe,” WHO, Copenhagen, 2009.

[21] World Health Organisation, “Guidelines for community noise,” WHO, Geneva, 1999.

[22] Institute of Environmental Management & Assessment, “Guidelines for environmental noise impact assessment,” IEMA, 2014.

[23] B&K, “Environmental Noise,” Brüel & Kjær, Nærum, Denmark, 2001.

[24] F. Anfosso-Le´de´e and Y. Pichaud, “Temperature effect on tyre–road noise,” *Applied Acoustics,* vol. 68, pp. 1-16, 2007.

Appendix A. Glossary

Term	Definition
A-Weighting	This is a measure of the overall level of sound across the audible spectrum with a frequency weighting (i.e. ‘A’ weighting) to compensate for the varying sensitivity of the human ear to sound at different frequencies.
dB	Abbreviation of decibel.
dB(A)	Abbreviation of A-weighted decibel.
Cruise by (CRS)	A test where the vehicle is driven / ridden passed the test site at a steady speed and throttle setting.
Decibel	The scale on which sound pressure level is expressed. In air sound pressure levels are defined as 20 times the logarithm of the ratio between the root-mean-square pressure of the sound field and a reference pressure ($2x10^{-5}$ Pa).
F (fast) time weighting	(1) Averaging times used in sound level meters. (2) Time constant of one second that gives a slower response which helps average out the display fluctuations. Unless stated, all noise levels presented in this report are Fast time weighting.
Frequency	Repetition rate of a cycle, the number of cycles per second (Hertz, Hz).
Full Type Approval (FTA)	The current type approval test for a new vehicle.
L_{AFmax}	The A-weighted maximum sound pressure level occurring in a specified time period.
L_{Aeq}	A steady noise level (weighted) which over a period of time has the same sound energy as the time varying noise.
Octave	The range between two frequencies whose ratio is 2:1.
Partial Type Approval (PTA)	A series of cruise by tests at more than one test speed. Note this is a term derived for this test work and is not an industry term.
RBKC	Royal Borough of Kensington and Chelsea
Sound level meter	Device used to measure sound pressure levels.
Wide Open Throttle (WOT)	A test where the vehicle approaches the test site at a steady speed and throttle setting, and once the test site is reached the operator fully opens the throttle.

Appendix B. Type Approval Levels

Sound level limits for passenger cars, M1, and light goods vehicles (up to 3,500 kg), N1, are presented in EU Regulation 51 [6], as reproduced below.

Vehicle category	Vehicles used for the carriage of passengers	Limit Values (dB(A))		
		Phase 1	Phase 2	Phase 3
M_1	PMR ≤ 120	72	70	68
	120 < PMR ≤ 160	73	71	69
	PMR > 160	75	73	71
	PMR > 200, no. of seats ≤ 4, R-point height < 450mm from the ground	75	74	72
N_1	M ≤ 2.5 t	72	71	69
	M > 2.5 t	74	73	71
Notes: PMR – Power to mass ratio (defined in paragraph 3.1.2.1.1. of EU Regulation 51) M – Technically permissible maximum laden mass				

Phase 1, 2 and 3 sound levels are described in Annex 11 of EU Regulation 51 [6]. Phase 1 limits came into use in July 2016, with phases 2 and 3 introduced, or due to be introduced, later.

Sound level limits (Euro 4) for two and three wheeled vehicles and quadricycles, are presented in EU Regulation 168/2013 [7], as reproduced below.

Vehicle category	Vehicles used for the carriage of passengers	Euro 4 sound level (dB(A))	Euro 4 test procedure
L3e	Two-wheel motorcycle Engine capacity ≤ 80 cm^3	75	Delegated act/UNECE regulation No 41
	Two-wheel motorcycle 80 cm^3 < Engine capacity ≤ 175 cm^3	77	
	Two-wheel motorcycle Engine capacity > 175 cm^3	80	
L4e to L7e-C	Two-wheel motorcycle with side-car and tricycle to heavy quadrimobile	80	Delegated act/UNECE regulation No 9

Appendix C. Subjective Test Raw Data

Vehicle	Description (Test ID)	Rating	Run	Maximum Sound Level (dB L_{AFmax})	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
E (Car) Aftermarket exhaust and engine mapping	Slow moving before hard acceleration (C1)	Rating	1	105	Noisy	Excessively Noisy	Excessively Noisy	Excessively Noisy	Excessively Noisy	Excessively Noisy
			2	105	Excessively Noisy	Excessively Noisy	Excessively Noisy	Noisy	Excessively Noisy	Excessively Noisy
		Comments			Pop & bangs unacceptable.	Backfire pushed from noisy to excessively.	Loud popping noise makes you squint.	Noise produced would warrant enforcement/ would warrant stop and further investigation.	Main rev not too loud, pop excessively loud/pop sound antisocial and causes ringing in ears.	Loud pops and bangs, unnecessary and not standard
	Drive by at 40 mph (C2)	Rating	1	97	Normal for that type of vehicle	Normal for that type of vehicle	Noisy	Loud but not disturbing	Normal for that type of vehicle	Noisy
			2	72	Normal for that type of vehicle	Normal for that type of vehicle	Loud but not disturbing.	Normal for that type of vehicle	Normal for that type of vehicle	Normal for that type of vehicle
		Comments			Deceleration loudest.	None	None	Could be gear selection causes noise rather than vehicle.	Very sedate sound, no issues.	Did not appear that noisy until pops and bangs, would be quieter in higher gear/not that loud appeared to be driver

