Work Order T0218 Roadside Vehicle Noise Measurements – Phase 3 Part C

Specialist Professional & Technical Services 2 (SPaTS 2) Lot 1 (March 2023)

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Executive summary

The Atkins Jacobs Joint Venture (AJJV) has undertaken research for the Department for Transport (DfT) into technologies that could be used to enable more targeted and efficient enforcement against excessively noisy road vehicles. These vehicles lead to annoyance and complaints from members of the public throughout the UK due to ‘excessive noise’ that is attributed to modified or defective exhaust systems, the use of aftermarket products and driving styles. The scope of the Phase 3 Part C of this research was focussed on assessing the performance of a noise camera in real-world conditions and reviewing and validating the noise threshold for enforcement that was proposed in Phase 3 Part A.

The Part C roadside trials were undertaken at four locations across the UK. The sites were selected from nominations made by local Members of Parliament (MPs) through a competition announced by the Secretary of State for Transport in April 2022. The sites used were in Keighley, South Gloucestershire, Great Yarmouth and Rubery and were selected to cover a variety of rural, suburban and urban areas that are known to be affected by excessively noisy vehicles.

The MicrodB ‘dBFlash’ noise camera was deployed at each of the roadside sites. This noise camera uses a microphone array and, for these trials, incorporated an automatic number plate reader (ANPR) camera. The noise camera was operated in ‘dummy enforcement’ mode (not issuing fines) to determine its effectiveness as a viable enforcement solution.

The trials took place from 18 October 2022 to 1 February 2023 with a total of 1,777 noise camera activations recorded during the trial period. Of these activations, 4% were considered attributable to excessively noisy vehicles based on the noise threshold proposed in Part B. False positives such as emergency vehicles were identified and excluded from further capture through adjustment of the noise camera’s settings where possible. The noise threshold was initially set intentionally low to capture a wide range of events and some non-noisy vehicles for comparison.

The AJJV and local residents noticed that deployment of the noise camera caused a deterrent effect, where drivers changed their behaviour at the trial sites to emit less noise or use an alternate route to avoid the noise camera. Though this reduced noise pollution close to the trial site, further consideration is required to prevent the issue from being transferred to neighbouring areas. The installation of additional units on alternate routes or use of a mobile noise camera could achieve this.

The project’s outcomes provide an objective and subjective evidence base that supports a noise level of 95 dB L_{Amax} at 7.5m being used for roads with 50 mph speed limits or lower to help inform a decision on whether enforcement action should be taken against a vehicle. Using a lower threshold would also capture vehicles which were noisy but not excessively so, requiring enforcement officers to cancel these false positives from the system manually and risking the potential of a non-offending driver being fined.

A cost benefit assessment of noise camera technologies was conducted to give an indication of the balance between upfront investment, running costs, and the number of activations that could be expected. At least two genuine noise camera activations per day would result in a cost neutral system. Mobile noise cameras could offer a more cost-effective solution particularly on local roads by targeting compliance and behavioural change over a wider area. Rising compliance over time will gradually reduce noise camera activations, but this is the objective of the technology and needs to be planned for.

1. Introduction

1.1. Background

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

The Department for Transport (DfT) is seeking to address this issue and has commissioned a number of research studies over the years to investigate excessively noisy vehicles and ways of enabling more effective enforcement. The most recent studies were Phases 1 and 2 of DfT's Roadside Vehicle Noise Measurement project, which identified automated noise cameras as a potential technological solution to address the challenges associated with roadside enforcement [2] [3]. In Phase 2, a prototype noise camera comprising a microphone, video camera, speed radar and Automatic Number Plate Reader (ANPR) was developed and tested to establish proof of concept. Since the completion of the Phase 2 study, interest in noise cameras as an enforcement tool has grown and a number of noise camera products have been tested or deployed in the UK [4], Europe [5] [6] [7], Taiwan [8] and the United States [9]. Limited information is publicly available on the performance of these products, however, including their suitability for deployment on UK roads, and which types of excessively noisy vehicle scenarios they are best equipped to address.

