

**Specialist Professional and Technical
Services (SPATS) Framework
Lot 1**

**Task 696
Roadside Vehicle Noise Measurement**

**Phase 1 Study Report and Technology
Recommendations**

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ATKINS **JACOBS®**

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Executive Summary

The Atkins Jacobs Joint Venture has undertaken research for the Department for Transport to identify and recommend options for methods and equipment available for the detection and enforcement of excessively noisy road vehicles. These vehicles, which have often been modified, lead to annoyance and complaints from the members of the public throughout the UK. Commonly, the 'excessive noise' that leads to complaints is attributed to modified or defective exhaust systems. Phase 1 of the project required engagement with police forces and local authorities about approaches of tackling excessively noisy vehicles and a literature review of approaches used around the world, appropriate test methodologies, and technologies trialled as enforcement measures.

The research indicated that softer enforcement measures such as advisory signage and promotional materials help to raise awareness of the issue but can be ineffective. The outcomes of educational programmes tackling excessive vehicular noise have been mixed.

In the UK and around the world, fines and vehicle rectification notices are used as enforcement measures. Some countries require vehicle owners to visit approved test centres to verify that the noisy modified exhausts have been replaced with legal, quieter models as part of the vehicle rectification notice. This is akin to the procedure used in the UK's Vehicle Defect Rectification Scheme.

The majority of UK police forces who responded to the survey subjectively assess whether vehicles cause excessive noise. This subjective assessment is undertaken by the police officer applying their judgement as to whether the vehicle is producing excessive noise and therefore does not comply with The Road Vehicles (Construction and Use) Regulations 1986. Where sound level meters are used for an assessment, the vehicles are tested against a set threshold noise level that is not bespoke to the specific vehicle (i.e. the threshold noise level does not refer to the type approval noise level specific to that make and model of the vehicle). This is consistent with approaches used worldwide.

The literature review identified three options that could be examined further to improve identification of excessively noisy vehicles and enforcement measures, which are:

- Improvements to existing reporting and enforcement practices. This would consist of minor improvements to existing online or digital reporting tools to make it easier for users to report excessively noisy vehicles / driving behaviours, and improved guidance for police officers for enforcement using subjective or objective methods.
- An automated noise camera system comprising a video camera, an automatic number plate reader (ANPR) and sound measurement equipment, where sound levels from passing vehicles are tested against a suitable noise limit. The system does not require the police to be in attendance but can be configured to provide real-time reports if required. A letter can be sent out requiring the registered owner to check, repair or replace their exhaust within a stated time period.
- An automated noise camera system comprising a video camera, an ANPR and sound measurement equipment capable of identifying acoustic signatures produced by passing vehicles, which can be used as a mechanism to reduce false positives. The acoustic signature and maximum sound levels would be compared with those associated with vehicles with illegal modified exhaust systems and appropriate noise limits. The system does not require the police to be in attendance but can be configured to provide real-time reports if required. A letter can be sent out requiring the registered keeper to check, repair or replace their exhaust within a stated time period.

Based on the strengths, limitations and the maturity of the technology involved, the noise camera solution that tests noise levels against predetermined noise limits is recommended for consideration for Phase 2 of the project, where trials and further research assessing the performance of this type of system is proposed. If this solution is progressed to Phase 2, trials will be used to select threshold noise levels for vehicle categories, taking into account the speed of travel and context of the site. This would result in a performance specification that could be issued prior to further testing. There is an opportunity to use the data collected during Phase 2 to characterise the acoustic signatures associated with excessively noisy vehicles. This information can be used to configure or set a performance specification for a more sophisticated noise camera system in the near future when the technology is fully developed.

Stakeholder engagement with police forces in the UK highlighted the need for improved guidance on enforcement of excessively noisy vehicles. Guidance for objectively and subjectively appraising noise levels emitted from exhaust systems would ensure a consistent nationwide approach to enforcement.

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1. Introduction

Background

The Department for Transport (DfT) has commissioned a research project to identify and recommend options for methods and equipment available for the detection and policing of excessively noisy road vehicles. High levels of noise have been linked to a number of human health issues and vehicle noise is a significant contributor to this, particularly in urban environments. Excessively noisy vehicles, which have often been modified, also lead to significant annoyance and complaints from the public in both urban and rural areas of the UK.

Current in-service noise compliance of vehicles is assessed through periodic roadworthiness testing (the MOT). However due to tampering and/or substitution of components, this is not found to provide adequate outcomes as evidenced with the number of motorcycles, cars and other vehicles in use which do not appear to comply with the relevant noise regulations.

The DfT has procured research through the Highways England SPaTS framework to inform policy on potential improvements to policing methods for noisy vehicles and highlight any technologies that could be used as an aid to detection and enforcement. The contract was awarded to the Atkins Jacobs Joint Venture (AJJV) during November 2018.

Project Definition

The primary aim of this project is to understand if there are reliable and robust ways of ascertaining noise emissions from an individual vehicle at the roadside which can then be used for enforcement purposes. This is to be achieved by a review of best practice approaches and technology, both existing and in development, and supported by trials and validation noise measurements as necessary. This work will assist in the development of future policy and enforcement of in-service noise limits.

The project comprises two distinct phases as follows:

- Phase 1 – Identification
- Phase 2 – Trials and analysis

The first phase of the research is to establish the methods currently used across the UK and internationally for policing excessively noisy vehicles and determine whether any strategies can be used more widely within the UK. Existing and prototype technologies for the detection of excessively noisy vehicles will also be identified and their feasibility of use, cost and reliability will be assessed. The technologies will be focussed on the assessment of in-use vehicle noise, such as a roadside pass-by noise detector, rather than the assessment of stationary noise.

Dependent on successfully identifying suitable technologies in Phase 1, the second phase of research will involve trials of the candidate technologies. If at the end of Phase 1 no suitable technologies are identified for use on UK roads then Phase 2 may not be taken forward. If proceeding to Phase 2, the capability and reliability of the respective technologies will be assessed and recommendations of their suitability will be provided.

This report discusses the key outcomes, findings and recommendations of Phase 1 and highlights the limitations and key risks identified. The structure of the report is as follows:

- Chapter 2 – Project scope
- Chapter 3 – Legislation and legal context
- Chapter 4 – Previous work
- Chapter 5 – Current approaches used in the UK
- Chapter 6 – Approaches to noise control
- Chapter 7 – Potential solutions
- Chapter 8 – Performance of potential solutions
- Chapter 9 – Recommendations for Phase 2
- Chapter 10 – Conclusions

2. Project Scope

Phase 1 Project Brief

The objectives of the two project phases are summarised below:

- Identify and review current examples of enforcement relevant to noisy vehicles in the UK and in other countries and determine best practice.
- Identify the role of community engagement and other similar ‘soft’ measures, review their suitability for wider use in the identification of excessively noisy vehicles.
- Identify technologies both existing and in development which could be applied for the identification of excessively noisy vehicles.
- Assess the strengths and limitations of the identified technologies, and make recommendations for trials in Phase 2.

To meet the objectives for Phase 1, the scope of work has been split into six tasks as shown in Table 2.1.

Table 2.1: Phase 1 scope

Task	Description	Location in report
1	To engage with stakeholders across the UK, including regional police forces, to determine how in-service noise compliance is currently enforced and what future strategies would be of most use	Chapter 5, Appendix A
2	To identify effective methodologies used in other countries for the enforcement of in-service noise compliance and determine their applicability for use in the UK	Chapter 6, Chapter 7
3	To identify, assess and recommend technologies which could be deployed at the roadside to identify high noise emitting vehicles during normal driving conditions.	Chapter 6, Chapter 7, Chapter 8, Chapter 9
4	To identify suitable methodologies or procedures for roadside noise measurement and vehicle identification.	Chapter 4, Chapter 5
5	To assess the accuracy, repeatability and reliability of vehicle noise measurement technologies, taking into account the impact of noise from other vehicles and the wider environment	Chapter 7, Chapter 8
6	To assess the associated costs, maintenance and support requirements of these technologies.	Chapter 7, Chapter 8

Phase 1 Methodology

Stakeholder engagement (task 1)

Regional police forces across the UK have been engaged with, particularly those who are at the forefront of enforcement of noise limits, to determine how in-service noise compliance is currently achieved, and what future strategies would be of most use. This was undertaken by means of an online survey issued to police forces via the National Roads Policing Intelligence Forum and contacting specific police forces known to be proactive in enforcing excessively noisy vehicles. A number of Local Authorities were also contacted to understand how they tackle this issue.

Full details of the approach and outcomes of stakeholder engagement are reported in Appendix A.

Identification of enforcement methodologies and roadside noise measurement technologies and procedures (tasks 2 and 4)

A literature review was undertaken to evaluate the outcomes of previous research aiming to identify and characterise excessively noisy vehicles, and relevant methodologies for roadside noise measurement. Existing UK legislation was also reviewed to understand the legal context for enforcement.

The literature review also encompassed internet searches to identify approaches used abroad for measuring noise and enforcement, including any noise limits used to determine compliance with local laws.

Appraisal of vehicle noise measurement technologies (tasks 3-6)

Technological solutions were identified from the literature review, including some technologies that could be potentially adapted and deployed in the UK. Based on the characteristics of the technological solutions, a number of conceptual systems are appraised for use in the UK, taking into account their strengths, limitations, accuracy, reliability and maintenance and support requirements. Where available, approximate cost information is provided.

3. Legislation and Legal Context

Introduction

The current UK legislative frameworks to control and mitigate noise produced by motor vehicles is summarised in Figure 3.1. This is split into the two stages of a vehicle's life, i.e. new (type approval) and in-service (i.e. MOT). This section outlines the legislation and standards directly related to these stages currently applicable in the UK. The controls related to imported vehicles, presented in Figure 3.1, are also described. It should be noted that the in-service controls listed relate only to whole vehicle noise or exhaust systems, i.e. they are not related to tyre/road noise.

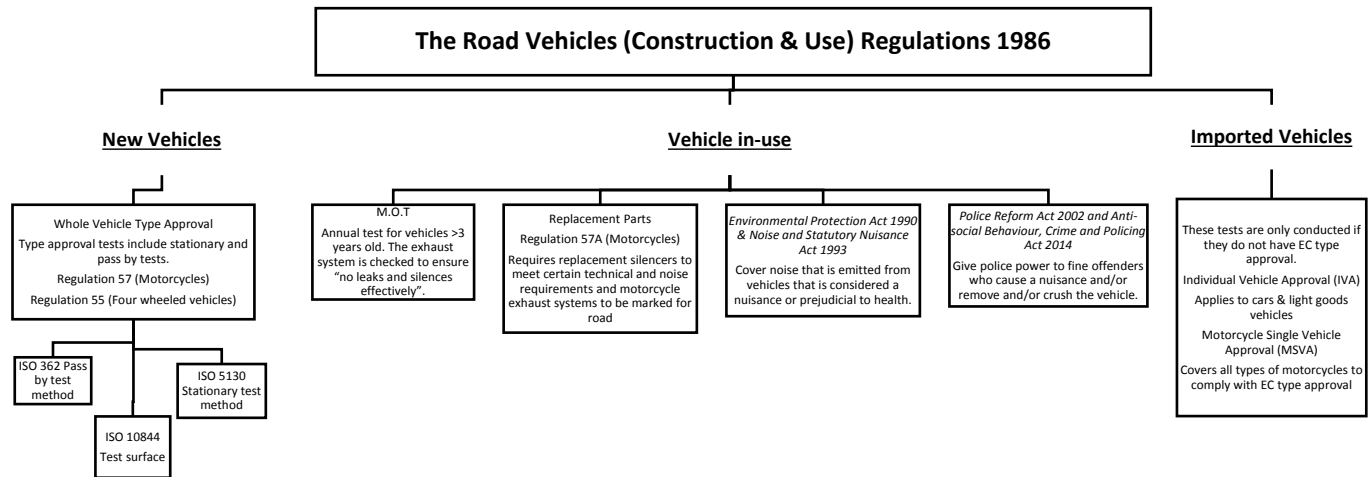


Figure 3.1. Flow diagram of current UK controls. Source: Adapted from Abbott et. al. [1]

Type approval

The testing of noise emissions from road vehicles is required under EU type approval procedures. Type approval is a procedure whereby a manufacturer can obtain certification from a competent authority that the product meets the requirements of a certain Directive.

Regulation (EU) 540/2014

The noise levels accepted for vehicle type approval are set out in Regulation (EU) 540/2014 [2] for motor vehicles and Regulation (EU) 168/2013 [3] for motorcycles.

Regulation (EU) 540/2014 which repeals European Directive 70/157/EEC [4], outlines limits on the sound levels from road vehicle and gives more representative procedures for measuring sound levels from exhaust systems and silencers. These limits have been tightened through several amendments. Limit values for eight types of passenger and goods vehicles range from 72 dB(A) to 80 dB(A). These limits are expected to be again tightened over 10 years. By 2026 the limit for most new passenger cars is expected to be 68 dB(A) [5].

Regulation (EU) 168/2013

This Regulation which repeals Directive 78/1015/EEC [6], establishes limits for the permissible sound level of motorcycles and requirements for exhaust or intake silencer. This provides a harmonised testing procedure with limit values for three categories of motorcycles from 63 dB(A) to 80 dB(A).

These type approval Regulations are implemented into UK law by The Motor Vehicles (Type Approval) (Great Britain) Regulations 1984 [7] that is made under the Road Traffic Act 1972 [8].

Road Vehicles (Construction and Use) Regulations 1986

The Road Vehicles (Construction and Use) Regulations 1986 [9], also made under the Road Traffic Act 1972 (as amended) [8], aim to ensure that vehicles used in the UK are built to a high standard. These Regulations are also used to implement EU Directives.

The following regulations address noise emission controls on road vehicles:

- Regulation 54 requires equipment such as silencers not to be altered in such way that the noise is greater than when it was first manufactured. Replacement silencers for mopeds and motorcycles

must comply with certain noise requirements which effectively imply there is no increase in noise emissions compared with the original silencer. In addition, no increase in noise must be caused by poor maintenance.

- Regulation 55 (for cars) and Regulation 57 (for motorcycles) require new vehicles to be controlled by type approval limits.
- Regulation 97 requires avoidance of excessive noise which includes the behaviour of the driver in operating the vehicle including the use of audible warning systems.

UNECE Regulation 51: “Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions”

This Regulation [10] outlines the procedures to be adopted for the assessment of noise during the type approval of cars, vans, trucks and buses. During the type approval process the method described in ISO 362 “Measurement of noise emitted by accelerating road vehicles” [11] [12] is followed. From 2016 a new test procedure, Additional Sound Emission Provisions (ASEP), was added to the type approval process. Although noise limits for vehicles types have been reduced over the years, there has been concern that limits have not translated into reduced levels of traffic noise. The ASEP introduces a test which is more representative of real life driving, especially in urban environments. The ASEP procedure requires four additional test runs past the microphones for every gear of the vehicle. These are undertaken to measure the noise from the passing vehicle at four different speeds for every gear.

A stationary test to the method given in ISO 5130:2007 “Acoustics - Measurements of sound pressure level emitted by stationary road vehicles” [13] is also undertaken at type approval. While the result from this test is not used to determine whether the vehicle passes type approval, it could be used by authorities to check in-service noise levels if made available.

UNECE Regulation 41: “Uniform provisions concerning the approval of motor cycles with regard to noise”

This Regulation [14] outlines the provisions relating to the type approval of motor vehicles having two or three wheels with regard to noise. Similarly to UNECE Regulation 51, noise emissions are measured using the methods defined by ISO 5130 [13] and ISO 362 [11] [12], but only the result from the acceleration test is used for type approval purposes. As with Regulation 51, there is now the requirement for tests under the ASEP procedure.

UNECE Regulation 63: “Uniform provisions concerning the approval of two-wheeled mopeds with regard to noise”

This Regulation [15] sets out noise emission limits for mopeds. The noise limits are aligned with those outlined in Regulation (EU) 168/2013.

UNECE Regulation 9: “Uniform provisions concerning the approval of category L2, L4 and L5 vehicles with regard to noise”

This Regulation [16] sets out noise emission limits for three-wheeled vehicles. The noise limits are aligned with those outlined in the Regulation (EU) 168/2013.

Testing standards for type approval

ISO 362-1:2015 – Measurement of noise emitted by accelerating road vehicles – engineering method. Part 1: M and N categories

ISO 362-1:2015 [11] specifies a method for measuring the noise emitted by road vehicles under typical urban traffic conditions. The test aims to approximate real world part throttle vehicle operation with a weighted average of a wide open throttle test at a target acceleration with a constant speed test. To achieve stable and repeatable test conditions, the procedure requires a Wide Open Throttle (WOT) test and a constant speed test. The WOT test specifies that a target acceleration be achieved. The gear selection for this test is determined by the target acceleration. The constant speed test is undertaken at 50 km/h. These tests are then combined in a weighted average which is a function of the actual acceleration achieved in the WOT test and the Power-to-Mass Ratio. The test track construction and road surface are required to meet the requirements of ISO 10844:2014 [17].

ISO 5130:2007+A1:2012 – Acoustics - Measurements of sound pressure level emitted by stationary road vehicles

ISO 5130:2007+A1:2012 [13] specifies a test procedure for measuring the noise level from road vehicles under stationary conditions. The test method essentially involves holding the vehicle at a set engine speed and measuring the noise level when the throttle is released. The microphone is positioned 0.5m from the exhaust outlet. As specifically stated by the Standard, this procedure is not intended as either a method to check the exhaust sound pressure level when the engine is operated at realistic loads nor a method to check the exhaust sound pressure levels against a general noise limit for categories of road vehicles.

ISO 10844:2014 – Specification of test tracks for the purpose of measuring noise emitted by road vehicles

ISO 10844:2014 [17] specifies the materials, design, construction and properties of a test surface in order to minimise inter-site variation in vehicle noise measurements due to texture characteristics, sound absorption and possibly mechanical impedance or stiffness properties of the surface layer.

In-service testing for cars and motorcycles

MOT

In the UK vehicles older than three years must pass an annual MOT test in order to inspect the roadworthiness of a car or motorcycle. When a vehicle fails an MOT, it is prohibited from being driven on the public highway, other than to or from the test centre if appropriate, until the defect is corrected. The testing consists of the following:

- The exhaust system is examined visually for any defects during the MOT test, such as holes in the pipes. Although this is an inspection that is undertaken mainly for safety reasons, it does identify exhaust systems that may be producing excessive noise due to poor maintenance or simply an old exhaust.
- A subjective assessment is also made as to the effectiveness of the silencer in reducing exhaust noise to a level considered to be average for the vehicle.

Environmental Protection Act 1990 & Noise and Statutory Nuisance Act 1993

The Environmental Protection Act (EPA) 1990 provides the principal controls over statutory nuisance, including noise nuisances, whether arising from industrial, leisure or domestic activities. The Noise and Statutory Nuisance Act 1993 amended certain sections of the EPA to make noise in a street a statutory nuisance. This applies to nuisance arising from vehicles (e.g. car alarms), machinery and other equipment such as loudspeakers. This does not cover general traffic noise.

Under Part III of the EPA, for noise to be classed as a statutory nuisance it must be prejudicial to health and/or is causing an unreasonable and persistent disturbance to the complainant's lifestyle.

Police Reform Act 2002 and Anti-social Behaviour, Crime and Policing Act 2014

Section 59 of the Police Reform Act 2002 gives the police powers to stop, seize and remove a vehicle if they have reasonable ground for believing that the motor vehicle is being used on any occasion in a manner which constitutes careless and inconsiderate driving (as defined by the Road Traffic Act 1988 [18]) or which is causing, or likely to cause, alarm, distress or annoyance to members of the public. Section 60 allows the relevant Secretary of State to make regulations relating to the removal, retention, release or disposal of motor vehicles seized in accordance with Section 59.

Following the amendment in Part 1 of Schedule 4 to the Police Reform Act 2002 (powers of community support officers), Schedule 10 "Powers of Community Support Officers" outlined in Chapter 12 of the Anti-social Behaviour, Crime and Policing Act 2014 has been modified to provide authorised officers with additional powers to issue a fixed penalty notice under Section 42 of that Act of contravening or failing to comply with a construction or use requirement about the use on a road of a motor vehicle in a way that causes excessive noise.

Control of non-original exhaust systems / components

UNECE Regulation 59: "Uniform provisions concerning the approval of replacement silencing systems"

This Regulation [19] outlines a process for ensuring standardisation of replacement silencing systems. The Regulation states that the acoustic efficiency of the replacement silencing system or components of

a system shall be verified by a test in accordance with Regulation 51. When the replacement silencing system or components are mounted on a vehicle, the noise level obtained using the two methods (i.e. ISO 362 and 5130) shall satisfy one of the following conditions:

- They shall not exceed the value obtained with the type of vehicle concerned when submitted for type approval
- They shall not exceed the noise values measured on the vehicle referred to above, when this is fitted with an exhaust silencing system corresponding to the type fitted to the vehicle when submitted for type approval

UNECE Regulation 92: “Uniform provisions concerning the approval of non-original replacement exhaust silencing systems for motorcycles, mopeds and three-wheeled vehicles”

This Regulation [20] outlines the noise emission limits for non-original replacement exhaust systems of different types for motorcycles, mopeds and three-wheeled vehicles. This includes silencing systems which differ significantly in such respects as:

- (a) Their components bear different trade names or marks,
- (b) The characteristics of the materials constituting a component are different or the components differ in shape or size; a modification in respect to coating (zinc coating, aluminium coating, etc.) is not considered a change of type,
- (c) The operating principles of at least one component are different,
- (d) Their components are combined differently.

The test methods described in the Regulation cross reference those in UNECE Regulation 41, i.e. ISO 5130 and ISO 362. The sound levels recorded for the in-motion tests shall not exceed the limits defined in Regulation 41 (for the motorcycle’s type) by 1 dB(A) or by more than 3 dB(A) for the stationary test. The noise limits are aligned with those outlined in Regulation (EU) 168/2013.

Control on imported or low volume production vehicles

Individual Vehicle Approval

In 2009, the previous Single Vehicle Approval system was replaced by the Individual Vehicle Approval scheme. This is a pre-registration inspection for vehicles imported, assembled or manufactured in very small numbers or as individual vehicles. It covers passenger cars, buses coaches, light and heavy goods vehicles, trailers and some special purpose vehicles.

As part of the approval process, vehicles are subject to a stationary exhaust noise test and must have a measured sound level not exceeding 99 dB(A). Alternatively, evidence of compliance can be demonstrated by a comparison test, where the vehicle noise-related technical specification is compared against the result of a static test which must be verified by an authorised test laboratory.

Motorcycle Single Vehicle Approval Scheme

The Motorcycle Single Vehicle Approval Scheme (MSVA) is a pre-registered inspection for mopeds, motorcycles, three wheelers and quadricycles that have not been type approved to European standards. MSVA also examines that the construction of amateur-built vehicles, rebuilt vehicles and vehicles using parts from a previously registered vehicle meet modern safety and environmental standards. Similar to SVA, it also provides an alternative to type approval for vehicles manufactured in very low volume. The test undertaken at MSVA is to the requirements given in Regulation (EU) 168/2013.

4. Previous work

The Transport Research Laboratory (TRL) has previously investigated the development and implementation of in-service noise tests for petrol engine vehicles, diesel engine vehicles and motorcycles. The most relevant tests conducted and reported by TRL in this regard has been summarised in this section.

Characterisation of excessively noisy vehicles when in motion

During 2008, two TRL studies were undertaken to characterise 'excessively noisy vehicles' based on noise measurements undertaken at two sites on the A34 (Newbury) [21] and two sites on the A30 [22] during normal traffic conditions. For each passing vehicle, the maximum noise level (L_{Amax}) and speed were captured together with video imagery to enable potential noise source identification. The relationship between noise and speed, where the maximum noise level of a passing vehicle is correlated to the logarithm of the vehicle's speed (in km/h), was used to identify which vehicles classify as excessively noisy. The studies focussed on pass-by noise levels from cars and medium/heavy goods vehicles.

Excessively noisy vehicles were identified in both studies by comparing the maximum pass-by sound pressure level produced by individual vehicles with the average pass-by sound pressure level for that vehicle category and speed at the test site. Vehicles that were 'excessively noisy' were defined based on the standard deviation from the regression line. For cars, those that were considered 'excessively noisy' had maximum pass-by noise levels in excess of one standard deviation from the average pass-by noise level for the same pass-by speed [22]. Based on this definition, cars that were classified as 'excessively noisy' had noise levels at least 3.1 dB L_{Amax} higher than with average noise levels [22]. The loudest vehicles were found to be 6 – 8 dB L_{Amax} noisier than the site average maximum pass-by measured noise [21]

Analysis of the spectral waveform of the maximum pass-by sound pressure level and video imagery enabled identification of specific acoustic features that increased the vehicle's noise emissions, namely:

- Low frequency sound from vehicle exhausts (below 500Hz), often with harmonic frequencies at approximately 63Hz and 125Hz [21]
- Body rattle from vehicles towing trailers at 800Hz and above [21]
- Other rattling sounds on heavy vehicles due to loose chains and slack metal fences surrounding loads, causing increased sound levels above 800Hz [21]
- Insecure curtain or canvas on medium or large heavy vehicles [21]
- Tyre noise [22].

Other data associated with the identified noisy vehicles, such as age, engine capacity and maximum gross weight, was also obtained from DVLA using the licence plates numbers recorded in the video imagery. The main findings of this study were:

- Modified exhausts or modified or defective silencers are the highest noise source for light vehicles (lower frequencies with harmonics at 100Hz and 200Hz) [22].
- Excessive noise from larger vehicles is due large engines, large tyres and poor aerodynamics. Poorly secured loads also generate excessive noise [22].
- Excessive noise from trailers being towed by cars and vans was shown to increased noise levels at 1.6kHz and above due to the rattle of the trailer [22].
- Older cars are also likely to present a worn engine / exhaust system which are likely to generate higher noise levels [21].

Characterisation of excessively noisy vehicles when stationary

Cars

A roadside in-service noise measurement programme was undertaken by TRL to assess the viability of the ISO 5130:2007 [23] stationary exhaust noise test procedure for roadside enforcement [24]. The roadside measurement testing programme conducted as part of this study was based on the methodology described in ISO 5130:2007 and was trialled on over 300 in-service cars of different ages to assess a wide variety of new and old exhausts. As participation in the roadside testing programme was voluntary, at least two separate measurements were undertaken on each vehicle to test as many

vehicles as possible. The sound pressure level was also measured in third-octave bands throughout the measurement, including the period of constant engine speed and deceleration to idle.

From the data collected, it was found that it was possible to identify modified exhausts by their overall sound emissions and from their frequency profile. Exhausts noted as being modified had an average measured level over 8 dB higher than the corresponding type approval level for the same vehicle type, compared to an average measured level 0.5 dB lower than the corresponding type approval level for the other cars measured [24]. Analysis of spectral data for two different Vauxhall Astras that were tested, where one was fitted with a standard exhaust and the other had a modified exhaust, indicated that there were large differences in the frequency profile of standard and modified exhausts between 100-700Hz, as shown in Figure 4.1. However, the study warned that the use of frequency profiles to specifically enforce against modified exhausts has the potential to be circumvented by manufacturers modifying the acoustic signature/frequency profile of their exhausts so that they would appear 'compliant' with any spectral criteria used to determine compliance [24].

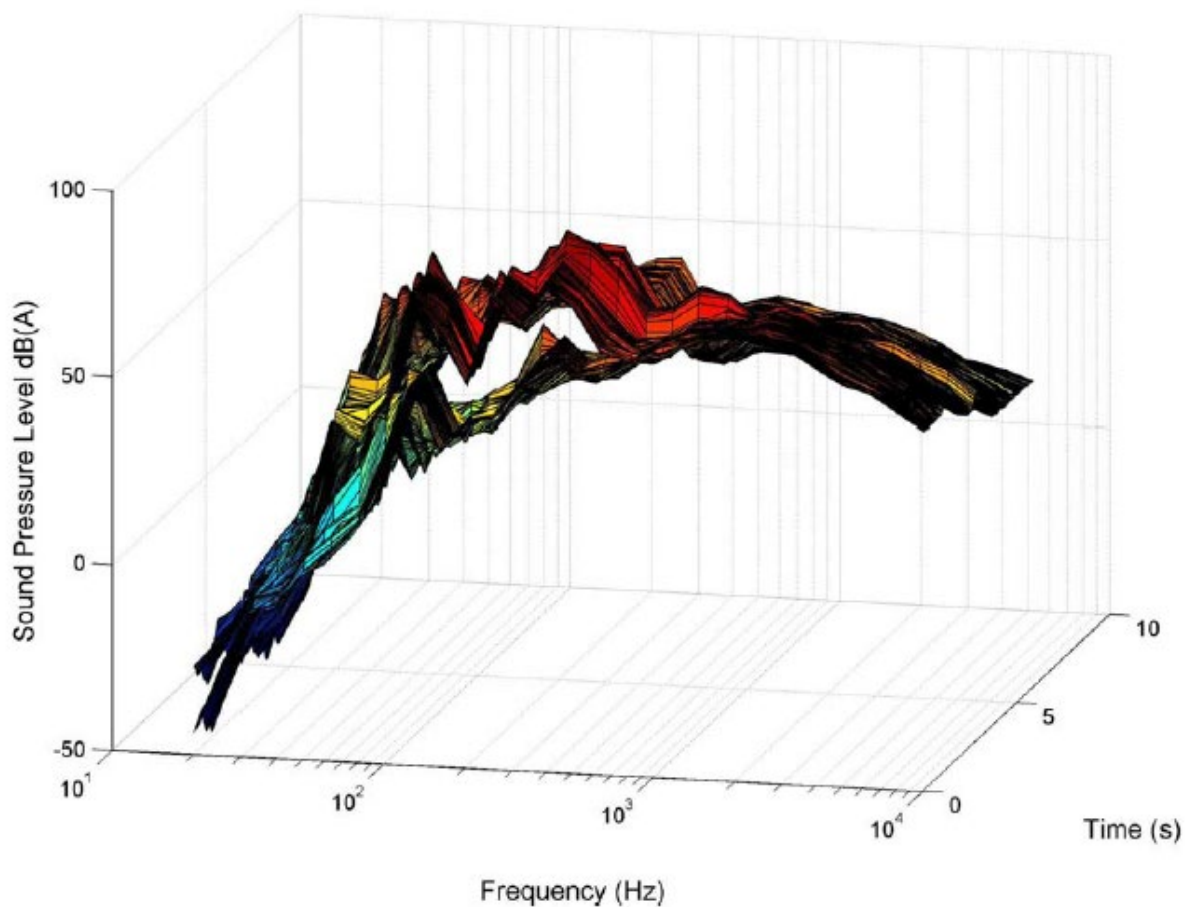


Figure 4.1: Frequency profiles of two Vauxhall Astras, including one fitted with a modified exhaust.
Source: Muirhead, Morgan and Morris [24]

The study also found that the noise emissions from exhaust systems varied with age, with noise emissions gradually increasing until the vehicle's exhaust is replaced, after which the cycle repeats every 5-6 years. The data also showed that the measured noise levels were nearly always below the type approval levels, regardless of the age of the vehicle [24]. However, the age of the vehicle is still important as it determines which type approval levels are applicable, or if type approval levels are applicable at all (e.g. classic cars pre-dating the introduction of type approval schemes).

Motorcycles

A similar study was also undertaken for motorcycles to identify testing methods for roadside enforcements of Regulation 54 of the Road Vehicles (Construction and Use) Regulations 1986 and to review approaches used by other countries [1]. As a large proportion of complaints received by the Department for Transport that were reviewed during the study concerned vehicles fitted with 'performance exhaust systems' [1], this suggests that compliance with legislation could be a problem. The study found that the overall noise levels measured from non-standard exhaust systems were 5.3–

17.4 dB L_{Amax} higher than standard exhausts. No specific spectral characteristics that differentiate standard and non-standard exhausts were identified [1]. It was found that comparing the range of the 'firing frequency' of the engine was marginally useful, and from this it was identified that motorcycles fitted with aftermarket exhausts were on average approximately 6 dB L_{Amax} louder than those fitted with standard products [1].

The findings are similar to those from an older study [25] that used a close proximity stationary noise test procedure and acceleration noise test described in European Union Directive 78/1015/EEC. The study found that motorcycles fitted with standard original equipment silencers or standard (new) silencers were found to give the lowest type approval levels and 'race' silencers fitted on the most powerful motorcycles generated maximum noise levels 9 dB above those measured with the original equipment fitted.

In-service testing

There are a number of research reports investigating, or commenting on, test parameters and methods to use for measuring noise from exhaust system [1] [25] [26] [27]. The outcomes of much of this research has shaped the requirements stipulated in current in-service testing standards. Some of the key points from these studies are stated below, supplemented with a detailed history of older research into in-service testing methods in provided in Appendix B.

During in-service noise testing for motorcycles, it was found that:

- The effect of changing the measurement distance from exhaust outlet can result in the measured noise levels not being comparable to type approval levels. An error of 0.1m in the placement of the microphone can alter the measured level by up to 1.5 dB [1]
- The maximum close proximity noise levels measured with low cost instrumentation (Class 2) were approximately 2 dB L_{Amax} higher than those obtained using the precision grade equipment (Class 1). This difference could be due to differences in the tolerances associated with the averaging time circuitry in the two instruments. [26]

Approaches to enforcement

Use of roadside testing

According to TRL research undertaken during 2009, Devon and Cornwall Police were proactive in using roadside noise testing as a means of enforcing against excessively noisy vehicles [24]. At the time of the study, they had used roadside noise testing to issue 281 fixed penalty notices [24]. Use of roadside noise testing was not commonplace, with only 7-8 police forces using measurement equipment [24]. Other police forces were reported to evaluate noise levels subjectively and expressed an interest in using measurement equipment [24]. Issuing Vehicle Defect Rectification Notices was acknowledged as a route to enforcement, as was prosecution under Regulation 54-2 of The Road Vehicles (Construction and Use) Regulations 1986 (as amended) [24].

