In-service vehicle noise measurement study

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Client: Department for Transport, Cleaner Fuels & Vehicle Divisions (CFV4)
(Simon Davies)

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Executive summary

Control of vehicle noise through legislation can play a significant role in reducing the negative impact of transport on the community. Presently the noise from all new road vehicles is currently controlled through the process of type-approval at the time of production. However, once a car or motorcycle is in-service there are very few accurate checks on the noise produced, and some vehicles are modified using after-market products.

The Department for Transport (DfT) currently receive a large number of complaints about the noise from individual vehicles, focusing on noise from exhaust systems.

DfT has therefore commissioned TRL to review in-service noise measurement techniques in other countries and develop a simple noise measurement technique for use in the UK in order to assist roadside enforcement of Construction and Use Regulation 54.

This project has been divided into two phases.

Phase 1: Initial review

This part of the study reviewed current literature in the subject area, performed an overall assessment of the problem, identified currently used and potentially usable in-service noise measurement techniques and assessed their suitability.

The following conclusions were reached:

- Previous work carried out by TRL on the development of an in-service noise test was constrained by the need for test results to correlate with type-approval levels
- A large proportion of complaints are due to those vehicles fitted with ‘performance exhaust systems’
- Other countries have shown little in the way of in-service tests that differ from the basic principals of the exhaust noise test defined in ISO 5130. Other areas of enforcement are concerned with subjective evaluations of noise levels
- Many different options are available to control the problem of noisy vehicles
- The use of UN-ECE Regulation 59, which addresses replacement exhaust systems, is a key area for the control of exhaust noise. Its adoption into national law should be examined, ensuring it covers all after-market products and components
- Similarly, the adoption of UN-ECE Regulation 92, the corresponding regulation for motorcycles, should also be investigated
- Several stationary exhaust noise measurement techniques are considered suitable for further investigation

Phase 2: Practical investigation of test methods

This part of the study evaluated the recommended tests, including their relation to type-approval levels, and made further recommendations for an in-service test method that could be undertaken at roadside locations for enforcement purposes.

The following conclusions were reached:

- A technology-based test method using an artificial noise source was found to be unsuitable for further development as a roadside test
- The candidate test methods were used to assess the acoustic performance of 8 different exhaust systems. The results indicated the poor acoustic performance of non-standard exhaust systems
The ISO 5130 test method and those involving slow acceleration to a predetermined target speed best differentiated between noise levels from different exhaust systems. However, the ISO 5130 method is preferred due to its standardisation and simplicity.

An examination of the effect of load on differentiating between noise levels from different exhaust systems showed that under steady speed conditions the method was suitable providing the assessment focussed on the frequency range 50 - 250 Hz i.e. the fundamental firing frequency range. Compared with similar assessments carried out under no load conditions, noise levels of standard and non-standard exhaust systems were marginally easier to differentiate.

An examination of the relationship between type-approval drive-by noise levels and ISO 5130 stationary noise levels suggested that the correlation between the two is poor. However the ISO 5130 method is the only one which properly assesses problem of excessive exhaust noise.

It is considered that an in-service roadside exhaust noise test would be a first step towards achieving the goal of identifying noisy exhaust systems. If a test following the methodology of the ISO 5130 type-approval stationary test were adopted this would potentially provide information regarding the performance of exhaust systems on new vehicles. However an extensive measurement programme would be required to collate information on how the acoustic performance of exhaust systems changes over time.

It is possible to create a database of exhaust noise levels that can be updated by enforcement agencies as roadside tests are carried out.
1 Introduction

1.1 Background to the project

Control of vehicle noise through legislation can play a significant role in reducing the negative impact of transport on the community. Presently the noise from all new road vehicles is currently controlled through the process of type-approval at the time of production. However, once a car or motorcycle is in-service there are very few accurate checks on the noise produced, and some vehicles are modified using after-market products.

Methods available for controlling vehicle noise generally tackle noise from the traffic stream, focussing on low-noise surfaces and noise barriers. However, individual vehicles that make excessive noise can cause widespread annoyance. A more targeted approach to noise control is therefore required to tackle this problem. DfT currently receive a large number of complaints about the noise from individual vehicles, focussing on noise from exhaust systems.

DfT has therefore commissioned TRL to review in-service noise measurement techniques used in other countries and to develop a simple noise measurement technique for use in the UK in order to assist roadside enforcement of Construction and Use Regulation 54. The project is divided into two phases.

Phase 1 consisted of the following three tasks:

- A review of current legislation for controlling noise from road vehicles including new and in-service vehicles for the UK and elsewhere
- An assessment of the perceived problem of excessively noisy exhausts including the level of complaints, trends in technology and changes in legislation that might influence the situation
- An assessment of techniques that could be used in the development of an in-service noise test, with the objective of identifying tests for further investigation

Phase 2 consisted of the following tasks:

- Evaluate the stationary exhaust noise tests recommended from Phase 1, focussing solely on passenger car exhausts
- Evaluate a test method whereby the vehicle engine was not used as the noise source
- Make recommendations for an in-service test method that could be undertaken at roadside locations for enforcement purposes

1.2 Overview of the report

The structure of the report is as follows:

- Chapter 2 presents a review of both UK and international procedures used for the assessment and control of in-service vehicle noise
- Chapter 3 provides an overview of complaints that are attributed to vehicle or traffic noise, the perception of excessively noisy exhausts and an examination of future changes in trends or technology that might influence the situation
- Chapter 4 considers possible process-based and technology-based solutions which could be used for tackling the problem of noisy vehicles

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1 It is noted that Phase 2 was initially to test a selection of exhaust systems fitted to various vehicles, namely cars, vans, motorcycles and scooters. However, since the majority of complaints are associated with cars, it was subsequently agreed with DfT to focus on multiple exhaust systems on a single car.
Chapter 5 provides a summary of the measurement programme used to evaluate the candidate test methods recommended in Phase 1, including details of the test vehicle and the type of exhaust systems examined.

Chapter 6 describes a series of noise injection tests which were carried out to explore the possibility of developing an in-service test method which would identify noisy exhaust systems without the need for starting the vehicle’s engine.

Chapter 7 provides a detailed description of each of the candidate (stationary) test methods recommended in Phase 1, together with the results of the measurements. A proposal for a stationary in-service noise test is also presented.

Chapter 8 investigates the potential practical application of the tests discussed in Chapter 7, including the creation of a database to provide a means of evaluating exhaust noise performance over lifetime.

Chapter 9 presents a summary of the whole project and the conclusions.

Appendix A presents photographs of the different exhaust systems tested during Phase 2.

Appendix B reports the exhaust noise levels from the individual Phase 2 tests.

Appendix C reports on portable rolling road dynamometer tests.

Appendix D examines the relationship between type-approval drive-by noise levels and ISO 5130 stationary noise levels.
PHASE 1: Initial review
2 Review of current procedures

This chapter presents a review of procedures that are used for the assessment and control of noise from cars, motorcycles and vans. Current procedures that cover new vehicles are described first, followed by controls that are in place for vehicles that are in-service.

Controls and procedures used in other countries to limit noise from vehicles in-service are then reviewed.

2.1 Current processes relevant to the UK

Figure 2.1 shows the current legislative frameworks in use in the UK to control and mitigate the noise produced by motor vehicles. The controls are split into the two stages of a vehicle’s life, i.e. new and in-service. Also shown in the Figure are the controls that relate to imported vehicles. 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 2.1: Flow diagram of current UK controls](image-url)
2.1.1 General specifications for road vehicles

The Road Vehicles (Construction & Use) Regulations 1986

The objective of this Regulation, made under the Road Traffic Act 1972, is to ensure that vehicles used in the UK are built to a high standard. The Regulations are also used to implement EU Directives.

Under the Regulations there are a number of areas which address noise issues in different ways. The first deals with new vehicles which are controlled by type-approval limits. The second deals with equipment such as silencers which must not be altered in such a manner that the noise is greater than when it was first manufactured and that 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. The third deals with maintenance, again ensuring that there is no increase in noise due to poor maintenance. Finally, there are regulations relating to the avoidance of excessive noise which includes the behaviour of the driver in operating the vehicle including the use of audible warning systems.

2.1.2 New vehicles

Type-approval

The testing of noise emissions from cars and motorcycles 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.

The noise levels accepted for vehicle type-approval are laid down in European Directive 70/157/EEC (European Communities, 1970) for motor vehicles and 78/1015/EEC (European Communities, 1978) for motorcycles.

Directive 70/157/EEC introduces limits on the sound levels from road vehicle and gives requirements for measuring sound levels from exhaust systems and silencers. Several amendments, the latest by Directive 2007/34/EC (European Communities, 2007), have reduced these permissible sound levels. Limit values for eight types of passenger and goods vehicles range from 74 dB(A) to 80 dB(A).

Directive 78/1015/EEC (European Communities, 1978) on motorcycles establishes limits for the permissible sound level of motorcycles and requirements for exhaust or intake silencer. Several amendments have been made to this and the current Directive in force is 97/24/EC (European Communities, 1997). This introduces a harmonised testing procedure with limit values for three categories of motorcycles from 77 dB(A) to 82 dB(A).

These type-approval Directives are implemented into English law by the Motor Vehicles (Type-Approval) (Great Britain) Regulations 1984 that is made under the Road Traffic Act 1972.

UN-ECE Regulation 51 (United Nations, 1996)

This Regulation outlines the procedures to be adopted for the assessment of noise during the type-approval of motor vehicles having at least four wheels. During the type-approval process, the method detailed in ISO 362 (Measurement of noise emitted by accelerating road vehicles; International Standards Organisation, 2007a) is used for the assessment. The result from this test is compared with that given in Directive 2007/34/EC to determine whether the vehicle has passed type-approval.

This procedure currently used for type-approval, known as R51.02, is under review by the UN-ECE working group WP29. A revised procedure, R51.03, is currently being run in parallel with the existing procedure for any vehicles passing through type-approval.
during the period from July 2007 to June 2009. The new procedure in R51.03 contains two separate tests and is designed to be more representative of the noise level of vehicles in an urban environment.

A stationary test to the method given in ISO 5130 (Measurements of sound pressure level emitted by stationary road vehicles; International Standards Organisation, 2007b) is also undertaken at type-approval. The result from this test is not used to determine whether the vehicle passes type-approval, but could be used by authorities to check in-service noise levels if made available.

UN-ECE Regulation 41 (United Nations, 1994)
This Regulation outlines the provisions relating to the type-approval of motor vehicles having two or three wheels with regard to noise. Similarly to Regulation 51, noise emissions are measured using the methods defined by ISO 5130 and ISO 362, but only the result from the acceleration test is used for type-approval purposes.

This standard specifies a method for measuring the noise emitted by road vehicles while moving. The test involves a vehicle approaching a line at a given speed (determined by various factors relating to engine power) and on reaching the line the throttle is opened wide until a point 20m further is reached. The maximum noise level is measured on either side of the vehicle at a distance of 7.5m from the centre line while the vehicle passes between the start line and a point 20m ahead. When developed, the test was intended to reproduce the noise levels which are generated by the principal noise sources during normal driving in urban traffic.

The standard 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.

The standard specifically states that the procedure is neither 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.

Measurements of vehicle noise can be influenced significantly by the type of road or test track surface on which the vehicles are run. In general the road surface parameters affecting the noise emission of vehicles are the texture characteristics, sound absorption and possibly mechanical impedance or stiffness properties of the surface layer.

This standard specifies the materials, design, construction and properties of a test surface in order to minimise inter-site variation in vehicle noise measurements. A surface that meets the requirements of ISO 10844 is specified for ISO 362 tests.
2.1.3 Existing controls for cars and motorcycles in-service

MOT

An MOT test is an annual inspection of the roadworthiness of a car or motorcycle. The first time a vehicle requires an MOT in the UK is no later than three years after registration. A failure of an MOT for any reason means that the vehicle is not roadworthy and is prohibited from being driven on the public highway, other than to or from the test centre if appropriate, until the defect is corrected.

During an MOT test, the exhaust system is examined visually for any defects, 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) 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 complainants lifestyle.

Police Reform Act 2002

Section 59 of this Act gives the police new powers to deal with the anti-social use of motor vehicles on public roads or off-road. It includes powers to stop and to seize and to remove motor vehicles where they are being driven off-road contrary to Section 34 of the Road Traffic Act 1988 or on the public road or other public place without due care and attention or reasonable consideration for other road users. It also gives powers to seize vehicles that are considered likely to cause annoyance. 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.

2.1.4 Control of aftermarket exhaust systems / components

UN-ECE Regulation 59 (United Nations, 1983)

UN-ECE Regulation 59 sets out a process for ensuring standardisation of replacement silencing systems, but this Regulation has no legislative force in the United Kingdom. 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
UN-ECE Regulation 92 (United Nations, 1992)

The approval of replacement exhaust silencing systems for motorcycles as defined by Regulation 92 has not been adopted by the UK or European Union. The Regulation contains provisions relating to the approval of (or components of) replacement exhaust silencing systems to be fitted as replacement parts to one or more specific types of two-wheeled motorcycles, other than those having a maximum design speed limited to 50 km/h.

The test methods described in the Regulation cross reference those in UN-ECE 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.

2.1.5 Imported vehicles

Single Vehicle Approval (SVA)

SVA checks that vehicles constructed for non-European Economic Area markets comply with UK law. Even vehicles outwardly similar to European-specification models, but intended for other markets, can be unsuitable for use in Britain without at least some modification.

SVA also checks that the construction of amateur-built vehicles, rebuilt vehicles and vehicles using parts from a previously registered vehicle meet modern safety and environmental standards. It also provides an alternative to type-approval for vehicles manufactured in very low volume, vehicles converted for the disabled prior to registration, as well as hearses and armoured vehicles for civilian use.

During the approval process, an exhaust noise test is required for all vehicles other than those having a date of manufacture before 1 Jan 1997 for which evidence can be provided to demonstrate compliance with a comparable non-European standard. This test is undertaken to the requirements of UN-ECE Regulation 51, except that the exhaust silencer(s) do not require pre-conditioning.