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

The Atkins Jacobs Joint Venture (AJJV) has been commissioned by the DfT through the National Highways SPaTS2 framework to undertake research into excessively noisy vehicles, building on the findings of Phases 1 and 2, and the latest available technologies that could be used to take action against them. The contract was awarded to the AJJV during December 2021 for Roadside Vehicle Noise Measurement Phase 3.

1.2. Project Definition

The primary aim of this project is to understand if noise camera technology can be used to automatically detect excessively noisy vehicles and enable more targeted and efficient enforcement. The use of noise cameras would enable automated collection of robust evidence to support the police and local authorities in successfully taking enforcement action against offenders (such as fines, vehicle defect rectification notices). Visible and publicised enforcement action is likely to improve public awareness of the issue and simultaneously deter drivers from generating excessive noise through certain driving styles or vehicle modification.

Phase 3 of the project comprises three distinct areas of work with the following objectives;

- Part A – Defining excessive noise
    - To investigate the advantages and disadvantages of using a single noise threshold or a set of noise thresholds for a range of vehicle types;

  - To investigate the effect of exhaust and silencer modifications on vehicle noise emissions and how these may acoustically characterise excessively noisy vehicles; and
  - To provide noise threshold recommendations, with associated tolerances, to be applied in real world driving environments that could be used by an automated system or a handheld device such as a sound level meter.
- Part B – Identifying, testing and recommending appropriate technology
  - To identify and review the latest available noise camera products to determine their suitability for UK roads and as an enforcement tool;
  - To test the performance of suitable noise camera products in controlled conditions; and
  - To develop a universal installation and deployment guide for any noise camera product that could be used by the police and local authorities.
- Part C – Roadside trials
  - To further test the performance of technology identified in Part B in real world driving environments, particularly in urban environments; and
  - Based on experience from the roadside trials, finalise the universal installation and deployment guide developed in Part B,

Parts A and B were undertaken in parallel and were completed in June 2022. The outcomes of Parts A and B are reported separately [10] [11]. Progression to Part C was wholly dependent on the successful outcomes of Parts A and B.

1.3. Part C Scope

Following the successful conclusion of Parts A and B, the DfT approved progression to Part C.The scope of Part C is limited to assessing the real-world performance of one suitable noise camera product when deployed in a roadside environment.

To meet objectives for Part C, the scope of work encompassed the following core activities:

- Selection of four appropriate locations for the roadside trials covering a variety of environments including two sites in urban contexts;
- Stakeholder engagement with local authorities and police forces;
- Identification and management of engineering constraints that could affect the trial;
- Operation of the noise camera in ‘dummy enforcement’ mode (i.e. carrying out contravention reviews as if enforcement were taking place but not issuing fines) to determine its effectiveness as a viable enforcement solution;
- Implementation and review of the noise threshold levels for enforcement recommended in Part A;
- Analysis of the noise camera data to confirm the presence of excessively noisy cars and motorcycles and to assess the noise camera’s performance; and
- Incorporation of feedback from local authorities, practical advice and lessons learned from the roadside trials into the universal installation guide.

This report discusses the research undertaken for the Part C scope of work described above. The universal installation and deployment guide, which was produced as part of Part B and updated following Part C, has been issued as a separate deliverable.

The structure of this report is as follows:

- Chapter 2 – Roadside Trial Methodology
- Chapter 3 – Trial Locations

- Chapter 4 – Roadside Trial and Noise Camera Performance
- Chapter 5 – Noise Levels of Excessively Noisy Vehicles
- Chapter 6 – Noise Levels for Enforcement
- Chapter 7 – Cost and Benefits
- Chapter 8 – Discussion
- Chapter 9 – Recommendations
- Chapter 10 – Conclusions

A glossary of technical terms used in this report is available in Appendix A.