Following discussions with police forces, the study recommended that roadside measurements should be carried out simply and efficiently by implementing a measurement system that is simple to use, robust and, portable and compact. This measurement system should comprise a Class 1 sound level meter, microphone with windshield and tripod [24].

Noise limit proposals

Several of the studies identified that limit values could be set for enforcement purposes based on the stationary in-service noise measurement data, taking into account the vehicle class and engine capacity [25] [26] [27]. For example, a study focussed on diesel-powered vehicles suggested a noise limit of 8 dB above the average for the vehicle class to allow for variability of noise levels within the vehicle class and non-standard factors relating to the test site [27].

A more recent study [24] proposed the use of MOTs and roadside testing by the police using the following provisional noise limits for cars when using the ISO 5130 stationary noise test, including allowances for the age of the exhaust and experience of the tester affecting the repeatability and reproducibility of the results:

- Roadside limit value: Type approval level + 10 dB
- MOT limit value: Type approval level + 5 dB

The proposed noise limits are based on the specific type approval levels for each make/model of car from its year of manufacture. This means that older vehicles should not be tested against more recent type approval levels for more recent models of the same vehicle.

Police forces who were already using objective means to establish if a vehicle was excessively noisy used a noise limit of 90 dB L_{Aeq} when conducting roadside stationary exhaust noise tests [24]. The study considered that this was appropriate since the majority of type approval levels reviewed during the study were below 85 dB L_{Amax} [24].

Other recommendations

In addition to roadside testing methods, one of the studies suggested further examination of using UNECE Regulation 59 as a means of controlling exhaust noise [1]. UNECE Regulation 59 is concerned with the replacement exhaust systems but its scope was revised and reworded recently in a way that would limit its effectiveness if adopted into national law [1]. The original scope of UNECE Regulation 59 was to “*contain provisions relating to the approval of silencing systems or components thereof to be fitted to one or more types of motor vehicles in categories M_1 and N_1 as replacement parts*” [28] but has now been reworded to cover silencing systems only [19].

5. Current approaches used in the UK

Police forces

One of the technical deliveries of the project is engaging with stakeholders who may be involved with responding to complaints about excessively noisy vehicles, namely police forces and Local Authorities. To understand how police forces determine how in-service noise compliance is currently enforced and what future strategies would be of most use, an online questionnaire was issued to the 43 police forces who are members of the National Roads Policing Intelligence Forum (NRPIF). This was supplemented by targeted contact with specific police forces known to have been proactive in enforcement based on news articles and previous research [24]. Responses were received from 16 police forces, providing a response rate of 37%. Full details about the online questionnaire and responses received from the police are provided in Appendix A. The key outcomes from the online survey are provided below.

- Just over two-thirds of the police forces who responded undertake action against excessively noisy vehicles / driving, with all those stating it was undertaken reactively (i.e. upon receiving a complaint). None of the police forces proactively take action in this area.
- When a police force takes action against excessively noisy vehicles it is mainly in the form of verbal warnings or fixed penalty notices. Over the span of one year, half of the police forces took any form of action whilst the other half of the police forces do not know if action was taken, took no action at all, or the question was non-applicable.
- Only one of the police forces has their own equipment to measure noise, and therefore the majority of investigations and prosecutions are undertaken based on a subjective test.
- When asked what would help to improve enforcement, the responses were generally around resources and equipment. However, changes to legislation was cited by one police force as having potential to improve the enforcement.

Although not included in the survey of police forces, the government of Jersey has published information about enforcement rates in response to a Freedom of Information Act request received during 2018 [29]. In Jersey, the legal noise limits that motor vehicles cannot exceed on public roads is enforced and 151 prosecutions were taken against noisy vehicles between 2013 and 2018 across all of the offense categories. 110 out of the 151 prosecutions were against defective exhausts. The number of offences for excessively noisy vehicles is similar to those indicated by the individual police forces who were able to provide this information in the online questionnaire.

Police campaigns

There have been several reports since 2008 documenting police campaigns to tackle excessively noisy vehicles and anti-social driving. In some cases, police forces utilised measurement equipment to gain an objective understanding of the noise levels whereas others utilised subjective assessments. In all cases, the targeted areas were brought to the force's attention by local resident complaints.

Campaigns by South Wales Police, Suffolk Police and Northamptonshire Police are examples of where monitoring equipment was used. Operation Le Mans, undertaken by South Wales Police, commenced in response to feedback from local residents [29]. For this operation, one handheld sound level meter was rented for the measurements. The vehicles were tested against a noise limit of 90 dB to include an allowance for wear and tear. It is likely that this threshold noise level was selected based on precedence set by the Devon and Cornwall Police [24]. Of the 25 modified exhausts that were tested, 21 were above the threshold noise level. Throughout the month-long operation, no fines were issued as the main aim was to educate drivers that it is an offence to have an excessively noisy exhaust [30].

Suffolk Police on the other hand issued £30 fines to 68 out of the 98 vehicles measured and the vehicle owners incurred the additional cost associated with reducing the noise level of the exhaust to within the legal limit. A threshold level of 90 dB was also used to determine whether an offence had been committed [31]. Additional enforcement was also implemented whereby if the driver was stopped again and the exhaust remained above the legal limit, a prosecution would be made through the courts and would attract a fine of up to £500 [31]. In some cases, prosecutions due to excessively noisy exhausts were coupled with other motoring offences, such as worn tyres or defective lights, [32]. Similarly, Northamptonshire Police coupled exhaust noise testing alongside routine road safety checks in Daventry and within the first weekend of monitoring three vehicles stopped were above the legal limit [33].

Reports of police campaigns that did not use noise monitoring equipment consisted of patrolling areas where residents had complained about excessively noisy vehicles, potentially as part of a broader campaign to tackle anti-social and inconsiderate driving [34] [35]. Drivers found to have excessively noisy vehicles based on subjective judgement were issued fixed penalty notices of £50 or £80 and a Vehicle Defect Rectification Notice under the Road Vehicle (Construction and Use) Regulations 1986, obligating the driver to fix the vehicle within 14 days [35].

The information drawn from the sources demonstrates that noise monitoring is not mandatory to enforce the law upon excessively noisy exhausts, but that offenders can be identified when taking a proactive approach. Another key aspect to the campaigns is the relationship between local residents and the police force, whereby residents provide good evidence in the potential 'hotspots' of excessive noise. This allows the associated police force to hone in on the most affected areas and ultimately provide a more efficient noise abatement campaign.

Local Authorities

To understand how Local Authorities take action against excessively noisy vehicles, several Environmental Health Officers at Local Authorities were contacted directly by the AJJV. A total of 20 Local Authorities were contacted, and ten responses were received. None of the Local Authorities who responded stated that they take active action against excessive vehicle noise. The few that take reactive action do so in a limited capacity. Most Local Authorities who receive complaints regarding excessive vehicle noise direct the complainant to the local police force. Several Local Authorities have stated they their powers of enforcement are limited. None reported the use of noise measurements as an enforcement measure, although one Local Authority reported having issued 40 penalty notices in 2018. Over half of the Local Authorities who responded said that they considered the police to be responsible for the enforcement of excessively noise vehicles/driving.

Full details of the stakeholder engagement with Local Authorities are provided in Appendix A.

Car cruises

A number of police forces and Local Authorities have taken action against 'car cruises', which are organised or impromptu meetings of drivers on a public highway to race or show off their cars [36]. Car cruises are associated with reports of anti-social driving and disturbing local residents due to excessive noise from modified exhausts, engine revving, and horn honking, as well as speeding and littering.

A number of approaches have been used by the police and Local Authorities to manage or crackdown on car cruising and anti-social driving from their participants, including:

- Closing roads and car parks [37] [38] [39]
- Publicising on social media and news outlets that they are aware of the car cruise and what action they would take if offences are committed [40] [41] [42]
- Raising awareness of noise-related anti-social driving offences in newspapers and on social media, as shown in Figure 5.1 [41] [43] [44]
- Coordinating with neighbouring police forces or local authorities to ensure that enforcement doesn't result in disturbance elsewhere [36] [45]
- Patrolling the area where the car cruise is planned to take place and taking action against anti-social behaviour or anti-social driving, including dispersal of gatherings [40] [44]
- Issuing Dispersal Orders under the Anti-Social Behaviour Act 2003 [46]
- Using Section 59 of the Police Reform Act 2002 to issue warnings or to seize vehicles [41]
- Engaging with car enthusiasts and people who attend car cruises to minimise disturbance and anti-social driving [41]
- Use of PSPOs under the Anti-social Behaviour, Crime and Policing Act 2014 to prohibit organising, promoting and participating in car cruises within a defined geographical area. Non-compliance is punishable by a fine of up to £1,000 or a Fixed Penalty Notice [37] [47] [48]
- Serving injunctions against 'persons unknown' that prohibit activities typically associated with car cruise (such as speeding, racing and causing obstructions to public highways) and consequences typically associated with car cruise, including excessive noise, public nuisance and annoyance to the public. Breaches of the injunction risk fines of up to £2,000 and prison sentences for being in contempt of court, as well as seizing the offending vehicle [36].

NOISE NUISANCE – LAWS & POWERS:



Under certain conditions, a Police Officer or PCSO has the power under section 59 of the Police Reform Act 2002 to seize and remove a vehicle from anyone driving carelessly, or acting in an anti-social manner. This can in certain circumstances be without prior warning.



If a local authority is satisfied that a statutory noise nuisance is occurring or is likely to occur from a vehicle in the street, a noise abatement notice will be served on the person responsible. Failure to comply can result in a fine of up to £5,000 and/or removal of the equipment.



In response to neighbourhood concerns, Essex Police are cracking down on illegal loud exhausts, which often disturb the sleep of local residents. On the first occasion you will receive a fixed penalty notice, with a summons to court for any repeats where you could be heavily fined. Although we are regularly using special new (legally approved) devices to provide us with an evidential decibel reading, these are not required in order to prosecute.

There are various other powers and laws which can be used in addition to those above.

Figure 5.1: Information posted by the police on social media to improve awareness. Source: Essex Roads Policing Unit [41]

Online reporting tools

Many police forces and Local Authorities have online reporting tools that residents can use to complain about noise or report a crime. The Local Authorities that use an online reporting method tend to have a simple form for users to complete and submit electronically [49] [50]. Some Local Authorities direct residents to smartphone apps that can be used to collate evidence and to report noise problems, allowing the user to record and submit audio as part of their evidence [51] [52] [53].

While there are no reports of police forces using smartphone apps to tackle excessively noisy vehicles, there are examples of online reporting tools being used to report anti-social driving and other traffic offences. Many police forces have an online reporting form on their website, such as those used by the Metropolitan Police and Hampshire Constabulary, which requires the complainant to report a “traffic incident” or a “potential driving offence”, and then provide witness contact details and information about the incident. Excessively noisy vehicles are not normally reported using their own category – this would be reported as a “vehicle causing disruption or nuisance” found under an “antisocial behaviour” menu [54] [55].

In some cases, police forces use more advanced online reporting tools, such as those produced by Operation SNAP and Operation Crackdown.

Operation SNAP

Operation SNAP is a joint initiative between all Welsh police forces and GoSafe Cymru to enable members of the public to report driving offences and submit photographs and videos as evidence [56]. These offences include:

- Dangerous driving
- Careless driving
- Driving without due care
- Using a mobile phone while driving
- Not wearing a seatbelt
- Red light and white line offences
- Not in proper control of vehicle
- Antisocial driving

Although Operation SNAP is not designed to target excessively noisy vehicles, instances of this could be reported as “antisocial driving”, along with inappropriate driving behaviours that cause excessive noise. Other police forces that are not part of Operation SNAP have their own tools for managing the submission and processing of photographic or video evidence for perceived driving offences. Nextbase hosts a webpage that directs users to the relevant online reporting pages for submitting photographs and videos as evidence of driving offences for every police force in England and Wales [57]. It also provides

a tool similar to Operation SNAP for those police forces who do not have a reporting page on their own websites to submit photographs or videos.

Operation Crackdown

Operation Crackdown is a joint operation between Sussex Police and the Sussex Safer Roads Partnership. The online reporting tool allows members of the public to report a number of traffic offences including instances of antisocial driving and “driving that is careless, deliberately aggressive or dangerous” [58]. The following offences can be reported using the tool:

- Careless/inconsiderate driving
- Driving under the influence of drugs or alcohol
- Driving whilst using a mobile phone
- Driving with no licence or insurance
- Excessive noise
- No MOT
- No seatbelt
- Overtaking on double white lines
- Red light (including temporary lights)
- School crossing patrol
- Underage driving
- Unnecessary obstruction
- Vehicle condition and use

According to statistics from the Operation Crackdown Data Portal, 454 reports were made for excessive noise between October 2017 and December 2018, representing 2% of total number of reports made [59].

Like the general reporting tools used by the police, Operation Crackdown requires the user to input details about the offending vehicle (number plate, vehicle type, make, model and colour), details about the incident and location, information about the driver, and contact details of the witness. The online reports are forwarded to the Sussex Police Road Policing Unit (local officers). A warning letter is sent to the registered keeper of the vehicle and the reports are stored in a database to identify and address hot spots. For this reason, reporting the number plate of the offending vehicle is essential for action to be taken.

A 12 month rolling history of reports is provided on the website’s data portal, where users can see the reports for different offences on a map [59]. The map indicates that there were 390 reports of “excessive noise” from individual vehicles during 2018, covering rural and urban areas, as shown in Figure 5.2 showing data to the end of 2018.

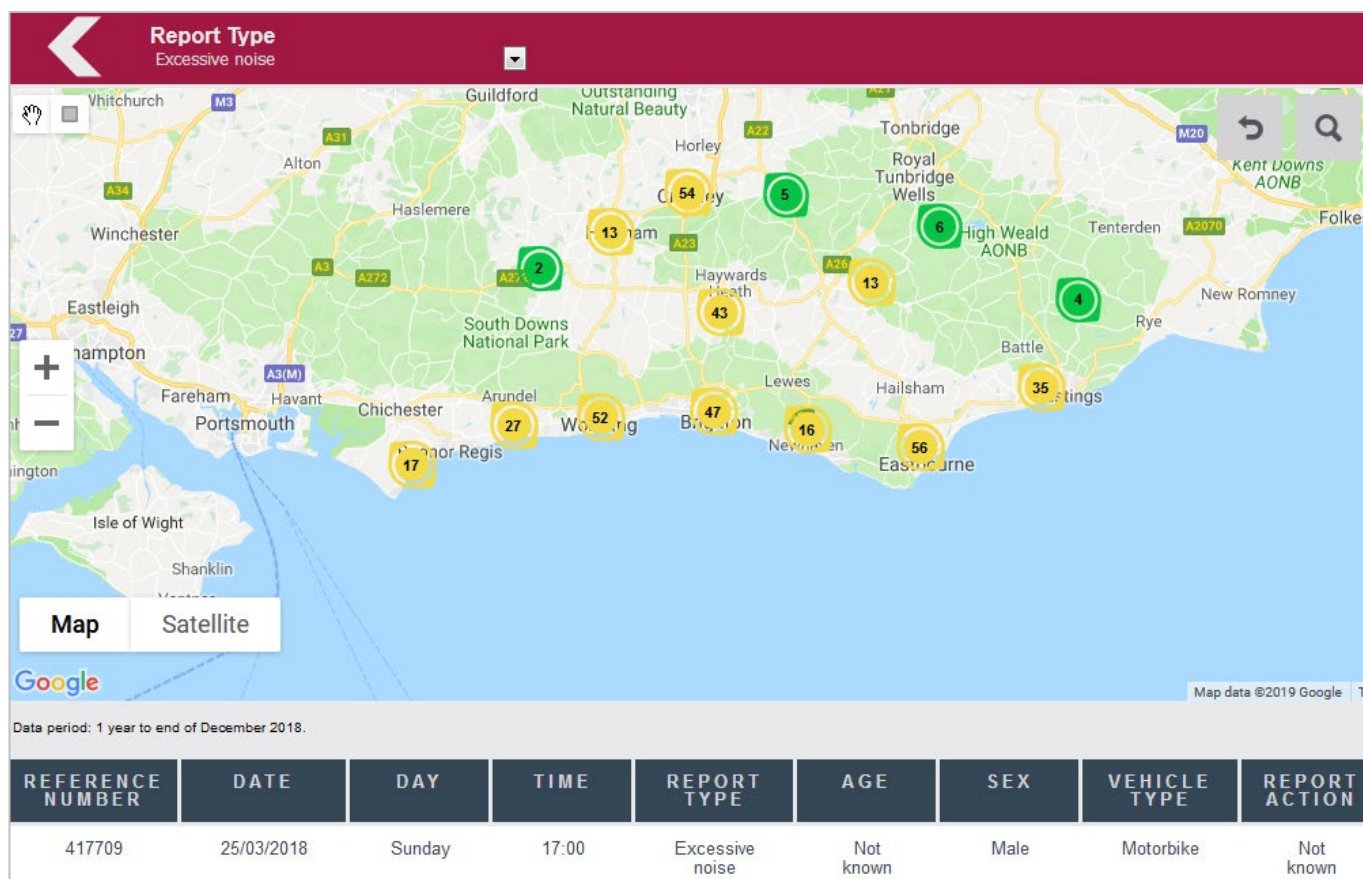


Figure 5.2: Operation Crackdown reports of excessive vehicular noise in Sussex during 2018. Source: Sussex Safer Roads Partnership [59]

Smartphone apps

There are several smartphone apps operated by third parties that send reports of crime to the police, although there are no specific apps that are endorsed by the police. Self Evident is an example of a free to download smartphone app that was trialed by the Metropolitan Police and was used to report a number of non-emergency crimes, including anti-social behaviour, hate crime, and motoring offences [60]. The app allows the user to report details and the location of the crime, and to upload photographs, videos and audio files. Once the report is submitted via the app, an email containing a link to the Self Evident crime report is sent to the relevant police force, who will follow up on the report by email or phone. Although the app could be downloaded and used by members of the public for free, the police were charged per report received through the app. Until recently, the operating costs of Self Evident were partially funded by the Mayor’s Office for Policing and Crime [60], however, the use of the app has been suspended since November 2018 for cost reasons [61]. Despite this, the benefits of the app were acknowledged by the Commissioner of the Police and it is understood that the Metropolitan Police is developing its own solution for submissions of digital data [61].

Testing methods

This section covers the current test methods used to measure noise from stationary or moving vehicles. Further details regarding historical research into in-service test methods which define the context of the current methods, can be found in Appendix B.

Test method for stationary road vehicles

ISO 5130:2007+A1:2012¹ [13] details a test method for the measurement of the exterior sound pressure levels from road vehicles under stationary conditions, through continuous measurement of the sound pressure level over a range of engine rotational frequencies (engine speeds). The test method is to be used for measuring noise from motorcycles, and “vehicles with at least four wheels and are used for

¹ A draft update of ISO 5130 was issued for consultation during 2018, with no changes to the test procedure compared to the current version of the Standard.

transporting passengers...or goods". The standard sets out the methodology for type approval measurements of vehicles, measurements at the manufacturing stage, measurements at official testing stations and measurements at roadside testing.

Site and environmental condition requirements for undertaking the test include acoustically reflective ground, no large reflective objects within 3m from the microphone location and every point of the vehicle. Alternatively, the standard provides specification for undertaking the test in a semi-anechoic chamber.

The test should be undertaken by suitably trained and experienced staff, with a Class 1 sound level meter (as defined in IEC 61672-1:2013 [62]) mounted on a stand and fitted with a windshield if necessary, provided the appropriate corrections are applied.

Measurements should be made with the engine compartment closed and the air conditioner turned off, however any automatic fan should not be interfered with. The engine should be brought to its normal operating temperature for the measurement. The microphone position is off-axis at an angle of 45° from the centre line of the exhaust pipe, at a distance of 0.5m, as shown in Figure 5.3. The measurement height is equivalent to the height of the exhaust pipe and at least 0.2m above ground level. Similar test configurations are provided in the standard for motorcycles and HGVs with elevated exhausts.

With the engine in neutral, the tests are undertaken at the engine speeds below, with a tolerance of ± 5%, and when the throttle/accelerator is released to measure the decay in noise until the vehicle is idling:

For vehicle category L (vehicles with fewer than four wheels and some types of car):

- 75% of the rated engine speed, where the rated engine speed is ≤ 5,000 RPM
- 50% of the rated engine speed, where the rated engine speed is > 5,000 RPM

For vehicle categories M and N (vehicles with at least four wheels that carry passengers or goods):

- 75% of the rated engine speed, where the rated engine speed is ≤ 5,000 RPM
- 3,750 RPM for a rated engine speed 5,000 – 7,500 RPM
- 50% of the rated engine speed, where the rated engine speed is ≥ 7,500 RPM

The measurement should include a period of constant engine speed (lasting at least 1 second) and the deceleration period. The maximum recorded noise level should be taken as the test value, and the test shall be repeated until three consecutive measurements that are within 2 dB L_{Amax} of each other are obtained. The test result would then be the arithmetic average of the three valid measurements.

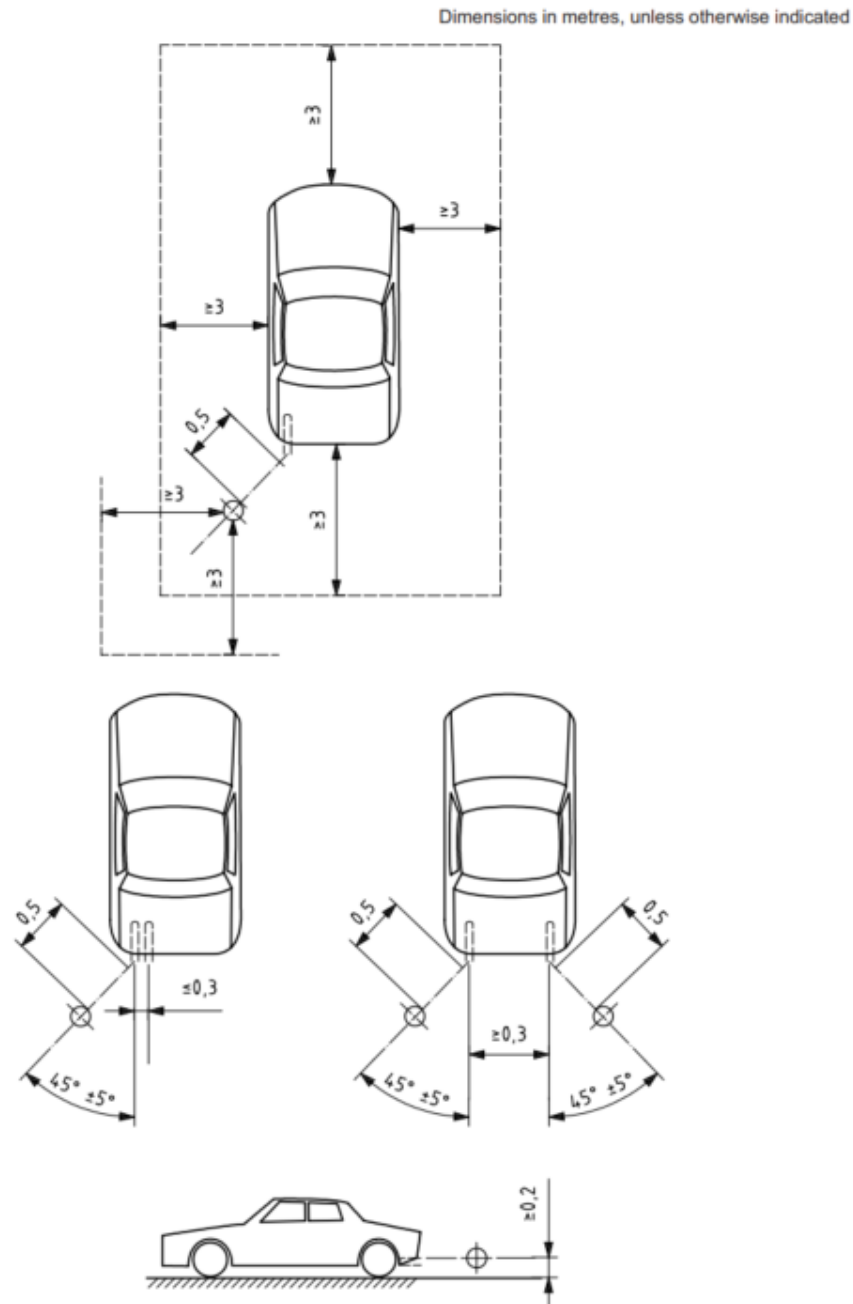


Figure 5.3: Examples of microphone positions for various exhaust locations (vehicle category M).
 Source: ISO [13]

Modified ISO 5130 test

There are examples of modified versions of the ISO 5130 stationary vehicle noise emission test being used in the UK by the police and motor racing industry. Essex Police [63] use ISO 5130 to test stationary cars, with the following alterations to allow for the testing environment without detriment to the tested vehicle:

- The engine speed tested for all cars is 50% of the maximum displayed on the vehicle’s tachometer
- No windshield correction is applied
- The measured noise levels are always rounded down rather than up or down
- The lowest measured value is used rather than the arithmetic average of the measurements.

In the motor industry, stationary noise emission testing follows standards set by governing bodies that are based on the ISO 5130 test procedure. More information on this is provided in the “Motor racing” section of this report.

The Devon and Cornwall Police were reported to use a modified version of the ISO 5130 test, where the equivalent continuous sound pressure level (L_{Aeq}) measured during the in-service tests was used as a basis for issuing fines [24]. The modified test was based on an engine test speed of 4,000 RPM [24].

Test method for accelerating road vehicles

Part 1 [11] and Part 2 [12] of ISO 362 provide a methodology for measuring noise levels using an acceleration test and a constant speed test method, noting that the test method and target acceleration rates are dependent on the power mass ratio of the vehicle. The Standard aims to measure vehicle noise under typical urban conditions. For certain types of vehicles, the test is undertaken for different gear/gear ratio conditions. Normally, the tests are undertaken on new vehicles during normal operating conditions, with tyres appropriate for the type of vehicle and at the correct inflation pressure. If this test is to be applied for measuring noise levels on live carriageways, these factors would become more variable.

The test is undertaken using two Class 1 sound level meters, positioned along a line perpendicular to the test track, at a distance of 7.5m from the centre line as shown in Figure 5.4. The microphones should be mounted at 1.2m above ground level, measuring the maximum sound pressure level from the vehicle pass-by.

ISO 362 requires at least four measurements for all test conditions to be made on each side of the vehicle and for each gear/gear ratio under test until four consecutive measurements that are within 2 dB L_{Amax} of each other are obtained. The measured sound pressure levels are arithmetically averaged for each side of the vehicle and the highest averaged value is corrected for the ratio between the measured acceleration and a value of acceleration representative of the same vehicle in typical urban conditions.

Like ISO 5130, the Standard stipulates conditions on the test site and its acoustic environment. The test site should be flat with no large reflective objects within a 50m radius from the centre of the test track. The surface of the track should be dry and acoustically reflective. The air temperature should be between 5°C and 40°C, and wind gusts below 5 m/s. The existing noise levels should be at least 10 dB L_{Amax} lower than the sound pressure level produced by the vehicle being tested or an appropriate correction should be applied if this is not possible.

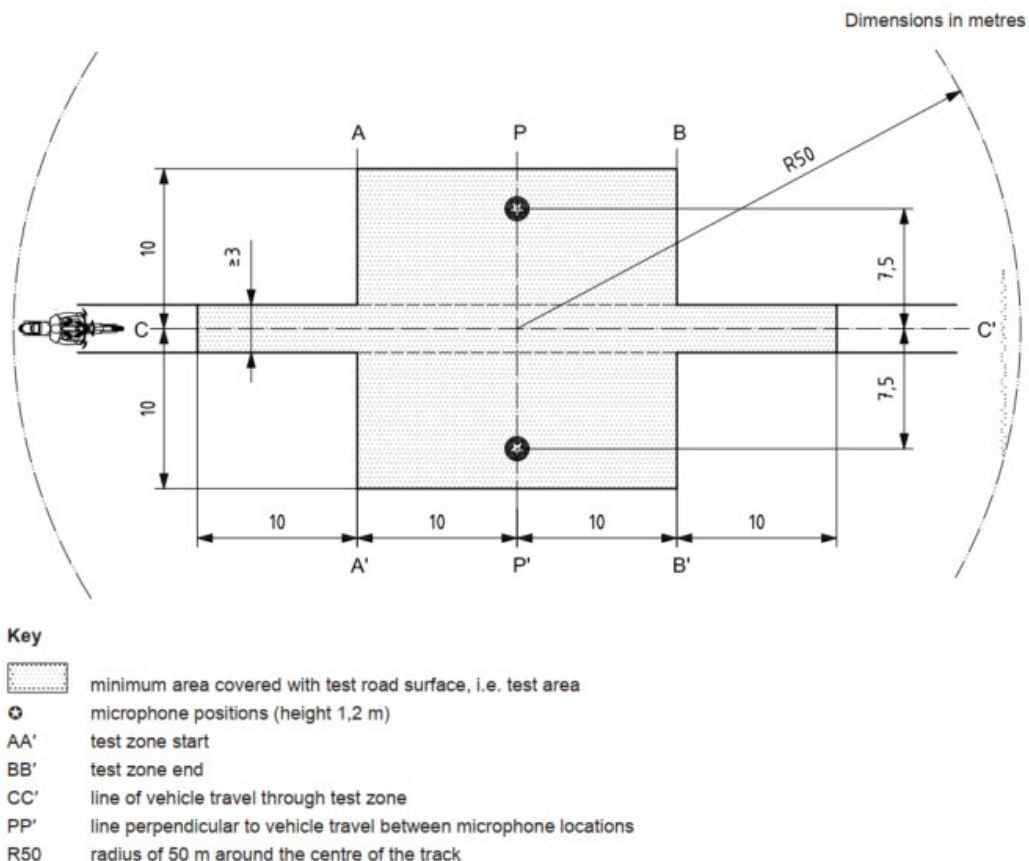


Figure 5.4: ISO 362:2009 test configuration Source: ISO [12]

Additional Sound Emission Provisions testing

Additional Sound Emissions Provisions (ASEP) is a working group developed as a result of revisions to ISO 362 and provides a technical basis for future revisions of UNECE Regulation 41 and Regulation 51. The aim of ASEP is encompassed within the following statement:

“The sound emission of the vehicle under normal driving conditions different from the conditions of the type approval test in Annex 3 shall not differ considerably from what can be expected from the type approval test result” [64]

An example of ASEP working to minimise the difference between sound emissions of vehicles under real-world conditions and the test procedures of ISO 362 can be found in the addition of extra tests introduced alongside the test procedures of ISO 362 designed to capture the vehicle’s noise at four different speeds for every gear [65]. Feedback from contracting parties indicated some concerns regarding the additional procedures, including the change in vehicle RPM used during the certification test, a desire to check ‘nonlinear’ behaviour, and a desire for an additional, independent, set of noise emission stringency tests for the approval of motor vehicles [64].

Recently ASEP has worked in partnership with the International Motorcycle Manufacturers Association to further develop guidance and testing procedures for motorcycle noise. Research has been undertaken to investigate a procedure that will allow noise testing of motorcycles within any throttle position, in all gears and at speeds of 20 – 100 km/h [66], with the initial results shown in Figure 5.5.

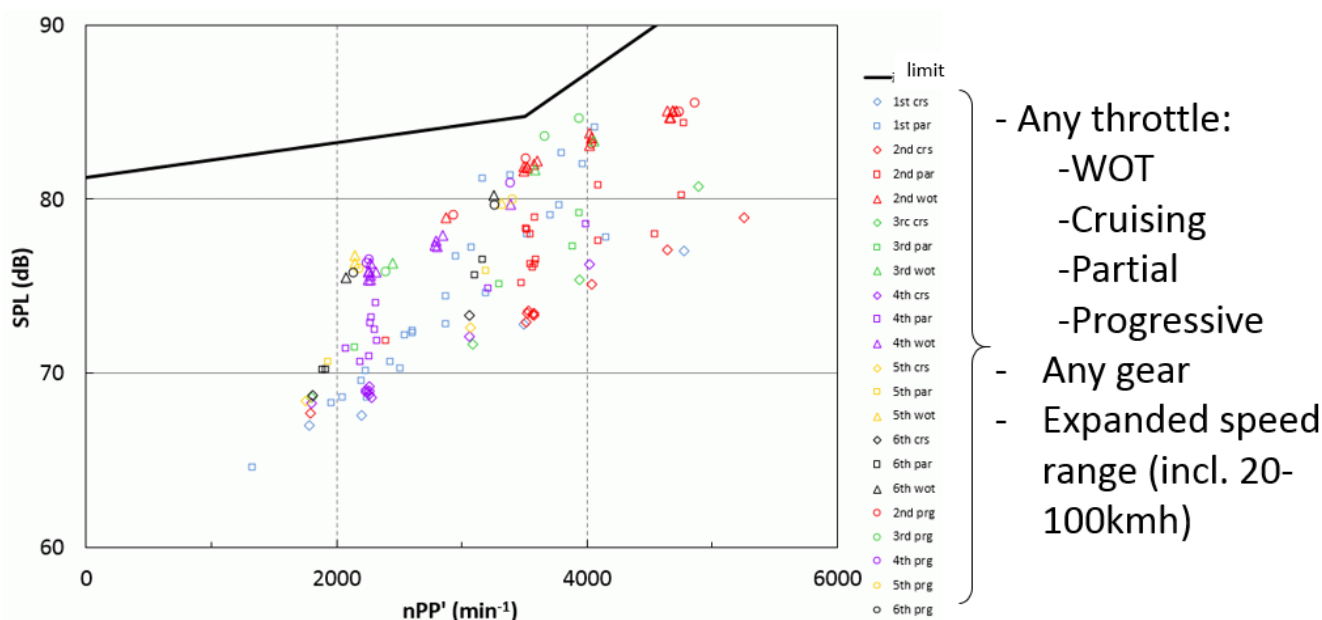


Figure 5.5: Sample of ASEP test results of a motorcycle with exhaust flaps [66]

Further on-going research and development includes the development of indoor vehicle noise testing. The benefits of indoor testing include the removal of uncertainty due to weather conditions which can affect both results and project costs due to test track overheads. The controlled indoor test environment also allows for results to be repeated to ensure consistency [66].