As an alternative, evidence of compliance can be demonstrated by a comparison test, comparing the vehicle noise-related technical specification and the result of a static test. The type approved vehicle must be presented to an authorised test laboratory to allow for back-to-back comparison.

A system of Enhanced Single Vehicle Approval (ESVA) exists for cars and light goods vehicles, for which no certificates are available to demonstrate conformity with a valid EC or national type-approval. This is normally those vehicles that are not manufactured for the European market. These vehicles have to meet the basic SVA requirements as well as additional aspects, including noise and silencers.

Motorcycle Single Vehicle Approval Scheme (MSVA)

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 checks 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 the relevant Directive (i.e. 97/24/EC).
If a vehicle has been approved by another European Economic Area (EEC) Member State to standards equivalent to those of MSVA, it is eligible for a Ministers Approval Certificate on the basis that evidence of the actual standards to which the vehicle was tested by or on behalf of the authorities in question.

### 2.1.6 Previous work on in-service noise testing within the UK

Previous work on the development of an in-service test for the UK was undertaken by TRL between 1994 and 1997. There were three main phases of the research work, which examined petrol engine vehicles, diesel engine vehicles and motorcycles. In all of this work the authors thought it a necessary requirement to have any test linked to type-approval results. This was in order to ensure that a vehicle could not fail an in-service test but pass the type-approval test.

These three phases of work are briefly described below.

**Petrol engine vehicles** (Harris et al., 1997)

The study on petrol engine vehicles examined a number of cars, ranging from those with high sales (e.g. Vauxhall Corsa, Peugeot 306) to others with lower sales than the standard vehicles (e.g. 4x4, sports, turbo charged). During this work, the EU type-approval test (i.e. ISO 362) was undertaken on each vehicle, together with the EU close proximity test (i.e. ISO 5130). Further tests developed by TRL were also trialled, both in standard ISO specified conditions and also in non-standard conditions that were designed to replicate ‘garage forecourt’ conditions.

It was found that the results of the test developed by TRL gave a higher degree of correlation with the type-approval test than the ISO close proximity test. This test involved the engine being accelerated rapidly under full throttle from idle and the noise level captured at 4000 rpm.

**Diesel engine vehicles** (Harris and Nelson, 1995)

This work covered a wide range of diesel engine vehicles, including from cars, buses and goods vehicles. As with the work on petrol engine vehicles, this work found that the TRL designed test had better correlation with type-approval than the ISO close proximity test.

**Motorcycles** (Harris and Nelson, 1994; Harris and Nelson, 1996)

A number of motorcycles and mopeds were tested during this work, which like the work on petrol engine vehicles examined standard and non-standard tests. This work also examined the variation found between race silencers and also those that were intentionally modified by the research team.

**Review of test methods** (Watts et al., 2005)

These reports also contained a review of the suitability of ISO 5130 as a method to control in-service noise. This showed that although the 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 noted 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".

2.2 Review of international in-service noise controls

Some countries routinely undertake in-service noise assessments, using measurements (either directly in accordance with ISO 5130 or incorporating elements of that standard), subjective assessments, or "label match-up" checks, as part of regular roadworthiness inspections. Examples of these are given below.

2.2.1 Australia

Label match-up is used in addition to annual inspections. Two labels must be stamped on the exhaust pipe; the Australian Design Rule 39/00 label and the new label specified in Clause 19 of Regulations from the Protection of the Environment Act 2000. The National Stationary Exhaust Noise Test Procedures (NSENTP) for In-Service Motor Vehicles was first introduced in 1999 as a national approach to measuring exhaust noise. The Australian Design Rule (ADR) 83/00 sets a new noise emission standard for motor vehicles adopts the UN-ECE Regulations for motor vehicle noise, which also refer to ISO 5130 "Acoustics – Measurement of Sound Pressure Levels Emitted by Stationary Road Vehicles" which provide the noise testing procedures for in-service vehicles.

Australian Design Rule (ADR) label (Federal Register of Legislative Instruments, 2005)

This Rule specifies the requirements for markings that must appear on the original exhaust system. The label only applies to the original factory fitted muffler and specifically relates to the markings appearing upon the factory fitted original "Silencing System Components". The ADR relevance disappears when the new vehicle leaves the showroom floor, but at the same time it may become subject to individual State based "in-service Regulations" where these exist.

Environmental Protection Authority label

On July 1, 2000, the Environmental Protection Authority introduced a requirement for all motorcycles fitted with an aftermarket exhaust to now carry an additional label. Clause 19 applies to all motorcycles, regardless of build date and whether an aftermarket muffler was fitted prior to the inception date of the Regulations or not.

Advertising Campaigns

An advertising campaign "Speeding: no-one thinks big of you" was launched in Australian in 2007, against speeding ‘boy racers’. Although mainly aimed at speeding, this also targeted modified vehicles.

2.2.2 New Zealand

Currently, section 7.4 of the Land Transport (Road User) Rule 2004 (New Zealand Government, 2007) provides for on-road enforcement of vehicle noise. Under this Rule, a police officer can issue an instant $150 infringement offence notice if a person operates a vehicle that creates noise which, having regard to all the circumstances, is excessive. This includes noise from stereos and "boom boxes". The Land Transport
Amendment Act 2005 increased the infringement fee for this offence to $250 and imposes 10 demerit points².

In addition to roadside enforcement, all vehicles undergo a subjective noise test during warrant and certificate of fitness (WoF/CoF) checks. This revving of the engine to simulate vehicle acceleration is consistent with the approach of ISO 362 in terms of capturing sounds typical of vehicle operation in urban driving conditions. The noise from an exhaust system must not be noticeably and significantly louder than it would have been when the motor vehicle was manufactured with its original exhaust system.

Police officers can also 'green sticker' a vehicle that is seen to breach the noise requirements of the Vehicle Equipment Rule 2004, directing that the vehicle is not to be driven on a road until it has passed a WOF test at an independent testing station.

In 2006, interim measures were implemented to allow an objective noise test to be introduced through the existing legal requirements of the Traffic Regulations. The objective noise test is based on the international ISO 5130 Measurement of noise emitted by stationary road vehicles test methodology. Noise levels for the interim objective noise test are required to be consistent with the current levels in the Traffic Regulations i.e. 95 dB(A) for light vehicles and a maximum of 100 dB(A) for motorcycles, when tested using the ‘stationary tailpipe’ noise test (i.e. ISO 5130).

The proposed amendment provides an opportunity to review the current decibel limits as these have been in place for more than twenty years. It is important to ensure that they are appropriate for the current New Zealand vehicle fleet, given the advances in vehicle technology over the last two decades.

2.2.3 Japan

A Proximity Stationary Noise Test suitable for application during vehicle inspections was put in place in the period 1986-89 which is closely aligned to the ISO 5130 method of quantifying vehicle exhaust noise. Limits currently are 96 dB(A) for cars.

2.2.4 America

The Environmental Protection Agency (EPA) sets noise emissions standards for motorcycles. The standard for street-legal exhaust noise emissions is 80 dB(A). All motorcycles are required to display an EPA label on the chassis and exhaust pipe. The "label match-up" program was designed as regulatory measure for states and municipalities to control motorcycle noise. Denver, Colorado has passed new motorcycle legislation designed to enforce noise emissions using the EPA Label Match-Up program that takes effect on July 1, 2007. The legislation allows police to ticket motorcyclists if a bike made after 1982 has a muffler lacking a mandatory factory U.S. Environmental Protection Agency noise certification stamp. Bikers have two weeks to show a judge they fixed the problem to avoid the $500 fine.

In California police officers have the power to enforce new noise legislation through an objective noise test. To promote quiet communities, the Californian government, law enforcement and civic groups have begun a campaign warning motorcycle riders to ride quiet or be cited for noise violations, as the poster below details.

² Drivers who accumulates 100 demerit points in a two year period will have their licences automatically disqualified for a period of 3 months, after which points are wiped.
2.2.5 Norway
In-service noise testing forms part of the periodical roadworthiness inspection (for passenger cars, it is first performed at four years old and every two years thereafter; for LGVs it is first performed at two years old and annually thereafter). However the assessment is initially subjective; measurements are only performed (in accordance with ISO 5130) when the inspectors evaluate the noise level to be abnormal and there is no obvious visible damage to the exhaust. All vehicles registered after 1992 have the stationary noise level stated on the vehicle licence papers together with the corresponding rpm level.

2.2.6 Germany
Detection of loud motorcycles in traffic or during the periodical technical inspection in accordance with the German Road Traffic Registration Regulations is commonplace, the stationary noise value measured at the roadside is compared to the type-approval noise level which is included in the registration documents. However, according to Steven (2006), an investigation into the current stationary roadside enforcement test method (ISO 5130), showed that of 400 motorcycles tested, only one third of illegal systems were detected by this test. As roadside enforcement tests cannot be performed under ideal conditions and with highly advanced measurement techniques, a draft test protocol has been developed, but not yet implemented.
3 Assessment of the problem

This chapter first provides a very brief overview of the number of complaints that are attributed to vehicle or traffic noise. The nature of the perceived problem of excessively noisy exhausts is then examined, followed by an examination of future changes in trends or technology that might influence the situation, including legislative changes.

3.1 Noise complaints

The Transport Trends Report (DfT, 2007a) highlighted the level of complaints regarding transport noise to Local Authority Environmental Health Officers. Figure 3.1 shows that noise complaints increased until 1995/96, but in most years since then there have been fewer complaints than in 1984/85. In 2003/04, complaints about road traffic noise were 22% lower than in 1984/85, while complaints about other sources of noise increased over the same period.

It should be noted that there is no distinction made in Figure 3.1 between general road traffic noise and noise from individual vehicles.

![Figure 3.1: Trends of road transport noise complaints to environmental health officers (1984-2005). Source: DfT (2007a).](image)

In February 2002, the Building Research Establishment (BRE) published the results of the 1999/2000 National Survey of Attitudes to Environmental Noise (BRE, 2002). This report contains a comparison with similar survey data from 1991. The following main trends were identified for road traffic:

- an increase in the proportion of respondents reporting hearing road traffic (from 48 to 54%)
- an increase in the number of respondents reporting hearing the following specific road traffic noise sources: private cars/vans (24 to 32%), residential/estate roads (10 to 14%), police/other sirens (10 to 14%), vehicles starting/stopping/ticking over (5 to 7%), motorways (1 to 6%)
- an increase in the proportion of people reporting being adversely affected by the following specific road traffic noise sources: private cars/vans (11 to 13%), motorways (1 to 3%)
an increase in the proportion of people reporting that road traffic noise made them depressed (2 to 5%)

Although some of these trends refer to general traffic noise which is not relevant to this study, they do show an increase in some relevant areas (e.g. noise from private cars/vans) that are likely to have increased further between 1999/2000 and 2008.

3.2 Poor maintenance of exhaust systems

An exhaust system could fail at any time and is only checked once a year when the car or motorcycle has an MOT inspection. Figures showing the sales of replacement exhausts are not readily available, but an indication of systems that suffer from poor maintenance can be found by examining MOT failure data.

Table 3.1 below shows the MOT failure rates in financial years 2005/06 and 2006/07. It should be noted that between 2005 and 2006, the MOT computerisation scheme was rolled out in MOT test centres, so not all data is available.

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>2006/07</th>
<th></th>
<th>2005/06</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tested</td>
<td>Fail rate</td>
<td>Tested</td>
<td>Fail rate</td>
</tr>
<tr>
<td>Classes 1 &amp; 2: Motorcycles</td>
<td>946,000</td>
<td>17.3%</td>
<td>325,600</td>
<td>18.5%</td>
</tr>
<tr>
<td>Classes 3 &amp; 4: Cars, vans and vehicles with up to 12 seats</td>
<td>26,299,000</td>
<td>33.2%</td>
<td>12,136,000</td>
<td>32.8%</td>
</tr>
<tr>
<td>Class 5: Passenger vehicles with more than 12 seats</td>
<td>51,700</td>
<td>28.3%</td>
<td>18,200</td>
<td>25.8%</td>
</tr>
<tr>
<td>Class 7: Goods vehicles (3000-3500kg)</td>
<td>522,875</td>
<td>43.2%</td>
<td>133,870</td>
<td>42.8%</td>
</tr>
</tbody>
</table>

The Table shows that in 2006/07 a third of all class 3 & 4 vehicles tested (i.e. cars) failed the MOT, which represents 8.7 million failures.

The 10 most common reasons for MOT failures by defect category are shown in Table 3.2. It can be seen that 3.8% of class 3 & 4 vehicles failed the MOT as a result of the exhaust system. This represents just over 330,000 vehicles failing the MOT as a result of a defective exhaust system. The main reasons for failure are likely to be corrosion and leaks, rather than noise. However, an exhaust that suffers from leaks is also likely to be noisy.

Exhaust systems were not among the top ten failure reasons for class 1 & 2 vehicles.
## Table 3.2: MOT failures by defect category. Source: VOSA (2007)

<table>
<thead>
<tr>
<th>Class 1 &amp; 2: Motorcycles</th>
<th>Class 3 &amp; 4: Cars &amp; light vans up to 3,000kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defect category</strong></td>
<td><strong>2006/07</strong></td>
</tr>
<tr>
<td>Lights</td>
<td>9.4%</td>
</tr>
<tr>
<td>Brakes</td>
<td>5.2%</td>
</tr>
<tr>
<td>Suspension</td>
<td>3.9%</td>
</tr>
<tr>
<td>Tyres</td>
<td>3.0%</td>
</tr>
<tr>
<td>Steering</td>
<td>2.4%</td>
</tr>
<tr>
<td>Fuel &amp; emissions</td>
<td>1.6%</td>
</tr>
<tr>
<td>Body</td>
<td>1.0%</td>
</tr>
<tr>
<td>Drive system</td>
<td>0.9%</td>
</tr>
<tr>
<td>Structure</td>
<td>0.9%</td>
</tr>
<tr>
<td>Road wheels</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Overall, it is considered that poor maintenance is unlikely to be a factor in the perceived problem of excessively noisy exhausts for cars or motorcycles, although it could be a factor for vans.