2. Roadside Trial Methodology

2.1. Product selection

The noise camera selected for the roadside trials was MicrodB's 'dBFlash' product, which was tested during the Part B track trial. This system uses a microphone array and a reference microphone to measure vehicle sound emissions and identify the vehicle's movements as it passes through a defined detection zone. The system is a prototype that has been developed to operate automatically in roadside environments. Once activated, the system is able to compare the vehicle recording against any additional criteria (such as vehicle noise level or weather conditions) to either validate or reject an event. These additional criteria are user-definable and include wind speeds and whether events with more than one vehicle in the detection zone should be rejected. An evidence package is only generated for 'validated' noise camera activations, if a vehicle is 'rejected' the data is automatically discarded.

Following the completion of Part B, the system was further developed to incorporate one or more automatic number plate recognition (ANPR) cameras to automate vehicle identification. This differs from many existing noise camera systems, which are reliant on enforcement officers to manually discern the number plate characters from the evidence package dataset. The number and configuration of the ANPR cameras used in this trial varied as the trial progressed.

The system can be mounted to upright infrastructure assets, such as lighting columns or CCTV masts. The desirable mounting height is approximately 5 metres for the microphone array and approximately 3 metres for the ANPR camera.

The product was selected based on the product's specific capabilities, the outcome of the Part B track trial and the suppliers' ability and availability to participate in the roadside trials, as well as the potential for the identified product to further the project's understanding of noise camera technologies.

2.2. Noise camera operation and data collection

2.2.1. Pre-trial planning and stakeholder engagement

Following discussions with the relevant stakeholders, the AJJV completed the necessary pre-trial arrangements linked to the installation, commissioning, operation and decommissioning of the noise camera at each site. The requirements varied from site to site but generally comprised the following activities:

- Agreement with stakeholders on the exact trial location and how the noise camera system would be powered and mounted;
- Agreement on the trial dates and details of any local publicity planned alongside the trial;
- Obtaining the required permits, consents and approvals for the noise camera system. This included road-space, consent from street furniture / lighting engineers at the Local Authority, traffic management while the noise camera is installed/removed;
- Risk assessments for the installation and operation of the noise camera incorporating review/feedback from stakeholders; and
- Notifying the local police force of the noise camera's position and trial dates.

The identification and agreement of a suitable existing asset to attach the noise camera to was a significant aspect of progressing the trial arrangements. The assets needed to be at least 5m in height, contain a power source and be sufficiently stable to support the weight of the noise camera without causing damage to the asset. The local authorities at each of the trial sites identified and consented to the use of existing street lighting columns or CCTV masts for the roadside trial, for both mounting and powering the noise camera, or completed necessary enabling works to allow the trial to take place at the location.

2.2.2. Installation and decommissioning

A detailed plan for the installation of the noise camera was formed taking into account the noise camera's installation requirements and the site conditions and constraints. This included consideration of power supplies, data connections and permits required to install and operate a noise camera. The AJJV engaged with the participating local authorities and police forces throughout the site commissioning process and worked with the noise camera supplier and installation subcontractors (where required) to install the noise camera at the identified sites. One noise camera was installed at each location. The noise camera was handled, installed, calibrated and removed from the trial sites by MicrodB.

Commissioning tests were undertaken once the noise camera was installed, which included observing a number of standard vehicle passes using the camera with the noise threshold set artificially low to check that the system was collecting and transmitting data correctly. Once the commissioning tests were completed, the noise camera's settings were adjusted to use the agreed noise trigger.

2.2.3. Operation

Once commissioned, the noise camera was operated in 'dummy enforcement' mode to determine its effectiveness as a viable enforcement solution. The noise camera was deployed for a defined period to allow it to collect data. The dummy enforcement approach meant that no 'live' enforcement took place during the trial using the data collected and that the local authority and police were not involved in the data collection or review process. No additional vehicle or driver information was collected relating to the vehicles triggering the noise camera to supplement the noise camera dataset.