Test method for vehicle pass-bys

ISO 11819-1:2001 [67] provides a test methodology for measuring tyre-road noise using the statistical pass-by method, which requires measuring the noise and speed of individual vehicles passing a fixed point on a live carriageway and processing the data after the testing to determine the acoustic performance of the road surface. Although the standard does not aim to measure or appraise noise from exhaust systems, there are aspects of the test methodology that can be applied to measuring excessively loud vehicles on a live carriageway [21] [22]. The relevant aspects of this are described herein.

The statistical pass-by method requires the maximum noise level (L_{Amax}) produced by an individual vehicle to be measured, using a “fast” time response. At least 180 vehicle pass-bys are required to meet the test requirements, consisting of 100 cars and 80 heavy goods vehicles, however this would not be necessary for excessively loud vehicles. The standard requires the tests to be carried out on a relatively straight and flat section of road, covering a length of 30-50m. Like the ISO 362 method, it requires the

microphone to be positioned 7.5m horizontally from the centre of the lane of travel (the test lane) at a height of 1.2m. The microphone should be oriented horizontally and perpendicular to the road. The test requires approximate free-field conditions, noting constraints from roadside furniture such as safety barriers, and requires the sound pressure level prior to the measurement to be 6 dB below the measured maximum noise level when the vehicles passes the microphone. The standard also recommends the use of third-octave band measurements to check that the spectral data from the measurement to ensure that the tested vehicle is representative of its vehicle class (for example, the vehicle is well maintained).

Motor racing

Guidance from governing bodies

Motorsport UK and the Auto-Cycle Union publish noise limits to be enforced at racing events in their respective handbooks, which are issued annually, for cars and motorcycles respectively [68] [69]. Although these limits would not be applicable to the public highway, the test methods and technology involved have been evaluated as part of this research.

These handbooks also describe the test methods to be used to determine compliance. Motorsport UK [68] states that static tests should be undertaken in accordance with the ISO 5130 testing methodology, but with different engine test speed requirements and a measurement height of 0.5m to 1m above ground level rather than the height of the exhaust pipe. Further static tests can be undertaken at 2m from the centre of the side of the car, at a height of 1.2m above ground level as shown in Figure 5.6. The noise limits for both static tests are shown in Table 5.1. Non-compliance with the stated noise limits would result in prohibition of the offending vehicles from starting until they become compliant. However, some vehicles are exempt from noise testing during certain events. Exempt vehicles consist of all cars registered before 1 January 1947 and Formula 1 and single-seater cars registered before 1 January 1967.

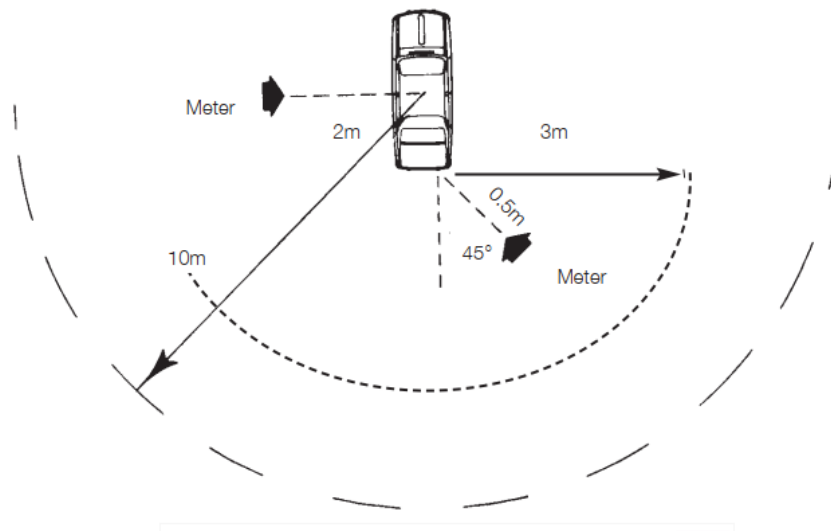


Figure 5.6: Motorsport UK static test. Source: MotorSport UK [68]

The Auto-Cycle Union [69] only require static tests to be undertaken for road racing events and Twinshock and Evo classes competing in Motocross events. The static tests should follow the ISO 5130 test method (including measurement height), based on the mean piston speed which varies according to the engine type. However, the guidance requires that the measured sound levels are rounded down (103.9 dB is recorded as 103 dB) and that the sound level meter is set to “slow” time-averaging during the measurement (samples sound once per second) instead of “fast” time-weighting stated in ISO 5130. Motorcycles participating in Motocross, Enduro and Speedway events are subjected to the Federation Internationale de la Motocyclisme’s (FIM) “Two Metre Max Test”, which requires exhaust noise emissions to be measured 2m from the rear of the motorcycle at a height of 1.35m above ground before the event. The measurement position should be 45° off axis from the exhaust pipe with the microphone at a horizontal orientation directed towards the motorcycle. The test requires the motorcyclist to open the throttle to maximum for one second during the measurement or before the rev limiter is reached, and the measured maximum sound pressure level is compared against the stated noise limits. Tolerances of +2-3 dB are applied during and after events, and allowances of up to 2 dB are applied depending on the air

temperature. The noise limits for the tests at 0.5m and 2m from the motorcycle's exhaust are presented in Table 5.1.

Table 5.1: Maximum noise limits from static tests required by motor racing governing bodies

Vehicle type and racing scenario	Test requirement	Maximum noise level (L_{Amax}) at specified distance	
		0.5m	2m
Car			
Car race, saloon and sports cars	Maximum at 3/4 maximum RPM	105 dB	93 dB
Car race, single seater and sports racing cars Autocross and rallycross	Maximum at 3/4 maximum RPM	108 dB	96 dB
Stage rally / autotest / trials	Maximum at 4,500 RPM	100 dB	88 dB
Road rally	Maximum at 2/3 maximum RPM	98 dB	86 dB
CCV	Maximum at 2/3 maximum RPM	100 dB	88 dB
Hillclimb and sprint, racing and sports libre cars	Maximum at 2/3 maximum RPM	110 dB	98 dB
Hillclimb and sprint, all other categories	Maximum at 2/3 maximum RPM	108 dB	96 dB
British Formula Three, British GT and British Touring Car Championships	Maximum at 3/4 maximum RPM	118 dB	n/a
Motorcycle			
Road racing	Maximum at mean piston speed depending on engine type, "slow" response ($L_{Amax,S}$) FIM Two Metre Max Test procedure	105 dB	n/a
Enduro	Throttle opened to maximum for up to 1 second or before rev limiter is reached (Two Metre Max Test)	n/a	112 dB
Motocross	All vehicles require the Two Metre Test, Twinshock and Evo classes also require a static test ($L_{Amax,S}$) FIM Two Metre Max Test procedure	96 dB for two-stroke engines 94 dB for four-stroke engines	112 dB for machines registered 2013 and onwards 115 dB for 2010-2012 machines
Speedway	FIM Two Metre Max Test procedure. Maximum at 11,000 RPM	n/a	112 dB

Source: Motorsport UK [68], Auto Cycle Union [69]

During the static testing, there are requirements for the ambient noise levels to not exceed 90 dB at 5m from the vehicle [69] and for the measured level to be 10 dB above the background noise level [68] [69]. The measurement instrumentation should be Class 1 or Class 2 precision.

In addition to the static noise monitoring, both governing bodies recommend noise measurements during motor racing events at selected locations near the race track or off-site. The Auto-Cycle Union stipulates a noise limit of 81 dB L_{Amax} at a distance of 100m from the track [69]. Motorsport UK requires that noise monitoring is undertaken during karting events, consisting of real-time noise measurements using a microphone suspended over the race track above the normal driving line on a straight section where karts are at their maximum power [68]. The following noise limits are set:

- 108 dB L_{Amax} at 1.8m ± 0.1m above the race track
- 105 dB L_{Amax} at 3.6m ± 0.1m above the race track

Noise management at race tracks

Race tracks use static noise limits stated in guidance from Motorsport UK and the Auto-Cycle Union to manage noise from motor racing [70] [71] [72] and vehicles are tested before admission to the race track in designated areas [72]. Logs are kept of the measured sound levels from all vehicles that can be submitted to the Local Authority or made publicly available [73].

In addition to static noise limits, drive-by noise limits are also used and are enforced by noise monitoring equipment at strategic locations [70] [72]. These are selected taking into account the vehicle behaviour at those parts of the track or circuit, such as acceleration, braking and gear changes. Cameras are used in combination with the measured noise levels to identify the offending vehicles so that they can be removed from the circuit until their noise emissions are compliant [70] [72] [74].

Drive-by noise limits are typically set at a distance of 20m from the race track or circuit, although this may vary subject to the circuit's design and site constraints. Silverstone set a drive-by noise limit of 102 dB L_{Amax} [70] at the measurement positions whereas Snetterton use a drive-by noise limit of 92 dB L_{Amax} for cars and motorcycles at a distance of 20m from the race track [71] [75]. In some cases, it might be possible to select a drive-by measurement position so that noise limits similar to those used for the static tests can be applied [76]. Brands Hatch sets drive-by noise limits according to the track usage scenario as shown in Table 5.2 [72], which are all based on maximum noise levels at 20m from the race track at an elevation of 2m above ground level.

Table 5.2: Brands Hatch noise limits

Scenario	Static noise limit (L_{Amax} , dB)	Drive-by noise limit at 20m (L_{Amax} , dB)
Indy Circuit		
Up to 60 days per year	105	92
Additional days	102	92
Grand Prix Circuit		
Up to 20 days per year	102	92
Up to 20 additional days per year	98 (Quiet Activity days)	n/a
Evening track events		
First day in any week	102	92
Days 2 and 3 in any week	102	90
Fourth day in any week	98	88
Non-Circuit Activity	105 or less	n/a
Quiet Activity Days	98	n/a

Source: MotorSport Vision Limited and Sevenoaks District Council [72]

Sometimes the drive-by noise limit is exceeded due to multiple vehicles passing the measurement point at the same time. This is managed at Mallory Park by setting the following allowances:

- For two vehicles passing simultaneously, the maximum noise level should not exceed the static test limit (same as the drive-by test limit) + 3.5 dB,
- For three vehicles passing simultaneously, the maximum noise level should not exceed the static test limit + 4.5 dB [76].

Further noise monitoring is often undertaken as dictated by noise management plans agreed with the relevant Local Authority and for compliance with planning conditions or noise abatement notices [76] [77]. This may comprise additional processing of drive-by data to calculate $L_{Aeq,30min}$ sound levels that may be required by the Local Authority [76] [77] or off-site monitoring near residential areas to ensure compliance with L_{Aeq} and L_{Amax} noise limits [76] [78]. Tyre squeal is also monitored [72] and movements causing excessive tyre squeal such as donuts, burn outs and drifting are banned [76].

Noise measurement instrumentation

Sound level meters

The testing methodologies described above using the ISO standards specify the use of Class 1 sound level meters when undertaking noise measurements. Class 1 sound level meters are precision instruments and provide the greatest level of accuracy and precision of the different sound level meter

classes. Class 2 sound level meters provide a lower level of precision across the range of sound frequencies measured. For example:

- At 1 kHz, the tolerance limits are ± 0.7 dB for Class 1 instruments and ± 1.0 dB for Class 2 equipment
- At 100 Hz, the tolerance limits are ± 1.0 dB for Class 1 instruments and ± 1.5 dB for Class 2 equipment
- At 63 Hz, the tolerance limits are ± 1.0 dB for Class 1 instruments and ± 2.0 dB for Class 2 equipment [62]

This indicates that the level of precision offered by different classes of sound level meter could have a marked effect on the accuracy of acoustic measurements for exhaust noise, which is an important factor to consider when using instrumentation for law enforcement. The survey of police forces indicated that those who use noise measurement equipment to perform stationary noise emission tests, use NTi XL2 analysers, which can be either Class 1 or Class 2 instruments depending on the microphone selected for the analyser.

Smartphone apps

The use of smartphone apps that measure noise levels is a topic that is generating a lot of interest in the acoustics community as the smartphone apps could offer a convenient alternative to a traditional sound level meter. Today, smartphones are readily available, affordable, lightweight and compact in dimensions, and the interface of the app can be designed to be user-friendly and intuitive for people without specialised knowledge in acoustics. Numerous noise measurement apps are currently available for the most common operating systems, but at present there are no specific apps for measuring vehicle noise. There is also no evidence to suggest that smartphone apps are currently being used by the police or Local Authorities to measure noise levels.

The suitability of smartphones for noise measurements has been the subject of numerous studies [79] [80] [81] [82]. The wide variety of smartphone models, operating systems and applications available on the market makes it impossible to draw general conclusions, but a comparison of results from various smartphone-based measurement systems with readings taken using Class 1 sound level meters show a broad degree of variation. For example, one study found that the measured noise levels with a smartphone app varied -28 dB to $+10$ dB compared with a Class 1 sound level meter, with the greatest discrepancies when the sound source contained a high proportion of low frequency content or impulsive characteristics [83]. These are the characteristics prevalent with exhaust systems, especially those that have been modified to make “cracking” or “popping” sounds.

It is generally accepted that the main factors affecting the accuracy of noise readings are the type of microphone being used, the type of analysis performed by the application and the experience of the individual performing the test (including correct positioning of the microphone, consideration for weather conditions, spurious noise induced from equipment handling). Training and the use of carefully stored external microphone attachments, separate calibrators, wind shields and tripods can alleviate most of these problems, improving accuracy, repeatability and reliability of the results. However, even with the use of an external microphone, the precision of the smartphone’s microphone and app may be too low and not conform the requirements of a Class 2 instrument. Therefore, a smartphone app would introduce uncertainty by not meeting the required technical standards or functionality, and is not appropriate for law enforcement purposes at the present time.

6. Approaches to noise control

This chapter discusses the approaches used to enforce against excessively noisy vehicles in other countries and the legal context that facilitates this, including ‘harder’ measures that penalise offenders and ‘softer’ measures encourage a behavioural change. Examples of vehicle identification technologies are also identified, along with requirements for formulating an evidence package to use as a basis for enforcement.

Legislation and enforcement methodologies

Australia

Australian states and territories have been tackling the issue of excessive vehicle noise for many years trialling various noise camera technological solutions and soft measures to educate and deter drivers from exceeding imposed noise thresholds. A majority of this work has focused on reducing the noise generated from truck engine brakes through various test trials conducted by individual Australian states [84], although instances of enforcement against excessively noisy cars and motorcycles have been reported.

For example, in Victoria sound level measurements were used for enforcement during 2018. A roadside police operation lasting a weekend targeted noisy vehicles in areas where complaints were received. Seven cars and one motorcycle tested by police failed the vehicle noise emission standards required by the Environment Protection (Vehicle Emissions) Regulations 2013 [85]. A fine up to \$800 can be issued for driving an excessively noisy vehicle. As a further enforcement measure during the operation, notices were issued under section 55AC of the Environment Protection Act 1970 [86] to the registered vehicle owners of excessively noisy vehicles that were not tested. The notice requires them to take their vehicles to a noise tester approved by the Environmental Protection Agency and obtain a compliance certificate to prove their vehicles meet legal noise limits [87].

Australian regulations include Australian Design Rules which manufactured vehicles must abide by and in-service standards which requires maintenance and modification limits for noise emissions. If thought to exceed appropriate noise levels, police require vehicles be sent for stationary noise testing at approved laboratories with noncompliance resulting in fines or cancellation of vehicle registration [88].

Australian Design Rule 28/01 [89] specifies sound level limits for different categories of vehicle when stationary or in motion. A note in the design standard explains that “A test is made on a stationary vehicle in order to provide a reference value for administrations which use this method to check vehicles in use.” The design standard also specifies the equipment to be used for sound level testing and the test conditions, including that the sound level meter is set to a “fast” response.

Australia accepts the technical requirements of UNECE Regulation 51/01 or 51/02 - “Vehicle Noise Emissions” [10] (as harmonised with EEC Directives 84/424 or 92/97- “The Sound Level of Vehicles”) as equivalent to Australian technical requirements, as long as the sound levels recorded during tests are lower than those contained in the Australian standard.

Canada

In Vancouver, British Columbia, Canadian police officers can issue a fine of \$109 and 3 demerit points based on a subjective assessment of the noise levels from the vehicle [90]. This method arises from a judgement in the British Columbia Supreme Court in 2012, which means that police no longer need to measure vehicle noise with a sound level meter. The British Columbia Motor Vehicle Act defines the noise limits for motorcycles (92 dB) and cars (84 dB).

Germany

In Germany, no information in relation to policing of noisy vehicles has been found, although research has been undertaken relating to the use of pass-by noise levels measured from vehicles for enforcement purposes [91]. The proposed test used a similar arrangement to that stated in ISO 362 but deviated from the standard in certain areas as a result of applying the test method to real world conditions rather than a test track environment. For example, the tests were not taken on roads complying with the ISO 10844 requirements for road surfaces, and the positioning of the microphone at a roadside position could affect results by introducing more absorption or reflection subject to the measurement location [91]. It proposed the use of wide open throttle test as a means of appraising noise levels in a real world environment, which has since become part of the ISO 362 testing methodology. The study also suggested the use of a

2 dB tolerance compared with type approval levels when using the ISO 362 test for law enforcement to account for the difference in the test environment [91].

India

In India, the Motor Vehicle Act prohibits the use of aftermarket exhausts on motorcycles using public roads if it is not stated on the vehicle's registration certificate [92]. According to local reports and anecdotal information [92] [93] [94], this is enforced by fining users of excessively noisy motorcycles INR 2,000, suspending the vehicle's registration certificate, and removal of the vehicle's exhaust.

New Zealand

Currently, enforcement of exhaust noise from vehicles in New Zealand is detailed in Land Transport Rule: Vehicle Equipment Amendment 2007 (the Rule amendment). The amendment aimed at reducing noise from the 'gross emitters', i.e. the noisiest vehicles in the fleet which are usually vehicles purposefully equipped with modified exhausts that exceed the legal noise limits [95]. The Rule amendment introduced more stringent noise emission limits for vehicles and improved the enforcement procedure by giving powers to inspectors undertaking periodic safety checks to refer a vehicle for an official noise tests. The legal noise limits currently enforced in New Zealand are summarised in Table 6.1.

Table 6.1: In-Use vehicle noise limits implemented in New Zealand

Vehicle Class	Noise level in Decibels (A)
Motorbikes with engine capacity of 125cm ³ or less (classes LC, LD, LE)	96
Motorbikes with engine capacity of more than 125cm ³ (classes LC, LD, LE)	100
Cars, 4x4s, light goods vehicles (classes MA, MB, MC and NA)	
- if first registered in New Zealand before 1 June 2008	95
- if first registered outside New Zealand before 1 January 1985 and first registered in New Zealand on or after 1 June 2008	95
- if first registered outside New Zealand on or after 1 January 1985 and first registered in New Zealand on or after 1 June 2008	90
- if a new vehicle first registered in New Zealand on or after 1 June 2008	90

Source: New Zealand Transport Agency [96]

As part of certification for use in New Zealand, manufacturers must undertake drive-by tests of noise emissions on their vehicles. A vehicle that has passed a drive-by test and is unmodified is compliant with New Zealand rules [95].

For all vehicles in service, noise from the exhaust must be similar to, or less than, the noise output from the exhaust system that was originally fitted when the vehicle was manufactured. The exhaust system may be noisier than the original one provided that the noise output is still below the legal noise limits.

Police officers can refer a vehicle to be tested for noise output as part of on-road policing and if the vehicle has been modified in a way that could increase its noise output. Additionally, all vehicles undergo a subjective noise test as part of the periodic Warrant of Fitness (WoF) checks [96]. A WoF inspection is also required when the original exhaust is modified, replaced or repaired to ensure the system is checked for noise output. During the test, the inspector uses judgement and experience to compare the level of exhaust noise from the vehicle against that of the original manufacturer's exhaust. If the exhaust is deemed to be noisier than the one provided by the manufacturer and is not clearly below the legal limits, the WoF inspector has the power to refer the vehicle for an objective noise emission test. The objective noise test consists of a ISO 5130 test of exhaust noise, and is carried out by certifiers trained and approved by the Low Volume Vehicle Technical Association.

If the vehicle fails to comply with legal noise limits during the objective test, is then ordered off the road until it is repaired, and must subsequently obtain a Low Volume Vehicle Certificate before a new WoF can be issued and the vehicle can circulate again.

Singapore

In Singapore, the Land Transport Authority regulates modifications to vehicles which produce excessive exhaust noise. Vehicles are required to undertake periodic mandatory inspections at authorised centres for road tax renewal to ensure they aren't producing excessive noise [97]. Noise emission standards are set by the National Environment Agency. Current Law enforcement practice includes road blocks and

measuring noise of vehicles. Noisy vehicles often cannot be caught on the spot unless traffic police are stationed at a certain place with a sound level meter and camera [98]. This is resource intensive, costly and neglects driving patterns [99].

The noise limits at 0.5m from the open end of the exhaust pipe for different vehicles classes imposed by the Environment Protection and Management (Vehicle Emission) Regulations [100] are summarised in Table 6.2. The in-service test method for new vehicles is based on European or Japanese standards.

Table 6.2: Vehicle noise limits in Singapore

Vehicle Class	Noise limits (dB, L_{Amax})		
	Before 1 July 1999	In-use from 1 July 1999	New vehicles
(a) Motor cycle (with or without a side car), scooter or trivan	106	99	94
(b) Motor car, taxi or station wagon (whether for passengers only or for goods and passengers)	105	103	97
(c) Goods vehicle or bus with gross vehicle weight not exceeding 3.5 tons	113	103	97
(d) Goods vehicle or bus with gross vehicle weight exceeding 3.5 tons	115	107	99

Thailand

In Thailand, the current noise limit for most vehicles, including motorcycles, is 90 dBA [101]. Increasing public concern about overly loud modified vehicles, and complaints raised to local authorities about disturbance from noisy vehicles, are driving the police to increase controls.

Thai law prescribes that changes of the engine or exhaust must be reported and approved by the relevant Land and Transport Office [102]. Any unapproved change can result in the police issuing a fine of 1000 baht and seizing of the vehicle until it is reverted to its original state [102].

Police forces in some urban areas (e.g. Bangkok) are also being trained and equipped with sound testing equipment in order to be able to undertake roadside checks of vehicle compliance with noise emission limits. Failure to comply with noise limits can result in the vehicle being banned from the road for 30 days and a 1,000 baht fine [101].

United Arab Emirates

In the UAE, it is illegal to drive a “noisy vehicle” [103] [104] although the definition of a noisy vehicle is not clearly defined and is therefore based on the judgement of individual police officers [105]. However, it is known that modifying cars to amplify sound is prohibited [106] and inappropriate car horn honking is an offence [105].

Enforcement measures consist of impounding the offending vehicle if it has been illegally modified, closing down workshops that modify vehicles to increase noise, fining drivers AED 2,000 for causing noise or AED 1,000 for illegal modifications, and adding penalty points to driving permits [103] [105] [107]. Enforcement measures resulted in 6,630 vehicles being impounded in Abu Dhabi during 2014 [106] and 935 vehicles in Sharjah during 2018 [105].

United States of America

Enforcement of excessively noisy vehicles differs from state to state, and can include the use of noise limits and requirements for compliant exhaust systems. Several states, if not all, include in their respective vehicle codes for rules prohibiting the modification of exhaust systems to amplify or increase noise levels, and requiring mufflers to be fitted that are not cut-out or bypassed [108] [109] [110]. Not all states use noise limits to enforce excessively noisy vehicles [111]. In terms of enforcement rates, it is reported that New Jersey issued 5,104 summons for loud exhaust systems in 2012 and 3,868 in 2016 [112]. Enforcement levels for “loud pipes” on motorcycles was substantially lower – 28 tickets were issued during 2012 and 10 in the first 9 months of 2017 [112].

In California, exhaust modifications are legal provided that they are compliant with the requirements stipulated in the California Vehicle Code [113]. According to Article 2.5 and Codes 27150-27151 of the California Vehicle Code, a legal exhaust is one that is fitted with a muffler and has noise levels that do not exceed 95 dB for vehicles lighter than 6,000 pounds (~2,720 kg) when using a static noise test. For

motorcycles, the noise limits are set to 80 dB for vehicles manufactured after 1985 and up to 92 dB for those manufactured before 1970. Car or motorcycle exhaust systems that are modified to increase or amplify noise in excess of the stated noise limits are prohibited [113].

Until 2019, enforcement consisted of issuing vehicle rectification notices, requiring the road user to repair their exhaust or change it for a quieter one, and then take it to a test centre for verification to demonstrate compliance within 30 days [114]. After the deadline for compliance has passed, fines or penalties may occur. Since 1 January 2019, when Assembly Bill No 1824 of 2018 [115] was enacted into law, police have powers to take “appropriate enforcement action” beyond issuing vehicle correction notices. This has allowed the police to issue immediate fines to offenders, starting at \$25 [116].

Other states, such as Florida, set speed-dependent noise limits based on drive-by noise limits at 50 feet (approximately 15m) from the centre of the lane in the direction of travel [108]. The noise limits are dependent on the age of the vehicle and the vehicle class, as shown in Table 6.3. Massachusetts uses a mixture of static and drive-by noise limits for motorcycles, with the test method selected depending on whether the motorcycle is for use off-road [109].

Table 6.3: Drive-by noise limits in Florida

Vehicle class and age		Sound limit at 50 feet (~15m)	
		35 mph or less	Over 35 mph
a) Motorcycles other than motor-driven cycles	Before 1 January 1979	82	86
	On/after 1 January 1979	78	82
b) Motor vehicles with a gross vehicle weight rating exceeding 10,000 pounds (~ 4,536 kg)	On/after 1 January 1975	86	90
c) For motor-driven cycles and any other motor vehicle not included in (a) or (b)	Before 1 January 1979	76	82
	On/after 1 January 1979	72	79

Source: The 2018 Florida Statutes, Title XXIII Motor Vehicles, Chapter 316 State Uniform Traffic Control, 316.293 Motor Vehicle Noise [108].

Softer measures

A number of ‘softer’ enforcement measures have been used to reduce disturbance to local residents from excessively noisy vehicles. These are measures that aim to improve compliance without penalising offenders, for example, by improving awareness of the issue, running education programmes, or imposing access restrictions or curfews. Examples of soft enforcement measures are described in more detail in the following subsections.

Public awareness campaigns

Police forces in India and Japan have used public awareness campaigns to advise road users that offences could be committed if their exhaust systems are excessively noisy [117] [118]. These campaigns largely consisted of issuing posters or flyers at key locations where drivers congregate, such as service centres and rest areas, and social media has also been used to distribute the message. Mechanics and vehicle workshops were also contacted to advise them not to fit aftermarket exhausts and the legal consequences of doing so. In Japan, this was supplemented with streetside inspections during an ‘illegal exhaust awareness month’ [118], while a social media-based system was promoted in India to help people disturbed by excessively loud vehicles to report them and send photographs of the vehicles number plate [117].



Figure 6.1: Public awareness materials used in India (left) and Japan (right). Sources: Maxabout [117], Hsu [118]

Similar public awareness campaigns have also been used in the USA. For example, the police at Sioux Falls, South Dakota, held free exhaust noise checking events over a one month period [119]. During these events, the exhaust noise was tested against a noise limit of 80 dB at 25 ft (approximately 7.5m). No information is available to evaluate how effective the public awareness campaigns in India, Japan and the USA were or whether they resulted in short-term or long-term decrease in complaints about excessively noisy vehicles.

Australia – multiple soft measures

Soft measures implemented around Australia specifically to combat loud truck braking include advisory signs, vehicle inspections, industry-based educational programs, curfews, and access restrictions [88]. Specifically, advisory signs are used to deter truck drives from using engine brakes in community areas (lowering noise emissions). This has found to be ineffective, reportedly having an inverse effect in some location [120].

Education programs have been found to have mixed results. Compliance with education programs has found to be high, although significant numbers of truck drivers fail to respond and continued to impact the community with excessively noisy engine brakes. It is noted by New South Wales that enforcement measures are usually necessary where high levels of compliance are required to achieve the outcome sought [88] in order to reduce complaints and disturbance to local residents. Curfews on trucks using roads were also found hard to police and ineffective as noise issues are relocated elsewhere. Similar soft measures applied to other motor vehicles would also be ineffective. The use of warning letters following triggering of noise cameras during trials were found to effectively reduce the amount of noise incidences [88]. Table 6.4 summarises the soft measures used in Australia and their effectiveness which reducing truck braking noise emissions.

Table 6.4: Soft Measures used in Australia and their effectiveness

Soft Measures	Effective	Result
Advisory Signs [120].	No	Ineffective with inverse effects
Education Programs [88]	No	Some compliance, although not 100%. Enforcement measures is needed for high levels of compliance.

Soft Measures	Effective	Result
Brochures [88]	No	Results weren't measured although no evidence of any improvement and the noise problem remains.
Curfews [88]	No	Ineffective. Hard to police and redirected noise issues to neighboring communities.
Access Restrictions [88]	No	Noise is relocated to surrounding areas
Warning Letters [88]	Yes	Effectively reduced the amount of noise incidences. High compliance

Measures using technology

In Edmonton, Canada, a four-month scheme was implemented whereby eight noise monitoring stations were attached to traffic lights within areas that were notorious for high levels of noise due to vehicles [121] [122]. The noise monitoring system worked in conjunction with a traffic camera so that when a predetermined threshold was exceeded, the camera is activated in order to identify the number plate of the offending vehicle. The selected threshold level was 85 dB(A) based on community noise standards [123] [124]. Enforcement would consist of issuing a fine to offending vehicles, however, this functionality was not used during the trial [122].

Four of the noise monitoring stations were equipped with digital display boards, as shown in Figure 6.2, which displayed the measured vehicle noise levels numerically to drivers even if they were below the threshold sound level [122] [124]. However, there were concerns that the displays would encourage drivers to test their cars output as opposed to driving normally [125]. During the trial, after reports of stunting at the digital display noise monitoring locations, the digital displays were deactivated [123].



Figure 6.2: Digital display and noise camera. Source Canada News [123]

The cost of the pilot project was initially estimated to be between \$50,000 - \$100,000 but the overall cost would be dependent on the equipment rental costs across the 4-month period [126], however, the final costs have not been readily documented.

Testing methodologies

The ISO 5130 style methodology has been adopted throughout Europe and in Australia, New Zealand and Japan as it is tied into the UNECE Regulation 41 and 51.

The United States of America and Canada use a standard produced by the Society of Automotive Engineers, SAE J 1492 [127], for stationary tests of light vehicles [114]. The standard is similar to ISO 5130 [13] and incorporates aspects of it into the measurement procedure [127]. Similarly, ISO 5130 incorporates aspects of SAE J 1492 in its methodology [13].

Automated technology for roadside vehicle noise measurement and vehicle identification

Noise cameras

Several countries have trialled the use of “noise cameras” to identify vehicles considered to produce excessive noise, including Australia, Canada (described above), Singapore and the United Arab Emirates. Although there are differences between the systems, they generally consist of at least one microphone, an ANPR and a video feed, with their outputs timestamped to form an evidence package. It should be noted that this is distinctly different from other systems known as “acoustic cameras”, which use an array of microphones to build up a two-dimensional picture of noise sources, sometimes overlaid over a video image.

Details about the noise camera systems used in Australia, Singapore and the United Arab Emirates are provided in the following subsections.

Australia

In Australia, noise camera trials have been undertaken in several states focussed on reducing braking noise from trucks rather than noisy exhaust systems. Table 6.5 provides details of the countrywide trials headed by the National Transport Commission.

Table 6.5: Outcomes of Australian noise camera trials

State	Year(s)	Description	Outcome
Tasmania [88]	2003	Trucks that triggered the camera were sent letters telling them to undergo repairs and upgrades. Only the loudest percentage of trucks were issued letters due to the uncertainty in the accuracy of the measurements.	Some truck owners were encouraged to upgrade their vehicles, as a result of being contacted.
Victoria [84]	2010	System issued notice to drivers when the noise camera was triggered requiring drivers to present vehicle for noise testing. Vehicles that were tested as too noisy needed to be rectified and re-tested. If vehicles didn't come to the test centre then the drivers' registration was suspended.	Numerous letters were issued, however, that was mainly due to false positives (noisy exhausts, rattling, and clanking). The state government raised issues with suitable background noise levels, credibility of certification and calibration of noise cameras, complexity of standard regulation, and the fairness of purely objective noise levels as being factors that needed to be addressed in order to reliably use noise cameras.
New South Wales [84]	2009	The noise camera triggered a letter that was sent to truck operators. Letter stated exceedance level and recommendations on how to fix the problem.	A 50% reduction in the number of exceedances of the in-service standard during the education program. It was found that 5% of the vehicles exceeding the in-service standard were responsible for 40% of the detections.
	2010	The government installed a noise camera with broad publicity. No letters were issued when triggered.	A significant reduction in the number of detections, with some evidence of a “halo effect” around the noise cameras. The community surrounding the noise camera site report an increase in noisy engine brakes following completion of the education programme.
South Australia [84]	Ongoing	Limited information available, but noise cameras were installed in strategic locations to objectively measure truck engine noise	Trials in South Australia have found that “less than one in every thousand heavy vehicle pass-bys resulted in a detection that exceeded the national standard”.