### 3.3 Poor design of replacement exhaust systems

Replacement exhaust systems fall into two main categories. The first of these is Original Equipment Manufacturers (OEM) parts, which are parts manufactured to the manufacturer’s original designs, either by the vehicle manufacturer or an approved exhaust manufacturer.

The second category of replacement exhaust systems is pattern parts. These are where an exhaust manufacturer essentially copies an OEM part and then sells the system as a replacement part for less money than an OEM part. These systems are able to be produced cheaper than OEM parts because modern exhausts use similar components that can be used over a range of products, making the construction process more efficient. While these exhaust systems are visually comparable with the original, they may not necessarily be in design.

It is not considered that these systems contribute to the perceived problem of excessively noisy exhausts.

### 3.4 Deliberate modification of the exhaust system

The deliberate modification of an exhaust system by altering a component of an existing system in order to create extra noise is considered not to be common these days. This is due to alternatives (i.e. ‘performance exhaust systems’) being more readily available at relatively affordable prices (see below). However, what is now common practice is the addition of components or replacement of some components in order to create additional noise. This is discussed below.
3.4.1 Performance exhaust systems

The after-market for so-called performance enhancing exhausts has increased in recent years, and there are now approximately 30 manufacturers, each offering an average of 12 products to the consumer for a wide range of vehicle types. This type of product is becoming readily available through the internet (including imports) and commercial outlets such as Halfords and Kwik-Fit. Products are available in a variety of styles for a range of new and old cars; the price of a performance enhancing exhaust can vary from £30 for a tail-pipe to in excess of £300 for a full system.

It is considered that it is these systems, which appear unregulated, that are by far the main problem area. More specifically, the problem areas for each of the vehicle categories being considered in Phase 1 are:

Scooters: Although there was a decline of this vehicle type in 2006 to 52,000, this vehicle type is often modified to give more acceleration and to be fitted with performance exhausts and other components.

Motorcycles: Generally the fitment of ‘race’ and ‘performance exhaust systems’. However there are certain controls on these parts such as the British Standard Kite system (BSI, 1990).

Cars: With ongoing increases in insurance premiums for younger drivers, true performance vehicles or sports cars are beyond the budget for the majority of younger drivers. Therefore, younger drivers tend to purchase cheaper vehicles and individualise these vehicles (e.g. with paintwork, styling, ‘performance exhaust systems’) in order for the vehicle to stand out and appear to be performance vehicles. The car category can also be susceptible to maintenance issues.

Vans: Generally, the main problem with this category is poorly maintained vehicles.

3.5 Future trends

This section examines potential trends in vehicle technology and other areas that could influence the number and nature of modified cars and motorcycles. It also examines indirect changes that could influence the extent of the problem.

3.5.1 Technology changes that might affect noise from vehicles

Diesel engine vehicles

Sales of vehicles with diesel engines are increasing rapidly compared with petrol engine vehicles. With the performance between the two engine types narrowing, it is possible that in the future it is diesel engine vehicles that will be modified. Performance exhaust systems are already available in the United States for large diesel pick-ups, so it is unlikely the UK will be far behind this trend.

The implications of this shift are not that high, as a diesel engine still produces gasses that need to exit the vehicle via an exhaust. The only possible consideration would be if a test were developed that required the engine to be accelerated to maximum rpm, as a diesel engine generally does not rev as high as a petrol engine.

SUVs and 4x4s

The increase in SUVs (Sports Utility Vehicles) and 4x4s is well documented. These vehicles tend to have large engines and tyres so it is possible that the problem of excessive noise could be shifted to another area of the vehicle, but considered unlikely.

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3 It is noted that the phrase ‘performance exhaust systems’ is almost exclusively a marketing phrase. As such, these exhaust systems may have little or no effect on the performance of a vehicle.
Modular exhaust systems
It is possible that, in the future, exhaust systems will follow the way other parts (e.g. radios) have gone and become less accessible to modification.

Electric cars
The concept of electric cars has been around for many years but their use has been limited in the UK. Such vehicles do not have a standard exhaust system and produce very little noise, so they would be difficult to modify.

3.5.2 Possible technology changes introduced to combat tests

Engine RPM limiters
It is possible that, in the future, engines may be designed not to produce high engine RPM if the vehicle is in, for example, neutral. This may be designed by manufacturers in order to protect engines or potentially used for other purposes. This technology has already been incorporated into alternative fuelled buses produced by Volvo. If a stationary test were developed that involved an engine being accelerated to high engine RPM then this could potentially be a problem.

Bungs or baffles
Bungs and baffles, also known as ‘dB killers’, are already available for exhaust systems and are designed to lower the level and directionality of noise from an exhaust system. The fitting of such systems to vehicles before any MOT-type noise test would need to be considered and restricted; it is not thought that such systems would be an issue for roadside tests.

Other areas on cars being modified to produce noise
If a restriction on noise from exhaust systems is successful then either manufacturers or owners might seek to make other areas of the vehicle noisy, although it is considered this is unlikely. Apart from the engine, the only other option is considered to be changes to somewhere else in the exhaust system. This could be closer to the engine, for example where the exhaust gasses first exit the engine. If a test is developed where the microphone is positioned mid-vehicle then this would go some way to tackling this potential issue.

Systems to limit engine power
Systems that limit engine power, usually by an Engine Management Unit (EMU), are known to exist and are used in situations where it is advantageous for the vehicle not to produce full engine power (and therefore noise). Such systems would only be of concern if an in-service noise test was required to reproduce type-approval levels, as measured levels may be higher than at type-approval.

Systems to limit exhaust gas flow
Devices within exhaust systems that limit the flow of gasses are known to exist, and are used to reduce the exhaust noise at low engine RPM, and utilising full flow at high engine RPM. At the present time these devices are only used on high performance sports cars, however, evidence of this technology is starting to be seen in production vehicles.
With the development of the Regulation 51.03 revised test for type-approval and an ASEP procedure (Annex 10), this issue has been addressed and the outcome so far is that these devices should be prohibited. Until these proposed amendments are in place this issue is likely to become more widespread.

3.5.3 Lifestyle changes

3.5.3.1 Increase in motorcycle use

Statistics showing the number of motorcycles in-service has been obtained from the Motorcycle Industry Association (MCIA, 2007). These indicate that:

- The use of motorcycles over 900 cc has steadily increased since 2000 from 189,000 to 313,000 in 2006
- The number of motorcycles with an engine size between 701-900 cc has been stable throughout the last six years
- Motorcycles with mid-range engines (501–700 cc) have become increasingly popular in recent years with an additional 70,000 motorcycles in use in 2006 than in 2000
- The number of motorcycles with an engine size of 126–500 cc fluctuated between 2000 and 2005 before decreasing to 209,000 vehicles in use at the end of 2006
- There was a significant increase in the number of motorcycles (101-125 cc) in use from 125,000 in 2000 to 193,100 in 2006
- There was a decrease in the number of two wheeled motor vehicles\(^4\) from 84,100 in 2000 to 52,000 vehicles in 2006

This data shows that overall trend of motorcycle ownership is increasing, especially those with large engines. This rise could be for a number of reasons; increasing congestion on Britain’s roads and in cities, longer summer months making the ‘riding’ season longer, more disposable income making it easier to own a car and motorcycle.

3.5.3.2 Climate change and outdoor lifestyle

Although climate change alone is unlikely to directly influence the number of noisy vehicles, it could lead to more people exposed which could in turn lead to more complaints.

In 2003, a parliamentary committee called for an increase in continental-style café culture in the UK’s towns and cities. Since this recommendation, ‘Cafefication’ has become big business.

In 2007 the growth in the UK café and coffee bar sector was predicted to continue at a rate of 8.9% for the next three years (Barton, 2007).

Another possible area that would lead to more people exposed is the increasing use of outdoor areas (e.g. gardens, parks) due to an increase in good weather.

Another indirect impact of climate change might be on the ownership of motorcycles. Motorcycles are often a second mode of transport for some people, who ride them frequently in summer months or on other clement days. An increase in good weather has the potential to increase noise nuisance from motorcycles, although not necessarily all of these would have modified exhaust systems.

\(^4\) In law, a moped is classed as a motorised two-wheeled vehicle with an engine capacity of less than 50cc and a maximum speed capability of 30mph.
3.5.3.3 **Personal identification**

The need by some to identify their vehicle from others is clearly shown by the rapid increase in the sales of personalised number plates. This is a trend that is only likely to increase. Although increasing the noise from a vehicle is not quite the same as having a personalised number plate, it demonstrates a general need by some to make a vehicle different from others, either visually or aurally.

It should be noted that some number plates are also seen as an investment, but it is considered unlikely this would ever be the case of a performance exhaust system.

3.6 **Future legislation**

This section deals with the issues relating to possible future legislation and its impact on vehicle noise emissions. The first two issues deal with changes in legislation relating to type-approval limits for both vehicles and tyres. The third issue deals with more effective measures relating to traffic management.

3.6.1 **Impact of changes to UN-ECE Regulation 51**

The most likely outcome from the current proposed changes to the test undertaken in Regulation 51 is that the existing test procedure will be replaced and new type-approval limits will come into force. These will be derived from the tests undertaken using the new test procedures.

Generally, when type-approval limits are changed or first introduced, there is a cost to the industry and to alleviate this impact the limit values are set so that they are not too onerous. It is likely that any changes to the type-approval limits following the proposed changes to Regulation 51 will have limited impact on reducing vehicle noise emissions. After some period of time, once the new method has been introduced, more stringent limits would be introduced which would have some impact on new vehicles entering the fleet.

However, until the majority of vehicles in the fleet have been quietened there would be little impact on overall reductions in traffic noise e.g. if a 5dB(A) reduction in limit values were introduced, it would require a 70% replacement of the vehicle stock to achieve a reduction of 3 dB(A) in overall traffic noise assuming the initial fleet consisted of acoustically similar vehicle types. This phenomenon is sometimes referred to as the ‘inertia effect’ (Sandberg, 2002). Some estimates have indicated that it may take 10 to 15 years before the impact of a limit change has a significant effect on overall traffic noise levels due to the lifetime of vehicles.

3.6.2 **Lowering tyre noise limits**

In 2001, Directive 2001/43/EC was published (European Communities, 2001). It established a test method for the type-approval of tyres with respect to noise emissions and introduced limit values for different types and widths of tyre. These limit values came into effect in the UK in 2003. Generally, it is regarded that the existing legislation has had or will have little impact on individual vehicle noise levels.

Some stakeholders hoped that stricter limits would have been introduced by 2008 but progress has been slow and the final decision has recently been delayed. Nevertheless, it is perhaps important to mention what effect introducing tighter control on tyre noise may have on the type-approval of vehicles.

Proposed changes to Regulation 51 will enhance the contribution of the noise that tyres have on type-approval levels. There is therefore the potential for manufacturers to meet any future noise limits by reducing the tyre noise component at the expense of noise
from the power train i.e. engine, exhaust and transmission. Although this will have benefits on high speed roads where tyre noise is a dominant contributor to traffic noise levels, in more densely populated areas, where vehicle speeds are less, overall noise emissions may not change significantly.

3.6.3 Traffic Management

Legislation controlling the movement of traffic, allowing local authorities to introduce traffic management schemes has been used to some extent in reducing the impact of potentially noisier vehicles.

Such schemes as the London Lorry Control Scheme (LLCS), first introduced in 1986, were designed to limit the movement of certain types of vehicle. The application of a similar system to certain types of cars, vans or motorcycles is possible but likely to be very difficult to achieve and police.

Other measures have been effective by reducing the demand on road space. For example, the London congestion charge, which has affected weekday daytime noise levels within the control area by reducing traffic flow, was introduced in 2003. The control area has been extended to the west of London and other cities are planning to introduce similar control measures.

The introduction of congestion charging has introduced for the first time the infrastructure to control the movement of vehicles through registration identification using CCTV. This has opened up the possibility to protect sensitive areas from certain vehicles which have negative environmental impacts in a much more cost-effective way. The London Low Emission Zone (LEZ) which began in February 2008 is one such example, although at this time it only covers goods vehicles. The introduction of such a scheme to improve air quality could initiate a similar scheme to include limiting vehicles based on type-approval noise limits.

The advantage of such measures compared to those described earlier, based on introducing more stringent limit values, is that their effectiveness is more immediate and does not suffer from long lead-in times.

3.6.4 UN-ECE Regulation 59

Although Regulation 59 has been covered already in Section 2.1.4, there are two issues with this document that would need to be addressed if it were adopted into national law. These are discussed below.

Currently, it is considered that individual components that make excessive noise would not be tested as they do not appear to be covered by this regulation. It is considered this is due to a simple issue over definitions. The scope of the Regulation is stated as “this Regulation contains provisions relating to the approval of silencing systems or components thereof to be fitted to one or more given types of motor vehicles in categories M1 and N1 as replacement parts”. Currently noisy exhaust systems are sold as ‘performance exhaust systems’ and it is considered this is why they are not covered by this Regulation.

This leads onto the second area of concern, as there is currently a proposal with GRB Working Group 29 to change the scope of Regulation 59 to read “this Regulation covers replacement silencing systems for vehicles of category M1 and N1”. If this amendment were approved then it would limit the effectiveness of this Regulation even further by not covering individual components.
4 Assessment of techniques for the control of in-service noise

This chapter first considers existing processes and legislation that could be used in the development of an in-service noise test. Possible process-based and technology-based solutions are then examined. Unless stated, all examples relate to cars, vans and motorcycles.

4.1 Existing processes and legislation

4.1.1 Developing in-service noise tests – links to type-approval

Before discussing the options for the control of in-service noise, it is important to consider the need to link the results from any test method to type-approval.