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Vehicle	Description (Test ID)	Rating	Run	Maximum Sound Level (dB L_{AFmax})	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
										manually. No enforcement required.
	Full acceleration up to monitoring site then shut off the allow engine braking (C3)	Rating	1	107	Noisy	Excessively Noisy	Excessively Noisy	Excessively Noisy	Excessively Noisy	Excessively Noisy
			2	82	Loud but not disturbing	Loud but not disturbing	Loud but not disturbing	Loud but not disturbing	Normal for that type of vehicle	Normal for that type of vehicle
		Comments			Pop is loudest.	Popping makes excessive.	Loud popping exhaust - Run 1.	Backfire caused by gear selection.	Pops and bags created excessive sound, without causes no issues.	Excessively noisy due to pops and bangs but general noise not bad.
	Drive by at 20 mph with higher gear (C4)	Rating	1	87	Loud but not disturbing	Loud but not disturbing	Noisy	Normal for that type of vehicle	Normal for that type of vehicle	Noisy
			2	78	Normal for that type of vehicle	Loud but not disturbing	Loud but not disturbing	Normal for that type of vehicle	Normal for that type of vehicle	Loud but not disturbing
		Comments			None	None	None	None	Not loud at all.	noisy but noisy for vehicle type and model, nothing to enforce against
	Same as C4 in stock condition	Rating	1	87	Loud but not disturbing	Normal for that type of vehicle	Noisy	Normal for that type of vehicle	Normal for that type of vehicle	Loud but not disturbing

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Vehicle	Description (Test ID)	Rating	Run	Maximum Sound Level (dB L_{AFmax})	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
	(C5)		2	75	Normal for that type of vehicle	Normal for that type of vehicle	Loud but not disturbing	Normal for that type of vehicle	Normal for that type of vehicle	Normal for that type of vehicle
		Comments			None	None	Not overly piercing - annoying not alarming.	None	Very sedate sound.	Loud but normal for the vehicle.
	In lower gear and hard acceleration (C6)	Rating	1	101	Noisy	Noisy	Excessively Noisy	Noisy	Loud but not disturbing	Excessively Noisy
			2	95	Noisy	Loud but not disturbing	Noisy	Loud but not disturbing	Loud but not disturbing	Noisy
		Comments			None	Excessive with pops.	Antisocial rather than alarming.	Gear selection affects noise, higher gear lessens noise.	Acceleration caused some volume but not disturbing.	Noisy when dropped down gears, pops and bangs very loud.
C (Motorcycle) Aftermarket exhaust with bung removed	Slow moving before hard acceleration (M1)	Rating	1	90	Not provided	Noisy	Noisy	Loud but not disturbing	Normal for that type of vehicle	Noisy
			2	91	Not provided	Excessively Noisy	Noisy	Normal for that type of vehicle	Normal for that type of vehicle	Noisy
		Comments			None	None	None	None	Not too loud at all.	I perceive motorbikes to be noisy so subjectively its noisy but not overly noisy.

Vehicle	Description (Test ID)	Rating	Run	Maximum Sound Level (dB L_{AFmax})	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
	Drive by at 40 mph (M2)	Rating	1	85	Noisy	Normal for that type of vehicle	Loud but not disturbing	Loud but not disturbing	Normal for that type of vehicle	Loud but not disturbing
			2	82	Not provided	Loud but not disturbing	Normal for that type of vehicle	Loud but not disturbing	Normal for that type of vehicle	Normal for that type of vehicle
		Comments			None	None	None	Gear selection affects noise.	Slight drive sound but not loud.	None
	Full acceleration up to monitoring site then shut off the allow engine braking (M3)	Rating	1	98	Noisy	Noisy	Loud but not disturbing	Noisy	Loud but not disturbing	Loud but not disturbing
			2	98	Noisy	Noisy	Noisy	Noisy	Loud but not disturbing	Loud but not disturbing
		Comments			None	None	None	Noisy but would not issue any penalty.	Starting to become loud but not an issue.	Again, loud but not overly noisy for the vehicle.
	Drive by at 20 mph with higher gear (M4)	Rating	1	97	Noisy	Loud but not disturbing	Noisy	Noisy	Normal for that type of vehicle	Noisy
			2	94	Noisy	Loud but not disturbing	Not provided	Noisy	Normal for that type of vehicle	Noisy
		Comments			None	None	None	None	Approach quiet but got louder, but not loud.	Noisy but expected due to vehicle.
	In lower gear and hard acceleration (M5)	Rating	1	96	Excessively Noisy	Noisy	Not provided	Noisy	Loud but not disturbing	Noisy
			2	97	Excessively Noisy	Noisy	Not provided	Loud but not disturbing	Normal for that type of vehicle	Noisy

Vehicle	Description (Test ID)	Rating	Run	Maximum Sound Level (dB L_{AFmax})	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
		Comments			None	None	None	None	Higher revs but again not disturbing/not overly loud.	None