Singapore

In Singapore, the NoivelCam system has been developed by the Nanyang Technological University and tested for identifying excessively noisy vehicles, including those that have been illegally modified or poorly maintained [99] [98]. The system consists of two highly directional shotgun microphones for measuring sound pressure levels and recording audio, an ANPR and a wide-angled view camera for continuous recording of video [98]. These components are connected to a controller for data acquisition and processing, as shown in Figure 6.3.

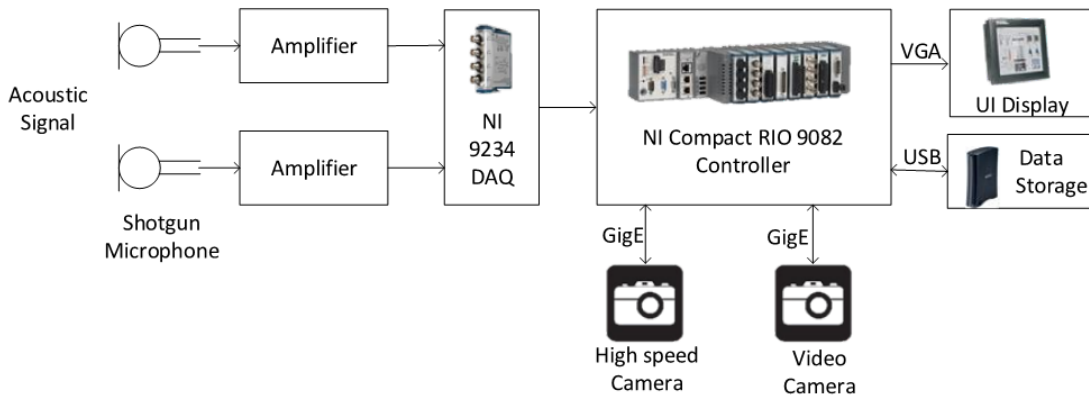


Figure 6.3: NoivelCam systems diagram. Source: Agha et al [98].

The system localises vehicles using the two microphones and can generate alerts if individual vehicles generate noise exceeding a predetermined threshold level. On each occasion when the data acquisition process is triggered by an exceedance of the threshold noise level, a report is saved including audio and video recording, vehicle number plate and time history of recorded sound pressure level at the microphones. These reports can then be further analysed to confirm violations and issue letters accordingly. The developers recommend the use of the ISO 362 pass-by-noise test standards for setting the threshold noise levels for excessively noisy exhaust systems.

NoivelCam is currently configured for single lane monitoring on multi-lane highways in an overhead deployment setup as shown in Figure 6.4 [99], although multi-lane detection is under development. Offline data processing algorithms identify the vehicle class and filter out false alarms produced by noise interference from neighbouring lanes on motorways.

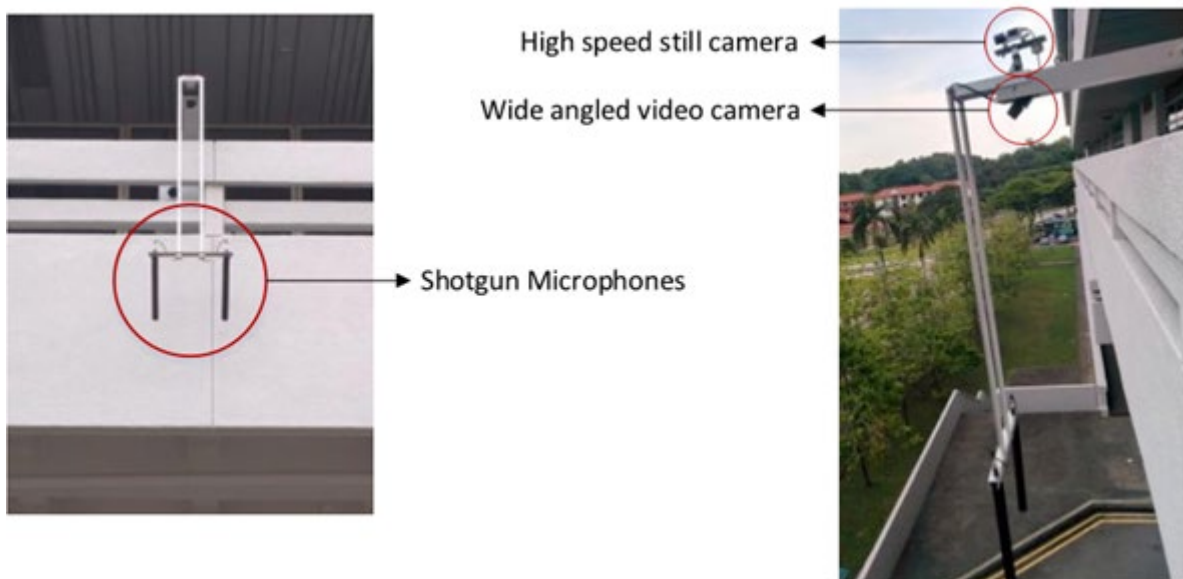


Figure 6.4: Deployment of NoivelCam. Source: Agha et al [98].

The accuracy of the system has been tested, with the estimated noise level at the source found to be within ± 0.8 dB compared to source measurements undertaken with a Class 1 sound level meter [99]. The use of shotgun microphones maximises focus on the monitored lane suppressing contributions from noise sources outside the lane by at least 10dB, with signal processing providing further support to identify the source. In some cases, manual inspection of audio-visual documentation is still required to identify false triggers or confirm violations [99].

Onsite testing has shown that the system provides sufficient information to assess situations where a vehicle travels in the monitored lane with no competing loud noise sources on neighbouring lanes. In certain instances however, the information is not conclusive to establish if the vehicle is in breach of noise thresholds, for example if noise from a loud vehicle (e.g. a truck) on a neighbouring lane affects the source identification [99].

United Arab Emirates

The Abu Dhabi Police Force has developed a noise camera, to tackle excessive noise produced from illegal modifications on cars [128]. Despite the publicity regarding noise cameras in Abu Dhabi, no technical information regarding the technology used or the deployment of the noise cameras has been made publicly available. However, it is claimed that the system consists of a sound level meter and a camera, and press releases show that the system will appear as depicted in Figure 6.5.



Figure 6.5: Abu Dhabi noise camera. Source: Altaher [128].

Beamforming technologies

Beamforming is a common technique used to analyse noise sources on airplanes and trains, involving an array of microphones to measure which area of the vehicle is producing noise and at what level.

The application of beamforming for pass-by measurements is very versatile because it is not only used to identify the main noise sources, but also to obtain additional information on the noise sources present in the car and their acoustic characteristics [129]. For example, spectral data can be collected to appraise the noise produced from specific vehicle components against, as shown in Figure 6.6 [130].

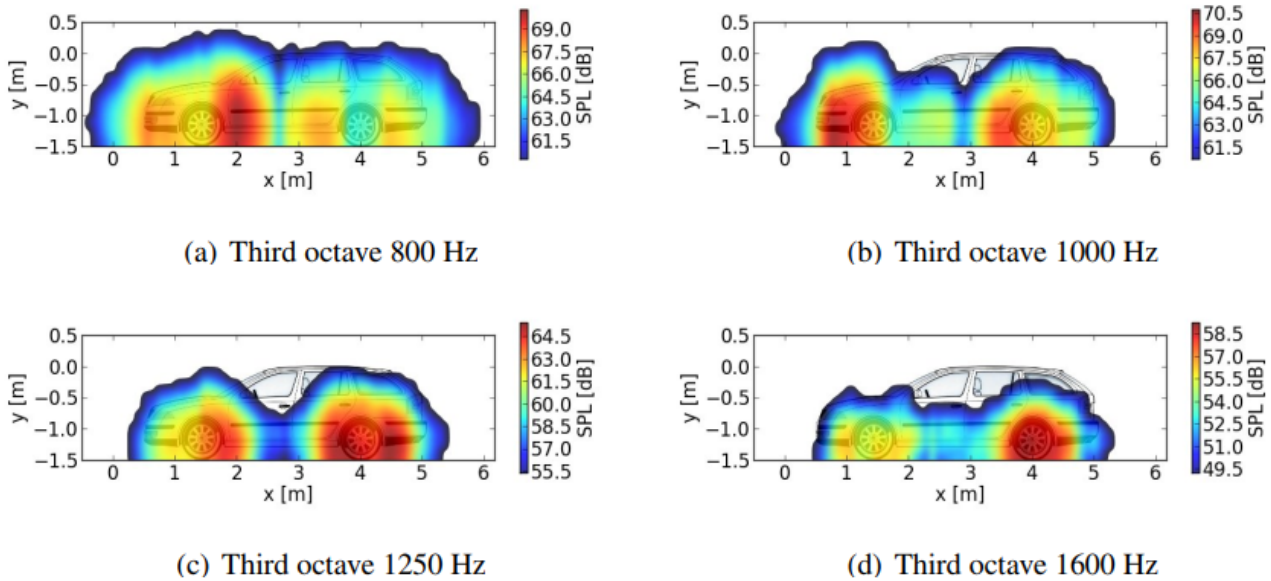


Figure 6.6: Measured noise levels of a vehicle moving at 80 km/h using beamforming. Source: Ballesteros et al [130]

The beamforming method has the following limitations:

- The simplest beamforming algorithms have poor resolution at low frequency [131], although this can be overcome by using more advanced processing algorithms to improve localisation [132]
- The pattern of the main beam can produce sidelobes, which influence the system's ability to detect high frequencies [129], which can be overcome by increasing the size of the microphone array (spatial resolution) [133] and optimising the beamwidth and processing algorithms [131].
- Simultaneously measuring using a large number of microphone sensors, which creates logistical issues and increases the cost of the technology [133],
- Transmitting and saving this large amount of acquired waveform data [133], and
- Being able to quickly process large data sets to visualise the results in real time [133].

Despite this, beamforming technologies can use acoustic signatures to differentiate illegally modified vehicle exhausts from those that are less likely to cause annoyance (i.e. compliant with the Road Vehicles (Construction and Use) Regulations 1986), as shown in Figure 6.7.

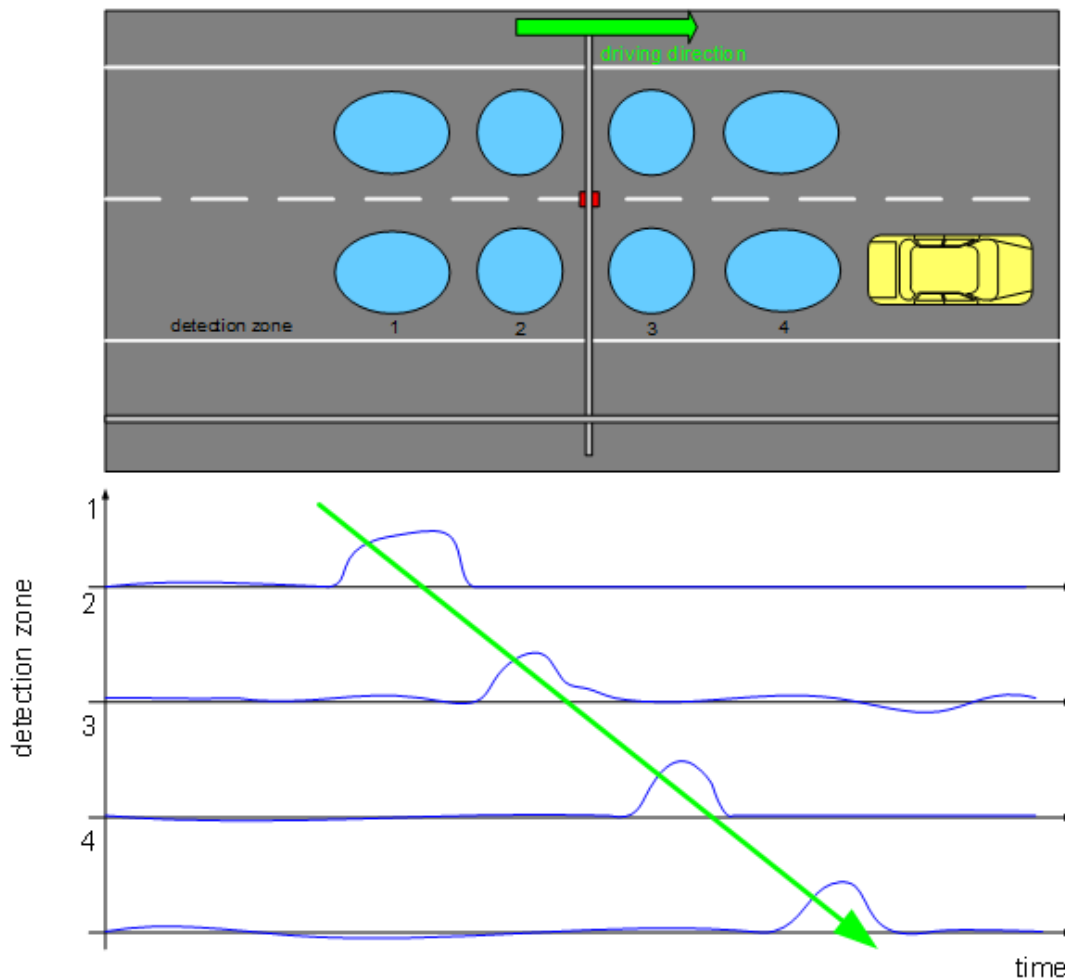


Figure 6.7: Akut's use of acoustic signatures to track and identify vehicles. Source: Graf [134]

Akut is a noise camera system developed in Austria that uses beamforming technology and has been successfully deployed in tunnels for incident detection purposes [135] [136] and on multi-lane high speed roads to identify certain vehicle classes that are required to pay toll charges. It uses artificial intelligence to learn the noise characteristics of the road it is deployed on and can be trained to identify illegally modified exhausts if required by processing the spectral content vehicle pass-bys. However, this particular product has not been used for detecting vehicles fitted with aftermarket exhaust systems to date and would require further development and testing prior to deployment for this purpose. Like the other noise camera systems, Akut can generate an alert when a vehicle is identified that meets the preferred acoustic requirements and prompt a letter to be issued to the owner of the registered vehicle. The system is currently under trial in the UK by Highways England in the Southwick Tunnel near Brighton. The system has also been used successfully elsewhere outside of tunnel environments.

Acoustic detection of gunfire

Although not designed to identify loud vehicles, two systems are available to law enforcement agencies which may have some application in this area. These systems have been used to detect gunfire and identify the shooter's location. The technology characteristics of the systems are similar and rely on the impulsive nature of gunfire sound, with sensors detecting the characteristics of gunfire – either a “pulse” or the supersonic shock wave generated due to the bullet traveling through the air.

An example is the Boomerang III system shown in Figure 6.8 [137], where the detection unit consist of seven small microphone sensors mounted on a mast to the rear of a military vehicle, as shown below. Each microphone detects the gunfire sound at slightly different times. The internal controller then computes the direction of the bullet, distance above the ground and range to the shooter. There is also a display system which tells the user the shooter's range, elevation and azimuth.



Figure 6.8: Boomerang III. Source: Raytheon [137]

As the system has been designed specifically to detect gunfire, the manufacturer has incorporated technology to filter out “non-ballistic” events. This would include noise arising from the vehicle where the mast is mounted, and other noise from around the vehicle (urban sounds). This would be a limitation in applying the technology directly, however the system is a useful reference for systems developed using “noise camera” techniques.

Another example is ShotSpotter, designed to determine the location of gun fire in an urban environment. An array of microphones is placed on either lamp post or on top of buildings or tall structure [138] [139]. The software filters out ambient background noise and listens for impulsive sounds characteristic of gunfire (called pulses). If the sensor detects a pulse it extracts pulse feature from the waveform, such as sharpness, strength, duration and decay time. If at least three sensors detect a pulse, this is identified as a gunshot. Triangulation is used based on the time difference of arrival and angle of arrival of the sound to determine a precise location.



Figure 6.9: ShotSpotter [138]

It is possible to discriminate between gunfire and normal community noises by placing acoustic sensors at wide distances so that only extremely loud sounds (like gunfire) can reach several sensors; this filtering technique is termed as ‘spatial filter’.

Creating an evidence package using an automated system

This section explores the potential requirements an automated system for enforcement would need in order to create a robust evidence package to use as a basis for enforcement.

Systems used in civic traffic enforcement

If an automated system is to be deployed to identify, detect and enforce against excessively noisy vehicles, it is likely that the processes, procedures and standards of proof will be substantially similar to those used in civic traffic enforcement. To this end, a functional block diagram for an automatic enforcement system has been developed and is shown in Figure 6.10. This consists of three principal elements. The first being the section of the system that detects the contravention, the second captures contemporaneous supporting evidence and the third creates a package suitable for secure transmission to a location where decisions about whether or not further action is required will be made.

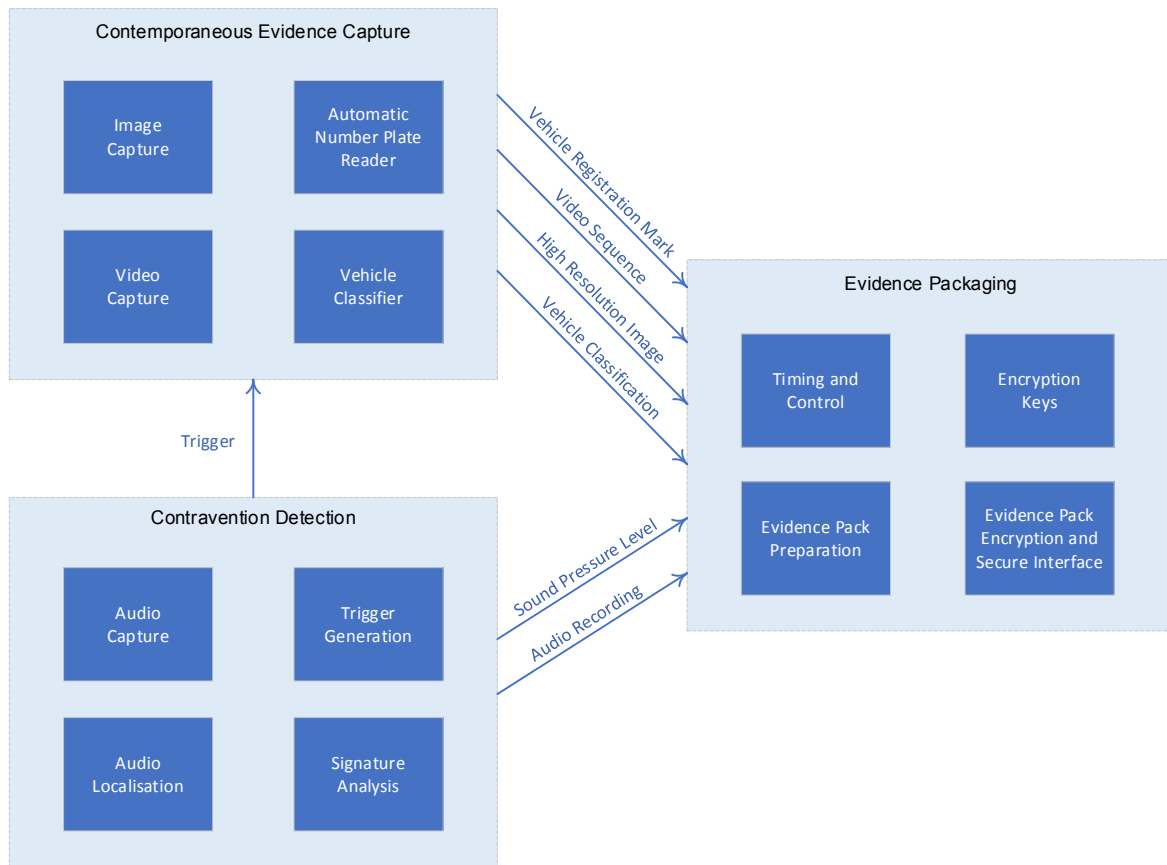


Figure 6.10: Functional block diagram for an automatic enforcement system

The three high level system functions act together to generate an evidentially acceptable package of images and metadata² that can be used to demonstrate that a motorist has contravened the relevant legislation. As an unattended system, it is expected that the system will have to meet requirements similar to those documented in the Department for Transport’s “Certification of Approved Devices”.

The three core subsystems shown in the functional block diagram are explained in more detail in the following sections in the context of excessively noisy vehicles.

Contravention Detection

The contravention detection system performs the function of analysing the soundscape and determining that an event of interest is occurring. This subsystem has four components:

- An audio capture element that uses one or more microphones to create a high quality audio recording of the soundscape,
- An element that extracts the location of the sound source. This can be by means of two or more microphones at set trigger positions, or by triangulation using a small number of microphones (possibly the same microphones as the audio capture element),
- A process that uses the incoming sound signal to generate a trigger condition, most likely by comparing the incoming sound level against a number of preset thresholds (possibly by time of day, frequency band or some other characteristic of the sound)
- A process that performs an analysis of the recorded sound to determine if the sound event is a motor vehicle. This may use spectral and temporal analysis to compare with a library of vehicle profile classes. This process will also generate a time referenced sequence of measured sound pressure levels.

This element of the overall system has the most uncertainty in the ability of the technology to perform the required function. A number of experiments, to be carried out in both controlled and real world

² Metadata is information about the data collected that, in this case, ties the various package contents together as a coherent whole. The metadata in this case will include the time of capture (of images, sound pressure levels and audio and video recordings), any relevant system settings and the vehicle registration mark.

environments, would be required to establish the capability of these technologies to meet the system requirements and to develop a detailed specification of the system's requirements.

Contemporaneous Evidence Capture

The Contemporaneous Evidence Capture element comprises a number of industry standard modules specified to provide appropriate supporting evidence that will allow a real world vehicle to be tied to the contravention. This subsystem will contain four components:

- A high resolution camera to provide one or more images of the contravening vehicle that allow the vehicle registration mark to be read by a human operator. The images provided will be in full colour to allow the make, model and colour of the vehicle to be extracted and any other distinguishing features to be captured. This will ensure that the contravening vehicle is uniquely identified for subsequent enforcement processing,
- A wide angle camera to capture a context video sequence. This video will also be full colour and the resulting video recording will contain a configurable amount of video from before the trigger event and will be used to demonstrate that the contravening vehicle is the only one that could have caused the trigger and that there are no other mitigating circumstances,
- An ANPR will provide a machine readable identifier for the vehicle creating the contravention. The ANPR element will use either its own camera or the high resolution image capture device as its image source,
- A vehicle classification sensor will be included to allow different thresholds to be used for cars and other classes of vehicle.

This element of the system is mature technology and is widely used in unattended enforcement.

Evidence Packaging

This component is another standard industry element and is responsible for collating the information generated by the other subsystems and creating a coherent evidence pack from it. This component would be similar to a standard evidence package from an unattended civil traffic enforcement system with limited changes to the configuration files. This element has four components:

- A timing and control component that synchronises the system time stamps with a recognised standard clock source. This ensures that any time-stamps used in the evidence package are correct to within 10 seconds of UK civil time. This component is also responsible for ensuring that enforcement only takes place at permitted times as defined in the equipment configuration settings
- The evidence pack preparation component takes the information generated by the other system components and wraps them up into a single multimedia object. This single object will typically contain an XML (or similar) descriptor of the file content and will contain an authentication token to prevent unauthorised modification of any element of the evidence pack
- The encryption and secure interface component will take the evidence package (including the authentication token) and encrypt it in accordance with the latest standards applicable to unattended civil traffic enforcement. The keys required for this process will be managed by the Encryption Key management component. The secure interface will allow the encrypted and authenticated evidence package to be safely sent over the public Internet. A secondary function of the secure interface is to receive and validate encrypted system configuration files. These files will be encrypted and authenticated in the same manner as the evidential packages.
- The Encryption Key management component will ensure that the encryption keys (technically one time session keys) used to encrypt the evidence pack are securely generated and appropriately encrypted before being appended to the transmitted evidence pack. This will be undertaken through the use of time bound Key Encryption Keys.

These components are standard elements of a DfT approved civil traffic enforcement system and will not need to be prototyped during for any future system.

Potential for integration with other systems

To limit associated cost, maintenance and support requirements for these technologies, it may be desirable to explore opportunities for integrating new technology with the existing systems intended for other purposes. For example, the following two systems have a similar number of technological requirements:

- Clean Air Zones, where ANPR cameras will be required to identify vehicles entering Clean Air Zones that are prohibited [140]
- Replacement of the National ANPR Data Centre used by police forces with a centralised and upgraded system serving England and Wales [141]

However, integration with or reliance on other third party systems could adversely compromise the integrity of the evidence package by introducing a source of uncertainty. For this reason, any future automated system for identifying and detecting excessively noisy vehicles is likely to need to be a standalone system.

Summary

The literature review has shown that appropriate test methods exist that can measure noise from excessively noisy vehicles when stationary or in motion, and research has been undertaken to characterise their spectral profile. Softer enforcement measures such as advisory signage and promotional materials help to raise awareness of the issue, but can be ineffective. There have been mixed results from educational programmes.

Around the world, fines and vehicle rectification notices are used as enforcement measures in a similar way to the UK. Some countries require vehicle owners to visit approved testers to verify that the noisy modified exhausts have been replaced with legal, quieter models as part of the vehicle rectification notice. This is akin to the procedure used in the UK's Vehicle Defect Rectification Scheme.

In the UK, it can be reasonably concluded that the majority of police forces subjectively assess whether vehicles cause excess noise based on recent stakeholder engagement with the police and previous research [24]. Where sound level meters are used, the vehicles are tested against a set threshold noise level that is not bespoke to the specific vehicle (does not refer to type approval levels specific to the make and model of the vehicle). Similar approaches are used worldwide.

There are several examples of automated noise camera systems being used to identify excessively noisy vehicles and issue letters to the registered keeper. Some of these systems test the noise emissions from individual vehicles against a predetermined noise limit, others are more sophisticated and can use acoustic signatures too. Automated systems would need to meet certain requirements to ensure that the data collected is robust and admissible for enforcement. The suitability of noise camera systems and other tools for vehicle identification and enforcement are discussed in Chapter 7.

7. Potential solutions

Identified technologies and appraisal methods

Types of technologies and appraisal methods

The review of approaches used worldwide to detect and enforce against excessively noisy vehicles indicated that several methods and technologies could be used for this purpose, and they generally fall into one of four categories, which are:

- Online or digital reporting tools managed by police forces or third party organisations collaborating with the police
- Manual appraisal of noise levels using subjective testing or handheld instruments that measure sound levels
- Noise cameras
- Systems using acoustic signatures to localise specific noise sources

The categorisation of the technologies and approaches identified in the review are summarised in Table 7.1. An analysis of the technologies and methods for each category is provided in the following subsections.

Table 7.1: Identified technologies

Technology /solution	Online / digital reporting tool	Manual sound level appraisal	Noise camera	Uses acoustic signatures
Operation SNAP	✓			
Operation Crackdown	✓			
Other police online reporting tools	✓			
Self Evident / Noise App / Local Authority noise reporting app	✓			
Sound level meter smartphone app		✓ (Quantitative)		
Subjective testing		✓ (Qualitative)		
Stationary noise testing (ISO 5130 or variant) using a sound level meter		✓ (Quantitative)		
Noise monitoring of trucks in Australia			✓	
Noise monitoring in Edmonton, Canada			✓	
Noise monitoring in Abu Dhabi			✓	
NoivelCam			✓	
Akut				✓
Boomerang III				✓
ShotSpotter				✓

Online / digital reporting tools

Several reporting tools were identified that can be used to submit non-emergency reports of perceived crimes or noise nuisance to the relevant authorities. Most of the reporting systems are accessed via webpages, although there are some instances of smartphone apps being used for this, particularly by Local Authorities. The online / digital reports can also offer the ability to submit digital evidence, such as photographs, videos and audio files. The strengths and limitations of each of the online / digital reporting tools is provided in Table 7.2.

Table 7.2: Appraisal of identified online and digital reporting systems

Technology / solution	Identifies vehicles?	Measures sound?	Advantages	Disadvantages
Operation SNAP	✓	X	<ul style="list-style-type: none"> Standard reporting form for processing driving offences Mature technology (low cost) Specifically for antisocial driving Can submit images and videos as evidence 	<ul style="list-style-type: none"> Enforcement dependent on the level of detail provided in the online report It is unclear to what extent the tool has been used to report excessively noisy vehicles
Operation Crackdown	✓	X	<ul style="list-style-type: none"> Standard reporting form for processing driving offences Provides statistics and maps about reports, giving the public confidence that something is being done Mature technology (low cost) Easy to report antisocial driving and excessive noise 	<ul style="list-style-type: none"> Enforcement dependent on the level of detail provided in the online report Action taken on reports of excessive noise is classed as “action unknown” – outcomes need to be better reported
Other police online reporting tools	✓	X	<ul style="list-style-type: none"> Standard reporting form for processing driving offences Mature technology (low cost) Can submit images and videos as evidence 	<ul style="list-style-type: none"> Some differences in the tools used by different police forces, but there is a degree of uniformity between them Not always obvious what offence excessive noise should be reported as Enforcement dependent on the level of detail provided in the online report
Self Evident / Noise App / Local Authority noise reporting app	✓	X	<ul style="list-style-type: none"> Standard reporting form Can attach digital evidence Potential to combine with other crime reporting Can be available on most operating systems Can submit images, videos and audio files as evidence 	<ul style="list-style-type: none"> Regular updates required when operating systems update Enforcement dependent on the level of detail provided in the report Cost/funding proven to be an issue when using a third party app

Based on the strengths and limitations identified in Table 7.2, it is considered that all of the identified online / digital reporting tools are appropriate for use in the UK to identify excessively noisy vehicles. Some of the reporting tools are easier to use than others, and if reporting excessively noisy vehicles and driving behaviours causing excessive noise is a priority, then some of the existing tools may require minor improvements to make it easier to do this and to demonstrate what action has been taken following the report submission.

Manual sound level appraisal

The literature review and stakeholder engagement with police forces indicated that they use two different approaches to determine whether a vehicle is excessively noisy or not. The most common approach is subjective assessment, which requires no specialist equipment. Another approach is to perform a stationary noise test using the ISO 5130 test methodology (or variation thereof) and to measure the noise emissions using a sound level meter. An alternate approach that is not currently used could involve the use of a smartphone app designed to act as a sound level meter. The strengths and limitations of each approach to appraising whether a vehicle is excessively noisy is provided in Table 7.3.

Table 7.3: Appraisal of identified manual sound level appraisal methods

Technology / solution	Identifies vehicles?	Measures sound?	Advantages	Disadvantages
Sound level meter smartphone apps	X	✓	<ul style="list-style-type: none"> • Portable, most police officers are likely to have a smartphone with them • Interface can be designed to be easy to use • Can be designed to provide quantitative output (numerical sound level readings) or a qualitative output (whether it exceeds a predetermined noise limit or not) 	<ul style="list-style-type: none"> • Lower accuracy compared with a normal sound level meter • Possible need for an external microphone • Not currently used for law enforcement in the UK or worldwide • High development costs to create a suitable app and ensure that the data collected is robust enough for enforcement • Does not identify vehicles that require testing
Subjective testing	X	✓	<ul style="list-style-type: none"> • No equipment costs 	<ul style="list-style-type: none"> • Qualitative measurement of sound • Does not identify vehicles that require testing unless a police officer encounters one • Recognised that an objective method would be more robust • Opinion of noise varies person to person
Stationary noise testing (ISO 5130 or variant) using a sound level meter	X	✓	<ul style="list-style-type: none"> • Quantitative measurement of sound • Uses an agreed methodology to ensure tests are repeatable and reliable 	<ul style="list-style-type: none"> • Stakeholder survey indicates that the sound level meters are not easy to use for a layperson • Consistent approach needed on how to use measured sound levels for enforcement • Does not identify vehicles that require testing unless the police officer encounters one • Expensive to hire or buy a sound level meter

Based on the strengths and limitations of each of the approaches discussed in Table 7.3, the methods currently used by the police (subjective testing and stationary noise testing) are appropriate for use in the UK, but guidance is required to ensure that a consistent approach is used nationwide. This guidance would include both objective and subjective methods to cover instances where police officers encounter a suspected noisy vehicle and may or may not have measurement instrumentation with them. While it is recognised that using a sound level meter would provide a more robust appraisal of noise emissions, they are expensive to buy and hire long-term, which has deterred some police forces from using specialist equipment. For example, a Class 1 sound level meter and acoustic calibrator can cost between £3,000 and £7,000 to buy depending on the level of functionality required, and would require laboratory calibration on a regular basis. The hire of an appropriate sound level meter and calibrator can cost £200 or more per week.

Use of a smartphone app as a sound level meter is not considered appropriate at this time for use in the UK to enforce noise limits, but can be reconsidered in the future if the technology improves.

Noise camera

Five examples of noise camera systems were identified, of which four are known to have been used for trials on live carriageways. The strengths and limitations of each noise camera system to appraising whether a vehicle is excessively noisy is provided in Table 7.4.