Establishing that an offence has taken place

Reviewing the captured data and video records and attempting to satisfy an enforcement officer that, on the balance of probabilities, an offence has taken place and that it is unambiguously possible to identify the offending vehicle.

Preparation of an evidence pack

Using the captured data and video records from the noise camera to prepare example packages of information (evidence packs) which demonstrate that an offence has taken place and that the captured vehicle is an offending vehicle.

Export of a contravention record

Exporting the captured data and video records to example packages that could, in the future, be sent to a member of the public to demonstrate that their vehicle has exceeded the pre-set noise threshold.

Figure 2-1 Dummy enforcement steps

Monitoring visits were undertaken to collect ground truth data to compare against the data collected by the noise camera to support the dummy enforcement. The time periods of the monitoring visits were selected based on recommendations from local stakeholders on when excessively noisy vehicles were most likely to be found. The three steps in a dummy enforcement session are shown in Figure 2-1 and were attempted for each trial site, with the first step being the main focus for this trial.

When noise-activated by a potential excessively noisy vehicle, the noise camera collected the noise levels attributed to individual vehicles, the vehicle's number plate, a still image, an audio clip and a video clip. This information comprises the 'evidence package' that would be transmitted to an enforcement officer for review.

If the pre-set noise threshold was not exceeded by a passing vehicle, the noise camera did not activate or transmit any data for processing. The noise camera supplier compiled a separate list of vehicles that were rejected by the noise camera and their corresponding noise levels. This additional information was used to support the data analysis and understanding of how the noise camera functions. No images, audio or video data were collected for the rejected vehicles.

2.2.4. Data transmission and storage

The noise camera collected the raw data and processed it within its internal computer to generate results files. The computer's hard disk was encrypted for data security. The processed data was transmitted from the noise camera to a server using a secure connection, and was transmitted at least once per day. Once the data was transmitted, it was deleted automatically from the noise camera's internal storage.

The noise camera transmitted the following datasets: noise level information (spreadsheet and graphs), an audio file, an image of the vehicle, an image or text file of the vehicle's number plate (from the ANPR) and a video clip of the vehicle.

The transmitted noise camera data was stored by the project on an access-restricted secure server.

2.2.5. Data privacy consideration

The information collected by the noise camera is considered as a form of personal data as it could be used to identify an individual.The project did not use the personal data collected from the trial to identify individuals.

The AJJV completed a Data Privacy Impact Assessment and Risk Register prior to commencing the roadside trials, that were reviewed on a regular basis. The mitigation actions identified in these documents were implemented before, during and after the trial to minimise risks associated with personal identifiable information collected by the noise camera.

Other than reviewing the quality of the ANPR data collected, no further processing of the ANPR data was undertaken.

When the noise camera data were collated for each trial site for analysis, the number plate data was converted to a unique tag that cannot be reverse engineered to give the number plate. If a vehicle activated the noise camera more than once, the same unique tag was assigned each time.

The noise camera was installed with a data privacy notice attached beneath the noise camera to explain the purpose of the trial to stakeholders and to allow drivers who do not wish to participate in the trial to have their data omitted, removed or sent to them in line with GDPR. No GDPR-related enquiries were received during the trial period and no trial data are excluded for this reason.

2.2.6. Noise threshold triggers

The noise threshold trigger is a noise level that is set within the noise camera to determine when a data package is captured for a particular vehicle. This data package is then analysed to determine whether the vehicle could be considered as excessively noisy. The noise threshold trigger level at each trial site was initially identified during the commissioning process by monitoring the noise level of a standard vehicle passing the noise camera. The AJJV then altered this initial threshold trigger level as needed after a few days of monitoring with the intention of only capturing noisy and excessively noisy vehicles. Further alterations to the noise trigger were made if too little data or too many vehicles that were not excessively noisy were being captured.