The introduction of an in-service noise test and associated noise criteria cannot address all the noise concerns covered in the Construction and Use Regulations. For example, to introduce an in-service test that would in some way prevent excessive noise due to inconsiderate behaviour would be impractical because excessive noise may not be dependent on noise level alone but on other circumstances such as time of day and location. However, apart from this issue, all the other mechanisms in the Regulations for controlling noise attempt to ensure that noise levels do not exceed those when new and are therefore related to type-approval levels.

In favour of linking to type-approval

By introducing an in-service noise test where the level can be directly related to type approved noise levels would have some advantage in that it would be aligned with the general approach of the Construction and Use Regulations.

An additional argument for having an in-service noise test which gives results that are correlated to type-approval levels is that the risk of a vehicle failing the in-service test but passing the type-approval test could be reduced.

Against linking to type-approval

The current test used for type-approval (i.e. ISO 362) is not representative of everyday driving conditions and, since it is a drive-by test, unsuited to roadside enforcement. The new test under UN-ECE Regulation 51 will go some way to addressing this issue, but results from this are unlikely to be available for a number of years.

A link to type-approval will also be restrictive on the range of in-service tests that can be considered, for example it would be difficult to consider frequency spectra in a test if this is not undertaken at type-approval.

4.2 Processed based techniques

This section considers various processed based methods that could be used to tackle the problem of noisy vehicles. For each idea, the main benefits and limitations are given, followed by an overall conclusion and recommendation.
## Process 1

**Description**  
Insurance companies are alerted when someone purchases or has fitted a ‘performance exhaust system’ or any performance enhancing product for a car or motorcycle.

It is assumed that very few ‘performance’ devices are declared as modifications to a vehicle for insurance purposes. If they were it is likely that premiums would increase and people may be deterred from fitting them. A similar system to this operates for the purchase of televisions, whereby the buyer completes a form on purchase and the address is checked for the purpose of a TV license.

**Benefits**
- May act as a deterrent to someone wishing to purchase a ‘performance exhaust system’ if they know that their insurance is likely to increase

**Limitations**
- Will not control the noise from those ‘performance’ systems already on vehicles
- Will require quite a lot of administrative work and ‘buy-in’ from insurance companies and stores
- May become complicated if the person purchasing the exhaust has more than one vehicle. Could also present problems if someone is buying an exhaust system and does not own a vehicle, or if purchasing an exhaust system for someone else
- Those who wish to make noise and can afford to still will

**Conclusion**  
Would not be effective enough in proportion to the effort required to implement, administer and enforce.  

*Not recommended to be taken forward.*

## Process 2

**Description**  
If a vehicle is fitted with a non-OEM or approved replacement exhaust system then this is noted at the MOT and the information is stored centrally (e.g. VOSA, DVLA) and this is highlighted when the insurance for the vehicle is due.

This process would benefit from a procedure where exhaust systems that have passed a Regulation 59 or 92 test have to carry a stamp.

**Benefits**
- May act as a deterrent to someone wishing to purchase a ‘performance exhaust system’ if they know that insurance is likely to increase

**Limitations**
- Would not capture those who change parts just before an MOT and then change them back after the MOT
- It would involve a change to the MOT test
- Would require quite a lot of administrative work and ‘buy-in’ from insurance companies and VOSA / DVLA
- Those who wish to make noise and can afford to still will
- Since it is an examination at an MOT, it would only examine those vehicles over 3 years

**Conclusion**  
Would not be effective enough in proportion to the effort required to implement, administer and enforce.  

*Not recommended to be taken forward.*
### Process 3

**Description**
The total exhaust outlet area on a vehicle, or of a part that is sold as a replacement, should be no larger than a given size or greater than a given area.

**Benefits**
- Easy to enforce and detect, either at roadside or at MOT

**Limitations**
- Would be restrictive as manufacturers of some vehicles which are currently available may have to reduce the size of exhausts
- Improvements in technology may develop so that exhausts could be made noisy even if smaller than at present
- Could only really be applied to new vehicles or products so would take a long time to become fully effective

**Conclusion**
Could be very effective, but unpractical and very restrictive.

*Not recommended to be taken forward.*

### Process 4

**Description**
Limit the number of exhaust outlets a vehicle may have. This Process could be used in combination with Process 3.

**Benefits**
- Easy to enforce and detect, either at roadside or at MOT

**Limitations**
- The majority of already noisy vehicles only have a single exhaust outlet
- Could only really be applied to new vehicles due to the need for potential re-design.
- Would be restrictive as manufacturers of some vehicles which are currently available would have to reduce the number of exhaust outlets on these vehicles

**Conclusion**
Unpractical and very restrictive.

*Not recommended to be taken forward.*
**Process 5**

**Description**  
Any devices which claim to increase the performance of a car or exhaust systems sold as 'performance' systems are not road legal and are only for 'track use'.

This process would benefit from a procedure where exhaust systems that have passed a Regulation 59 or 92 test have to carry a stamp of approval.

Would benefit also from a system whereby it is an offence for a garage to fit certain components or only someone with a ‘track licence’ can have such components fitted.

**Benefits**
- May remove 'performance exhaust systems' from road vehicles

**Limitations**
- Difficult to regulate and detect for some parts, but exhausts may be easier to detect than others
- The name of such devices could easily be changed allowing them to still be sold for road vehicles
- May increase the number of 'home made' systems to increase noise

**Conclusion**  
Could be effective but would require a lot of administrative work and could be manipulated.

*Not recommended to be taken forward.*

---

**Process 6**

**Description**  
Increase the taxation costs for vehicles that produce more noise, or have a sliding scale depending upon noise level.

This process would only work in conjunction with an in-service noise test undertaken at an MOT.

**Benefits**
- The increased costs of owning a motor vehicle might discourage some people from modifying their vehicles
- Changes in taxation levels for vehicles can be changed relatively easily as they are for emissions
- Might help to promote low-noise vehicles

**Limitations**
- Would not capture those who change parts just before an MOT and then change them back after the MOT
- Would require a change to the MOT test
- Those who wish to make noise and can afford to still will

**Conclusion**  
Has the potential to be very effective as high taxation levels might deter many from fitting systems that make excessive noise. However, anything concerning taxation could be very difficult to implement and changes to the MOT test would be required.

*Not recommended to be taken forward.*
**Process 7**

*Description*  
Examination of the adoption of Regulation 59 into national law, ensuring it covers all aftermarket products and components.

*Benefits*  
- Will ensure that all replacement exhaust systems and components are covered by a noise test

*Limitations*  
- The time scale and work required to adopt the Regulation could be long
- May still require the introduction of enforcement measures (e.g. a roadside noise test) to control existing vehicles or where ‘home’ modifications are made to approved systems
- This may require the introduction a ‘stamping’ system to indicate those systems and components that have passed the Regulation 59 test

*Conclusion*  
Could be very effective if it also covers components.

**Recommended to be taken forward.**

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**Process 8**

*Description*  
Only complete exhaust systems can be sold as replacement parts.

*Benefits*  
- Would eliminate a lot of add-ons that are just designed to make noise
- Complete systems would be subject to Regulation 59 (if adopted)
- Could promote the use of long life materials (e.g. stainless steel) as manufacturers could be encouraged to make exhaust systems that last longer

*Limitations*  
- Complete exhaust systems could still be noisy
- Could be difficult to implement and police
- Would be very expensive to replace minor defects in exhausts and may deter some from having the problem fixed until absolutely necessary, which may have safety and noise issues

*Conclusion*  
Would be very effective if implemented with Regulation 59, although would be very restrictive and could be expensive for consumers.

**Not recommended to be taken forward.**
### Process 9

**Description**  Further examination of other datasets relating type-approval noise levels to the results of stationary tests. This would be undertaken to determine whether existing data can be used to set in-service noise levels.

**Benefits**  ● May mean an extensive testing phase isn’t necessary if a relationship between type-approval noise levels and stationary tests is found

**Limitations**  ● Would be unlikely to take account of any increase in noise level caused solely by the age of the exhaust  
     ● Would still be hindered, like previous work, by attempting to link an in-service test to type-approval levels

**Conclusion**  An examination of the datasets would be relatively easy and may indicate vehicle types that do not follow relationships.  

*Recommended to be taken forward.*

### Process 10

**Description**  Examination of the adoption of UN-ECE Regulation 92 (for the approval of replacement exhaust silencing systems for motorcycles).

**Benefits**  ● Would ensure most motorcycle exhaust systems and potentially components are noise tested

**Limitations**  ● May be difficult to adopt as Regulation 92 has not currently been accepted by the EU

**Conclusion**  Would be an effective means of controlling noise from motorcycles.  

*Recommended to be taken forward.*

### Process 11

**Description**  The use of P-plates for newly qualified drivers (or those in a certain age band) and the prohibiting of any vehicle modifications to a car with P-plates.

**Benefits**  ● Since some younger drivers modify vehicles to produce excessive noise, a restriction placed on them at an early age may reduce the desire to modify a vehicle

**Limitations**  ● A ‘modification’ would need to be defined in order to be enforced  
    ● The process may need to restrict all modifications, including those that do not produce extra noise, in order to be enforceable  
    ● Restrictive if a modified vehicle is shared by an experienced and a younger driver  
    ● Would be seen as over restrictive, although the concept could probably be introduced for other reasons and this may be a benefit

**Conclusion**  The idea of P-plates to control excessive noise from exhaust systems would be problematic and therefore would need a lot of research before it could be considered as a viable option.  

*Not recommended to be taken forward.*
**Process 12**

**Description**  The development of a standard vehicle, or vehicles, that have to be used by drivers of a certain age or experience level and cannot be modified.

**Benefits**
- As it is perceived that it is mainly younger drivers who modify vehicles to produce excessive noise, a restriction placed on them at an early age may reduce the desire to modify a vehicle
- The standard vehicle could be made with enhanced safety features

**Limitations**
- Would be very restrictive on car manufacturers who currently design and build vehicles aimed at the younger motorist
- Would be restrictive on those who genuinely need other types of vehicle, for example someone who lives in a remote location and may require a 4x4 vehicle
- Would require exemptions where a younger or inexperienced driver requires use of a certain type of vehicle for business purposes
- A ‘modification’ would need to be defined in order to be enforced
- A standard vehicle from new would be prohibitively expensive for most newly qualified young drivers

**Conclusion**  This idea would be too restrictive on vehicle manufacturers and drivers.  

*Not recommended to be taken forward.*

**Process 13**

**Description**  Increased training for MOT testers to ensure that current assessment guidelines are applied correctly.

**Benefits**
- Would make use of existing mechanisms (i.e. the current check at an MOT) to control the problem

**Limitations**
- The assessment method would still only be subjective
- Would not capture those who change parts just before an MOT and then change them back after the MOT

**Conclusion**  Is unlikely to be effective as it would offer no real difference from the existing condition

*Not recommended to be taken forward.*
## Process 14

**Description**
Prohibit the use of high-revving 2-stroke engines for motorcycles.

**Benefits**
- Would remove small motorcycles and scooters that often exhibit high noise levels

**Limitations**
- Would be very restrictive by removing more affordable motorcycles and scooters
- Could only be effective on new vehicles and so would take a long time to have an impact

**Conclusion**
Could be very effective but also very restrictive and would take a long time to have an impact

**Not recommended to be taken forward**

## Process 15

**Description**
Advertising campaigns aimed at influencing those who modify vehicles in order to increase noise.

**Benefits**
- Would be relatively low cost and would not require any legislative changes

**Limitations**
- Likely to only influence a minority

**Conclusion**
Unsure whether it would work and is not a long term or lasting solution.

**Not recommended to be taken forward**

## Process 16

**Description**
The government to encourage manufacturers to produce vehicles with modular exhaust systems, therefore limiting the possibility of modification.

**Benefits**
- May gradually phase out the majority of exhaust systems that can be modified

**Limitations**
- May be difficult for Government to be seen to be influencing how car manufacturers design their vehicles
  - Would take a long time to become effective for the majority of vehicles, especially for older vehicles that tend to be modified
  - May still not completely solve the problem as the end pipe of an exhaust system would still be assessable for modification

**Conclusion**
A very long term and potentially complicated solution that may require some form of government incentive to get it started.

**Not recommended to be taken forward**
Process 17

Description An MOT test for vehicles every six months (still only for vehicles over three years old).

Benefits
- This will provide a second check each year on those vehicles producing excessive noise

Limitations
- Likely to increase the cost of motoring and require an increase in MOT test centres
- Would only tackle those exhaust systems that become noisy due to poor maintenance, unless a noise test was introduced at an MOT
- Would not capture those who change parts just before an MOT and then change them back after the MOT
- May increase the rate of MOT evasion as two tests per year may be seen as an unnecessary burden

Conclusion Would really only be a burden to motorists and unlikely to reduce the problem of vehicles producing excessive noise.

Not recommended to be taken forward.

4.3 Technology based techniques

This section considers various techniques or technology based methods that could be used to tackle the problem of noisy vehicles. For each idea, the main benefits and limitations are given, followed by an overall conclusion and recommendation.

Technique 1

Description All new exhaust products (and components) must be type approved by a test on a rig at an approved test centre. This test would require the injection of an acoustic signal into the exhaust system.

This could be one option for further testing of systems and components if Regulation 59 is extended to cover all systems.

Benefits
- Every product and component on an exhaust system would be tested

Limitations
- Those companies who just make one part of a system would have to build it into an approved system to be tested
- The test is unlikely to reproduce real-life noise levels
- Due to differing exhaust sizes, several rigs may need to be developed
- The input signal required may be unsuitable for the identification of noise from some designs of exhaust
- Would not be possible to undertake such a test at the roadside

Conclusion The test would be restrictive and create a lot of extra work for single component manufacturers.

Not recommended to be taken forward.
## Technique 2

**Description**  
The injection of an acoustic signal into the exhaust system from the outlet, with a measurement either of the reflected spectrum at the outlet or the non-invasive measurement of the transmitted spectrum at or near the engine.