Table 7.4: Appraisal of identified noise camera systems

Technology / solution	Identifies vehicles?	Measures sound?	Advantages	Disadvantages
Noise monitoring of trucks in Australia	✓	✓	<ul style="list-style-type: none"> Standalone system Similar system can be created easily in the UK using proprietary equipment Tests against pre-determined noise limits Can collect spectral information Successful in Australia Easy installation 	<ul style="list-style-type: none"> Training required to configure and use the interface (may be overcomplicated for layman) Specification required to define what a noisy vehicle is, which is dependent on site set-up Liable to vandalism and theft once installed
Noise monitoring in Edmonton, Canada	✓	✓	<ul style="list-style-type: none"> Standalone system Similar system can be created easily in the UK using proprietary equipment Can collect spectral information Tests against pre-determined noise limits Easy installation 	<ul style="list-style-type: none"> Training required to configure and use the interface (may be overcomplicated for layman) Specification required to define what a noisy vehicle is, which is subject to site set up Liable to vandalism and theft once installed
Noise monitoring in Abu Dhabi	✓	✓	<ul style="list-style-type: none"> Noise monitoring is reportedly identifying several noisy vehicles 	<ul style="list-style-type: none"> Unclear how the equipment is targeting noisy exhausts Limited information publicly available about how the technology works and how it may have improved compliance where installed

Technology / solution	Identifies vehicles?	Measures sound?	Advantages	Disadvantages
Noise monitoring on UK race tracks	✓	✓	<ul style="list-style-type: none"> • Standalone system • Technology is mature – products exist that can do this with limited extra development required • Can collect spectral information • Tests against pre-determined noise limits • Retrieve information via data dump or in real-time • Easy installation 	<ul style="list-style-type: none"> • Training required to configure and use the interface (may be overcomplicated for layperson) • Further information required to confirm information security (encryption) / data protection • Liable to vandalism and theft once installed • Specification required of what a noisy vehicle is, which may be dependent on the site setup
NoivelCam	✓	✓	<ul style="list-style-type: none"> • Standalone system • Developed to detect excessively noisy vehicles • Reliable identification of the noise source in simple traffic conditions • Multi-lane and lower cost versions are under development 	<ul style="list-style-type: none"> • Currently a prototype technology but could meet the requirements when fully developed • Prototype built from expensive equipment • System currently being improved to better distinguish which lane the noisy vehicle was detected in • Can only be installed on a gantry or bridge • Liable to vandalism once installed

Based on the strengths and limitations of each of the approaches discussed in Table 7.4, all of the noise camera systems identified are appropriate for use in the UK except for the noise monitoring system used in Abu Dhabi. This specific system is not considered appropriate at this time due to the lack of information publicly available about this system to fully determine its suitability.

The noise camera systems used in Australia, Canada and at UK race tracks use similar noise monitoring systems that are connected to an ANPR camera and camera/video feed to form a standalone system. Basic versions of these systems can be set up easily but can be expensive. Based on the trial in Canada, the costs for implementing a basic noise camera system at eight locations for a four month period could cost £38,000 to £76,000.

NoivelCam offers the potential to be of use in the UK and could be a more sophisticated solution than the other noise cameras when it is fully developed. It is likely to be more expensive than the basic noise cameras when the product is ready for market.

Use of acoustic signatures

Three products were identified that use acoustic signatures to determine whether an “event” has taken place and to generate an alert accordingly. An analysis of the strengths and limitations of each of the technologies using acoustic signatures is provided in Table 7.5.

Table 7.5: Appraisal of identified technologies using acoustic signatures

Technology / solution	Identifies vehicles?	Measures sound?	Advantages	Disadvantages
Akut	✓	✓	<ul style="list-style-type: none"> • Standalone system • Potential to reduce false positives through use of artificial intelligence and analysis of spectral profile of vehicle pass-bys • Technology is commercialised and deployed in Europe for identifying vehicles 	<ul style="list-style-type: none"> • Technology requires development to identify noisy vehicles (using criteria to be determined) for each vehicle class • Further development required for a more mobile/portable system • Cost uncertain until a detailed performance specification can be provided • Liable to vandalism and theft once installed
Boomerang III	X	✓	<ul style="list-style-type: none"> • Can localise sound sources using a microphone array • Good tolerance to high ambient noise levels 	<ul style="list-style-type: none"> • Not currently used for noisy vehicles. • Further development required to integrate with other components required for an automated solution • Microphone array is not compact • Liable to vandalism and theft once installed
ShotSpotter	X	✓	<ul style="list-style-type: none"> • Can localise sound sources using triangulation from multiple sensors 	<ul style="list-style-type: none"> • Not currently used for noisy vehicles. • Further development required to integrate with other components required for an automated solution • Liable to vandalism and theft once installed • Sensors need to be installed at several locations in order to triangulate

Based on the strengths and limitations of each of the approaches discussed in Table 7.5, Akut is considered appropriate for use in the UK once it has been developed and configured for excessively noisy vehicles. The cost of Akut is dependent on specification required for the system, but is expected to be more expensive than the noise camera systems due to the increased sophistication of the technology and the development costs incurred to adapt and test the technology for excessively noisy vehicles.

At the present time, Boomerang III and ShotSpotter are not considered suitable for use in the UK as the technologies require much more development to become suitable for identifying and detecting excessively noisy vehicles and driving styles. The triangulation approach used by ShotSpotter is potentially relevant for use in the UK, for example, by networking multiple basic noise cameras at similar locations to help localise noisy vehicles on busy roads such as dual carriageways or motorways.

Recognised noise testing standards

A number of standards and testing methodologies have been identified that are relevant to measuring noise from excessively noisy vehicles for enforcement. The current approach used by the police forces in the UK who measure sound levels is to undertake stationary noise tests using a simplified version of ISO 5130, such as the approaches used by Devon and Cornwall Police and Essex Police [24] [63]. These approaches are suitable for enforcement purposes as the simplifications are not at detriment to the vehicle being tested, however, the same simplified test procedure should be used by all UK police forces using measurement equipment for a consistent approach and to reduce legal challenges.

The existing test procedures used by the police focus more on testing cars, as measurements of motorcycles reportedly include additional noise from body rattle and vibration, making it more difficult to obtain a clean measurement of exhaust noise [63]. However, as motorcycle exhausts are readily accessible on the vehicle, this is not considered problematic as aftermarket products can be identified from visual inspection [63].

The test procedures for moving vehicles, ISO 362 and ISO 11819, are both relevant to measuring noise from individual vehicles in traffic streams. These testing methods are best suited to automated solutions rather than situations where a police officer is investigating reports of a specific noisy vehicle, and some of the noise camera solutions specify that ISO 362 should be used to set threshold noise levels for their products [99].

Options for improving enforcement

Proposed options

Based on the outcome of the review of existing technologies and noise appraisal methods, three options are proposed for improving the detection of noisy vehicles and enforcement. These options are:

- Option A – Improvements to existing reporting and enforcement practices. This would consist of minor improvements to existing online or digital reporting tools to make it easier for users to report excessively noisy vehicles / driving behaviours, and improved guidance for police officers for enforcement using subjective or objective methods.
- Option B – An automated noise camera system comprising a video camera, an ANPR camera and sound measurement equipment, where sound levels from passing vehicles are tested against a suitable noise limit. The system does not require the police to be in attendance but can be configured to provide real-time reports if required. A letter can be sent out requiring the registered keep to check, repair or replace their exhaust within a stated time period.
- Option C – An automated noise camera system comprising a video camera, an ANPR camera and sound measurement equipment capable of identifying acoustic signatures produced by passing vehicles. The acoustic signature and maximum sound levels would be compared with those associated with vehicles with illegal modified exhaust systems and appropriate noise limits. The system does not require the police to be in attendance but can be configured to provide real-time reports if required. A letter can be sent out requiring the registered keep to check, repair or replace their exhaust within a stated time period.

Further details of the three options are provided in the following subsections.

Option A – Improvements to existing reporting and enforcement practices

Online reporting tools are already widely used by the police as a method of intelligence gathering about offences, but it is not always clear to which offence type excessively noisy vehicles and driving behaviours causing noise should be reported. For example, it could be considered a “motoring offence” or “antisocial behaviour” and the distinction between the two may not be clear to members of the public seeking to report noisy vehicles. Minor improvements to some of the existing online reporting tools can be made to make it more obvious how to report noisy vehicles. Any changes to the existing online reporting interfaces should be coordinated through the digital policing strategy set out in the Policing Vision 2025 [142]. It is understood that progress tracking of online reports is a feature that will be introduced as part of the Policing Vision 2025 [142], allowing users who make reports of crime to have some reassurance that their reports are being taken seriously and to see evidence of action being taken.

A smartphone app could also be introduced as an online reporting tool for a variety of crimes as well as antisocial driving and excessively noisy vehicles. Development of a smartphone app reporting tool would also need to be coordinated with current digital policing initiatives and strategies [142].

Although the improvements to online reporting tools would still require police resources to investigate complaints, it would improve the user experience for members of the public and potentially encourage additional reports of possible offences in the future.

Current enforcement practices can be improved by providing guidance to the police so that a consistent approach is taken regardless of whether they are using subjective or objective methods to determine whether an offence has occurred. For subjective methods, this can include a list of acoustic characteristics to listen for when the vehicle of interest makes noise, and a “noise thermometer” so that the police officers have an improved understanding of how loud different noise sources are to compare the noise generated by the vehicle of interest against. This would help the police exercise their professional judgement as to whether an offence has taken place.

For objective methods, the improved guidance would consist of an agreed version of the ISO 5130 stationary noise emissions test to use, the overall testing procedure, and how to interpret the measured noise levels to determine what action should be taken. The guidance currently used by Essex Police goes some way to achieving this [63] and could potentially become used nationwide.

Option B – Noise camera system using measured sound levels

The use of a noise camera system such as those deployed in Australia, Canada and Singapore would automate the identification and detection of an excessively noisy vehicle. These are standalone encrypted systems, ensuring that the evidence package is robust. These systems could be deployed temporarily for short-duration use, such as targeting antisocial driving hotspots or car cruises, or long-term use if deemed appropriate. The systems can be installed on residential roads, junctions and high speed roads depending on the specific technology selected and installation constraints. As the systems would be deployed on live carriageways, aspects of the ISO 362 and ISO 11819 test methods could be used to standardise the measurement parameters. Based on the technology currently available, it is expected that the system would be a basic noise camera assembled using proprietary products. This is because more sophisticated products (such as NoivelCam) are not yet fully developed. Provided that the more sophisticated products meet the required performance specifications when fully developed or ready for market, they could be used instead of the basic noise cameras.

Once an offending vehicle is identified that exceeds a predetermined noise limit, the evidence package can be reviewed by the police to ensure that the evidence is robust prior to taking action. For example, the review would check that the noise exceedance wasn't caused by an emergency services siren or multiple vehicles passing the measurement location simultaneously. Depending on the level of complexity required, the noise limits can be set for different vehicle categories or potentially link to a database of type approval noise levels, noting that an allowance would be required to allow for wear and tear and the position of the microphone relative to the road. A set of noise limits may be required to take into account the speed limit of the road(s) at the monitoring site.

If the offence is legitimate, a letter can be sent out to the registered keeper of the vehicle. This would provide an obligation to rectify the vehicle and provide evidence that this has been done within a defined timeframe. A fine or fixed penalty notice may also be issued.

Option C – Noise camera system using measured sound levels and acoustic signatures

The use of a noise camera system that uses acoustic signatures would operate in a similar way as described for Option B and enforcement would consist of the same process. It would also be a standalone encrypted system that can automate identification and detection of excessively noisy vehicles, and can use multiple noise limits so that appropriate noise thresholds can be used for different vehicle classifications and road types.

The acoustic signature of the vehicle passing the measurement location can be used in combination with the maximum noise level from the pass-by to identify exhaust systems that are modified or causing excessive noise due to poor maintenance. This would provide more confidence in the noise camera system by reducing the number of false positives from two vehicles passing the measurement location at the same time. The system may also be able to differentiate between driving styles causing excessive noise and noisy exhaust system using acoustic signatures provided that this information is available. If deployed long-term, the system may also be able to use artificial intelligence to evaluate noise in different driving situations, such as at specific junctions or certain road geometries, and identify excessively noisy vehicles from a traffic stream under “normal” driving conditions.

At the present time, there are no fully developed products or systems that can detect excessively noisy vehicles or driving styles. Akut is the most suitable of the identified systems using acoustic signatures

that could be used for enforcement of noise levels in the future, and would be the easiest to adapt or modify for detecting excessively noisy vehicles.

Appraisal of options

The strengths and limitations of the three options are discussed in Chapter 8, where they are appraised for their suitability for detecting and enforcing excessively noisy vehicles in the UK. An effective system will need to be able to reliably relate the sound data acquired to a specific vehicle, and meet the legal requirements for handling personal data and providing a robust evidence package.

Each option is scored based on the assessment criteria shown in Table 7.6. The assessment criteria that have the highest priorities are weighted to signify their importance in determining the viability of the proposed options. The highest scores are those for the best performing systems, with a maximum overall score of 160.

Table 7.6: Scoring criteria

Question	Low Score (1)	High Score (5)	Weighting	Maximum score
How accurate, repeatable and reliable is the system?	Low levels of accuracy, repeatability and reliability	High levels of accuracy, repeatability and reliability	10	50
What is the risk of legal challenge?	High risk of legal challenge	Low risk of legal challenge	4	20
What are the development costs?	Expensive, high uncertainty regarding cost	Inexpensive, low uncertainty regarding cost	4	20
What are the purchase / operational costs?	Expensive, high uncertainty regarding cost	Inexpensive, low uncertainty regarding cost	4	20
Is the system standalone?	The system requires inputs from other systems.	The system is standalone.	1	5
Is the system portable?	The system would take a substantial time to set-up.	The system is easy to move from location to location.	1	5
Is the system fully developed?	The system needs substantial work to develop into an operating system.	The system has already been developed to a complete operating system	1	5
Does the system automatically detect noisy vehicles?	The system does not automatically detect noisy vehicles	The system is able to automatically identify noisy vehicles	1	5
Does the system automatically gather evidence?	The system requires further input/data/actions to generate an evidence package.	The system contains sufficient data and processes to generate an evidence package	1	5
Does the system run automatically?	The system requires significant user input to operate the system.	The system works independently or automatically	1	5
Is there a Personal Data risk?	High risk	Low risk	1	5
What is the likely maintenance regime?	High level of maintenance expected.	Low level of maintenance expected.	1	5

Question	Low Score (1)	High Score (5)	Weighting	Maximum score
Ability to deal with different road layouts, gradients, traffic behaviour and traffic speeds	The system operates under specific site conditions only	The system is flexible and can be used for a range of site conditions	1	5
Are there any specific requirements or constraints for the monitoring or test site?	The test site strongly affects the ability of the solution to operate effectively	The test site requirements are flexible or the technology operates independently of site conditions	1	5

8. Performance of potential solutions

Appraisal of strengths and limitations

Option A – Improvements to existing reporting and enforcement practices

Minor improvements to existing online reporting tools can make it easier for members of the public to report excessively noisy vehicles and monitor what action is being taken following the submission of their reports. The mapping feature used in Operation Crackdown can be useful for identifying problem areas and coordinating resources between local teams to investigate the reports. Other existing reporting tools could be improved by allowing submissions of digital media as evidence (if available) provided that the legal data protection and privacy requirements are adhered to. According to Operation Crackdown, excessively noisy vehicles account for approximately 2% of the total number of online reports made through the online reporting system [59], so to offer value for money it makes sense that reporting of excessively noisy vehicles remains part of reporting tools that allow reporting of other offences. Any changes to existing tools and the introduction of any approved smartphone reporting tool in the future would require coordination with the digital policing strategy highlighted in Policing Vision 2025.

Police would still be required to follow-up on reports of excessively noisy vehicles, particularly where multiple reports are made in the same geographical area or if the report is sufficiently detailed to enable further action to be taken. Improved guidance on enforcement would ensure that a consistent approach is taken regardless of whether they are using subjective or objective methods to determine whether an offence has occurred. It would also minimise the risk of challenges when it is deemed that an offence has occurred.

An appraisal of the benefits and limitations of Option A are provided in Table 8.1.

Table 8.1: Appraisal of Option A

Item	Description
Strengths	<ul style="list-style-type: none"> • Most police forces already have an online reporting system, there is already a degree of consistency between police forces. Minor changes would not significantly change existing operational processes • Can include digital media (photographs, videos, audio) in report submission • Improved guidance on enforcement provides a consistent nationwide approach • Lower risk of being challenged, especially when objective noise measurements are taken
Weaknesses	<ul style="list-style-type: none"> • Improvements to the online report tools would not influence the quality of the information provided by users of the reporting tools • The system does not include acoustic (sound pressure level) data in the online report • The system would not significantly change the current approach to identification, detection and enforcement of noisy vehicles • Reports are reliant on members of the public having access to the internet and a computer/smartphone, so may not be accessible to all members of the public
Opportunities	<ul style="list-style-type: none"> • Can improve consistency between police forces • Potential for minor improvements to online reporting to be made via digital policing strategies rather than through a separate project • Can be combined with the other two options • Provision of information showing where offences are reported and the action taken (enforcement rates) would demonstrate to members of the public that the issue is being taken seriously
Threats	<ul style="list-style-type: none"> • Police time required to investigate individual complaints • Insufficiently detailed reports can prevent meaningful action from being taken • Provision of advice when using subjective noise appraisal methods may deter the police from using objective (measurement) methods

Option B – Noise camera system

Noise camera systems already exist in a variety of forms, such as those used in motorsport or trialled in Australia and Canada. Some testing, development and configuration may be required to ensure that the equipment can robustly detect excessively noisy vehicles and avoid false positives caused by other noise sources (such as trains using a nearby railway line, emergency services siren). Basic systems, such as those assembled from proprietary products, may not work effectively on dual carriageways and motorways, although this is dependent on the number of monitoring sites deployed and the number of microphones used. Some work is required to fine-tune threshold setting, taking into account legal noise limits for different vehicle categories, the speed and age of the vehicle, the position of the microphone and the road layout.

As the noise camera systems are standalone and self-contained, the combination of a video of the vehicle, its number plate and the measured noise emissions would create a robust evidence package for police officers to review prior to taking action. The noise camera would need to encrypt the data collected so that it can be accessed securely by the police. The system would also need to be physically secure to avoid vandalism and theft.

An appraisal of the benefits and limitations of Option B are provided in Table 8.3.

Table 8.3: Appraisal of Option B

Item	Description
Strengths	<ul style="list-style-type: none"> • Can be portable • Can be automated • Can be used for a variety of road layouts and traffic conditions • Can potentially use different noise limits for different vehicle classes • Creates a robust evidence package • Does not require police attendance
Weaknesses	<ul style="list-style-type: none"> • Likely to be expensive • Possible mounting/installation constraints – liaison with Local Authorities may be required • May need to advertise monitoring locations in advance • Requires the police to review the evidence package prior to taking action • Unlikely to differentiate between noisy vehicles and noisy driving styles • Potentially less effective on dual carriageways and motorways • Difficult to enforce against vehicles with foreign number plates • More sophisticated systems are not fully developed
Opportunities	<ul style="list-style-type: none"> • Can be combined with online reporting tools to identify suitable installation sites
Threats	<ul style="list-style-type: none"> • May require third parties to install or relocate the system and/or to undertake maintenance or calibration • System stores personal data so would need to be encrypted and meet legal requirements surrounding privacy • Needs to be installed at locations to avoid vandalism or theft • Drivers of modified vehicles use alternate routes to evade identification

Option C – Noise camera system using acoustic signatures

As stated for Option B, noise camera systems already exist in a variety of forms. However, their overall performance can be enhanced by taking into account the acoustic signature of passing vehicles as well as their maximum pass-by noise level. The use of acoustic signatures should reduce the number of false positives by filtering out high maximum noise levels caused by other reasons, such as loud rattles from trailers passing the measurement position or emergency services sirens, and better identify vehicles from a traffic stream that have been illegal modified or require maintenance.

The use of an artificial intelligence (AI) system in Option C could improve the rate of detection which may allow the system to be used in a wider range of traffic conditions than for Option B, which has to rely on the differentiation of noise from individual vehicles in the traffic stream. Conditions may include situations

with higher congestion or with faster traffic speeds or more lanes of traffic. With sufficient data the system may be able to differentiate between different causes for the high noise which may improve the detection of noisy exhausts in different ages or types of vehicles, and separate out driving style characteristics from modified or defective exhaust systems.

Depending on the specific product deployed, the system has the potential to be used on local roads, junctions and motorways. A bespoke product for detecting vehicles with noisy exhausts systems does not yet exist, so development costs would be incurred to characterise a set of acoustic signatures for excessively noise vehicles for each vehicle class and to adapt existing technology for this purpose.

Like the noise camera systems that don't use acoustic signatures, the system would be standalone and self-contained, and provide a robust evidence package for police officers to review prior to taking action. The noise camera would need to encrypt the data collected so that it can be accessed securely by the police. The system would also need to be physically secure to avoid vandalism and theft.

An appraisal of the benefits and limitations of Option C are provided in Table 8.4.

Table 8.4: Appraisal of Option C

Item	Description
Strengths	<ul style="list-style-type: none"> • Can be portable • Can be automated • Can be used for a variety of road layouts and traffic conditions, including dual carriageways and motorways • Can potentially use different noise limits for different vehicle classes • Creates a robust evidence package • Artificial intelligence systems can determine the typical road noise level at the installation site, aiding identification of 'atypical' vehicles that cause excessive noise during normal driving conditions • Does not require police attendance
Weaknesses	<ul style="list-style-type: none"> • Likely to be expensive • Possible mounting/installation constraints – liaison with Local Authorities may be required • Set-up is likely to be complex • May need to advertise monitoring locations in advance • Requires the police to review the evidence package prior to taking action • Potentially less effective on busy roads, dual carriageways and motorways • Difficult to enforce against vehicles with foreign number plates • Technology not fully developed
Opportunities	<ul style="list-style-type: none"> • Can be combined with online reporting tools to identify suitable installation sites • With development could be used to differentiate between noisy vehicles and noisy driving styles
Threats	<ul style="list-style-type: none"> • May require third parties to install or relocate the system and/or to undertake maintenance or calibration • System stores personal data so would need to be encrypted and meet legal requirements surrounding privacy • Needs to be installed at locations to avoid vandalism or theft • Drivers of modified vehicles use alternate routes to evade identification • The acoustic signatures used to characterise noisy vehicles need to be robust and able to withstand slight differences to the frequency profiles of different modified exhaust products, as well as changes to the frequency profile to evade detection.

Scoring of the proposed options

Taking into account the strengths and limitations identified above, each of the options has been scored using the approach proposed in Chapter 7. The scores for each option, and the basis for those scores, are shown in Table 8.5.

Table 8.5: Appraisal of options

Question	Max. score	Option A		Option B		Option C	
		Score	Justification	Score	Justification	Score	Justification
How accurate, repeatable and reliable is the system?	50	12	Accuracy is dependent on the quality of the data inputted in the online report (e.g. number plates) and whether a subjective or objective noise measurement method is used.	40	The system could be accurate, repeatable and reliable when fully developed.	42	The system could be more accurate, repeatable and reliable when fully developed by reducing false positives.
What is the risk of legal challenge?	20	8	Information submitted in the online report will be biased by the opinion of the submitter. Medium to low risk of legal challenge from enforcement once guidance for police is introduced.	8	Challenges around automated detection of incidents.	8	Challenges around automated detection of incidents.
What are the development costs?	20	16	Low development costs for online tool as covered by existing digital policing proposals. Limited development costs for creating guidance for enforcement.	8	Cost dependent on the level of complexity required and the specification of the system. Off-the-shelf complete systems are still under development but basic ones can be assembled using proprietary products.	4	Cost dependent on the level of complexity required, intelligence of the AI, and the specification of the system. Existing off-the-shelf systems require development for using to identify noisy vehicles.
What are the purchase / operational costs?	20	16	Costs limited to asset management, storage of data, and maintenance of the system. Calibration of sound level meters (if used).	8	Purchase of equipment (microphones, ANPR, camera, integration hardware) and regular calibration.	4	Purchase of equipment (microphones, ANPR, camera, integration hardware) and regular calibration. Potentially more expensive than Option B.
Is the system standalone?	5	5	Existing online systems are self-contained. Acoustic information readily obtainable by police officers.	3	Dependent on development - may require input from ANPR or other systems.	3	Dependent on development - may require input from ANPR or other systems.
Is the system portable?	5	4	Online tools can be used on multiple device types. Police officers can travel to investigate online reports.	3	System likely to need precise configuration on site.	3	System likely to need precise configuration on site.
Is the system fully developed?	5	4	The online reporting tools already exist with further improvements proposed by Policing Vision 2025. Subjective and objective noise testing methods are currently in use.	3	Work required to develop into system, some existing systems use this type of approach for similar tasks.	2	Work required to develop the system, at least one existing system exists with potential for use.
Does the system automatically detect noisy vehicles?	5	1	Requires members of the public and police to identify noisy vehicles.	3	Has potential to automatically detect noisy vehicles.	4	With AI, has potential to automatically detect noisy vehicles.
Does the system automatically gather evidence?	5	3	Gathers some information useful in evidence but requires manual input from members of the public and police officers.	4	Has potential to automatically gather evidence package.	4	Has potential to automatically gather evidence package.
Does the system run automatically?	5	3	Online system runs automatically, but requires action after entry made	4	Requires intervention once evidence package prepared.	4	Requires intervention once evidence package prepared.
Is there a Personal Data risk?	5	2	Depends on the security of the online system and actions of the user (e.g. also posting evidence on social media). Data collected directly from police officers has low risk.	3	Personal data likely to be captured. Risks around preparing and sending evidence packages.	3	Personal data likely to be captured. Risks around preparing and sending evidence packages.
What is the likely maintenance regime?	5	5	Upgrades to existing reporting tools covered by existing budgets. Low maintenance costs if sound level meters are used by the police.	2	Maintenance likely to be higher if connections to other systems needed, and if system to be moved from site to site frequently.	2	Maintenance likely to be higher if connections to other systems needed, and if system to be moved from site to site frequently.
Ability to deal with different road layouts, gradients, traffic behaviour and traffic speeds	5	5	System is independent of road layout and traffic conditions.	4	System will be able to deal with different road types and layouts and different traffic scenarios once setup and fully configured.	4	System will be able to deal with different road types and layouts and different traffic scenarios once setup and fully configured.
Are there specific requirements or constraints for the monitoring or testing site?	5	4	Test site selected by the police when investigating reports.	3	Automated system needs to be fixed to street furniture and secured to prevent vandalism and theft.	3	Automated system needs to be fixed to street furniture and secured to prevent vandalism and theft.
Total Score	160	88		96		90	

Discussion of outcomes

The analyses provided above show that Option B was scored the highest and offers the best potential for identifying and measuring sound levels from excessively noisy vehicles using existing technology while incurring minimal development costs for a basic system. The noise camera technology for more sophisticated and flexible systems is not yet mature and development costs would be required to adapt existing promising systems (such as NoivelCam) to meet the required specification. Testing of the system, regardless of its level of complexity, would be required to ensure that its 'contravention detection' subsystem meets the technical requirements for collating an evidence package. As the system can be automated and standalone, it has the potential to create a robust evidence package once fully tested and configured. This would provide a more efficient approach to combatting excessively noisy vehicles compared with investigating individual online reports with incomplete information.

Option C scored slightly less than Option B despite proposing a similar noise camera solution, which reflects the technological maturity of systems using acoustic signatures. Existing products that use acoustic signatures (such as Akut) are not yet configured to detect excessively noisy vehicles and extra development costs would be incurred to do this. Suppliers willing to modify their products to cater for detection of excessively noisy vehicles would also require a detailed performance specification in order to update their products accordingly.

Option A has the lowest score as it would not significantly improve the overall situation. This is because online reporting tools are already widely used by the police and the minor improvements suggested are unlikely to improve the quality of the information provided in the reports, which affects what action can be taken. Improvements to digital policing as a whole, as proposed by the Policing Vision 2025, would improve efficiency in processing reports and lead to a better experience overall for members of the public using the online reporting tools [142]. Provision of guidance to the police on how to enforce noise limits can ensure a consistent approach to tackling excessively noisy vehicles nationwide, and address feedback from stakeholder engagement undertaken with police forces in the UK. Even if an automated solution such as Option B is progressed, there will still be situations where a police officer will be required to investigate an excessively noisy vehicle, and any new guidance on this subject would be applicable and useful.

9. Recommendations for Phase 2

Recommendations

Based on the analyses and scoring of the three options appraised in the previous chapter, it is recommended that Option B is taken forward for further testing in Phase 2. This noise camera system was shown to offer the greatest potential for identifying and enforcing traffic offences using technology currently available, and would provide the police with a robust evidence package prior to investigating offences.

Although Options A and C did not score as highly as Option B, there are aspects of these options that warrant further consideration when taking into account the legal context and outcomes of stakeholder engagement undertaken for this project. Although there is no need to further investigate online or digital reporting tools, especially in the context of digital policing commitments currently under development as described in the Policing Vision 2025, there is a clear need for improved guidance on enforcing noise limits on excessively noisy vehicles. This would ensure that a consistent approach is taken nationwide, whether using an objective or subjective method to appraise noise levels emitted from exhaust systems. As Option C is fundamentally similar to Option B, it is suggested that data collected during Phase 2 can be used to characterise the acoustic signatures associated with excessively noisy vehicles. This information can be used to form the basis of a more sophisticated noise camera system in the near future when the technology is fully developed.

Actions for Phase 2

The aim of Phase 2 is to further investigate the ability of a noise camera system in the measurement and detection of excessively noisy vehicles, primarily cars and motorcycles. Analysis of the measurement data will be undertaken in order to set appropriate threshold noise levels that could be used for enforcement, taking into account the speed limit of the road, vehicle class, and position of the noise camera. This information can be applied to existing or future automated noise camera systems as trigger mechanisms. No work will be undertaken to design user interfaces for a noise camera system.

The methodology suggested for Phase 2 is described below and is broken down into a number of tasks which are described individually in the following subsections.

The main tasks identified in Phase 2 are:

- Liaison with authorities
- Site selection
- Equipment development
- Trials
- Analysis
- Reporting

Task A - Liaison with authorities

For any trial to be successful, since it requires work alongside the public highway, liaison and agreement with certain parties is considered essential. The relevant Local Authorities and police forces will be contacted in advance of the trials taking place in their areas, and will be informed of the aims of the trials, the proposed test sites, test methodology and equipment involved. Alternative sites will be sought if the police or Local Authority indicate that they are not willing for a trial to occur in their area.

Task B – Site selection

A possibility is for the trials to initially be undertaken in a controlled environment (i.e. test track). This would allow any system to be examined with few external variables to influence the results, such as a lot of traffic or a high background noise level. However, since any system would always need to be testing in a roadside environment it is considered the best approach to move straight to this test scenario.

It is proposed that roadside measurements are undertaken at two different locations. The exact locations cannot be chosen without further consideration and a site visit, and also the authorities who will be contacted as part of Task A may have suggestions. Candidate test sites will be selected based on research undertaken in Phase 1 of this project and the project team's local knowledge of various areas to select as potential trial sites.

It is envisaged that in order to capture the passage of noisy vehicles (cars and motorcycles), each location would be a single carriageway road with a reasonable traffic flow, ideally in an urban / semi-urban environment and a speed limit of less than 50 mph. A location with a speed limit above 50 mph is considered undesirable for the trial since above this speed the noise from the passing vehicles is dominated by tyre noise rather than engine / exhaust noise. However, consideration would be given to roads with a higher speed limit if these are identified by authorities as locations with a large number of noisy vehicles. Other factors which need to be considered during the site selection are:

- Location of equipment;
- Staff safety and security of equipment; and
- Avoidance of attracting attention or crowds.

Task C – Equipment development

The work in this task will focus on assembling a system that can trigger when a certain acoustic feature is detected. Several different trigger levels for vehicle identification will be selected and then tested as part of Task D. It is anticipated that these will include, but not be limited to, a trigger if a maximum level is reached and a trigger based on characteristics of an individual frequency band. Situations such as the vehicle activating the trigger not being the closest to the microphone will be considered.

Before use on the public highway, the system will be tested in a controlled environment, e.g. the car park of an AJJV office.

Task D – Trials

It is recommended that the trials are a week in length, with one day being attended by staff from the AJJV. Attendance by representative from DfT, the local police force and/or the Local Authority will be suggested. By having staff or others in attendance, a subjective view can also be obtained on what may be an excessively noisy vehicle. During the trial the various triggers developed during Task B will be tested to identify a noisy vehicle. For the duration of the trial, one or two video cameras would be used to continuously film the passing traffic. Audio will be recorded temporarily when the trigger is activated in order to aurally identify any acoustic sources of trigger activation. All data will be stored appropriately in accordance with current data protection guidance and procedures.

It is recommended that one trial is undertaken over a Bank Holiday weekend, since this is a period when traffic levels maybe high and members of the public with excessively noisy vehicles are likely to drive them.

Task E - Analysis

Following the trial, the characteristics of those vehicles activating the trigger level will be examined. This will focus on the following:

- Did the system capture those vehicles that were subjectively identified as being excessively noisy;
- The confidence that the correct vehicle was identified;
- Could the possible sources of excessive noise be identified from the video; and
- Were any identified vehicles the result excessive noise from compliant vehicles due to adverse driver behaviour.

Task F – Reporting

A report will be produced following the work during Phase 2. This will report the activities and finding of all five Tasks and make recommendations for applicability of the developed system. Covered in the report will be:

- The reliability, accuracy and repeatability of the system;
- The applicability of the system to other roadside environments;
- The cost of further development of the system;
- Suggestions for appropriate trigger levels; and
- Recommendations on the suitability of the system for improved compliance with vehicle noise legislation.

Summary of Phase 1

The outcomes of Phase 1 as summarised in Table 9.1, with reference to the objectives specified for Phase 1.