2.3. Data analysis

2.3.1. Review of evidence package contents

The evidence package collated by the noise camera for each excessively noisy vehicle comprised audio and video clips accompanied with measured noise levels and still images of the top and rear of the detected vehicle. Number plate information from the ANPR camera is also included in the evidence package.

For each noise camera activation, key data were extracted from the evidence package. These data included:

- The date and time of the noise camera activation;
- The vehicle type activating the noise camera and the number and types of vehicles shown within the detection zone;
- The position of the detected vehicle within the detection zone (the traffic lane the detected vehicle was using);
- The detected vehicle’s number plate;

- The pass-by noise level (dB L_{Amax}) of the detected vehicle in the frequency ranges 200 Hz to 6 kHz and 50 Hz to 20 kHz, noting that the noise camera corrects measured noise levels for distance and the results are expressed at the type approval reference distance of 7.5 metres from the road lane's centreline;
- Audible vehicle noise characteristics; and
- Road and weather conditions.

Any car or motorcycle with measured noise levels above 80 dB L_{AFmax} was analysed for excessively noisy characteristics. This was carried out by listening to the audio files provided in the evidence packages. The vehicle noise characteristics were as follows:

- Exhaust noise – varied noise produced by the exhaust of a vehicle, can be high or low frequency depending on the vehicle;
- Engine noise - tends to be a mid-range frequency noise, generated by induction of air into the engine;
- Pops and bangs - engine remapping which puts excess fuel into the hot exhaust causing it to combust, generating an impulsive sound like a gunshot and provides a distinct rumbling;
- Acceleration – vehicle noise can be heard to increase in frequency as the speed of the vehicle increases;
- Antisocial driving – vehicle noise generated by antisocial driving style which causes excess disturbance, such as wheel spin.

The audio files in the evidence package were listened to in order to determine if the vehicle was excessively noisy. If the vehicle was deemed to be excessively noisy, the two most prominent of the above characteristics were assigned to it.

As the audio in the files provided was normalised, it was not possible to assess the absolute noise level of the vehicle aurally from the evidence package. Further analysis was undertaken using maximum noise levels stated in the evidence package, audio characteristics of the vehicle, knowledge and experience gained from site visits and track trials.

2.3.2. Validation of noise camera activations

The trial data and ground truth data were compared to assess the noise camera's performance at each of the trial sites, and its ability to complete the dummy enforcement steps shown in Figure 2-1. The key focus of the analysis was on the first step, where the noise camera activations and corresponding evidence packages were reviewed to determine whether the system correctly captured cars and motorcycles subjectively identified as excessively noisy. The data were also reviewed to determine if the sources of excessive noise were identifiable within the evidence package, give confidence that the correct vehicle was identified, and whether the excessive noise could be attributed to adverse driver behaviour.

Occurrences where the noise camera activations were not found to correspond to excessively noisy cars or motorcycles (false positives) were identified and discussed with MicrodB if further explanation was required.

To support the validation of noise camera data, ground truth data from monitoring visits were compared with noise camera activations to confirm that excessively noisy vehicles were successfully able to activate the noise camera. This activity was also undertaken to identify situations resulting in false negatives, where an excessively noisy vehicle was observed during the monitoring visit but was not detected or was 'rejected' by the noise camera. At least one monitoring visit was undertaken for each trial site during time periods where excessively noisy vehicles are most likely to be prevalent according to local stakeholders. The site visits comprised noise measurements and subjective assessment of whether cars and motorcycles passing the noise camera were excessively noisy.

During Part A [10], it was found that personal perception of the vehicle was influenced by the driving style as well as noise level. Instances were identified in both the track trial and roadside trial where vehicles were perceived as excessively noisy, but had noise levels lower than 95 dB L_{AFmax}.

Noise monitoring equipment was positioned at approximately the same distance from the road as the noise camera but at a height of 1.5 metres. The noise measurement equipment was set up to record 1 second data comprising 1/3 octave band spectra and L_{AFmax} data for the duration of the site visits.