**Benefits**  
- Would not require the engine of the vehicle to be running
- Should be very reproducible as it would require very little input from an operator once the equipment is in place

**Limitations**  
- Would be a measurement of the sound pressure level from a signal passing the other way along an exhaust to that which it was designed
- Would require sophisticated and expensive equipment, which could be difficult for roadside use
- Could be inappropriate for a vehicle with several exhausts, as each could pass a test but overall the vehicle may still be noisy
- May not be applicable to all vehicle types due to the location of exhaust/manifold systems
- May not work for rear or mid-engine vehicles
- The test would only focus on exhaust systems, and not whole vehicle noise

**Conclusion**  
The test would be very complicated to undertake and would not be a measure of the real life noise from an exhaust system.

*Not recommended to be taken forward.*

## Technique 3

**Description**  
Non-invasive injection of an acoustic signal into the exhaust system at or near the engine, with measurement at or near the outlet.

**Benefits**  
- Would not require the engine of the vehicle to be running

**Limitations**  
- Engines vary considerably so a signal may reach the exhaust easily for one vehicle but not on others
- Signal likely to be required to be very strong in order to produce a meaningful signal at the exhaust outlet
- Would require sophisticated and expensive equipment, which could be difficult for roadside use
- Could be inappropriate for a vehicle with several exhausts, as each could pass a test but overall the vehicle may still be noisy
- May not be applicable to all vehicle types due to the location of exhaust/manifold systems
- May not work for rear or mid-engine vehicle

**Conclusion**  
The test would be very complicated to undertake and would not be a measure of the real life noise from an exhaust system.

*Not recommended to be taken forward.*
### Technique 4

**Description**  
A noise test (to be developed – see Section 4.3.2) suitable for application for roadside spot checks.

**Benefits**  
- The test would collect a large amount of data in a short time that could be used to further develop limits for roadside testing

**Limitations**  
- Would create additional work and initial expense for parties carrying out the tests

**Conclusion**  
A noise test could allow an accurate measure of the noise produced by a vehicle and could be used at the roadside.  

*Recommended to be taken forward for further development.*

### Technique 5

**Description**  
If an exhaust system is identified at an MOT that is not an OEM or a complete replacement part that has passed Regulation 59 or 92 test, then the vehicle must undergo, at the owners expense, an assessment (to be developed – see Section 4.3.2) at an approved test house or another test station before an MOT certificate can be issued. Also included is any vehicle that the MOT tester considers is excessively noisy.

**Benefits**  
- Will act as a deterrent for noisy exhaust being fitted at the owners will know extra expense would be required
- Will only require a quick check at an MOT

**Limitations**  
- Would not capture those who change an exhaust before an MOT and then change it back afterwards
- Would create some extra work for test houses and testing stations
- OEM or approved exhaust systems could be modified internally so they are identical on the outside to the real part
- Will only test vehicles that are over three years old
- Would require the adoption of Regulation 59 and 92 to be fully effective.

**Conclusion**  
Would require a lot of development work and changes to the MOT test procedure.  

*Not recommended to be taken forward.*
## Technique 6

**Description**  
Using laser technology to measure the standing waves within the exhaust system, with limitations put on certain wave profiles that are identified as producing excessive noise at the exhaust outlet.

**Benefits**  
- Ability to scan along the whole exhaust system
- If equipment could be made portable, the test could be undertaken at a lot of locations and background noise is unlikely to be important

**Limitations**  
- May be difficult to undertake the test if the whole of the exhaust system is not assessable
- The test would require a lot of development to understand the standing wave propagation within an exhaust system
- Likely to require expensive and sophisticated equipment

**Conclusion**  
A test is likely to be very expensive and time consuming to develop.  
Not recommended to be taken forward.

## Technique 7

**Description**  
Developing the use of an acoustic camera to measure the noise level and to quantify the propagation effect at the rear of the vehicle.

**Benefits**  
- The camera would provide a detailed picture of sound propagation around the whole vehicle
- May be easier to compare a standard exhaust against a non-standard exhaust with the use of an acoustic picture
- The results from a test may be useful for demonstration and raising awareness purposes

**Limitations**  
- The equipment required is very expensive and the output requires a lot of processing and analysis
- Would not be practical for use at an MOT testing station or the roadside, as the system has 32 microphones

**Conclusion**  
Would be effective at determining what parts of the vehicle are creating excessive noise, but systems would be very expensive and impractical to use in most situations.  
Not recommended to be taken forward for enforcement, but has potential uses for purposes such as raising awareness.
Technique 8

Description
A measurement of sound power level from an exhaust system.

Benefits
- A measure of the sound power (i.e. the acoustic energy) of an exhaust system is independent of distance, so site considerations are less important

Limitations
- The equipment to measure sound power is expensive
- Measuring sound power level can be time consuming and would require an operator with knowledge of acoustics.

Conclusion
The same information can be obtained with a routine measurement of sound pressure level.

Not recommended to be taken forward.

Technique 9

Description
A measure of the vibration from an exhaust system. Such a test could involve an accelerometer fixed to a surface near to the exhaust outlet.

Benefits
- Does not require a control on background noise

Limitations
- Would only identify those vehicles that are noisy due to low frequency noise (mainly 'performance exhaust systems')
- Would require expensive equipment in order to detect vibration
- The accelerometer would need to be close to the exhaust, which may prove difficult with vehicles that have multiple exhaust outlets
- May just be a measure of the rate at which gases leave the exhaust

Conclusion
Method does not offer any clear benefits over the use of a normal sound level meter.

Not recommended to be taken forward.

Technique 10

Description
A measure of the noise inside the vehicle.

Benefits
- As the measurement is undertaken inside the vehicle it would require very little space to conduct test
- If a level is measured at the drivers position then it might be possible to link any limit value to exposure levels on H&S grounds, but this would only apply if the vehicle was a ‘work area’

Limitations
- The effectiveness of the vehicle sound proofing would have a strong influence on measured noise levels
- Would not be effective for motorcycles
- The test would be intrusive as it would require the operator to fix equipment inside the vehicle

Conclusion
Would not be a representative measure of the noise outside the vehicle.

Not recommended to be taken forward.
Technique 11

**Description**
If the noise level from the exhaust of a vehicle can be significantly reduced by applying a standard 'bung' then it is deemed to be making excessive noise and would fail any test. This would be a subjective assessment only.

**Benefits**
- The method would not require any measurement of noise level

**Limitations**
- Although the noise level may be reduced by the application of the bung, this cannot automatically imply that the exhaust is excessively noisy
- Although the noise level may be able to be reduced, this may affect other aspects of the vehicle (e.g. emissions)
- A standard bung applicable for each type of exhaust system may be difficult to produce
- Damage to the exhaust system may occur

**Conclusion**
The method would still be subjective and would offer little benefit over the existing subjective assessment.

Not recommended to be taken forward.

4.3.1 Test solution considerations

The development of an in-service test is necessary for many of the processes and techniques described in Chapters 4.2 and 4.3. Several factors must be considered that will influence the usefulness of any test. These are:

- whether the test is undertaken on a stationary or moving vehicle
- whether the test can be undertaken at the roadside
- whether there is anything to be attached to the test vehicle
- the likely consistency/repeatability of results
- the influence of background noise levels on the test
- whether the result of the test can be influenced by the operator
- the level of technology and amount of equipment required
- any risks to the test vehicle and operator
- whether the test is applicable to all necessary vehicles
- whether a target level would be set through a link to a type-approval level or set subjectively
- whether the results of the test could be altered (through vehicle technology) or the test interfered with by anyone wishing to do so
- whether the test addresses areas of vehicle technology which may give rise to additional noise sources in the future
- whether any target level would be an average noise level or a maximum noise level. Consideration would also need to be given to the components of the signal (e.g. frequency spectra) to be considered for target levels
- the location of the test microphone
- the potential noise impact on the area where the test is being undertaken
As already noted, the location of the microphone for any stationary test is an important consideration. Table 4.1 below shows the benefits and limitations of each potential position.

### Table 4.1: Microphone location options

<table>
<thead>
<tr>
<th>Microphone location</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>General exhaust area</td>
<td>Used presently so guidelines for positioning of the microphone are well documented.</td>
<td>Only focuses on exhaust noise and not whole vehicle.</td>
</tr>
<tr>
<td></td>
<td>Target level would be high since it is a test close to the exhaust, so the level of background noise is less important.</td>
<td>Operator is exposed to higher noise level if equipment is not remote.</td>
</tr>
<tr>
<td></td>
<td>It measures where the problem currently is.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Most existing equipment uses exhaust noise as the means to detect RPM, so the signal would be strong.</td>
<td></td>
</tr>
<tr>
<td>Side of vehicle</td>
<td>A measure of whole vehicle noise.</td>
<td>Overall target level may need to be lower so the background noise level may be more important.</td>
</tr>
<tr>
<td></td>
<td>This is future proof in case future high noise levels are produced from anywhere else on vehicles (e.g. engine, exhaust manifold).</td>
<td>Existing equipment that can ‘listen’ for RPM may not work this far from the exhaust.</td>
</tr>
<tr>
<td></td>
<td>Test position could be used to measure other noise sources if ever required (e.g. noise from in-vehicle audio systems)</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3.2 Test solutions

The tests outlined in this section cover ideas where an actual noise level from a stationary car or motorcycle is measured, and are therefore applicable as a roadside test. The main benefits and limitations with each test method are also listed. These exclude areas that would be equally applicable to all tests, for example the possibility of technology being developed to hinder the tests.

**Test 1**

**Description**

When the vehicle is stationary, accelerate the vehicle engine to maximum and measure the maximum noise level when held in this position.

**Benefits**

- Easy to conduct the test
- Would not require a measure of engine speed

**Limitations**

- Some vehicles currently prevent high revving when stationary and cut-off the engine, which could prevent the test being undertaken
- Potential to damage some engines due to high revving

**Conclusion**

There is the potential for damage to engines and the test would not be a measure of noise when the vehicle is operating at normal conditions.

**Not recommended for development.**
**Test 2**

*Description*
Conduct the same stationary noise test as specified by UN-ECE Regulation 51 test (i.e. ISO 5130).

*Benefits*
- The test is already defined by an ISO standard
- Off the shelf equipment is already available to undertake this measurement
- May be easier than other tests to set a limit value as a lot of data already exists for these tests

*Limitations*
- Provides only a measure of exhaust noise due to the close proximity of the microphone to the exhaust
- Would need a measure of engine speed
- The test is quite time consuming as a steady engine speed needs to be obtained, which can be difficult, especially on motorcycles

*Conclusion*
As a standard test it would be useful to include it in any test programme as a control.

**Recommended to be considered further as a test option.**

---

**Test 3**

*Description*
Measure the maximum noise level from the vehicle when the engine is started.

*Benefits*
- Would be easy and quick to undertake
- Would be difficult to manipulate or evade
- Would not require a measure of engine speed

*Limitations*
- May not be suitable for roadside testing as the noise target level would be low. Therefore background noise levels could contaminate the results.

*Conclusion*
Could be a very simple solution for a test method.

**Recommended to be considered further as a test option.**
### Test 4

**Description**
With the vehicle stationary, accelerate the engine to a predetermined level (by either a fast or slow rise) then measure the maximum noise level once the target engine speed is reached.

**Benefits**
- The test would be quick and easy to undertake as it would not require an engine speed to be reached and maintained

**Limitations**
- The target engine speed must be compatible and consistent for all vehicles
- Would require an accurate and unobtrusive measure of engine speed
- The rate of acceleration will be operator dependant

**Conclusion**
Could be a useful test as it can measure when the engine is at normal operating speeds.

*Recommended to be considered further as a test option.*

### Test 5

**Description**
With the vehicle stationary, the engine is slowly accelerated to a predetermined level (e.g. 4,000 rpm) and then decreased back to idle and a measure of the average or maximum noise level over the time period is taken.

**Benefits**
- May be more realistic of vehicles in use as it would measure an average over a range of engine speeds

**Limitations**
- The test may not be very repeatable as it would be dependant on the operator
- Would require an accurate and unobtrusive measure of engine speed

**Conclusion**
Could be a useful test as it can measure when the engine is at normal operating speeds.

*Recommended to be considered further as a test option.*

### Test 6

**Description**
An extension to Test 4, with the noise level being measured at a number of engine speeds during the acceleration process (e.g. 2,000 and 3,000 rpm)

**Benefits**
- The test would be quick and easy to undertake as it would not require an engine speed to be reached and maintained
- Will give a more realistic measure of the noise level and may capture those engines that are disproportionally quiet at some speeds and noisy at others

**Limitations**
- Would require more sophisticated equipment than other test options
- The rate of acceleration will be operator dependant

**Conclusion**
Could be a useful test as it can measure when the engine is at normal operating speeds.

*Recommended to be considered further as a test option.*
### Test 7

**Description**  
A measure of noise when the vehicle is at idle, either a maximum or average level over a set time period.

**Benefits**  
- Would be easy and quick to undertake
- Would be difficult to manipulate or evade
- Would not require a measure of engine speed

**Limitations**  
- Idle speeds will vary between vehicles
- May not be suitable for roadside testing as the noise target level would be low. Therefore background noise levels could contaminate the results

**Conclusion**  
Could be a very simple solution for a test method.  
**Recommended to be considered further as a test option.**

---

### 4.4 Summary of recommendations

From the work conducted in Phase 1 the following processes were recommended:

- The adoption of UN-ECE Regulations 59 and 92, ensuring that they address replacement exhaust system parts
- The development of several stationary exhaust noise measurement techniques that could be used for roadside enforcement purposes

These stationary exhaust noise tests are examined in detail in Phase 2.
PHASE 2: Practical investigation of test methods
5 Details of the test programme

5.1 Introduction to the test programme

From the recommendations made in Phase 1 and discussions with DfT, it was decided to proceed with a test programme which concentrated on identifying excessively noisy car exhausts in order to assist the roadside enforcement of Construction and Use Regulation 54.

Section 5.2 describes the vehicle and the type of exhaust systems used in the test programme. Section 5.3 provides a summary of the measurement programme which includes artificial source noise injection and rolling road tests as well as the stationary tests recommended in Phase 1.