Table 9.1: Summary of Phase 1 outcomes

Task	Description	Summary of outcome
1	To engage with stakeholders across the UK, including regional police forces, to determine how in-service noise compliance is currently enforced and what future strategies would be of most use	<ul style="list-style-type: none"> Police forces were contacted via the NRPIF to complete an online survey about enforcement of excessively noisy vehicles. The response rate to this survey was 37%. The most common method of enforcement is by using subjective assessment of noise levels. Some police forces use sound level meters but have found them expensive to use long term or difficult to use. The needs for better resources, equipment, guidance and a potential change to legislation were highlighted as constraints that were preventing the police from being more active in enforcement. Local Authorities largely defer the matter to the police, but some issue Public Space Protection Orders as a means of enforcement.
2	To identify effective methodologies used in other countries for the enforcement of in-service noise compliance and determine their applicability for use in the UK	<ul style="list-style-type: none"> The enforcement methodologies used in the UK and worldwide are similar – fining owners of vehicles and requiring them to repair their vehicle accordingly. Some countries require owners of noisy vehicles to provide proof that they have been fixed. This is akin to the UK's Vehicle Defect Rectification Scheme.
3	To identify, assess and recommend technologies which could be deployed at the roadside to identify high noise emitting vehicles during normal driving conditions.	<ul style="list-style-type: none"> Noise camera solutions were identified that are capable of achieving this, for example, those used in motorsport and in Canada and Australia More advanced noise camera solutions, such as NoivelCam and Akut, are currently under development. These have the potential to reduce false triggers and ultimately provide a more useful system when fully developed.
4	To identify suitable methodologies or procedures for roadside noise measurement and vehicle identification.	<ul style="list-style-type: none"> ISO 5130 and simplified variants of it are suitable for stationary roadside testing. This would require a police officer to identify a vehicle to test beforehand. ISO 362 (and ISO 11819) are appropriate for use to test noise when vehicles are in motion. Research undertaken in Germany suggests tolerances to use when applying ISO 362 in real world conditions. Noise measurement technology can be combined with ANPR and video cameras to form an automated solution that does not require police attendance.
5	To assess the accuracy, repeatability and reliability of vehicle noise measurement technologies, taking into account the impact of noise from other vehicles and the wider environment	<ul style="list-style-type: none"> A detailed review of the performance of a number of identified systems has been undertaken in Chapter 7. Two types of noise camera systems were appraised as potential options for improving the detection of noisy vehicle and enforcement of

Task	Description	Summary of outcome
		noise limits. Systems using acoustic signatures, when fully developed, are more likely to reduce false positives associated noise from other vehicles and the wider environment as they would undertake a more detailed analysis of the acoustic data collected from the system prior to generating a report.
6	To assess the associated costs, maintenance and support requirements of these technologies.	<ul style="list-style-type: none"> • Indicative costs are provided for each of the technology types. • Development costs for systems that are not yet ready for market are difficult to estimate, resulting in higher levels of uncertainty about the overall costs for technologies that are not yet mature. • Maintenance costs for noise measurement technologies consists primarily of annual calibration of the microphones / sound level meters / acoustic calibrators

10. Conclusions

The Atkins Jacobs Joint Venture has undertaken research for the Department for Transport to identify and recommend options for methods and equipment available for the detection and policing of excessively noisy road vehicles. These vehicles, which have commonly been illegally modified, lead to significant annoyance and complaints from the members of the public throughout the UK. The research consisted of engagement with police forces and local authorities about approaches of tackling excessively noisy vehicles and a literature review of approaches used around the world, appropriate test methodologies, and technologies trialled as enforcement measures.

The survey of UK police forces highlighted lack of resources and equipment were the main constraints for taking action against excessively noisy vehicles, noting that covering large geographic areas where reports are made is also a challenge. Better guidance on how to appraise and enforce against noisy vehicles would also help them and ensure a consistent approach across the UK. Regardless of what technological solution is used to improve identification, detection and measurement of noisy vehicles, provision of improved guidance would be essential for a standardised and robust enforcement strategy to be effective and implemented.

The literature review and responses from the survey of police forces indicated that the UK uses similar approaches to enforcement as other countries around the world. Fines and vehicle rectification notices are the main enforcement measures. The majority of police forces in the UK subjectively assess whether vehicles cause excess noise and those equipped with sound level meters test vehicles against a simple threshold noise level. Similar approaches to determining the noisiness of a vehicle are used worldwide. An effective system for identifying excessively noisy vehicles would need to be able to identify the sound emission from an individual vehicle and determine if the emitted sound is considered acceptable for that category of vehicle. As well as identifying sound originating from specific vehicles, the system will need to be able to isolate sound from unrelated sources including other vehicles and wider environmental noise.

Three options for improving the detection of excessively noisy vehicles and enforcement were identified, which were appraised against a set of performance criteria. Of these options, a noise camera solution (Option B) is recommended for further consideration in Phase 2 of the project. An automated noise camera solution has the potential to improve enforcement by capturing sufficient data to indicate that an offence has occurred before the police act on it. However, further work is required to select threshold noise levels for different vehicle classes and speeds of travel relative to the mounting position of the noise camera system. If this solution is progressed to Phase 2, trials will be undertaken to address these points, which can be used to configure any future noise camera solution or to include in a performance specification that can be issued prior to further testing. Trials of more sophisticated noise camera solutions, such as those being developed by NoivelCam and Akut, could be undertaken at a future date when the products are fully developed and ready for market.

However, there are aspects of the two other options that warrant further consideration. Although noise cameras using acoustic signatures to identify excessively noisy vehicles are not fully developed, there is an opportunity to use the data collected from the noise camera trialled in Phase 2 to characterise the acoustic signatures associated with excessively noisy vehicles. This information can be used to configure or set a performance specification for a more sophisticated noise camera system in the near future when the technology is fully developed.

Stakeholder engagement with police forces in the UK highlighted the need for improved guidance on enforcement of excessively noisy vehicles. While it may not be possible to equip every police force with a sound level meter in the short-term, the provision of guidance for objectively and subjectively appraising noise levels emitted from exhaust systems would ensure that a consistent approach to enforcement is taken nationwide.

11. References

- [1] P. G. Abbott, R. E. Stait, M. Muirhead, M. Clifton and M. J. Ainge, "In-service noise measurement study. Published Project Report PPR384.," TRL, Wokingham, 2009.
- [2] European Parliament and Council for the European Union, "Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC," 2014.
- [3] European Parliament and Council for the European Union, "Regulation (EU) No 168/2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles," 2013.
- [4] European Council, "Council Directive 70/157/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles," 1970.
- [5] Vehicle Certification Agency, "Cars and Noise," 2019. [Online]. Available: <https://www.vehicle-certification-agency.gov.uk/fcb/cars-and-noise.asp>. [Accessed 25 02 2019].
- [6] European Council, "Council Directive 78/1015/EEC of 23 November 1978 on the approximation of the laws of the Member States on the permissible sound level and exhaust system of motorcycles," 1978.
- [7] "The Motor Vehicles (Type Approval) (Great Britain) Regulations 1984".
- [8] "Road Traffic Act 1972".
- [9] "Road Vehicles (Construction and Use) Regulations 1986".
- [10] United Nations Economic Commission for Europe, "UNECE Regulation 51 Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions," 2019.
- [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 362:2009 Measurement of noise emitted by accelerating road vehicles - Engineering method - Part 2: L category," ISO, Geneva, 2009.
- [13] International Organization for Standardization, "ISO 5130:2007 +A1:2012 Measurement of sound pressure level emitted by stationary road vehicles," ISO, Geneva, 2012.
- [14] United Nations Economic Commission for Europe, "UNECE Regulation 41: Uniform provisions concerning the approval of motor cycles with regard to noise," 2018.
- [15] United Nations Economic Commission for Europe, "UNECE Regulation 63: Uniform provisions concerning the approval of two-wheeled mopeds with regard to noise," 2006.
- [16] United Nations Economic Commission for Europe, "UNECE Regulation 9: Uniform provision concerning the approval of category L2, L4 and L5 vehicles with regard to noise," 2017.
- [17] International Organization for Standardization, "ISO 10844:2014 Specification of test tracks for the purpose of measuring noise emitted by road vehicles," ISO, Geneva, 2014.
- [18] "Road Traffic Act 1988".
- [19] United Nations Economic Commission for Europe, "UNECE Regulation 59: Uniform provisions concerning the approval of replacement silencing systems," 2015.
- [20] United Nations Economic Commission for Europe, "UNECE Regulation 92: Uniform provisions concerning the approval of non-original replacement exhaust silencing systems for motorcycles, mopeds and three-wheeled vehicles," 2017.
- [21] G. R. Watts and R. E. Stait, "Characteristics of vehicles producing excessive noise and ground-borne vibration - Phase 1. Published Project Report PPR202.," Transport Research Laboratory, Wokingham, 2008.

- [22] R. E. Stait and M. Clifton, "Characteristics of vehicles producing excessive noise and ground-borne vibration - Phase 2. Published Project Report PPR246," Transport Research Laboratory, Wokingham, 2008.
- [23] International Organization for Standardization, "ISO 5130:2007 Acoustics - measurement of sound pressure level emitted from stationary road vehicles," ISO, Geneva, 2007.
- [24] M. Muirhead, P. A. Morgan and L. Morris, "Proposals for in-service car noise testing. Published Project Report PPR506.," Transport Research Laboratory, Wokingham, 2010.
- [25] G. J. Harris and P. M. Nelson, "In-service noise testing - Motorcycles fitted with non-standard and defective exhaust silencers. PR/SE/188/96.," TRL, Wokingham, 1996.
- [26] G. J. Harris and P. M. Nelson, "Development of in-service noise testing procedures for road vehicles (preliminary report). PR/ENV/062/94," TRL, Wokingham, 1994.
- [27] G. J. Harris and P. M. Nelson, "Development of an in-service noise testing procedure for diesel powered road vehicles. PR/SE/120/95," TRL, Wokingham, 1995.
- [28] United Nations Economic Commission for Europe, "Addendum 58 of Regulation 59: Uniform provisions concerning the approval of replacement silencing systems," UNECE, Geneva, 1983.
- [29] States of Jersey, "Excessive noise from motor vehicles (FOI)," 10 09 2018. [Online]. Available: <https://www.gov.je/Government/Pages/StatesReports.aspx?ReportID=3858>. [Accessed 25 02 2019].
- [30] A. Bolter, "Police crackdown on deafening car exhausts," Wales Online, 30 August 2010. [Online]. Available: <https://www.walesonline.co.uk/news/wales-news/police-crackdown-deafening-car-exhausts-1905480>. [Accessed 25 02 2019].
- [31] BBC, "Drivers fined for noisy exhausts by Suffolk Police," BBC News, 22 07 2010. [Online]. Available: <https://www.bbc.co.uk/news/uk-england-suffolk-10726415>. [Accessed 25 02 2018].
- [32] M. Hunter, "Stowmarket: Police operation targets motorists breaking the law," East Anglian Daily Times, 25 09 2013. [Online]. Available: <https://www.eadt.co.uk/news/stowmarket-police-operation-targets-motorists-breaking-the-law-1-2801559>. [Accessed 25 02 2019].
- [33] Northamptonshire Police, "New equipment allows action on noisy exhausts," Northamptonshire Police, n.d.. [Online]. Available: <https://www.northants.police.uk/simple/press-release/new-equipment-allows-action-on-noisy-exhausts>. [Accessed 25 02 2019].
- [34] Hertfordshire Police, "Police patrols to combat anti-social driving in Stevenage," Hertfordshire Police, 03 08 2018. [Online]. Available: <https://www.herts.police.uk/news-and-appeals/Police-patrols-to-combat-anti-social-driving-in-Stevenage>. [Accessed 25 02 2019].
- [35] Kent Online, "Boy racers beware as police get tough on noisy exhausts," Kent Online, 07 04 2008. [Online]. Available: <https://www.kentonline.co.uk/kent/news/boy-racers-beware-as-police-get-tough-on-no-a103818/>. [Accessed 25 02 2019].
- [36] City of Wolverhampton Council, "Car cruising injunction," n.d.. [Online]. Available: <http://www.wolverhampton.gov.uk/article/5901/Car-cruising-injunction>. [Accessed 25 02 2019].
- [37] C. Gavaghan, "EXCLUSIVE: Council to shut seafront to stop organised car cruise," The Scarborough News, 19 05 2017. [Online]. Available: <https://www.thescarboroughnews.co.uk/news/exclusive-council-to-shut-seafront-to-stop-organised-car-cruise-1-8551305>. [Accessed 25 02 2019].
- [38] BBC, "'Dangerous drivers' prompt Scarborough car cruise crackdown," BBC News, 26 03 2018. [Online]. Available: <https://www.bbc.co.uk/news/uk-england-york-north-yorkshire-43543694>. [Accessed 25 02 2019].
- [39] S. Jones, "Joint operation between police and council disrupts large car cruise event in Milton Keynes," MK Citizen, 28 08 2018. [Online]. Available: <https://www.miltonkeynes.co.uk/news/joint-operation-between-police-and-council-disrupts-large-car-cruise-event-in-milton-keynes-1-8616759>. [Accessed 25 02 2019].
- [40] South Wales Argus, "Police warning ahead of car cruise at Spyttly Retail Park, Newport," 22 04 2016. [Online]. Available: <https://www.southwalesargus.co.uk/news/14445773.police-warning-ahead-of-spyttly-car-cruise/>. [Accessed 25 02 2019].
- [41] Essex Roads Policing Unit - South, ""Are you a car enthusiast? Do you attend car meets? Are you a club Mod/organiser? We're busy preparing to launch a new Op to ensure a consistent and

- fair, but very robust approach to meets - dangerous and anti-social driving won't be tolerated.”, Twitter, 11 02 2019. [Online]. Available: https://twitter.com/EP_RPU_South/status/1095000184461934592. [Accessed 25 02 2019].
- [42] Thames Valley Police Milton Keynes, ““TVP are aware of a car cruise taking place this evening in MK. We would like to remind attendees to drive responsibly. Anti-social driving or dangerous driving will not be tolerated”,” Twitter, 27 05 2018. [Online]. Available: https://twitter.com/tvp_mk/status/1000788555269136390. [Accessed 25 02 2019].
- [43] J. Evans, “Four people arrested at Port Talbot car cruise event,” Wales Online, 17 07 2017. [Online]. Available: <https://www.walesonline.co.uk/news/local-news/four-people-arrested-port-talbot-13345037>. [Accessed 25 02 2019].
- [44] J. Evans, “Two hundred people turn up to another 'car cruise' event as police say they will continue to tackle them,” Wales Online, 17 08 2017. [Online]. Available: <https://www.walesonline.co.uk/news/local-news/two-hundred-people-turn-up-13487316>. [Accessed 25 02 2019].
- [45] MK FM, “Car parks closed this evening in Milton Keynes ahead of ANOTHER planned car cruise event,” 15 09 2018. [Online]. Available: <https://www.mkfm.com/news/local-news/car-parks-closed-this-evening-in-milton-keynes-ahead-of-another-planned-car-cruise-event/>. [Accessed 25 02 2019].
- [46] A. Papworth, “Roads are not racetracks, police warn after planned 'car cruises',” East Anglian Daily Times, 06 11 2018. [Online]. Available: <https://www.eadt.co.uk/news/essex-police-section-59-police-reform-act-warning-in-response-to-car-cruises-1-5766011>. [Accessed 25 02 2019].
- [47] Safer Essex Road Partnership, “Thurrock Council and Essex Police to ban car cruising at Lakeside,” 16 12 2015. [Online]. Available: <https://saferessexroads.org/thurrock-council-and-essex-police-to-ban-car-cruising-at-lakeside/>. [Accessed 25 02 2019].
- [48] Stockport Metropolitan Borough Council, “Public Space Protection Orders, 3 - Car cruising,” 17 03 2017. [Online]. Available: <https://www.stockport.gov.uk/pspo/car-cruising-pspo>. [Accessed 25 02 2019].
- [49] Tunbridge Wells Borough Council, “Make a Noise Complaint,” 2019. [Online]. Available: <http://www.tunbridgewells.gov.uk/find-and-contact-us/do-it-online/eforms/Noise-Complaint>. [Accessed 25 02 2019].
- [50] Bracknell Forest Council, “Report a noise nuisance,” 2019. [Online]. Available: <https://www.bracknell-forest.gov.uk/business-information/environmental-health/noise-nuisances/forms/report-noise-nuisance>. [Accessed 25 02 2019].
- [51] Newcastle-under-Lyme Borough Council, “Bothered by Noise? There's an App for That,” 2019. [Online]. Available: <https://www.newcastle-staffs.gov.uk/news/bothered-noise-theres-app>. [Accessed 25 02 2019].
- [52] Bracknell Forest Council, “Noise nuisances,” 2019. [Online]. Available: <https://www.bracknell-forest.gov.uk/business-information/environmental-health/noise-nuisances>. [Accessed 25 02 2019].
- [53] The Noise App, “Simplify Noise Reporting and Investigation,” 2019. [Online]. Available: <https://www.thenoiseapp.com/#/>. [Accessed 25 02 2019].
- [54] Metropolitan Police, “Report a road traffic incident,” 2019. [Online]. Available: <https://www.met.police.uk/ro/report/rti/report-a-road-traffic-incident/>. [Accessed 25 02 2019].
- [55] Hampshire Constabulary, “Report a road traffic incident,” 2019. [Online]. Available: <https://www.hampshire.police.uk/ro/report/rti/report-a-road-traffic-incident/>. [Accessed 25 02 2019].
- [56] GoSafe Cymru, “Operation SNAP,” 2019. [Online]. Available: <https://gosafesnap.wales/>. [Accessed 25 02 2019].
- [57] Nextbase, “Caught an incident on your dashcam or another device? Send footage directly to your local police force.,” 2018. [Online]. Available: <https://www.nextbase.com/en-gb/national-dash-cam-safety-portal/>. [Accessed 25 02 2019].
- [58] Sussex Police, “Operation Crackdown,” 2019. [Online]. Available: <https://webcontact.sussex.police.uk/ASDPRS/default.aspx>. [Accessed 25 02 2019].

- [59] Sussex Safer Roads Partnership, "Operation Crackdown, Data Portal," 2019. [Online]. Available: <http://dashboard.sussexsrp.org.uk/opcrackdown/>. [Accessed 25 02 2019].
- [60] Witness Confident, "Do the right thing. It's Self Evident.," [Online]. Available: <https://witnessconfident.org/self-evident-app>. [Accessed 08 03 2019].
- [61] Just Evidence and the Metropolitan Police, "The MPS and the Self Evident App," 2018. [Online]. Available: https://witnessconfident.org/images/MPS_App_briefing.pdf. [Accessed 08 03 2019].
- [62] International Electrotechnical Commission, "IEC 61672-1 Electroacoustics - Sound level meters - Part 1: Specifications," IEC, Geneva, 2013.
- [63] Essex Police, "Procedure - Loud Exhaust Offences, H 0504," 13 06 2017. [Online]. Available: <https://www.essex.police.uk/getmedia/5a4aaf2f-105f-419d-9ea4-2dd658945d07/H0504-Procedure-Loud-Exhaust-Offences.pdf>. [Accessed 25 02 2019].
- [64] L.-F. Pardo, "ASEP, from 2005 to 2019: Background informations and future works.," in *1st Meeting of the Informal Working Group*, Tianjin, China, 2016.
- [65] Bruel and Kjaer, "Vehicle Pass-By Noise," [Online]. Available: <https://www.bksv.com/en/Applications/product-noise/Vehicle-pass-by-noise#collapse82969219-7c02-4a97-ac5d-55d02496baae>. [Accessed 08 03 2019].
- [66] L.-F. Pardo, "Indoor pass-by noise, France. GRB 67th Session.," 24 01 2018. [Online]. Available: <http://www.unece.org/fileadmin/DAM/trans/doc/2018/wp29grb/GRB-67-11e.pdf>. [Accessed 08 03 2019].
- [67] International Organization for Standardization, "ISO 11819:2001 Measurement of road surface influence on road traffic noise - Part 1: Statistical Pass-by Method," ISO, Geneva, 2001.
- [68] MotorSport UK, MotorSport UK Yearbook 2019, 63rd edition, Staines: The Royal Automobile Club Motor Sports Association Ltd, 2019.
- [69] Auto-Cycle Union, Auto-Cycle Union Bikesport GB, 2019 Handbook, Rugby: Auto-Cycle Union Ltd, 2019.
- [70] Silverstone Circuits Ltd, "Car Track Day Terms and Conditions," 2019. [Online]. Available: <https://www.silverstone.co.uk/terms-and-conditions/car-track-days-terms-conditions/>. [Accessed 05 02 2019].
- [71] MotorSport Vision Ltd and Breckland Council, "Noise Management Plan relating to Snetterton Racing Circuit," 2012. [Online]. Available: <http://www.snetterton.co.uk/media/975274/Snetterton%20Noise%20Management%20Plan%20July%202012.pdf>. [Accessed 25 02 2019].
- [72] MotorSport Vision Ltd and Sevenoaks District Council, "Noise Management Plan relating to Brands Hatch Racing Circuit," 2016. [Online]. Available: <http://www.brandshatch.co.uk/media/1740418/2016%20NMP%20Signed%20Version.pdf>. [Accessed 25 02 2019].
- [73] Goodwood, "Noise Management," 2019. [Online]. Available: <https://www.goodwood.com/estate/motor-circuit/history/noise-management/>. [Accessed 25 02 2019].
- [74] Goodwood Road and Racing, "Noise Testing GW Circuit," 2012. [Online]. Available: <https://www.youtube.com/watch?v=K4mYhgIsQf8>. [Accessed 25 02 2019].
- [75] Snetterton, "Noise Testing Information," 2011. [Online]. Available: http://www.snetterton.co.uk/media/975291/snnoisedocument_for_website_2010_rm.pdf. [Accessed 25 02 2019].
- [76] Mallory Park Circuit, "Noise Management Plan 2015," 2015. [Online]. Available: <https://www.malloryparkcircuit.com/wp-content/uploads/2015/05/Mallory-Park-Noise-Management-Plan-2015-V5-Active.pdf>. [Accessed 25 02 2019].
- [77] Goodwood Motor Circuit, "Goodwood Motor Circuit and Aerodrome Noise Control: A guide for neighbouring communities," 2011. [Online]. Available: <http://www.chichester.gov.uk/CHttpHandler.ashx?id=15480&p=0>. [Accessed 25 02 2019].
- [78] SPLTrack, "Silverstone Circuit," 2012. [Online]. Available: <http://spltrack.co.uk/silverstone-2/>. [Accessed 25 02 2019].

- [79] J. Shelton, "Developments in Sound Measurement Instrumentation," Environment Technology (Publications) Ltd, 01 02 2016. [Online]. Available: <https://www.envirotech-online.com/article/health-and-safety/10/svantek/developments-in-sound-measurement-instrumentation/1990>.
- [80] C. A. Kardous and P. B. Shaw, "Evaluation of smartphone sound applications," *The Acoustical Society of America*, vol. 135, no. 4, pp. EL186-192, 2014.
- [81] C. A. Kardous and P. B. Shaw, "Evaluation of smartphone sound applications (apps) using external microphones - A follow-up study," *Journal of the Acoustical Society of America*, vol. 140, no. 4, p. EL327, 2016.
- [82] C. A. Kardous and M. Celestina, "New NIOSH Sound Level Meter App," Centers for Disease Control and Prevention, 17 01 2017. [Online]. Available: <https://blogs.cdc.gov/niosh-science-blog/2017/01/17/slm-app/>.
- [83] J. Tingay, "A discussion on the use of app-based noise measurement tools," *Acoustics Bulletin*, vol. 42, no. 5, pp. 17-20, 2017.
- [84] National Transport Commission, "Review of the national in-service standard for engine brake noise," NTC Australia, 2013.
- [85] "Environmental Protection (Emission Regulations) 2013, S.R. No 159/2013".
- [86] "Environmental Protection Act 1970, No. 8056 of 1970".
- [87] Environment Protection Agency Victoria, "EPA listens to complaints about noisy vehicles," 15 02 2018. [Online]. Available: <https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/february/15/epa-listens-to-complaints-about-noisy-vehicles>. [Accessed 25 02 2019].
- [88] J. McIntosh and R. Hannaby, "Australian / New Zealand Governments' response to truck compression brake noise," in *Internoise 2012*, New York City, 2012.
- [89] "Vehicle Standard (Australian Design Rule 28/01 - External Noise of Motor Vehicles) 2006".
- [90] M. Devlin, "Vancouver police using their ears, not decibel meters, to target loud vehicles," CTV News Vancouver, 17 05 2017. [Online]. Available: <https://bc.ctvnews.ca/vancouver-police-using-their-ears-not-decibel-meters-to-target-loud-vehicles-1.3431708>. [Accessed 25 02 2019].
- [91] H. Steven, "Proposal for investigations related to roadside enforcement tests based on pass-by noise measurements," TUEV Nord Mobilitaet, Hannover, 2006.
- [92] M. Hinchcliffe, "Police hammer noisy motorbike exhausts," *Motorbike Writer*, 12 07 2017. [Online]. Available: <https://motorbikewriter.com/police-hammer-noisy-exhausts/>. [Accessed 25 02 2019].
- [93] Maxabout, "Motorcycles With Loud Exhausts Fined By Bengaluru Traffic Police," 11 08 2018. [Online]. Available: <https://news.maxabout.com/bikes/bangalore-traffic-police-loud-exhausts/>. [Accessed 25 02 2019].
- [94] CarToq, "Bangalore Traffic Police SEIZE & destroy aftermarket Royal Enfield silencers, yet again!," 11 08 2018. [Online]. Available: <https://www.cartoq.com/bangalore-traffic-police-seize-destroy-aftermarket-royal-enfield-silencers-yet-again/>. [Accessed 25 02 2019].
- [95] New Zealand Transport Agency, "Land transport rules," 2019. [Online]. Available: <https://www.nzta.govt.nz/resources/rules/vehicle-equipment-amendment-2007-qa.html>. [Accessed 25 02 2019].
- [96] New Zealand Transport Agency, "Noise tests for exhausts," 2019. [Online]. Available: <https://www.nzta.govt.nz/vehicles/warrants-and-certificates/warrant-of-fitness/noise-tests-for-exhausts/>. [Accessed 25 02 2019].
- [97] "Vehicular Noise Control," National Environmental Agency, Singapore.
- [98] A. Agha, R. Ranjan and W. Gan, "Noisy vehicle surveillance camera: A system to deter noisy vehicle in smart city," *Elsevier*, vol. 117, pp. 236 - 245, 2017.
- [99] A. Agha, W. Gan, Y. Chong and B. Ang, "A Noisy Vehicle Surveillance Camera (NoivelCam) System," in *Internoise 2014*, Melbourne, Australia, 2014.
- [100] "Environment Protection and Management (Vehicle Emissions) Regulations 1999 (as amended), Schedules 4, 6 and 7".

- [101] Thai PBS, "Police to get tough on cars with loud engine noise," 03 01 2018. [Online]. Available: <http://englishnews.thaipbs.or.th/police-get-tough-cars-loud-engine-noise/>. [Accessed 25 02 2019].
- [102] S. Riva, "Silent Nights: Phuket police ordered to tackle noisy motorbikes," Phuket News, 10 09 2017. [Online]. Available: <https://www.thepuketnews.com/silent-nights-phuket-police-ordered-to-tackle-noisy-motorbikes-63812.php#55a0eRLr4IEITIZp.97>. [Accessed 25 02 2019].
- [103] United Arab Emirates Government, "New UAE traffic law comes into force," 2018. [Online]. Available: <https://government.ae/en/information-and-services/justice-safety-and-the-law/road-safety>. [Accessed 25 02 2019].
- [104] Gulf News, "All 138 UAE traffic violations, fines and black points," 18 02 2018. [Online]. Available: <https://gulfnews.com/lifestyle/community/all-138-uae-traffic-violations-fines-and-black-points-1.1546486>. [Accessed 25 02 2019].
- [105] A. Abdullah, "935 noisy vehicles face music in Sharjah in 2018," Khaleej Times, 21 01 2019. [Online]. Available: <https://www.khaleejtimes.com/news/transport/935-vehicles-seized-in-uae-for-breaking-this-traffic-law>. [Accessed 25 02 2019].
- [106] The National, "Almost 7,000 vehicles impounded in Abu Dhabi for noise modifications," 08 01 2015. [Online]. Available: <https://www.thenational.ae/uae/transport/almost-7-000-vehicles-impounded-in-abu-dhabi-for-noise-modifications-1.118583>. [Accessed 25 02 2019].
- [107] S. A. Amir, "Hundreds of motorists fined for driving 'noisy' cars in Abu Dhabi," The National, UAE, Abu Dhabi, 2018.
- [108] "Florida Statutes 2018. FLA. STAT. § 316.293 (2018)".
- [109] The 191st General Court of the Commonwealth of Massachusetts, "Massachusetts General Laws, Chapter 90, § 7S, 7T, 7U, 16."
- [110] "Cal. Veh. Code § 27200-27207, 40610," 2019.
- [111] American Automobile Association, "Digest of Motor Laws," 2019. [Online]. Available: <https://drivinglaws.aaa.com/tag/motorcycle-noise-limits/>. [Accessed 25 02 2019].
- [112] J. Higgs, "Do cops actually write tickets for loud exhaust systems? We checked.," NJ, 28 10 2017. [Online]. Available: https://www.nj.com/traffic/index.ssf/2017/09/do_cops_actually_write_tickets_for_loud_exhaust_systems_we_checked.html. [Accessed 25 02 2019].
- [113] California Legislative Information, "California Vehicle Code," 2019. [Online]. Available: <http://leginfo.legislature.ca.gov/faces/codesTOCSelected.xhtml?tocCode=VEH&tocTitle=+Vehicle+Code+-+VEH>. [Accessed 25 02 2019].
- [114] California Bureau of Automotive Repair, "Vehicle Exhaust Noise Level Certification," 2019. [Online]. Available: https://bar.ca.gov/Consumer/Referee_Program/Vehicle_Exhaust_Noise_Level_Certification.html. [Accessed 25 02 2019].
- [115] California State Government, "Assembly Bill No 1824 (2017-2018), Ch 38-4," 2018. [Online]. Available: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB1824. [Accessed 25 02 2019].
- [116] California Car Laws, "California Vehicle Exhaust Laws," 2019. [Online]. Available: <http://www.californiacarlaws.com/exhaust-noise/>. [Accessed 25 02 2019].
- [117] Maxabout, "Chandigarh Traffic Police Puts A Ban on Loud Aftermarket Exhausts," 15 03 2018. [Online]. Available: <https://news.maxabout.com/bikes/traffic-police-ban-loud-exhausts/>. [Accessed 25 02 2019].
- [118] B. Hsu, "Nihon Life: June is illegal exhaust awareness month in Japan," Japanese Nostalgic Car, 01 06 2016. [Online]. Available: <http://japanesenostalgiccar.com/news-june-is-illegal-exhaust-awareness-month-in-japan/>. [Accessed 25 02 2019].
- [119] KDLT News, "Sioux Falls Police Conduct Free Exhaust Checks," 13 06 2015. [Online]. Available: <https://www.kdlt.com/2015/06/13/sioux-falls-police-conduct-free-exhaust-checks/>. [Accessed 25 02 2019].
- [120] National Transport Commission, "Engine Brake Noise - Final Proposal and Regulatory Impact Statement," 2007.

- [121] E. Stolte, "'Photo radar for noise': Electronic displays, cameras being tested in eight spots," *Edmonton Journal*, 16 08 2018. [Online]. Available: <https://edmontonjournal.com/news/local-news/photo-radar-for-noise-electronic-displays-cameras-being-tested-in-eight-spots>. [Accessed 25 02 2019].
- [122] City of Edmonton Council, "Vehicle Noise Monitoring Pilot," 2018. [Online]. Available: https://www.edmonton.ca/transportation/traffic_safety/vehicle-noise-monitoring-pilot.aspx. [Accessed 25 02 2019].
- [123] Canada News, "Edmonton turns off 4 vehicle noise displays after complaints of stunting, intentional noise," 13 09 2018. [Online]. Available: <https://canada-news.org/edmonton/edmonton-turns-off-4-vehicle-noise-displays-after-complaints-of-stunting-intentional-noise/>. [Accessed 25 02 2019].
- [124] N. Riebe, "Noise-control technology now on Edmonton streets, listening and watching," *CBC News*, 15 08 2018. [Online]. Available: <https://www.cbc.ca/news/canada/edmonton/edmonton-photo-radar-noise-monitoring-cameras-1.4787069>. [Accessed 25 02 2019].
- [125] CTV News, "Edmonton to crack down on loud vehicles with photo radar-style tech," 18 08 2018. [Online]. Available: <https://www.ctvnews.ca/canada/edmonton-to-crack-down-on-loud-vehicles-with-photo-radar-style-tech-1.4058257>. [Accessed 25 02 2019].
- [126] City of Edmonton Council, "Vehicle Noise, City Operation Report CR4772," 2018. [Online]. Available: <http://sirepub.edmonton.ca/sirepub/agdocs.aspx?doctype=agenda&itemid=59527>. [Accessed 25 02 2019].
- [127] Society of Automotive Engineers, "SAE J1492-2008 (R) Measurement of Light Vehicle Stationary Exhaust System Sound Level, Engine Speed Sweep Method," 2008.
- [128] N. Altaher, "Noise-measuring radars in Abu Dhabi residential areas soon," 05 04 2016. [Online]. Available: <https://gulfnews.com/uae/transport/noise-measuring-radars-in-abu-dhabi-residential-areas-soon-1.1704485>. [Accessed 25 02 2019].
- [129] J. A. Ballesteros, E. Sarradj, M. D. Fernandez, T. Geyer and J. Ballesteros, "Noise source identification with beamforming in the pass-by of a car," *Applied Acoustics*, no. 93, pp. 106-119, 2015.
- [130] J. A. Ballesteros, E. Sarradj, M. D. Fernandez, T. Geyer and M. J. Ballesteros, "Methodology for pass-by measurements on cars with beamforming," in *Berlin Beamforming Conference*, Berlin, 2014.
- [131] R. P. Doughty, "A new derivation of the adaptive beamforming formula," in *Berlin Beamforming Conference*, Berlin, 2018.
- [132] H. E. Camargo, P. A. Ravetta, R. A. Burdisso and A. K. Smith, "A comparison of beamforming processing techniques for low frequency noise source identification in mining equipment," [Online]. Available: <https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/acobp.pdf>. [Accessed 08 03 2019].
- [133] D. Farrell, "Using acoustic beamforming for pass-by noise source detection," *National Instruments*.
- [134] F. Graf, "Acoustic Detection of Wrong Way Drivers," 2019.
- [135] F. Graf and M. Gruber, "Rapid Incident Detection in Tunnels Through Acoustic Monitoring - Operating Experiences in Austrian Road Tunnels," in *9th International Conference, Tunnel Safety and Ventilation*, Graz, Austria, 2019.
- [136] Joanneum Research, "Acoustic Tunnel Monitoring," 2019. [Online]. Available: <https://www.akut-tunnel.com/>. [Accessed 25 02 2019].
- [137] Raytheon, "Boomerang III," 2019. [Online]. Available: <https://www.raytheon.com/capabilities/products/boomerang>. [Accessed 25 02 2019].
- [138] ShotSpotter, "ShotSpotter Technology," 2019. [Online]. Available: <https://www.shotspotter.com/technology/>. [Accessed 25 02 2019].
- [139] ShotSpotter, "Gunfire Location Detection, Sensor Analysis and Reporting Patents," 2019. [Online]. Available: <https://www.shotspotter.com/patents/>. [Accessed 25 02 2019].
- [140] Department for Environment Food and Rural Affairs and Department for Transport, "Draft Clean Air Zone Framework," Defra, London, 2016.