The noise monitoring measurement data was cross-referenced with the validated and rejected vehicles data provided by the noise camera. Distance calculations were undertaken on the ground truth noise monitoring equipment to align measurements with the noise camera data at the reference distance of 7.5 metres. The maximum noise level of the vehicle pass-by was exported from the noise measurements and compared to the noise camera’s rejected vehicle data, the reasoning for the vehicle’s rejection was evaluated.

The quality and format of the evidence packages generated automatically by the noise camera were reviewed to complete the second and third steps of dummy enforcement, which relate to evidence package preparation and exporting a contravention record.

2.3.3. Noise threshold validation

The roadside trial data adds to the evidence base collected from previous trial phases to further inform the suitability of one or more noise limits for enforcement against excessively noisy vehicles. The roadside trial data were analysed to review, and if necessary, update the recommendation made in Part A [10] that 95 dB L_{AFmax} is a suitable noise limit for enforcement. This was undertaken by ascertaining the causes of noise levels above 80 dB L_{Amax} at 7.5 metres using information provided in the evidence package generated for each noise camera activation and ground truth data where available.

3. Trial Locations

3.1. Site selection

The roadside trial sites were selected through an application process announced by the Secretary of State for Transport during April 2022 [12]. Members of Parliament (MPs) were invited to nominate a suitable location in their constituencies where the roadside trial could take place, and to provide technical and contextual information to support the application. This information included:

- The proposed trial site location and local conditions;
- The availability of suitable existing street furniture to install and power the noise camera;
- Willingness of the local authority, local highway authority and police to be proactively involved in the trial and gain experience using the technology;
- Evidence of the applicant/relevant stakeholders being able to work together to ensure that the noise camera trial can take place within the designated trial period;
- Ability for the trial to take place at the nominated location during Autumn/Winter 2022;
- The scale and type of excessively noisy vehicle problem at the nominated location; and
- Previous actions taken to tackle the issue.

A copy of the application form issued to MPs is available in Appendix C.

A total of 75 applications were received, representing a variety of rural and urban contexts. The AJJV reviewed and scored each application to allow the sites to be ranked based on these criteria:

- The type of vehicle noise problem described in the application and the likelihood of excessively noisy vehicles being present during the trial period;
- Whether the applicant/relevant stakeholders have taken action to reduce or resolve the problem in the past;
- Willingness of the applicant/relevant stakeholders to provide support with making arrangements for the noise camera trial and to be proactively involved while the trial is taking place;
- Road layout at the proposed trial location;
- Ability to use existing infrastructure and street furniture for powering and installing the noise camera to minimise costs;
- Quality of information provided in the application (to enable immediate action to be taken to progress trial arrangements);
- Potential for additional constraints that could delay or prevent the trials taking place at the proposed location;
- Potential for the information provided to introduce uncertainty or additional project risks; and
- Whether the trial could genuinely bring about a meaningful positive change.

Unsuitable sites were not taken forward for further consideration. This included sites affected by general traffic noise (like motorways) rather than single events of excessive noise, sites with significant installation constraints, or where the situation described by MPs would not reduce technical uncertainties or risks identified in the previous project phases.

The 12 best-scoring applications were shortlisted for further consideration. Four of the shortlisted areas were taken forward for the trial, taking into account further information provided by the local authority and police stakeholders and the trial objectives. Consideration was also given to testing the noise camera in a selection of environments, with at least two sites in urban contexts, and enabling multiple stakeholders to gain experience of using the technology by trialling the noise camera in different local authority or police areas.

3.2. Selected sites

Twelve of the nominated trial locations were shortlisted from the applications received, covering a mixture of rural, urban and suburban environments. A description of the shortlisted sites is provided in Table 3-1.