5.2 Vehicle and exhaust systems

The vehicle used for testing the different exhaust systems was a Ford Focus, selected for the following reasons:

- a wider range of after-market exhausts are available for this type of vehicle
- it is commonplace within the used-car market
- it lends itself to modification in terms of enhanced visual appearance.

Details of the vehicle are provided in Table 5.1 and a photograph is shown Figure 5.1.

<table>
<thead>
<tr>
<th>Table 5.1: Vehicle details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle details</strong></td>
</tr>
<tr>
<td>Manufacturer</td>
</tr>
<tr>
<td>Model</td>
</tr>
<tr>
<td>Engine</td>
</tr>
<tr>
<td>Maximum Rated Power</td>
</tr>
<tr>
<td>Year of manufacture</td>
</tr>
<tr>
<td>Mileage</td>
</tr>
</tbody>
</table>

Table 5.2 provides details of all the exhaust systems tested including the original system and a new standard exhaust system supplied by the vehicle manufacturer. For ease in reporting, each exhaust system configuration has been alphabetically labelled.
Table 5.2: Details of exhaust systems

<table>
<thead>
<tr>
<th>Exhaust system ID</th>
<th>Details of exhaust system</th>
<th>Type-approval method</th>
<th>Exhaust components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Catalytic converter</td>
</tr>
<tr>
<td>A</td>
<td>Original: Single pipe – 45 mm diameter</td>
<td>UNECE Reg. 59</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>Standard: Single pipe – 45 mm diameter</td>
<td>UNECE Reg. 59</td>
<td>X</td>
</tr>
<tr>
<td>C</td>
<td>After-market: Single pipe – 100mm diameter</td>
<td>Not known</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>After-market: Twin pipe – 75 mm diameter</td>
<td>Not known</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>After-market: Single pipe – 90 mm diameter</td>
<td>Not known</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>After-market: Single pipe – 90 mm diameter</td>
<td>Not known</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>After-market: As F + middle box</td>
<td>Not known</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>After-market: Single pipe – 100 mm diameter</td>
<td>Not known</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Patent part: Middle + Back Box Single pipe 45 mm diameter</td>
<td>UNECE Reg. 59</td>
<td></td>
</tr>
</tbody>
</table>

1 Note that in exhaust system H the middle box is connected directly to the tail pipe, without a back box, as shown in Figure A.7.
A photograph of each system is shown in Appendix A.

The selection of exhaust systems covered a wide range of different designs, both single and twin pipes, ranging in diameters from the standard 45 mm to 100 mm. The following details provide further information about the exhaust configurations.

- **Exhaust A:** This is the exhaust system that was on the vehicle at the start of the project. Due to the vehicle’s low mileage and previous history, it is considered that this exhaust is the one which was fitted when the vehicle was manufactured.

- **Exhaust B:** After initial tests were carried out on the original exhaust (Exhaust A), the whole exhaust system was replaced, including the catalytic converter, middle and back boxes, by a standard exhaust system supplied by the vehicle manufacturer.

- **Exhausts C to F:** These systems replaced the back box of the standard exhaust system (Exhaust B). The catalytic converter and middle box from the standard exhaust system (Exhaust B) were retained on the vehicle for testing. This represents the typical procedure adopted when replacing an exhaust system for the purposes of changing the sound quality or visual appearance.

- **Exhaust G:** This configuration replaced the standard middle and back boxes with after-market products.

- **Exhaust H:** Here both the middle and back box exhaust of the standard configuration (Exhaust B) were replaced. It is noted that on this exhaust system the middle box is connected directly to the tail pipe, without a back box.

- **Exhaust I:** This is a pattern-direct replacement system, (i.e. an exhaust design equivalent to that supplied at manufacture, but manufactured by a third party) and replaced both the middle and back box of the standard configuration (Exhaust B).

### 5.3 Test programme

The test programme outlined in Table 5.3 is comprised of three different test modules, which can be summarised as follows:

- **Tests using an artificial noise source (noise injection):** These tests were designed to explore the possibilities for testing without starting the vehicle engine and were undertaken with the exhaust either un-mounted (i.e. tested in a laboratory) or mounted on the vehicle as standard. These tests are reported in Chapter 6.

- **Stationary tests using the engine as the noise source:** These tests, recommended in Phase 1, were all carried out with no load on the engine and are reported in Chapter 7.

- **Tests operating the vehicle on a rolling road using the engine as the noise source:** These tests were undertaken to examine the effect load on the engine has on noise emissions and are reported in Appendix C.
## Table 5.3: The test programme

<table>
<thead>
<tr>
<th>Test</th>
<th>Exhaust system description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>Artificial noise source: Un-mounted exhaust (Laboratory)</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>Artificial noise source: Vehicle mounted exhaust</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>D</td>
</tr>
<tr>
<td>Engine noise source: Phase 1 recommended tests (Tests 2-7)</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Engine noise source: Rolling Road Dynamometer</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>D</td>
</tr>
</tbody>
</table>
6 Artificial noise source (noise injection) tests

This chapter describes a series of noise injection tests, using an artificial noise source, which were carried out to explore the possibility of developing an in-service test method which would identify excessively noisy exhaust systems without the need for starting the vehicle’s engine.

The first set of measurements was carried out in the laboratory and the second set of measurements was carried out with the exhaust systems fitted to the vehicle.

6.1 Stand-alone exhaust tests (laboratory)

6.1.1 Test procedure

For the laboratory set of measurements, a Brüel & Kjær (B&K) signal generator was used to produce white noise\(^5\). This was connected to a loudspeaker that could be easily fitted to the input pipe of the catalytic converter which was connected to the standard middle box. Figure 6.1 shows the general layout of the measurement set up.

![Figure 6.1: General layout of the measurement set up](image)

The loudspeaker (not shown) was fitted to the catalytic converter. This was then connected to the middle and back boxes of the exhaust. The microphone was positioned, in turn, at the centre of each outlet pipe on the back box. Therefore, in the case of twin bore exhausts, no measurement of the total noise level was possible.

Throughout each measurement the power output of the signal from the generator was kept constant. The microphone was connected to a CEL Type 593 sound level meter set on SLOW response with an A-weighted filter. For each measurement the average sound pressure level was recorded over 30 seconds.

6.1.2 Results

Initial measurements were carried out with no back box fitted and the noise level at the centre of the output pipe from the middle box recorded. The average noise level recorded was 93.1 dB(A). Subsequent measurements were carried out with different

\(^5\) White noise is a randomly generated signal where the energy is equally distributed across the frequency range. For these measurements the range was from 20Hz to 10kHz.
back boxes fitted and the average noise level recorded. The results of these measurements are presented in Table 6.1 and Figure 6.2.

**Table 6.1: Average noise levels recorded for different exhaust systems**

<table>
<thead>
<tr>
<th>Exhaust system</th>
<th>Average noise level dB(A)¹</th>
<th>Noise reduction provided by back box dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without back box</td>
<td>93.1</td>
<td>---</td>
</tr>
<tr>
<td>Single pipe – 45 mm diameter (Exhaust B)</td>
<td>69.0</td>
<td>24.1</td>
</tr>
<tr>
<td>Single pipe – 100 mm (Exhaust C)</td>
<td>74.7</td>
<td>18.4</td>
</tr>
<tr>
<td>Twin pipe – 75 mm (Exhaust D)</td>
<td>Centre of nearside pipe</td>
<td>71.2</td>
</tr>
<tr>
<td></td>
<td>Centre of offside pipe</td>
<td>73.2</td>
</tr>
</tbody>
</table>

¹ These numbers are an average of three measurements

**Figure 6.2: Graph showing the acoustic performance of exhaust systems B, C and D**

From these results the noise reduction offered by the standard back box, which is specifically designed for the vehicle, was 24.1 dB(A). This reduction was 2.2-5.7 dB(A) greater than that obtained using the non-standard exhausts C and D.

The above results indicate that this type of approach for assessing exhaust noise may be reasonably successful in identifying excessively noisy exhaust systems.
The application of this approach to exhaust systems when fitted to a vehicle is discussed in Section 6.2.

6.2 Vehicle-mounted exhaust tests

Unlike the previous tests carried out in the laboratory, when testing the exhaust mounted on the vehicle, it was not possible to inject the sound source directly into the catalytic converter and so an alternative approach was developed.

6.2.1 Test procedure

The test procedure involved using the signal generator to provide white noise to the loudspeaker which was placed in the engine compartment of the vehicle. The microphone, which was connected to the sound level meter, was positioned 0.5 m from the end of the tail-pipe along the centre line.

Figure 6.3: Loudspeaker positioned in the engine compartment

Figure 6.4: Position of microphone
Figure 6.3 and Figure 6.4 show the placement of the loudspeaker and the microphone respectively.

The average sound pressure levels with the sound level meter set on A-weighted SLOW response were recorded. Throughout each measurement the power output of the signal from the generator was kept constant and the bonnet of the vehicle was closed.

A second series of measurements was carried out using the “inverse” situation, where the loudspeaker was connected to the tail-pipe (shown in Figure 6.5) and the microphone positioned in the engine compartment (shown in Figure 6.6).

![Figure 6.5: Loudspeaker sealed to tail-pipe](image)

![Figure 6.6: Microphone positioned in engine compartment](image)
6.2.2 Results

The results of the measurements when the loudspeaker was mounted in the engine compartment are shown in Figure 6.7.

![Figure 6.7: Average noise levels at 0.5m from tail-pipe using loudspeaker sound source positioned in the vehicle engine compartment](image)

The results shown in the Figure indicate that the acoustic performance of the standard exhaust system is not as good when compared with systems C and D. This is contrary to the results found in the laboratory which clearly showed that the standard exhaust system B was significantly better than systems C by 5.7 dB(A) and either 2.2 or 4.2 dB(A) better than system D depending upon which outlet pipe was used for the measurement.

The most likely reason for these differences in performance is that with the loudspeaker mounted in the engine compartment of the vehicle, the sound source is not directly connected to the exhaust system. Sound propagated down the exhaust system cannot be easily held constant for different exhaust systems due to several factors which will affect how the sound from the loudspeaker enters the exhaust system. For example, differences in the thickness of the outer casing of the exhaust system will affect the level of sound propagated in the exhaust system. It is therefore concluded that this method would not be suitable for identifying excessively noisy exhaust systems.

The results of the measurements for the “inverse” situation when the loudspeaker was sealed to the tail-pipe are shown in Figure 6.8. They indicate that again, the acoustic performance of the standard exhaust system is not as good when compared with systems C and D and therefore contrary to the results found in the laboratory.

The likely reason for this difference in performance, despite the direct coupling of the sound source to the exhaust system, is that the sound propagation in the exhaust system during these tests is reversed from that conducted in the laboratory. The acoustic performance of the exhaust system is dependent on the acoustic impedance of the individual elements of each component of the exhaust system. Reversing the direction of propagation alters the acoustic impedance of these individual components.
and therefore alters the overall acoustic performance of the whole exhaust system. It is therefore concluded that this method would not be suitable for identifying excessively noisy exhaust systems when mounted on a vehicle, i.e. at the roadside.

Figure 6.8: Average noise levels in the engine compartment with the loudspeaker sound source sealed at the tail-pipe of the exhaust system
7 Engine noise source tests

This chapter describes the test procedures that were proposed from Phase 1 of the project and the corresponding results. For the purposes of consistency, the test numbers in this report follow those used in Phase 1.

7.1 Test procedure

The different tests were as follows:

- **Test 2**: The stationary noise test as specified by UN-ECE Regulation 51 test, i.e. BS ISO 5130
- **Test 3**: Measure the maximum noise level from the vehicle when the engine is started
- **Test 4**: With the vehicle stationary, accelerate the engine to a predetermined level then measure the maximum noise level once the target engine speed is reached. Two operating conditions were evaluated:
  - **Test 4a**: applied the throttle rapidly to a target speed of 5000 rpm and then the throttle was released
  - **Test 4b**: applied the throttle slowly to a target speed of 4000 rpm before the throttle was released
- **Test 5**: With the vehicle stationary, the engine was accelerated to a predetermined level and then decreased back to idle and a measure of the average or maximum noise level over the time period is taken. Four operating conditions were evaluated:
  - **Test 5a**: used a target engine speed of 2000 rpm, with a slow increase and decrease of the engine rpm
  - **Test 5b**: used a target engine speed of 4500 rpm, with a slow increase and decrease of the engine rpm
  - **Test 5c**: used a held target engine speed of 2000 rpm and the throttle was released rapidly
  - **Test 5d**: used a held target engine speed of 4500 rpm and the throttle was released rapidly
- **Test 6**: This was carried out as part of **Test 4b**, with the noise level being measured at a number of intermediate engine speeds during the acceleration process. Two different operating conditions were evaluated:
  - **Test 6a**: used an engine speed of 2000 rpm
  - **Test 6b**: used an engine speed of 3000 rpm
- **Test 7**: A measure of maximum noise when the vehicle is at idle

A single measurement position was selected for use in all of the tests. Various positions were considered for measuring the noise, e.g. 0.5 m from the nearside of the vehicle and midway between the wheels at a height of 1 m. However, the standard measurement position described in ISO 5130:2007 (BSI, 2007) for assessing noise from stationary vehicles was adopted, i.e. 0.5 m from the centre of the outlet pipe at an angle of 45°. This decision was made for the following reasons:

- Noise levels would not be affected by changes in vehicle design
- Noise levels would be less likely to be contaminated by background noise levels which is an important consideration for in-service testing
● It is an internationally recognised method which is used at type-approval. This has important implications in developing an in-service test, which will be further discussed in Chapter 6 which examines an application of the method.

In the case of the twin exhaust system, the centre of the outlet is taken midway between the twin exhaust outlets.

An important requirement for most of the tests was to be able to monitor both exhaust noise and engine speed simultaneously. Depending on the type of test, this would either allow a noise level at a given engine speed to be recorded or determine the engine speed when the maximum noise level was recorded.