- [141] UK Authority, "Police to get new national ANPR system," 23 05 2018. [Online]. Available: <https://www.ukauthority.com/articles/police-to-get-new-national-anpr-system/>. [Accessed 25 02 2019].
- [142] National Police Chiefs' Council and Association of Police and Crime Commissioners, "Policing Vision 2025," NPCC, London, 2016.
- [143] G. J. Harris and P. M. Nelson, "Development of an in-service noise testing procedure for motorcycles. PR/SE/037/94," TRL, Wokingham, 1994.
- [144] G. J. Harris, P. M. Nelson and R. E. Stait, "Development of an in-service noise testing procedure for petrol powered road vehicles. PR/SE/296/97," TRL, Wokingham, 1997.
- [145] British Standards Institution, "BS 5383:1976 Method for measurement of reverberation time in auditoria," BSI, London, 1976.
- [146] D. Morrison and P. M. Nelson, "The development of a close proximity noise test for stationary vehicles," in *Internoise*, Munich, 1985.
- [147] European Council, "EU/EC 84/424/EEC-1984 council directive amending directive 70/157/eec on the approximation of the laws of the member states relating to the permissible sound level and the exhaust system of motor vehicles," 1984.
- [148] Council of the European Union, "Council Directive No 92/53/EEC of 18 June 1992 amending Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers," 1992.
- [149] G. Watts, P. Nelson and M. Balsom, "An examination of vehicle noise test procedures. PRR044," TRL, Wokingham, 2005.
- [150] "Nationales Verkehrslärmschutzpaket 2007," Federal Ministry for the Environment, Nature Conservation and Nuclear Security, 2007.
- [151] Federal Ministry for Environment, Nature Conservation and Nuclear Security, "Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes, Verkehrswege-Schallschutzmaßnahmenverordnung," 1997. [Online]. Available: <https://www.bmu.de/gesetz/24-verordnung-zur-durchfuehrung-des-bundes-immissionsschutzgesetzes/>. [Accessed 25 02 2019].
- [152] Federal Ministry for Justice and Consumer Protection, 1990, amended 2014. [Online]. Available: https://www.gesetze-im-internet.de/bimschv_16/BJNR010360990.html. [Accessed 25 02 2019].
- [153] European Commission, "Commission Directive 2007/34/EC of 14 June 2007 amending, for the purposes of its adaptation to technical progress, Council Directive 70/157/EEC concerning the permissible sound level and the exhaust system of motor vehicles," 2007.
- [154] Cirrus Research, "What's the Difference Between a Class 1 and Class 2 Sound Level Meter?," [Online]. Available: <https://www.cirrusresearch.co.uk/blog/2011/10/whats-the-difference-between-a-class-1-and-class-2-sound-level-meter/>. [Accessed 08 03 2019].
- [155] Additional Sound Emission Provisions, "IMMA inputs to R51 ASEP," in *ASEP 9th Session*, Geneva, Switzerland, 2018.

APPENDIX A – Survey of Stakeholders

**Specialist Professional and Technical
Services (SPATS) Framework
Lot 1**

**Task 696 Roadside Vehicle Noise Measurement
Survey of Stakeholders**

March 2019

ATKINS **JACOBS®**

Member of the SNC-Lavalin Group

Reference Number: 1-696 / P04102075
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Executive Summary

The Department for Transport (DfT) wishes to understand the potential to improve enforcement against vehicles which are excessively noisy, particularly when being operated in areas where people live, study or work. In addition, the DfT wants to understand better the current and best practice in road vehicle noise enforcement both across the UK and in other countries, and to identify technologies that could assist with enforcement through road side measurement of the noise of passing vehicles.

The Atkins Jacobs Joint Venture (AJJV) has been commissioned to undertake this project on behalf of the Department. The overall aim of this project is to provide the Department for Transport (DfT) with a greater understanding of how the issue of excessively noisy road vehicles is policed both across the UK and in other countries and to determine whether suitable candidate technologies are available for the purposes of:

- Identifying excessively noisy road vehicles;
- Improving compliance with vehicle noise legislation; and
- Supporting future policies on the noise emissions of road vehicles.

This first technical delivery of the project is a survey of stakeholders, which includes police forces and Local Authorities.

The aim of the survey of police forces was to determine how in-service noise compliance is currently enforced and what future strategies would be of most use. To achieve this an online questionnaire was issued to the 43 police forces who are members of the National Roads Policing Intelligence Forum (NRPIF). Responses were received from 16 police forces, providing a response rate of 37%.

Just over two-thirds of the police forces who responded undertake action against excessively noise vehicles / driving, with all those stating it was undertaken reactively (i.e. upon receiving a complaint). None of the police forces proactively take action in this area.

Only one of the police forces have their own equipment to measure noise, and therefore the majority of any prosecutions are undertaken by a subjective test.

When asked what would help to improve enforcement, the responses were generally around resources and equipment. However, changes to legislation was cited by one police force as having potential to improve the enforcement. Specifically, they suggested legislation should set a noise level threshold at which police forces must take action for enforcement against noisy vehicles/driving and detail the burden of evidence. Of those who do not currently enforce in this area, the main response was a suggestion that better resources and/or equipment was required, whereas those police forces who have been more active in this area have suggested that they require better guidance on enforcement.

The survey of Local Authorities was undertaken by direct contact with Environmental Health Officers. A total of 20 Local Authorities were contacted, and ten responses were received. Most who receive complaints direct those complainants to the local police force. None reported the use of noise measurements as an enforcement measure, although one Local Authority reported having issued 40 penalty notices in 2018.

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APPENDICES

APPENDIX A – Covering letter sent to police forces

12. Introduction

The Department for Transport (DfT) wishes to understand the potential to improve enforcement against vehicles which are excessively noisy, particularly when being operated in areas where people live, study or work. In addition, the DfT wants to understand better the current and best practice in road vehicle noise enforcement both across the UK and in other countries, and to identify technologies that could assist with enforcement through road side measurement of the noise of passing vehicles.

The Atkins Jacobs Joint Venture (AJJV) has been commissioned to undertake this project on behalf of the Department. The overall aim of this project is to provide the Department for Transport (DfT) with a greater understanding of how the issue of excessively noisy road vehicles is policed both across the UK and in other countries and to determine whether suitable candidate technologies are available for the purposes of:

- Identifying excessively noisy road vehicles;
- Improving compliance with vehicle noise legislation; and
- Supporting future policies on the noise emissions of road vehicles.

Previous work has shown that roadside tests using an approach similar to that of ISO 5130³ have been used in a number of different police campaigns within the UK. These include examples from Cardiff, Suffolk and Devon and Cornwall Police, who all used a not-to-exceed limit of 90 dB(A). The aim of this first technical deliverable of the contract is to undertake and report on a survey of UK police forces to identify current approaches to the enforcement and reporting of vehicle noise. In addition, the aim was to understand what future approaches would be of use to police forces.

This report presents the results from an on-line questionnaire that was sent to all UK police forces. In addition, the findings of a targeted survey of Local Authorities and stakeholders in industry is also presented.

³ The International Standard ISO 5130 “Acoustics – Measurement of noise emitted by stationary road vehicles – survey methods” (2007). The standard requires the measurement of the maximum noise level from a stationary vehicle (or motorcycle) while the engine is allowed to rapidly decelerate from a specified engine speed.

13. Survey Methodology

Police Forces

The aim of the survey of police forces was to determine how in-service noise compliance is currently enforced and what future strategies would be of most use. To achieve this, the AJJV designed an online questionnaire that was reviewed and approved by the DfT. An email which contained a covering letter explaining the aims of the project and purpose of the questionnaire was circulated by the DfT via the National Roads Policing Intelligence Forum (NRPIF) to the 43 police forces in England and Wales. This covering letter contained a link to the online survey, and the police forces were requested to respond within two weeks and there was no reminder issued. A number of police forces known to be proactive in enforcing excessively noisy vehicles were also contacted separately. The NRPIF was considered to be the most appropriate forum to raise the topic. However, with the NRPIF being comprised of police forces in England and Wales, the geographical scope was therefore restricted to these two areas.

A copy of the covering letter can be found in Appendix A. The online questionnaire contained 11 questions consisting of multiple choice and open response questions regarding vehicle noise. For some questions a particular response then precluded the answering of some subsequent questions. The questions were:

- Q1. Which police force do you represent?
- Q2. How often do you take action against excessively noisy vehicles/driving?
 - Never (go to Q10)
 - Reactively – when complaints are received
 - Actively through targeting groups / locations
 - I don't know
- Q3. How many of the following actions did you take between January 2018 and December 2018 in relation to excessively noisy vehicles/driving?
 - Number of verbal warnings
 - Number of fixed penalty notices
 - Number of prosecutions at court
 - Other
- Q4. Do you work with the Local Authority to tackle excessively noisy vehicles/driving?
 - No (go to Q6)
 - Yes. Please enter the Local Authority details
 - I don't know
- Q5. If you work with the Local Authority, please select how you work with them
 - They inform us of complaints
 - They suggest areas for targeting
 - We provide details of environmental health or another local authority branch
 - Other reason
- Q6. Do you use any other legislation other than the Road Vehicles (Construction and Use) Regulations to enforce excessive vehicle noise?
 - Yes – please list
 - No
 - I don't know
- Q7. What noise limit (in decibels) do you enforce and how has this been derived?
- Q8. Do you use the ISO 5130 test method for this enforcement?

- Yes
 - Yes, but a modified version. Please provide details
 - No. Please provide details of the test method used
 - No, we don't enforce
 - I don't know
- Q9. What test equipment do you use to measure vehicle noise?
 - Q10. What, if anything, would help you to improve enforcement against excessively noisy vehicles/driving?
 - Nothing needed
 - Change in legislation, please provide details
 - Better equipment, please provide details
 - More resources, please provide details
 - Other, please provide details
 - Q11. Do you provide members of the public with a means of reporting excessively noisy vehicles/driving – for example a reporting website / phone number / email address? – If so, please provide further details

Local Authorities

The survey of Local Authorities was undertaken by direct contact with Environmental Health Officers. The Local Authorities were identified through responses from the police survey, where a contact was already known by the AJJV within a Local Authority, or where it was considered or known that the Local Authority had issues with vehicles causing excessive noise. A total of 20 Local Authorities were contacted, and ten responses were received.

A questionnaire approach, as used for the police forces, was not utilised due to project timescales and there not being an obvious mechanism to contact all Local Authorities. The questions asked of the Local Authorities are listed below:

- Q1. How often do you take action against excessively noisy vehicles?
- Q2. Do members of the public contact you to complain about excessively loud vehicles?
- Q3. When you receive complaints about excessively loud vehicles, how do you enforce it?
- Q4. Do you work with the police to investigate complaints or to take action against excessively loud vehicles? How does the arrangement work?
- Q5. Do you undertake any noise measurements when investigating complaints about excessively loud vehicles? If so, what method do you use (ISO 5130 or something more general)?
- Q6. What noise limits do you use to decide whether a vehicle is excessively loud?
- Q7. How many fixed penalty notices did you issue between January 2018 and December 2018? How many prosecutions at court over the same period?
- Q8. Has any action taken resulted in fewer complaints from local residents?
- Do you have any additional comments about this topic?

Other Stakeholders

Contact was made via email with the Federation Internationale de Motocyclisme, who had expressed an interest to the DfT of contributing to the project. However, no response was received and so these are not considered further.

14. Police Force Survey Results

Survey Respondents

The questionnaire was sent out to police forces across England and Wales.

Out of 43 police forces, 16 responded to the survey, which is a response rate of 37%. There is no single figure which can be used to determine if a survey response rate is considered to be 'good' or 'reliable', as it is very much dependent upon factors such as target population, incentive to participate, and time limits. From a qualitative survey such as this, the achieved response rate of 37% is considered to be a satisfactory number to draw conclusions.

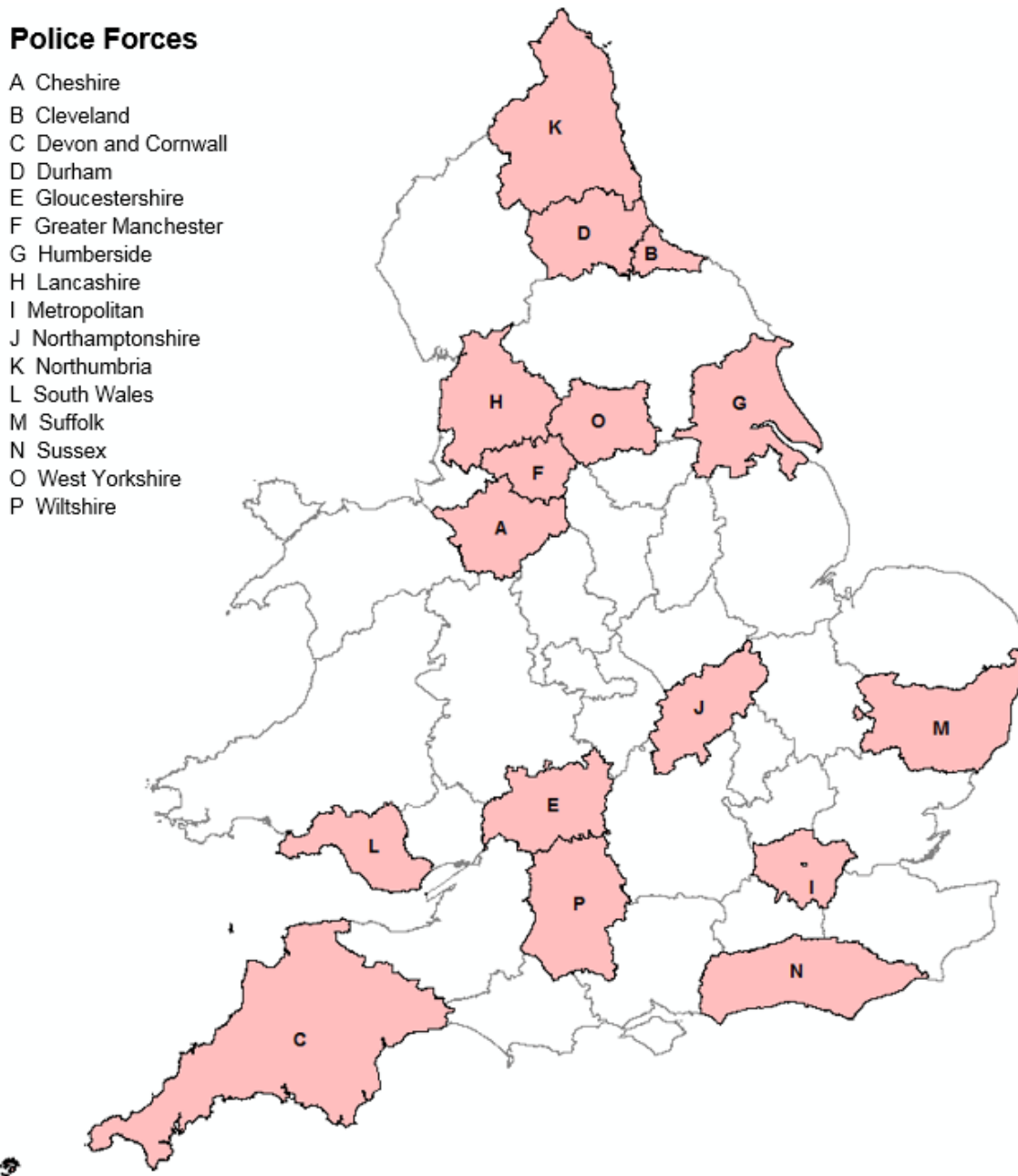


Figure 3-1. Geographic location of police forces that responded to survey

Cleveland and Durham police forces provided a combined response to the questionnaire, however, for the purpose of this assessment their responses are treated individually in the analysis section. Also, Devon and Cornwall responded to the questionnaire three times. The three separate survey answers have been coalesced into one overall response for the Devon and Cornwall police force.

The geographical spread of responses across the country is considered reasonable and does include police forces covering urban areas and also large areas of countryside.

Survey Analysis

The responses provided in this section are not assigned to a particular police force and do not represent the order the forces are listed in Figure 3-1 (i.e. police force A does not correspond to police force 1). The responses from the police forces are reported in full and no further information is available.

Question 1: Which police force do you represent?

The police forces are shown in Figure 3-1 above.

Question 2: How often do you take action against excessively noisy vehicles/driving?

The respondents were asked how often the police force took action against excessively noisy vehicles/driving. Out of all the respondents, 63% stated that they reactively take action against noisy vehicles when a complaint is received, 31% of the respondents never take action, and 6% of the respondents do not know how often their police force takes action. None of the respondents proactively take action against noisy vehicles.

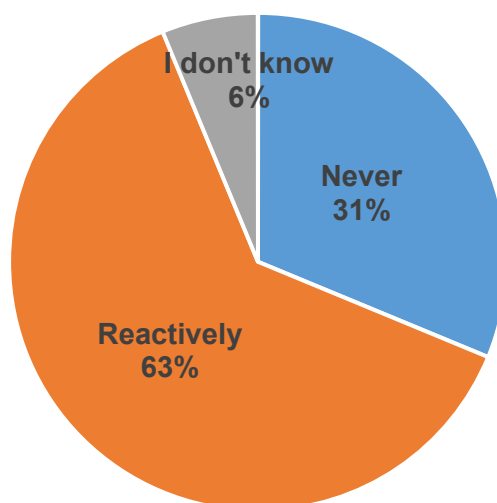


Figure 3-2. Question 2 police force responses

For Question 2, if the respondents replied 'never' they were asked to skip to Question 10 whilst those that answered 'reactively' or 'I don't know' were asked follow up questions. Those that answered as 'never' are treated as 'non-applicable' (N/A) in Questions 3 – 9. For Question 3 – 9 there were ten police forces where answers have been analysed.

Question 3: How many of the following actions did you take between January 2018 and December 2018 in relation to excessively noisy vehicles/driving?

Question 3 asked respondents what types of actions have taken against noisy vehicles/driving and how many times the action has been applied. The types of actions were grouped into four categories: 'verbal warnings', 'fixed penalty notices', 'prosecutions at court', and 'other'. For each action the respondents had an open response option to put in text or a value.

Table 3-1 shows the number of actions taken to address excessively noise vehicles. The table shows that more than half of the respondents either take no action or do not know if action was taken. Out of the four categories available, most known actions taken were in the form of verbal warnings and fixed penalty notices.

Table 3-1. Question 3 police force responses

Police Force ID	Number of Actions Taken				Total
	Verbal warnings	Fixed penalty notices	Prosecutions at court	Other	
Police Force 2	0	1	0	0	1
Police Force 3	Unknown	0	Unknown	15	15
Police Force 4	Unknown	0	Unknown	Unknown	0
Police Force 6	21	1	0	32	54
Police Force 8	30	0	0	0	30
Police Force 9	Unknown	Unknown	Unknown	Unknown	0
Police Force 10	Unknown	0	0	0	0
Police Force 12	0	2	0	12	14
Police Force 13	Unknown	7	Unknown	Unknown	7
Police Force 14	0	0	0	1	1
Police Force 15	Unknown	43	2	Unknown	45

The only indication of what was classified as ‘Other’ was from police force 3, who stated that the ‘Other’ were issued under the Vehicle Defect Rectification Scheme.

Questions 4 and 5: Do you work with the Local Authority to tackle excessively noisy vehicles/driving?

Question 4 asked the police force respondents whether they worked with Local Authorities in addressing the issue of noisy vehicles. Based on the results shown in Figure 3-3, half of the respondents (50%) do not work with Local Authorities on this issue.

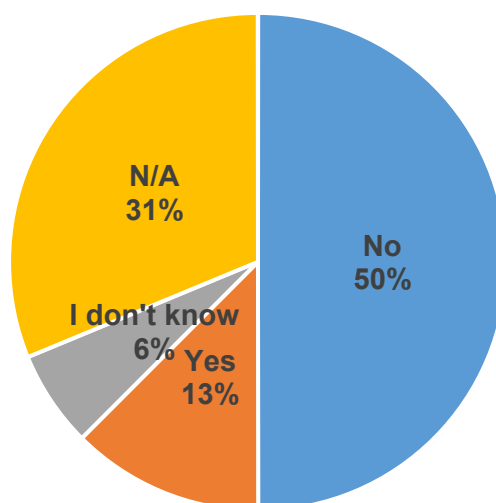


Figure 3-3. Question 4 police force responses

Two respondents (police force 6 and 14) that do work with Local Authorities stated that they do so when complaints are referred to them from the Local Authority (from follow up Question 5, which asked how the force works with the Local Authority).

Questions 6: Do you use any legislation other than the Road Vehicles (Construction and Use) Regulations to enforce excessive vehicle noise?

Question 6 asked respondents what legislation they used to enforce excessive vehicle noise. Around two-thirds of the respondents (63%) do not use any other legislation aside from Road Vehicles (Construction and Use) Regulations. One police force (police force 6) uses Anti-Social Behaviour Orders (ASBO) in conjunction with Road Vehicles (Construction and Use) Regulations.

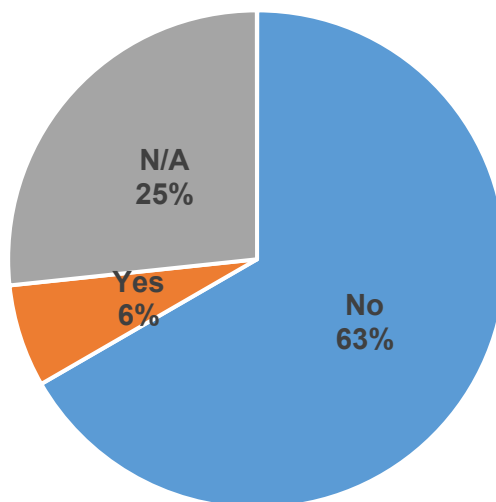


Figure 3-4. Question 6 police force responses

Two police forces (police forces 3 and 4) commented that owners that have modified their vehicle and made it excessively loud do not always declare this on their insurance policy. Police officers are able to undertake an insurance check which could result in the insurer voiding the owner’s insurance policy if the vehicle is found to be undeclared as modified, which could result in an offence for driving without valid insurance.

Questions 7: What noise limit (in decibels) do you enforce and how has this been derived?

Question 7 was presented as an open response. Table 3-2 lists the responses for all of the police forces who provided an answer to this question. Only one respondent (police force 10) specified an enforced absolute noise limit (82 dB), however, this was only during an enforcement trial. Police forces 4 and 10 suggest that noise limit enforcement is limited by whether or not the police force has noise testing equipment. The majority of respondents utilise subjective means to enforce noise limits, whilst some have stated that an absolute noise limit is non-applicable.

Table 3-2. Question 7 police force responses

Police Force ID	What noise limit (in decibels) do you enforce and how has this been derived?
Police Force 3	Noise limits aren’t applicable as guidance states that if loud to ear and not fitted to car when manufactured, then it is an offence.
Police Force 4	Stated noise limits are not applicable as the guidance states if it is considered louder than when the vehicle was manufactured, it could be an offence
Police Force 8	Currently have no noise testing equipment in the force, so any action is taken in relation to Road Vehicles (Construction and Use) Regulations.
Police Force 9	N/A

Police Force ID	What noise limit (in decibels) do you enforce and how has this been derived?
Police Force 10	We trialled enforcement above these levels in 2016, but as the equipment we were using was only on loan to the force, we have not continued with any enforcement at all since. The below was included on the initial trial warning letter given to drivers when they were tested. A four-wheeled vehicle used on or after 1 st October 1983 must not exceed 82 dB. Some exceptions apply and in these exceptions the limit is increased to 99 dB.
Police Force 12	We will generally utilise exhaust legislation such as removal of baffles/defects if appropriate. Local Authorities in the area do not engage with us on joint operations for this issue
Police Force 14	We enforce from 90 dB. 82 dB is the legal limit.
Police Force 15	We do not.

Question 8: Do you use the ISO 5130 test method⁴ for this enforcement?

The responses to Question 8 are presented in Figure 3-5.

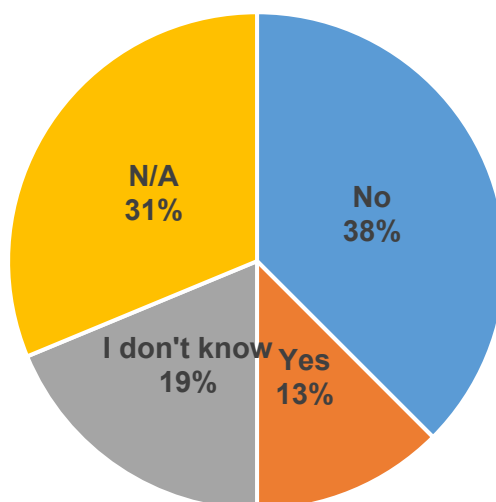


Figure 3-5. Question 8 police force responses

Based on the figure, approximately a third (38%) of the respondents do not use ISO 5130, around a fifth (19%) of the respondents don't know if the police force uses ISO 5130, and 13% of the respondents use ISO 5130 for enforcement. One respondent stated that they do not use ISO 5130 because it is non-applicable for noise limit enforcement.

Question 9: What test equipment do you use to measure vehicle noise?

Table 3-3 lists the open responses to Question 9. None of the respondents use testing equipment to measure vehicle noise. Three respondents (police forces 3, 4, and 6) rely on subjective listening by a 'competent person' to measure vehicle noise. Two respondents (police forces 9 and 10) specify that the police force does not have any testing equipment.

Table 3-3. Question 9 police force responses

Police Force ID	What test equipment do you use to measure vehicle noise?
Police Force 2	None
Police Force 3	Subjective listening

⁴ The International Standard ISO 5130 "Acoustics – Measurement of noise emitted by stationary road vehicles – survey methods" (2007). The standard requires the measurement of the maximum noise level from a stationary vehicle (or motorcycle) while the engine is allowed to rapidly decelerate from a specified engine speed.

Police Force ID	What test equipment do you use to measure vehicle noise?
Police Force 4	Subjective listening
Police Force 6	Standard reasonable person
Police Force 9	Do not have test equipment
Police Force 10	A Neutrik NTI XL2 sound level meter was trialled, but not purchased due to budget
Police Force 12	N/A
Police Force 13	None
Police Force 14	NTi audio XL2 handheld acoustic analyser

Question 10: What, if anything, would help you to improve enforcement against excessively noisy vehicles/driving?

Question 10 was a multiple choice question, that asked for respondents to choose from five categories: ‘nothing needed’, ‘change in legislation’, ‘better equipment’, ‘more resources’, and ‘other’. Based on which categories were ticked, respondents were asked to provide details in an open response.

Figure 3-6 shows which categories would improve enforcement of noisy vehicles. More than half of the respondents (56%) stated that ‘more resources’ and ‘better equipment’ would facilitate enforcement, whilst less than half considered that a ‘change in legislation’ (6%) and ‘other’ means (38%) would improve enforcement.

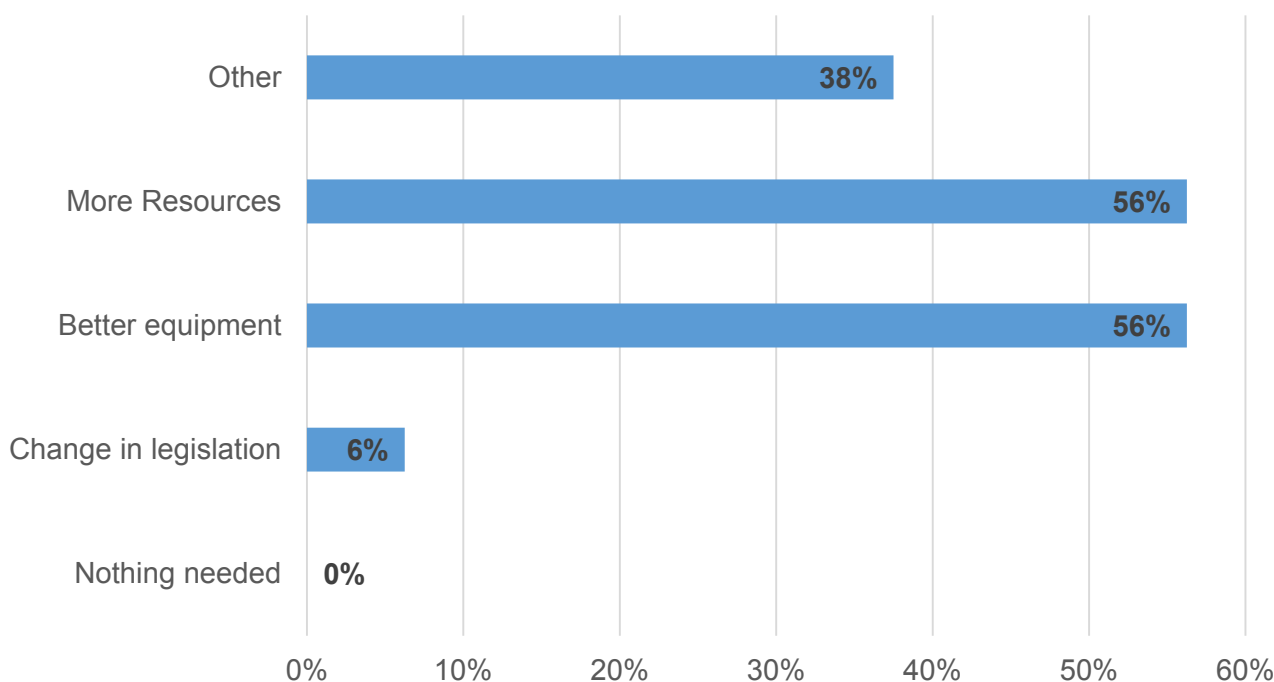


Figure 3-6. Question 10 police force responses

When asked to provide detail on improvements under each category, a number of police forces commented on the same improvement across multiple categories (i.e. there are similar improvements mentioned under ‘more resources’ and ‘other’) which has resulted in some overlap between the categories on areas of improvement.

From the one respondent (6%) that selected ‘change in legislation’ needing improvement, the feedback on this improvement was that legislation should set a noise level threshold at which police forces must take action for enforcement against noisy vehicles/driving and detail the burden of evidence.

In terms of ‘better equipment’, the 56% of respondents that chose this category stated that police forces should be supplied with standardised sound level meters in order to be able to quantifiably enforce excessive noise. One police force suggested updating the equipment so that it is more user friendly.

There were multiple detailed responses on how ‘more resources’ would improve enforcement. Some respondents identified that police force staff shortages limit officers from being able to address low level offences. One respondent stated that the substantial geographical area of each police force limits the extent of noise policing and that local resources could be more pivotal in addressing excessive noise. Another respondent stated that the Driving and Vehicle Standards Agency and/or police guidance could be updated regarding noise limits. A number of respondents said that staff should be provided with training on noise monitoring and noise enforcement.

For the ‘other’ category respondents flagged improvements such as training on excessive noise and increase awareness on what constitutes as excessive vehicle noise. A respondent stated that noise “offences are very difficult to prove and therefore [the] numbers of enforcement are minimal”. Improving guidance and/or codes of practice were also mentioned for the ‘other’ category.

Of those who do not currently enforce in this area, the main response to Question 10 was a suggestion that better resources and/or equipment was required, whereas those police forces who have been more active in this area have suggested that better guidance is needed.

Question 11: Do you provide members of the public with a means of reporting excessively noisy vehicles/driving – for example a reporting website / phone number / email address?

Question 11 was an open response question. Table 3-4 summarises the respondents’ answers. Four respondents (police forces 1, 2, 9, and 11) don’t provide the public with any means of reporting excessive noise. Based on the responses, a number of respondents (police forces 3, 4, 5, and 10) direct the public to the non-emergency 101 phone number for noise complaints. One respondent (police force 7) provides the public with an email address, another (police force 8) refers them to the Local Authority, and another respondent (police force 12) received reports on noise issues.

Table 3-4. Question 11 police force responses

Police Force ID	Do you provide members of the public with a means of reporting excessively noisy vehicles/driving?
Police Force 1	No
Police Force 2	No
Police Force 3	People phone in on the 101 system. We can have multiple reports for the same vehicle.
Police Force 4	The 101 system is used by members of the public to report noisy vehicles. Sometimes there are several calls about the same vehicle.
Police Force 5	We direct the public to report it via national 101 number. Also, the noise related message is prerecorded on the 101 pre-recorded message.
Police Force 6	N/A
Police Force 7	There is nothing specific. The public can use the 101 email address or the local email address for their LPA policing team.
Police Force 8	Noise complaints as a whole are generally referred to the Local Authority.
Police Force 9	No
Police Force 10	Members of the public can phone the contact centre. We also have a Road Traffic Incident reporting page on our website. We have nothing dedicated to noisy vehicles themselves.
Police Force 11	No
Police Force 12	An online reporting tool is available for reporting excessively loud vehicles, but we have limited skills to deal with these effectively.
Police Force 13	Nothing other than normal reporting channels.
Police Force 14	Anyone can contact the police control room to make a complaint, which will then be resourced to the relevant unit.
Police Force 15	Only through the 101 system.
Police Force 16	Yes, through 101 and online.

15. Local Authority Survey Results

Of the 20 Local Authorities who were contacted, responses were received from ten of these. Those where replies were received are:

- Brighton and Hove City Council
- City of Bradford Metropolitan District Council
- City of York Council
- Elmbridge Borough Council
- Kirklees Council
- Mid Devon District Council
- North Somerset Council
- Poole Borough Council
- Royal Borough of Kensington and Chelsea
- Trafford Council

For each Local Authority an Environmental Health Officer (EHO) was contacted as they are the most likely to receive complaints. The responses received are given below. It should be noted the alphabetical order in which they are listed above does not correspond to the order provide in subsequent tables.

Question 1: How often do you take action against excessively noisy vehicles?

Table 4-1 details the answers Local Authorities provided to Question 1. Four Local Authorities (Local Authority 1, 4, 6, and 10) do not take action against noisy vehicles, two Local Authorities (Local Authority 7 and 9) do not keep records on noisy vehicle investigations, and three Local Authorities (Local Authority 1, 3, and 8) take action in a limited capacity. Also, two Local Authorities (Local Authority 1 and 8) depend on the local police force to take action against excessively noisy vehicles.

Table 4-1. Question 1 Local Authority responses

Local Authority ID	How often do you take action against excessively noisy vehicles?
Local Authority 1	It all depends around what your definition of excessive noise is? We have proactive Police and Council Office Patrol running during the busier times of year (usually the summer months) to tackle the breaches of the Public Spaces Protection Order.
Local Authority 2	Never.
Local Authority 3	We never formally investigate noise from bikers' events. We deal with car park owners in the case of car cruising complaints.
Local Authority 4	Never.
Local Authority 5	N/A
Local Authority 6	We do not investigate excessively noisy vehicles.
Local Authority 7	We have no record of taking action against excessively noisy vehicles.
Local Authority 8	Very rarely if ever, as Police generally deal with noise from vehicles. The only exception being noise associated with delivery vehicles.
Local Authority 9	We cannot quantify this as we do not record noisy vehicles as a distinct complaint category.
Local Authority 10	We do not get involved with noise levels from vehicles.

Question 2: Do members of the public contact you to complain about excessively loud vehicles?

Table 4-2 shows that some Local Authorities receive complaints (Local Authority 1, 3, 6, 7, 8, and 9), however, for most it is on infrequent occasions (Local Authority 3, 6, and 7). Two Local Authorities (Local Authority 7 and 8) refers members of the public to their local police force. Two Local Authorities (Local Authority 2, 4, and 10) do not receive complaints, however, Local Authority 4 does point out that they receive complaints about early morning deliveries.

Table 4-2. Question 2 Local Authority responses

Local Authority ID	Do members of the public contact you to complain about excessively loud vehicles?
Local Authority 1	Yes.
Local Authority 2	No.
Local Authority 3	Occasionally: - during “ Bikers Night” (every Tuesday evening during summer months; - “Car cruising” events being carried out at local car parks
Local Authority 4	No. Only for early morning deliveries.
Local Authority 5	N/A
Local Authority 6	Yes, very infrequently.
Local Authority 7	Members of the public rarely contact Environmental Health’s Pollution and Noise Control to complain about excessively loud vehicles, if they do we would ask them to report the vehicle to the Police.
Local Authority 8	Yes, they are often referred onto the Police.
Local Authority 9	Yes.
Local Authority 10	No.

Question 3: When you receive complaints about excessively loud vehicles, how do you enforce it?

Table 4-3 summarises the responses for Question 3.

Table 4-3. Question 3 Local Authority responses

Local Authority ID	When you receive complaints about excessively loud vehicles, how do you enforce it?
Local Authority 1	We ask residents to provide a witness statement which has to include the vehicle registration. If the statement passes the burden of proof that any of the conditions of the Public Spaces Protection Order has been breached, then an Fixed Penalty Notice will be issued.
Local Authority 2	N/A
Local Authority 3	We refer them to the police or deal with car park owner for the “car cruising” noise complaints (see response in Table 4-2).
Local Authority 4	Local Authorities have no power to enforce.
Local Authority 5	If we get complaints for noisy vehicles on the highway then there is nothing we can do about it and refer the complaints to the police. If we get a complaint about noise from a vehicle – say on someone’s drive (e.g. a revving motorcycle) – then we can issue a Community Protection Warning under the Anti-Social Behaviour, Crime and Policing Act 2014. If persistent, we could then issue a Community Protection Notice. We can also write to people first and issue an informal warning.
Local Authority 6	We consider this is a matter that is appropriately covered by The Road Vehicles (Construction and Use) Regulations 1986 (as amended).
Local Authority 7	N/A

Local Authority ID	When you receive complaints about excessively loud vehicles, how do you enforce it?
Local Authority 8	The complaints are generally referred onto the police unless noise concerns delivery noise.
Local Authority 9	We have no power to enforce against noisy vehicles when they are traffic – see Environmental Protection Act 1990, Section 79 (6A) (a). Stationary vehicles in the street may be dealt with under the provisions of the Environmental Protection Act 1990, Section 79 (1) (ga). Noise from vehicles parked on premises would be investigated under the provisions of the Environmental Protection Act 1990, Section 79 (1) (g) or Section 43 of the Anti-social Behaviour, Crime and Policing Act 2014.
Local Authority 10	We would only get involved if the noise levels were in connection with stationary vehicles playing loud music or revving their engines.

Question 4: Do you work with the Police to investigate complaints or to take action against excessively loud vehicles? How does the arrangement work?

Figure 4-1 summarises the responses for Question 4. Four of the ten Local Authorities (Local Authority 1, 3, 8, and 9) work with the police to investigate noisy vehicles and three Local Authorities (Local Authority 2, 6, and 10) does not work with the police on the matter. Local Authority 10 state the following: “we would review this if requested to but this has not happened”. For the Local Authorities that work with the police, they do so by sending the complaints to the police.

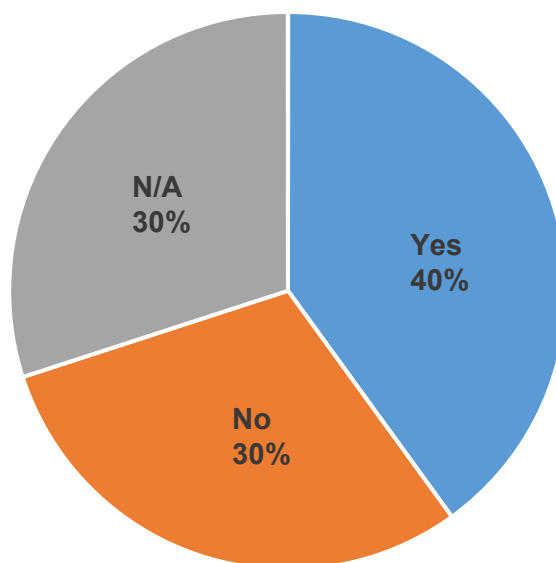


Figure 4-1. Question 4 Local Authority responses

Question 5: Do you undertake any noise measurements when investigating complaints about excessively loud vehicles? If so, what method do you use (ISO 5130 or something more general)?

For Question 5, Table 4-4 shows that most of the Local Authorities do not undertake objective noise measurements. Local Authority 9 states that it is at the attending officer’s discretion to measure noise levels.

Table 4-4. Question 5 Local Authority responses

Local Authority ID	Do you undertake any noise measurements when investigating complaints about excessively loud vehicles? If so, what method do you use (ISO 5130 or something more general)?
Local Authority 1	No.
Local Authority 2	No.
Local Authority 3	N/A
Local Authority 4	N/A
Local Authority 5	N/A
Local Authority 6	N/A
Local Authority 7	N/A
Local Authority 8	No, we only assess as potential statutory noise nuisances.
Local Authority 9	We are not required to take objective noise measurements in determining the existence or likely occurrence/recurrence of a statutory nuisance. Digital sound recording equipment may be deployed at the investigating officer's discretion.
Local Authority 10	No

Question 6: What noise limits do you use to decide whether a vehicle is excessively loud?

Table 4-5 shows that none of the Local Authorities specify any set noise limits for excessively loud vehicles. As shown in Table 4-5, most Local Authorities do not measure noise levels and, thus, do not abide by absolute noise limits.

Table 4-5. Question 6 Local Authority responses

Local Authority ID	What noise limits do you use to decide whether a vehicle is excessively loud?
Local Authority 1	We can only take enforcement action if the vehicle breaches conditions of the Public Space Protection Order
Local Authority 2	N/A
Local Authority 3	N/A
Local Authority 4	N/A
Local Authority 5	N/A
Local Authority 6	N/A
Local Authority 7	N/A
Local Authority 8	N/A
Local Authority 9	Officers normally make a subjective assessment of the noise level and take into account factors such as loudness, frequency, time and duration, the nature and locality of the neighbourhood, standard of comfort, motive, level of interference and, most importantly, reasonableness, in determining a statutory nuisance.
Local Authority 10	We don't tend to enforce as we don't have a problem with loud vehicles.

Question 7: How many fixed penalty notices did you issue between January 2018 and December 2018? How many prosecutions at court over the same period?

Table 4-6 shows only one Local Authority has issued penalty notices for excessively noisy vehicles and no Local Authority has prosecuted noisy drivers in court.

Table 4-6. Question 7 Local Authority responses

Local Authority ID	How many fixed penalty notices did you issue between January 2018 and December 2018? How many prosecutions at court over the same period?
Local Authority 1	We issued 40 penalty notices and no prosecutions in court.
Local Authority 2	We do not issue penalties notices nor prosecute in court.
Local Authority 3	N/A
Local Authority 4	N/A
Local Authority 5	N/A
Local Authority 6	N/A
Local Authority 7	N/A
Local Authority 8	N/A
Local Authority 9	N/A
Local Authority 10	N/A

Question 8: Has any action taken resulted in fewer complaints from local residents?

Local Authority 1 and 3 state that taking action against excessively noisy vehicles has resulted in fewer complaints from members of the public, as shown in Table 4-7.

Table 4-7. Question 8 Local Authority responses

Local Authority ID	Has any action taken resulted in fewer complaints from local residents?
Local Authority 1	Yes.
Local Authority 2	No action has been taken.
Local Authority 3	Yes.
Local Authority 4	N/A
Local Authority 5	N/A
Local Authority 6	N/A
Local Authority 7	N/A
Local Authority 8	N/A
Local Authority 9	N/A
Local Authority 10	N/A

16. Conclusions

The AJJV has considered the responses received from the 16 police forces and ten Local Authorities in the context of the aims of this task, which was to determine how in-service noise compliance is currently enforced and what future strategies would be of most use. Out of 43 police forces, 16 responded to the survey, which is a response rate of 37%. The low activity in the enforcement of excessively noisy vehicles may have contributed to the response rate, with police forces potentially not responding due to limited activity in the area. However, this response rate is a limitation of the analysis. The ten survey responses from Local Authorities would also be a limiting factor in drawing conclusions.

Current enforcement and prosecutions

Just under two-thirds of the police forces who responded undertake action against excessively noisy vehicles / driving, with all respondents stating it was undertaken reactively (i.e. upon receiving a complaint). None of the police forces proactively take action in this area.

Current enforcement is through a subjective test and not through the undertaking of noise measurements. Of those who had taken action in relation to excessively noisy vehicles/driving during 2018, these were either in the form of verbal warnings, fixed penalty notices, or through the use of the Vehicle Defect Rectification Scheme. None reported prosecutions going to court.

One Local Authority is active in the area of enforcement and works with the police during busier times of year to tackle excessively noisy vehicles/driving, and stated they had issued 40 penalty notices in 2018.

Equipment and testing

Only one of the police forces who responded have their own equipment to measure noise, and therefore noise measurement tests are not undertaken by the majority of police forces. Local Authorities often own noise measurement equipment but generally do not use it to investigate complaints about excessively noisy vehicles.

Dealing with complaints

For police forces, the main channel for receiving complaints was highlighted as using the national 101 number, although once police force did state they directed complaints to the Local Authority. One police force reported having an online reporting tool for members of the public to use.

Within Local Authorities, the response varied, with some stating they did not receive any complaints and others stating they do. Of the ten Local Authorities who responded, six indicated they either refer the complaint to the police or that they have no power to enforce in this area.

Legislation

Only one of the police forces stated that they use legislation other than the Road Vehicles (Construction and Use) Regulations, with Anti-Social Behaviour Orders (ASBO) reported as being used for enforcement.

Local Authorities responded that they have no powers to take action when a vehicle is on the road, but can take action when vehicles are parked on premises by using either the Environmental Protection Act 1990 or the Anti-social Behaviour, Crime and Policing Act 2014.

Future strategies

For future strategies aiming to encourage and improve enforcement of excessively noisy vehicles/driving, it was generally reported by the police forces that improvements in resources and equipment would assist. However, changes to legislation or better guidance on noise limits was cited by one police force as what could be improved.

Of those who do not currently enforce in this area, the main response was a suggestion that better resources and/or equipment was required, whereas those police forces who have been more active in this area have suggested that better guidance is needed.

APPENDIX A – Covering letter sent to police forces



Department
for Transport

Great Minster House
33 Horseferry Road
London
SW1P 4DR

09 January 2019

Dear Sir/Madam

Excessive vehicle noise enforcement

The Department for Transport has commissioned the Atkins/Jacobs joint venture to undertake a project examining the potential to improve enforcement against vehicles (including motorcycles) which are excessively noisy. The first phase of this project is to understand current approaches to the enforcement of vehicle noise and attitudes towards future strategies.

As part of this we would be grateful if you could **complete a short online survey by Friday 25th January**. The survey consists of only 11 questions and can be accessed by the following web link:

<https://www.mysurveygizmo.com/s3/4775334/Excessive-vehicle-noise-enforcement>

This survey asks for; statistics relating to previous actions taken by police forces to enforce excessive vehicle noise; how police forces work with local authorities on this issue; what legislation police forces utilise; and what test methods and equipment are used.

Alternatively, if you would like to provide answers by speaking with one of the project team then please contact either of the following:

[Redacted contact information]

Yours sincerely

[Redacted signature]

International Vehicle Standards

APPENDIX B – Historic research on in-service testing

This appendix discusses the outcomes from historic research projects into in-service noise testing undertaken by TRL.

Development of in-service noise testing procedures for road vehicles (preliminary report) [26]

This study aimed to evaluate the most suitable in-service test for motorcycles and mopeds by testing their noise emissions in an indoor environment such as that found in an MOT test workshop [26].

As a general rule, an in-service test for vehicle noise should be inexpensive and simple to undertake and have the following characteristics:

- Allow checks to be conducted in a variety of ambient noise situations including roadside locations and indoors.
- The measurement microphone should be placed so it is sensitive to exhaust system failures as well as faults with the power unit.
- The vehicle under study should be operated such that the noise generated during the test is reasonably correlated with the noise it would produce during the standard type approval test procedure.

In-service tests were performed on a representative sample of fifteen different motorcycles which covered a wide range of engine capacities, makes and style. The test sample included:

- Motorcycles fitted with replacement silences.
- 2-stroke mopeds which could be easily modified to affect their noise emission.
- Trail bikes which have little shielding of the engine.
- Road/sport machines, with both air and water cooling in order to assess the effect of the shielding of the water jacket.
- Touring machines with large, low revolution engines.

In order to evaluate the sensitivity of results obtained from measurements taken in close proximity, some measurements were undertaken on the same motorcycle both outdoors and in three different enclosed locations. The outdoor measurements were conducted on the TRL standard ISO test surface, which is the surface normally used for vehicle noise type approval testing.

All testing was undertaken according to the close proximity test procedure laid down in ISO 5130:1982. For this study noise measurements were repeated six times at each measurement location and the averaged result recorded. Measurements were also repeated with the microphone positioned at different distances from the motorcycle exhaust in order to assess the rate of attenuation with distance at the measurement sites chosen. The indoor tests were mainly conducted with the motorcycle positioned centrally in the room as far away from the walls as possible, though additional measurements also taken with the motorcycle placed close to a wall to establish the effect of vehicle position within the room. The main findings of this study were:

- Noise measurements recorded close to the sound source (i.e. using a 0.5m microphone position), will not be significantly affected by reverberation in a typical enclosed space that might be used for motorcycle testing. Reflections from individual surfaces will also have little effect on the measurements provided the motorcycle under test is positioned centrally, away from reflective walls.
- The adverse effects of reverberation, reflections and room resonances might be controlled by placing acoustically absorbing panels around the test vehicle. This may offer a means of standardising the measurement conditions for all types of test locations.

Development of an in-service noise testing procedure for motorcycles [143]

A programme of research and testing was undertaken in three phases to evaluate procedures appropriate for the assessment of in-service vehicle noise. This report described the work undertaken as part of Phase 1 which deals with the development of in-service test procedures for motorcycles and mopeds in both outdoor and indoor environments. Phase 2 [27] and Phase 3 [144] of this programme are concerned with similar studies for diesel and petrol engined vehicles.

In-service tests were performed on a representative sample of fifteen of the most sold motorcycles based on the new registrations made in 1993 provided by the Motor Cycle Industry Association which cover the range in-use as well as the most popular types. The test sample included:

- Motorcycles fitted with replacement silences.
- 2-stroke mopeds which could be easily modified to affect their noise emission.
- Trail bikes which have little shielding of the engine.
- Road/sport machines, with both air and water cooling in order to assess the effect of the shielding of the water jacket.
- Touring machines with large, low revolution engines.

In order to evaluate the influence of non-standard test site conditions on the noise levels produced in close proximity to the test vehicle, the in-service tests were undertaken in both outdoor and indoor spaces which meet the Standards as well as in non-standard outdoor and indoor test sites.

Noise measurements were taken on each motorcycle at each of the test site locations using the close proximity test procedure described in the European Union Directive 78/1015/EEC [6] using both Class 1 and Class 2 instrumentation in order to provide information on the additional errors which may be introduced due to the use of lower cost test equipment with lower specification tolerances.

Each motorcycle was also tested using the drive by type approval test procedure. In addition, some of the close proximity tests were repeated with absorptive panels placed in the vicinity of the measurement microphone to reduce potential effects of reverberation and standing waves in the enclosed spaces. Reverberation time measurements were also undertaken according to the method described in BS 5363:1976 [145] in order to assist with the interpretation of the close proximity noise data recorded indoors. The main findings of this study were as follows:

- The test procedure described in the European Union Directive 78/1015/EEC [6] was a relatively simple test to perform which could be carried out without the need for complex instrumentation. The test procedure gave a satisfactory degree of reproducibility of the test if a standard test location is used.
- The noise levels recorded indoors under these test conditions were however not consistent with the test levels obtained at the standard outdoor test site. The errors were particularly noticeable when the motorcycles were positioned at the centre of each workshop with differences ranging between 0 and 6 dB(A) depending upon the motorcycle type and site location. There errors are likely to be due to the acoustical characteristics of the room including reverberation time and standing waves.
- Given that different indoor test locations will have different acoustical characteristics over the frequency range of interest as well as the range of motorcycles that will need to be tested will also generate noise emissions with widely differing frequency characteristics, in-service test procedures based on measurement taken inside an enclosed space such as a garage test bay or workshop are not suitable.
- These errors were found to be reduced when the motorcycle was positioned in an open doorway with the exhaust pointing outward and were virtually eliminated when the motorcycle was tested in a non-standard outdoor space. It has therefore been concluded that any outdoor location will be suitable to carry out in-service testing on motorcycles provide the existing ambient noise levels are not excessively high. This includes, but not limited to, garage forecourts, outside workshops and at the roadside.
- Close proximity noise measurements recorded with low cost instrumentation were approximately 2 dB(A) higher than those obtained using the precision grade equipment. This difference could be due to differences in the tolerances associated with the averaging time circuitry in the two instruments.
- Based on the results obtained in this study, possible close proximity noise limits for small (i.e. <80cc), medium and large capacity machines it has been suggested to be set at 91 dB(A), 94 dB(A) and 99 dB(A) respectively as there would be a low probability that a motorcycle would fail to comply with this limits and then would subsequently pass the drive-by type approval test.

Development of an in-service noise testing procedure for diesel powered road vehicles [27]

A programme of research and testing was undertaken by TRL in three phases to evaluate procedures appropriate for the assessment of in-service vehicle noise. This report described the work undertaken as part of Phase 2 which deals with the development of in-service test procedures for diesel powered cars, trucks and buses.

Based on the results obtained in Phase 1 where it was found indoor in-service testing to result in potential errors due to the uncertain influence of reverberation and standing wave effects, only outdoor in-service testing was conducted on diesel vehicles as part of the Phase 2 study.

In-service tests were performed on a representative sample of ten diesel vehicles including two cars, two Light vans and trucks, two medium goods vehicles, two heavy goods vehicles and two buses. These vehicles were tested according to type approval drive-by and close proximity procedures described in the European Union Directive 70/157/EEC [4] (Amended by 81/334/EEC and 84/424/EEC). In addition, testing was also conducted following the procedure described by Morrison and Nelson [146] which involved free acceleration of the vehicles engine and the measurement of noise in close proximity but midway between the engine and exhaust outlet.

In order to evaluate the influence of non-standard test site conditions, the in-service tests were undertaken in both an ideally 'open' space standard as well as a non-standard outdoor test site (i.e. close to reflective surface such as a wall). The main findings of this study were as follows:

- The close proximity exhaust noise test procedure described in the European Union Directive 84/424/EEC [147] has been found to be a simple test to perform which could be carried out without the need for complex instrumentation. However, the test procedure gave results which were not particularly highly correlated with the type approval noise levels obtained under standard test conditions for the same vehicle sample (i.e. $r=0.64$).
- A higher degree of correlation ($r=0.88$) was obtained when locating the microphone midway between the exhaust and engine with the engine accelerated from idle to governor run out (GRO) rather than allowed to freely decelerate from a fixed engine speed, as specified in the EU procedure. By ensuring that the engine is accelerated over its operating range the noise emission characteristics are then more closely related to the drive-by acceleration test than they are when the engine is allowed to decelerate freely. For these reasons a higher degree of correlation between the close proximity noise levels and the type approval noise levels would be implicitly expected for this form of the test procedure
- It was however noticed that having the microphone located between the centre of the engine and the exhaust the measured noise level also contained noise generated by both engine related sources and gas flow noise at the exhaust outlet.
- Vehicles with a large separation between the engine block and exhaust outlet should avoid being tested using close proximity measurement to the exhaust outlet alone, as with the EU test procedure, since this will not detect excessive noise from engine and other power unit related components. The centre microphone method should be performed instead.
- Close proximity measurements undertaken using the centre microphone method at a non-standard test space have been found to be significantly contaminated by reflections from nearby walls. In order to reduce these measurement errors to be reasonably small in practice (e.g. a repeatability of, say, 2 dB(A) or less) then the minimum requirements for the test location should be a flat hard surface with no reflecting facades, buildings etc. within five metres of the external sides of the vehicle.
- Based on the above, it has been concluded that in-service tests on diesel vehicles can be carried out with acceptable repeatability in an outdoor location such as an open space on a garage forecourt, or at the roadside. The method of measurement should use a microphone located in close proximity to the vehicle, midway between the centre of the engine and the exhaust outlet. The distance of the microphone from the centre-line of the vehicle should be two metres and the height of the microphone above the surface should be 1.2 metres. The engine should be accelerated rapidly from idle to governor run out. A further requirement is that during the vehicle operation and noise measurement, the ambient noise should be at least 10 dB(A) below the maximum noise levels measured from the vehicle.
- Using the results of this study a limit value was defined as 8 dB(A) above the corresponding average close proximity test level predicted by the regression line relating the noise levels from the two tests. This would allow for the variability in the data within the vehicle group and to allow for non-standard site specific factors. It is expected a low probability of vehicles failing to meet the proposed close proximity limits and so would subsequently pass the drive-by type approval test.

In-service noise testing – Motorcycles fitted with non-standard and defective exhaust silencers [25]

This study was an extension to the Phase 1 study on in-service testing methods on motorcycles and moped undertaken by TRL [143]. A greater range of motorcycle/silencer combinations were examined using the recommended in-service test procedure in order to establish in-service noise limits for

motorcycles fitted with replacement, modified, defective or off-road performance (race) silencers so to identify those producing excessive noise.

A total of 26 silencer systems were tested on 9 motorcycles including manufacturers original equipment silencers in both new and used condition, a selection of legal replacement silencer systems, race silencers not legal for use on public roads and silencers which had been modified to simulate defects generated by either tampering (i.e. baffles removed) or corrosion.

Based on the results obtained in Phase 1 where it was found indoor in-service testing to result in potential errors due to the uncertain influence of reverberation and standing wave effects, the in-service tests were undertaken in both a standard (open space) and a non-standard test site.

Noise tests were conducted for each motorcycle at both measurement sites using the close proximity stationary noise test procedure described in European Union Directive 78/1015/EEC [6]. Type approval acceleration noise tests were also performed for each motorcycle at the standard measurement site following the procedure set out in Directive 78/1015/EEC [6]. The main findings of this study were as follows:

- It was confirmed that the in-service motorcycle noise test procedure described in Directive 78/1015/EEC [6] was a relatively simple test to perform, could be undertaken without the need for complex instrumentation and gave a satisfactory degree of reproducibility of the test results
- It was also demonstrated that non-standard outdoor spaces such as garages forecourts, outside workshops and at the roadside would, with a few exceptions, all be suitable for in-service testing
- Motorcycles fitted with standard original equipment silencers or standard (new) silencers were found to give the lowest type approval levels
- 'Race' silencers fitted on the most powerful motorcycles generated noise levels 9 dB(A) above those measured with the original equipment fitted
- Considering both the results obtained in this study and those previously reported [143], a limit value has been suggested as 19 dB(A) and 20 dB(A) above the corresponding type approval limit values for close proximity noise tests undertaken in standard and non-standard open sites respectively. Using this rationale, the following in-service noise limit ranges for motorcycles have been suggested:
 - Category 1 motorcycles, i.e. ≤ 80 cc: 93 – 97 dB(A)
 - Category 2 motorcycles, i.e. $> 80 - \geq 175$ cc: 95 – 99 dB(A)
 - Category 3 motorcycles, i.e. > 175 cc: 98 – 102 dB(A)
- With these limits it is expected a very low probability of motorcycles failing to meet the proposed close proximity limits and so would subsequently pass the drive-by type approval test
- While lower limits could be imposed to identified illegal machines there may be a higher risk of failing some motorcycles which are legal.

Development of an in-service noise testing procedure for Petrol powered road vehicles [144]

A programme of research and testing was undertaken by TRL in three phases to evaluate procedures appropriate for the assessment of in-service vehicle noise. This report described the work undertaken as part of Phase 3 which dealt with the development of in-service test procedures for petrol powered road vehicles ranging from cars through to light commercial vehicles.

In-service tests were performed on a representative sample of 16 petrol powered vehicles of different engine size, engine power, number of cylinders, engine/exhaust outlet position, height of body from ground and body size. These vehicles were tested according to EU type approval drive-by acceleration test [148], as well as using two close proximity test procedures which are carried out with a stationary test vehicle. These were the test described in the EU type approval Directive and a procedure proposed in an earlier study of in-service noise test methods [146] which involved free acceleration of the vehicles engine and the measurement of noise in close proximity but midway between the engine and exhaust outlet.

In order to evaluate the influence of non-standard test site conditions, the in-service tests were undertaken in both an ideally 'open' space as well as a non-standard outdoor test site (i.e. close to reflective surface such as a wall), to represent a location where in-service testing might be carried out in practice (i.e. at the roadside or on a garage forecourt as part of a MOT test). The main findings of this study were as follows:

- The results obtained using the procedure described by Morrison and Nelson [146] gave a higher degree of correlation with the results of the type approval drive-by test as well as being more repeatable than the EU close proximity test.
- In-service tests on petrol vehicles can be conducted with acceptable reproducibility in standard and non-standard outdoor spaces. However, in order to achieve a reproducibility of 3 dB(A) or less in a non-standard location this site should present a flat hard surface with no reflecting facades, buildings etc. within five metres of the external side of the vehicle.
- The recommended method of measurement should use a microphone located in close proximity to the vehicle, midway between the centre of the engine and the exhaust outlet. The distance of the microphone from the centre-line of the vehicle should be 2m and the height of the microphone above the test surface should be 1.2m. The engine should be accelerated rapidly under full throttle from idle to approximately 4,500 RPM. An appropriate tachometer device is needed to trigger the measurement of the test sound level when an engine speed of 4,000 RPM is reached.
- Considering the results obtained in this study a limit value has been suggested as 7 dB(A) above the corresponding average close proximity test level to allow for the variability in the data within the vehicle group and to allow for non-standard site-specific factors.

An examination of vehicle noise test procedures [149]

This study examined the technical issues associated with the range of test procedures that could be considered for future vehicle noise testing. Noise tests were undertaken on a range of vehicles including cars, sport cars, 4x4, vans, minibuses, buses and HGVs. By reviewing the suitability of ISO 5130 as a method to control in-service noise it was noticed that although this standard was developed as a technical standard for the measurement of noise in close proximity, there was a particular problem in using the method for in-service testing concerning the reliable measurements of the engine speed. It was found that not all vehicles are fitted with tachometers and to use the vehicle's instrumentation to set the initial engine speed condition is not ideal. It was recommended that testing should be carried out with a remote system designed specifically for conformity checking and which can be calibrated independently. A further concern over the use of the method arose because it is not clear whether the mode of operation of the vehicle will give rise to noise levels which are well correlated with the noise generated by vehicles undergoing the type approval test. It was noted that the Standard clearly states that "the value obtained using the method are not representative of the total noise emitted by vehicles in motion".

APPENDIX C – Glossary and abbreviations

Acoustic signature	The spectral profile and acoustic characteristics of a single noise source or collection of noise sources or components forming a system. In the context of this project, the acoustic signature refers to detailed information about the sound produced by a passing vehicle.
AI	Artificial intelligence.
AJJV	Atkins Jacobs Joint Venture.
ANPR	Automatic Number Plate Reader.
ASEP	Additional Sound Emissions Provisions.
A-weighting	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear. A-weighted sound is often denoted by 'A' in noise indices, for example L_{Aeq} and L_{Amax} .
Category L2	Three-wheeled vehicle of any wheel arrangement with an engine cylinder capacity in the case of a thermic engine not exceeding 50 cm ³ or 4kw and whatever the means of propulsion a maximum design speed not exceeding 50 km/h.
Category L4	A vehicle with three wheels asymmetrically arranged in relation to the longitudinal median plane with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm ³ or whatever the means of propulsion a maximum design speed exceeding 50 km/h (motor cycles with sidecars).
Category L5	A vehicle with three wheels symmetrically arranged in relation to the longitudinal median plane with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm ³ or whatever the means of propulsion a maximum design speed exceeding 50 km/h.
Category M	Motor vehicles with at least four wheels that are used for the carriage of passengers (such as cars or buses).
Category N	Motor vehicles with at least four wheels that are used for the carriage of goods (such as vans, heavy goods vehicles).
dB, dBA	Decibel, A-weighted decibel.
Decibel	The unit of measurement for sound.
DfT	Department for Transport.
DVLA	Driver and Vehicle Licencing Agency.
EPA	Environment Protection Agency.
EU	European Union.
Fast response	Noise measurement with a 125 ms time constant, meaning that the sound pressure level is sampled every 125 ms. This is sometimes denoted in noise indices by 'F', such as L_{AFmax} .
FIM	Federation Internationale do la Motocyclisme.
Firing frequency	Number of combustions that occur per second within a single engine cycle.
Frequency	Rate at which sound wave crests reach a given point (cycles per second), measured in Hertz. Low frequency sounds have long wavelengths, resulting in a bass sounds (e.g. engines, thunder). High frequency sounds have short wavelengths and have a higher pitch (e.g. bird song, emergency vehicle siren).
HGV	Heavy goods vehicle.
IMMA	International Motorcycle Manufacturers Association.
IVA	Individual Vehicle Approval.
ISO	International Organization for Standardization.
$L_{Aeq,T}$	The equivalent continuous A-weighted sound pressure level during time period T.
$L_{Amax,T}$	The maximum A-weighted sound pressure level measured during time period T.

Main beam	In beamforming, this refers to the region around the direction of maximum radiation, usually within 3 dB of the peak of the main beam. It covers the largest area(s) in polar radiation pattern images.
MSVA	Motorcycle single vehicle approval scheme.
Noise	Unwanted sound.
Noise camera	System comprising a sound level meter, ANPR and video camera that can be used to identify vehicles producing excessive noise.
NRPIF	National Roads Policing Intelligence Forum.
RPM	Revolutions per minute (engine speed).
Sidelobes	In beamforming, these are smaller beams that are away from the main beam and usually occur in undesired locations that can never be completely eliminated.
Slow response	Noise measurement with a 1 second time constant, meaning that the sound pressure level is sampled once every second.
TRL	Transport Research Laboratory.
Type approval	A procedure whereby a manufacturer can obtain certification from a competent authority that their product meets the requirements of a certain European Directive.
UNECE	United Nations Economic Commission for Europe.
Wavelength	The distance between the two peaks (or two troughs) of a sound wave, measured in metres.
WoF	Warrant of fitness.
WOT	Wide open throttle.



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