A simple method for monitoring engine speed which would not require instrumenting the vehicle was developed which used the acoustic signature from the exhaust system. In a four-stroke combustion engine, an acoustic pulse is propagated through the exhaust system from each cylinder for every two revolutions of the engine. The frequency of these pulses is often referred to as the firing frequency of the engine. A frequency analysis of these pulses using a signal analyser allows the fundamental firing frequency to be measured directly and the engine speed can be calculated using the following relationship:

$$\text{Engine speed} = 120 \times \left[ \frac{\text{firing frequency}}{\text{Number of cylinders}} \right] \text{ rpm} \quad (4.1)$$

A multi-channel B&K Pulse Analyser (a real-time frequency analyser) was used to monitor both engine speed and exhaust noise simultaneously using two acoustic inputs\(^6\). Figure 7.1 shows a typical measurement layout used for all the tests carried out.

![Figure 7.1: Typical measurement layout](image)

Microphones were fitted with windshields to reduce any noise from air turbulence around the microphone which might have contaminated the recordings. Prior to and after each

\(^6\) In practice it is possible to use a single microphone to monitor both exhaust noise and engine speed depending on background noise levels. For these tests however two microphones were used in case low frequency background noise contaminated the results. The microphone monitoring engine speed was positioned close to the outlet pipe but off-set to one side so it didn’t shield the microphone monitoring the noise.
measurement session both channels of the analyser were calibrated using a 94 dB B&K microphone calibrator.

All measurements were carried out outdoors at a sufficient distance from any structures which could have affected the readings. Measurements were carried out only when weather conditions were dry and calm and when there were no other extraneous noise sources prevailing which would have influenced the measurements.

Before starting measurements the engine of the vehicle was operated for a sufficient period to allow the engine to reach normal operating temperatures.

All the tests were carried out with the clutch engaged and in neutral gear with no load on the engine.

### 7.2 Results

During each test the B&K Analyser was programmed to calculate sound pressure levels every 30 ms over a 7.5 s period. The sampling rate and time period were sufficient to measure engine speed to within an accuracy of 10 rpm over the range of interest and sufficiently long enough to capture the entire event for each test procedure. The operator carrying out each test manually triggered the analyser to start recording prior to each test and stored the information for later analysis after each test was complete. Each test was repeated three times.

![Figure 7.2: Typical output from analysis of test showing variation in noise (upper trace) and engine speed (lower trace)](image)

Figure 7.2 shows a typical output from the analysis of exhaust noise and engine speed data resulting from an ISO measurement (Test 2). In this test the engine speed is held...
at 3750 rpm prior to the throttle being released and this is illustrated by the red line in the Figure. As the engine speed drops towards 3000 rpm the properties of the modified exhaust induce a resonance in the exhaust gases resulting in an increase in the noise level. The peak noise resulting from this effect and the corresponding engine speed are highlighted in the Figure by line XX. In the case of the standard exhaust any potential resonance at around 3000 rpm has been effectively silenced and the largest resonance actually occurs at just over 1000 rpm by which time the noise levels have dropped considerably. This is highlighted in the Figure by the vertical line YY. As such the peak noise recorded during a stationary ISO measurement with a standard exhaust fitted is the noise at the start of the test when the engine speed is being held at 3750 rpm.

This procedure is typical of the analysis that was carried out for all tests. The relevant data collected from each plot was dependent on the specific requirements of each test. For most tests the peak noise level was the required metric and sometimes this resulted from a resonance peak, as with the modified exhaust in Test 2, and sometimes this was a result of a high engine speed, as with the standard exhaust in Test 2. Note that for Tests 6a and 6b noise levels were recorded at 2000 and 3000 rpm respectively during the acceleration process. The peak levels for these tests were recorded as Test 4b.

The results from each test are shown in Table 7.1. Each value is an average of three readings rounded to the nearest whole integer. Appendix B plots the data contained in Table 7.1 for each test separately.

The first column in Table 7.1 shows the results for the standard exhaust system, B, when new. The values in brackets were measured near the end of the testing period and were carried out by the same operator. For each test there is good agreement between the first and second values, generally within 1 dB(A), indicating reasonably good repeatability.

Comparing the noise levels for the standard exhaust system, B, with the pattern-direct replacement exhaust system, I, showed only a small average increase of 1.4 dB(A). Similar comparison between B and the non-standard exhausts, C to H, across all tests showed that noise levels, on average, were between 5.3 to 17.4 dB(A) higher, as indicated in the final row shown in Table 7.1. The most notable increase in noise of 17.4 dB(A) compared with the standard exhaust was from exhaust system H. This is perhaps unsurprising as this particular design of exhaust system does not incorporate a back box and has a larger bore pipe along the whole length.

To investigate which test might be suitable for differentiating between noise levels from legally compliant and excessively noisy exhaust systems, the average differences in noise levels for each test were derived and are shown in the final column of Table 7.1.

- Test 5a shows the highest difference of 11.5 dB(A) followed by Tests 2 and 4b which provide similar differences of 10.8 dB(A)
- However, if the excessively loud exhaust system H is removed from the averaging, these differences are reduced to 10.2 dB(A) and 9 dB(A) for Test 5a and Test 2 respectively
# Table 7.1: Sound power levels from the proposed Phase 1 exhaust noise tests

Maximum noise levels for Tests 2, 3, 4, 5 and 7; Noise level at 2000 rpm for Test 6a; Noise level at 3000 rpm for Test 6b

<table>
<thead>
<tr>
<th>Test</th>
<th>Standard exhausts</th>
<th>Non-standard exhausts</th>
<th>Average difference for exhausts C-H relative to exhaust B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B I</td>
<td>C D E F G H</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>72 (73)</td>
<td>82 83 81 82 77 92</td>
<td>10.8</td>
</tr>
<tr>
<td>3</td>
<td>70 (71)</td>
<td>78 75 76 73 74 87</td>
<td>7.2</td>
</tr>
<tr>
<td>4a</td>
<td>83 (85)</td>
<td>90 102(^1) 86 88 84 100</td>
<td>8.7</td>
</tr>
<tr>
<td>4b</td>
<td>74 (75)</td>
<td>80 89(^2) 81 81 80 98</td>
<td>10.8</td>
</tr>
<tr>
<td>5a</td>
<td>67 (68)</td>
<td>71 76 74 75 81 80 85</td>
<td>11.5</td>
</tr>
<tr>
<td>5b</td>
<td>79 (78)</td>
<td>80 83 84 81 81 80 97</td>
<td>5.3</td>
</tr>
<tr>
<td>5c</td>
<td>67 (68)</td>
<td>71 74 74 81 78 85</td>
<td>10.2</td>
</tr>
<tr>
<td>5d</td>
<td>78 (80)</td>
<td>79 84 84 82 81 82 93</td>
<td>6.3</td>
</tr>
<tr>
<td>6a</td>
<td>67 (68)</td>
<td>64 73 75 74 68 71 83</td>
<td>7.0</td>
</tr>
<tr>
<td>6b</td>
<td>71 (73)</td>
<td>69 78 77 78 77 75 96</td>
<td>9.2</td>
</tr>
<tr>
<td>7</td>
<td>56 (56)</td>
<td>60 60 60 61 58 61 65</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Average difference across all tests compared with exhaust B: 1.4 6.5 8.5 5.9 6.1 5.3 17.4 ---

\(^1\) Higher value the result of faster acceleration from a different operator
\(^2\) Acceleration performed up to 5000 rpm and not 4000 rpm as standard

Clearly this analysis supports several test procedures which differentiate noise levels between standard exhausts (which are legally compliant, e.g. see Section 2.1.1) and noisier exhaust systems. However, in looking to create a suitable roadside test, there are a number of reasons for adopting the Test 2 methodology over and above the Test 5a methodology:

- Test 2 requires controlling the throttle to maintain steady engine speed before rapidly releasing the throttle. This procedure is less operator dependent than Tests 5a and 4b where it is required for the operator to slowly increase the...
throttle to a pre-determined target speed and therefore, potentially influence the final result

- Test 2 is based on an internationally recognised method for assessing noise emissions from stationary vehicles and therefore more acceptable as a method for in-service testing. In fact, some countries already use methods based on ISO 5130 for in-service testing, e.g. Australia

- During type-approval testing of new vehicles, noise emission levels according to BS ISO 5130 are collected as part of the type-approval system. This information is not currently published in the UK, as agreed between the UK authorities and the type approval authorities. However, collective information for all type-approvals is published in Europe. If the in-service test was based on the same test method, then stationary type-approval noise levels have potential practical application with regard to an in-service exhaust noise test, since they could potentially form the basis of a databank which could be interrogated. This is further discussed in Chapter 8

### 7.3 Evaluation of stationary test results in relation to drive-by type approval measurements

Vehicle noise is regulated such that a vehicle only has to satisfy limit values for the drive-by test; there is no limit value for the stationary test – the value is only reported. It might therefore be considered useful if the drive-by test and the stationary test were well correlated. Previous work with only a limited dataset was reported by TRL (see Section 2.1.6) which suggested that there was no relationship between the two.

As noted in the previous section, collective type-approval information, which was not available at the time of the previous study, is now published in Europe. Using this comprehensive dataset, obtained from Kraftfahrt-Bundesamt (2007), the opportunity was therefore presented to confirm that no such relationship exists. It can therefore be concluded that drive-by type approval noise levels have no practical application with regard to an in-service exhaust noise test.

The results of this are presented in Appendix D.
8 Application of the test method and associated results

Type-approval testing prescribes noise limits for new vehicles. However, there is little information available on how vehicle noise levels change with time and it is not practical to repeat the type-approval test at the roadside.

Therefore an alternative approach/test method is required and it is considered that an in-service exhaust noise test would be a first step towards achieving this goal, as proposed in the previous chapters.

If a suitable roadside test based on the ISO 5130 type-approval stationary test method were adopted, as recommended in Chapter 7, this could potentially provide the first level of information required, i.e. stationary noise levels for exhaust systems on new vehicles.

A key requirement for the effective application of the chosen test is that it must be capable of identifying those vehicles with noisy exhausts that are perceived to be the source of noise nuisance during normal use (i.e. those that cause disturbance when passing by residential properties, etc.), not just those that are noisy during the test.

This requirement was investigated by comparing exhaust noise levels measured on a rolling road, i.e. with the vehicle operating with engine loads, gears and rpm representative of normal vehicle operation, and those measured using the ISO 5130 stationary noise levels. The results, presented in Appendix C, showed similar relationships between noise and engine speed for the two methods. However, it should be noted that these tests were only conducted for a single standard exhaust and two non-standard exhausts.

It is recognised that for an exhaust noise test to be applicable, supporting information is also required which describes the typical acoustic performance of standard exhausts over time. Since such information is unlikely to be available, it is clear that some form of databank must be established.

To address this issue, it would be necessary to undertake an extensive measurement programme of vehicles fitted with the original exhaust, an OEM exhaust or a pattern-match exhaust of various ages. Ideally at least 50 vehicles of each make/model/year would need to be tested. However, through careful selection, a reduced sample set may indicate a clear relationship between exhaust age and exhaust noise. This would help to establish the distinction between an excessively noisy after-market exhaust and an aging standard exhaust. This information would then be required to be stored in a form which could be interrogated.

The following example illustrates a prototype exhaust noise database that has been developed within the current project, based upon an Excel spreadsheet of exhaust noise data and corresponding vehicle information that has been compiled from a German catalogue of vehicle type-approval emission figures (Kraftfahrt-Bundesamt, 2007).

- The user first selects the make, model, type and age of the vehicle of interest. Existing noise data for this vehicle are then recalled and displayed in the front end interrogation dialogue box of the database (Figure 8.1) in the form of the original stationary type-approval noise level and the running average of all previously accepted results (if any) for the same car type of the same age
- The user then enters the number plate of the car being tested, the roadside location of the test and the test result
- The user can then accept or reject the test result (based on some predefined defined criteria such as being within 6 dB(A) of the running average for example)
- If the result is accepted it is stored in the database and the running average updated. If it is rejected it is stored in the database but the running average is
not updated. In this way any abnormally loud exhausts can be immediately identified and do not influence the expected level for a standard exhaust.

![Exhaust Noise Database](image)

**Figure 8.1: Example of an exhaust noise database front-end interrogation dialogue box**

This form of database could be built up through roadside testing by enforcement agencies in order to reinforce the accurate identification of excessively noisy exhausts.
9 Summary and conclusions

Presently the noise from all new road vehicles is currently controlled through the process of type-approval at the time of production. However, once a car or motorcycle is in-service there are very few accurate checks on the noise produced, and some vehicles are modified using after-market products.

DfT has commissioned TRL to review in-service noise measurement techniques in other countries and develop a simple noise measurement technique for use in the UK.

Phase 1: Initial review

A review was undertaken regarding the nature of the problem of noisy vehicles and an assessment was carried out examining methods used in other countries. The main conclusions drawn are:

- Previous work on the development of an in-service noise test was constrained by the need to correlate a test with the type-approval level
- A large proportion of complaints are due to those vehicles fitted with ‘performance exhaust systems’
- Other countries have shown little in the way of actual tests that differ from the basic principles of ISO 5130. Other areas of enforcement are concerned with subjective evaluations of the noise level
- Many different options are available to control the problem of noisy vehicles, using both process and technology
- The use of UN-ECE Regulation 59 is a key area for the control of exhaust noise
- Future trends will only make the problem worse if it is not tackled now
- Systems are in place on vehicles that may hinder, either intentionally or not, the undertaking of some in-service tests

From these conclusions and from the methods that were evaluated, it was recommended that the adoption of UN-ECE Regulations 59 and 92 should be examined, ensuring they covers all aftermarket products and components.

In addition, in order to capture those noisy vehicles currently in use and provide a means of roadside enforcement, it was recommended that a test should be developed that could be used at roadside locations for enforcement purposes. Several stationary exhaust noise measurement techniques were considered suitable for further investigation for this purpose.

In parallel with the test development, it was also recommended that further examination of datasets that relate type-approval level to the results of stationary tests is undertaken.

Phase 2: Practical investigation of test methods

A detailed measurement programme was prepared to carry out the following tasks:

- Investigate technology-based test methods using an artificial noise source
- Assess trials of six candidate test methods as recommended from Phase 1
- Examine the effect of load on differentiating noise levels between standard and non-standard exhaust systems
- Consider the potential application of the test method and associated results
Examine the relationship between type-approval drive-by noise levels and ISO 5130 stationary noise levels

The findings from this work are as follows:

**An investigation of technology-based test methods using an artificial noise source**

The technology-based test method using an artificial noise source was found to be unsuitable for further development as a roadside test. Mounting the sound source under the bonnet of the vehicle and measuring noise at the tail-pipe or reversing the procedure with the loudspeaker sealed to the tail-pipe failed to replicate the results from similar measurements carried out under laboratory conditions. The cause for this failure was due to differences in the transmission path between the noise source and the microphone as sound propagated through the exhaust system.

**Assessment trials of six candidate test methods as recommended from Phase 1.**

The six candidate test methods were used to assess the acoustic performance of 8 different exhaust systems consisting of:

- a standard system - 45mm single pipe supplied by the vehicle manufacturer
- 6 non-standard systems ranging from five with 75 to 100 mm diameter single pipes one with twin 75 mm pipes
- one pattern-direct system with a 45 mm single pipe

The six candidate test methods can be conveniently divided into five groups;

- the ISO 5130 method
- the start-up method
- rapid acceleration to a pre-determined target speed
- slow acceleration to a pre-determined target speed
- idling

When comparing the noise levels from the standard exhaust with those from the non-standard exhausts, averaged across all test methods, the noise levels from the non-standard exhausts were on average between 5.3 to 17.4 dB(A) higher than that recorded for the standard exhaust. A similar comparison with the pattern exhaust showed only a small increase of 1.4 dB(A). These results clearly indicate the poor acoustic performance of non-standard exhaust systems. The exhaust system which produced the largest difference had no back box and consisted of a straight through 100 mm single pipe.

Analysis to investigate which test method might be suitable for differentiating noise levels between standard and non-standard exhaust systems indicated that the ISO 5130 method and those involving slow acceleration to a pre-determined target speed performed best.

However, a suitable roadside test based on the ISO 5130 method is preferred for the following reasons:

- It is less operator-dependent and will therefore provide more reliable results
- It is an internationally recognised method of assessment and therefore more acceptable as an in-service test method
- A databank of stationary noise emission levels for new vehicles, based on this method, already exist which could be interrogated for the purposes of in-service testing
An examination of the effect of load on differentiating noise levels between standard and non-standard exhaust systems.

Under steady speed conditions, measurements carried out to assess the acoustic performance of standard and non-standard exhaust systems using a portable rolling road dynamometer showed that the method was suitable for differentiating noise from standard and non-standard exhaust systems providing the assessment examined noise levels in the frequency range 50 - 250 Hz i.e. the frequency range where the fundamental firing frequency occurs. Compared with similar assessments carried out under no load conditions, improvements in differentiating noise levels between standard and non-standard exhaust systems showed marginal improvements.

The results from this small study do not warrant further consideration in developing a method for in-service testing for cars but should not be ruled out when considering other road vehicles such as motorcycles.

A consideration of potential application of the test method and associated results

It is considered that an in-service exhaust noise test would be a first step towards achieving the goal of identifying noisy exhaust systems. If a test based on the ISO 5130 type-approval stationary test were adopted this would immediately provide information regarding the performance of exhaust systems on new vehicles. However an extensive measurement programme would be required to collate information on how the acoustic performance of exhaust systems changes over time.

A prototype database which could be populated through the roadside testing of enforcement agencies for this purpose has been developed.

An examination of the relationship between type-approval drive-by noise levels and ISO 5130 stationary noise levels

Results suggest that stationary noise levels cannot be used to derive type-approval drive-by noise levels. However, the ISO 5130 method is the only one which properly assesses the problem of excessive exhaust noise.

9.1 Recommendations for further work

As a result of this work the following recommendations are made:

- The adoption of UN-ECE Regulations 59 and 92 into law should be examined, ensuring they cover all aftermarket products and components
- A series of controlled pass-by tests, in which exhaust noise is measured, should be conducted and the results compared to those from a stationary ISO 5130 test to provide further evidence that the stationary test reliably identifies exhausts that sound excessively noisy to the public
- A database should be compiled to help understand the effect of exhaust age on noise so that this may be taken into account when setting future limits for a roadside test
Acknowledgements

The work described in this report was carried out in the Noise and Vibration Group of C4S of the Transport Research Laboratory. The authors are grateful to Phil Morgan who carried out the technical review and auditing of this report.

References


Appendix A   Photographs of exhaust systems

Figure A.1: Exhaust B - Standard - Single pipe – 45 mm diameter

Figure A.2: Exhaust C – After-market - Single pipe – 100 mm diameter
Figure A.3: Exhaust D – After-market - Twin pipe – 75 mm diameter

Figure A.4: Exhaust E – After-market - Single pipe – 90 mm diameter
Figure A.5: Exhaust F – After-market - Single pipe – 90 mm diameter

Figure A.6: Exhaust G – After-market - Middle + Back Box
Figure A.7: Exhaust H – After-market - Single pipe – 100 mm diameter

Figure A.8: Exhaust I – Patent part - Middle + Back Box Single pipe 45 mm diameter
Appendix B  Exhaust noise levels from individual tests

B.1 Results from Test 2

B.2 Results from Test 3
B.3 Results from Test 4a

B.4 Results from Test 4b
B.5 Results from Test 5a

![Bar chart showing maximum noise levels for different exhaust system IDs (B-I)].

B.6 Results from Test 5b

![Bar chart showing maximum noise levels for different exhaust system IDs (B-I)].
### B.7 Results from Test 5c

<table>
<thead>
<tr>
<th>Exhaust System ID</th>
<th>Maximum Noise Level (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>67</td>
</tr>
<tr>
<td>B</td>
<td>68</td>
</tr>
<tr>
<td>C</td>
<td>71</td>
</tr>
<tr>
<td>D</td>
<td>74</td>
</tr>
<tr>
<td>E</td>
<td>74</td>
</tr>
<tr>
<td>F</td>
<td>81</td>
</tr>
<tr>
<td>G</td>
<td>78</td>
</tr>
<tr>
<td>H</td>
<td>85</td>
</tr>
<tr>
<td>I</td>
<td>71</td>
</tr>
</tbody>
</table>

### B.8 Results from Test 5d

<table>
<thead>
<tr>
<th>Exhaust System ID</th>
<th>Maximum Noise Level (dB(A))</th>
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</thead>
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B.9 Results from Test 6a

MAXIMUM NOISE LEVEL dB(A)

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B.10 Results from Test 6b

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B.11 Results from Test 7

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Appendix C  Portable rolling road dynamometer tests

A key requirement for the effective application of the proposed stationary in-service noise test (the ISO 5130 test) is that it must be capable of identifying those vehicles with noisy exhausts that are perceived to be the source of noise nuisance during normal use, i.e. those that cause disturbance when passing by residential properties, etc.

This Appendix examines the use of measurements taken using a portable rolling road dynamometer.

C.1 Test procedure

The objective of these measurements was to compare the relative differences between noise levels from standard and non-standard exhausts when testing under load with those measured when testing with no load on the engine. This assists in determining the practicality of exhaust noise testing at the roadside.

In these tests, the engine was accelerated in 3rd gear up to predetermined speeds of 1000, 2000, 3000, 4000 and 5000 rpm at an average of 11.5, 26.1, 41.4, 56, 65.4 HP respectively. The noise levels were measured when the engine was running steadily at each of the chosen engine speeds. For comparative purposes, the measurements were repeated under no load conditions at the same pre-determined speeds. Analysis of the measurement data was performed using the methodology described in Chapter 7.

Figure C.1 shows the vehicle mounted on the portable rolling road dynamometer with the microphones in position.

![Figure C.1: Vehicle positioned on portable rolling road dynamometer](image)

Figure C.2 shows a more detailed photograph of the dynamometer and the rolling road.


C.2 Results

Figure C.3 shows the average noise levels when the engine was under load and operating at steady engine speeds for three different exhaust systems, B (Standard), C (100 mm diameter Single) and D (75 mm diameter Twin). Below 3000 rpm, noise levels from the standard exhaust system B are 2 to 5 dB(A) lower than the non-standard C and D. Although above 3000 rpm there is no significant difference between the exhaust systems these data are contaminated by background noise from the car engine and dynamometer.

![Figure C.3: Average noise level, dB(A), for different exhaust systems operating under steady engine speeds with engine under load](image)
For comparison Figure C.4 shows the equivalent results measured when the engine was not under load. At low engine speeds, around 1000 rpm, there is little difference in noise levels. Initially, as engine speed increases, differences in noise levels between the standard and non-standard systems become more noticeable. The maximum difference occurring at around 2000 rpm where noise levels are about 5 to 8 dB(A) higher for the non-standard exhaust compared with the standard system. As engine speed increases further towards 5000 rpm, differences in noise levels between the standard and non-standard systems becomes more variable ranging from about 1 to 5 dB(A) depending on engine speed.

![Graph showing noise levels vs. engine speed for different exhaust systems.](image)

**Figure C.4: Average noise level, dB(A), for different exhaust systems operating under steady engine speeds with engine not under load**

Results from the original exhaust system, A, have also been included in this figure. As the exhaust system ages, detritus will build-up inside the system altering the acoustic impedance of the individual elements that make-up the system. Altering the acoustic impedances will have a detrimental impact on acoustic performance resulting in higher noise levels. These results show that while the original system is louder than the standard exhaust system, particularly at low engine speeds, it does not exhibit the sharp increase in noise level between 1000 and 2000 rpm associated with the modified exhausts. The issue of dealing with old exhaust systems in the context of developing a roadside test is discussed in Chapter 8.

Comparing Figure C.3 and Figure C.4, it had been expected that there would have been greater differences in noise levels between the standard and non-standard exhaust systems when operating under load than when tested without load. As mentioned above this is a result of contamination of the measured levels in the vicinity of the exhaust outlet by the high noise levels generated by the engine under load together with the noise from the rollers of the dynamometer.
To examine this further, it was possible to reanalyse the data from exhausts B-D using a reduced frequency range of 50-250 Hz which, for the selected engine speeds, predominantly includes noise associated with the firing frequency of the exhaust and reduces contamination from other sources such as the dynamometer rollers. Figure C.5 shows the results of this analysis.

It can be seen that there are clear differences in noise levels between the standard and non-standard exhaust systems over much of the operating speed of the engine. On average, the non-standard exhaust systems were about 6 dB(A) higher, in the frequency range 50 to 250 Hz, at all but the highest engine speed.

![Figure C.5: Average low frequency (50 - 250 Hz) noise level, dB(A), for different exhaust systems operating under steady engine speeds with engine under load](image)

The results from this small study suggest that further consideration to the use of a dynamometer in conducting in-service testing for cars is not warranted. However, it should not be ruled out when considering other road vehicles such as motorcycles.
Appendix D  Examining the relationship between Type-Approval drive-by noise levels and ISO 5130 stationary noise levels

Figure D.1 shows the relationship between Type-Approval drive-by noise levels and stationary noise levels obtained from data published by Kraftfahrt-Bundesamt (2007). This analysis was only carried out for motor cars.

A regression line has been drawn through the data showing that the variance of the regression is very small, 0.08 indicating that only 8% of the variance in type-approval levels can be explained by variations in the stationary noise level.

To examine this further the same relationship was analysed for specific car types for individual manufacturers. An example is shown in Figure D.2 for diesel and petrol Volkswagens.

The results show again that there is a poor correlation between type-approval drive-by noise levels and stationary noise levels derived from ISO 5130. For diesel Volkswagen cars the variance of the regression was 0.05 compared with 0.18 for petrol Volkswagen cars.

Similar analysis was carried out on other car types from different manufacturers and again similar results were obtained.

The conclusions that can be drawn from these results are that stationary noise levels cannot be used to derive type-approval drive-by noise levels.
In addition, the results show that controlling drive-by noise levels under full throttle acceleration does not necessarily control stationary noise levels. Figure D.1 shows that for cars with a typical type-approval level of 74 dB(A) can produce stationary noise levels from about 70 dB(A) to about 105 dB(A), a range in noise levels of 35 dB(A).

Clearly, to assess noise levels derived from an in-service test method based on ISO 5130, a database of stationary noise levels is required so that appropriate criteria noise levels can be developed.
Control of vehicle noise through legislation can play a significant role in reducing the negative impact of transport on the community. Presently the noise from all new road vehicles is currently controlled through the process of type-approval at the time of production. However, once a car or motorcycle is in-service there are very few accurate checks on the noise produced, and some vehicles are modified using after-market products.

The Department for Transport (DfT) currently receive a large number of complaints about the noise from individual vehicles, focussing on noise from exhaust systems. DfT therefore commissioned TRL to review in-service noise measurement techniques in other countries and develop a simple noise measurement technique for use in the UK in order to assist roadside enforcement of Construction and Use Regulation 54.

The project was divided into two phases.

Phase 1 reviewed current literature in the subject area, performed an overall assessment of the problem, identified currently used and potentially usable in-service noise measurement techniques and assessed their suitability.

Phase 2 evaluated the recommended tests, including their relation to type-approval levels, and made further recommendations for an in-service test method that could be undertaken at roadside locations for enforcement purposes.

Other titles from this subject area:

PPR268 An evaluation of instantaneous emission models. T J Barlow, P G Boulter and I S McCrae. 2007
PPR270 Scoping study on the potential for instantaneous emission modelling: summary report. T J Barlow, P G Boulter and I S McCrae. 2007
PPR269 The links between micro-scale traffic, emission and air pollution models. P G Boulter and I S McCrae. 2007
PPR262 Primary NO₂ emissions from road vehicles in the Hatfield and Bell Common Tunnels. P G Boulter, I S McCrae and J Green. 2007