Table 3-1 Shortlisted trial sites

Location of shortlisted trial site	Location type	Description of issue described in the MP application
Southend	Urban, seafront	Frequent destination for anti-social driving by drivers of modified vehicles and motorcycles, particularly at weekends. Car cruises take place regularly.
Great Yarmouth	Urban, seafront	Frequent destination for drivers of modified vehicles. Car and motorcycle enthusiasts often congregate which regularly leads to anti-social behaviour and inappropriate use of the highway.
Eastbourne	Suburban, seafront	Destination for drivers of modified vehicles, particularly cars. Excessive vehicle noise has resulted from speeding, “racing”, illegal manoeuvres and car meets.
A29 Bury Hill, South Downs	Rural	Regular visits by motorcyclists from across the area. 70% of speeding vehicles are stated as being motorcycles.
A272 Halfway Bridge, South Downs	Rural	Road noted as being popular with motorcyclists due to the site layout.
Cheddar Gorge	Rural	Frequent destination for drivers of modified vehicles, particularly cars. Various driving styles also described.
A44 Fish Hill, Broadway	Rural	Anti-social and unsafe driving from motorcyclists. The area is popular with motorcyclists due the site layout and topography.
Keighley	Suburban, rural	Anti-social driving from modified cars on residential streets and town centre roads in the late evenings and early mornings.
Rubery	Urban	Modified cars and motorcycles use the high street regularly, where they race and rev their engines.

Milton Keynes	Urban	Weekly car cruises take place with modified vehicles and different driving styles reported, sometimes on private land.
A4174 Bristol Ring Road, Barrs Court	Suburban	Cars and motorcycles with modified exhausts noted as occurring regularly.
A34 bypass at Wilmslow	Urban	Modified cars and supercars racing along section between roundabouts causing disturbance to over a third of the local area. Location with considerable amount of stakeholder complaints.

Following further review and discussions with stakeholders, the four locations taken forward for the roadside trials were:

1. Keighley, to represent a typical residential street in a suburban or rural setting;
2. A4174 Bristol Ring Road, to represent locations affected by noisy vehicles on dual carriageways or motorways;
3. Great Yarmouth seafront, to represent an urban environment in an exposed seafront location, and a destination for some with noisy vehicles; and
4. Rubery, to represent an urban location in area of mixed residential and commercial use.

All four sites had the support from local authorities for potential roadside trials in their area. The majority of the sites were noted as having concerns from both cars and motorcycles.

Table 3-2 Selection rationale

Trial site	Justification for selection
Keighley	The site is considered representative of a residential environment in a suburban or rural setting. As the site is located on a straight downwards sloping road, there is an increase in the likelihood of vehicle acceleration passing the site when travelling eastbound due to the roads downhill nature. Local residents have complained about drivers of modified vehicles deliberately making excessive vehicle noise in the past. The absence of major roads or any other dominant noise sources in the surrounding area means that the site has a low ambient noise level, providing a noise climate similar to the testing during Part B.
A4174 Bristol Ring Road, Barrs Court	The site is considered representative of locations affected by excessively noisy vehicles on dual carriageways and motorways. This would provide a challenging environment to test the noise camera due to higher ambient noise levels close to the road and the presence of more than one lane of live traffic in the noise camera’s detection zone. The site was considered to have good potential for capturing noisy vehicles due to the high traffic flow, reports of noisy vehicles from several sources, and its location after a roundabout being where harsh acceleration is more likely to occur to speed up to the roads speed limit of 50 mph.
Great Yarmouth seafront	The site is considered representative of an urban environment at a seafront location, which can be attractive destinations for anti-social driving and creating excessive vehicle noise. Car meets occasionally take place at car parks close to the seafront, attracting a wide variety of modified and

Trial site	Justification for selection
	excessively noisy vehicles. The site has a straight and flat road where sharp acceleration is possible. It is in an open and exposed setting that may experience higher wind speeds than the other trial sites. The local authority and police force have received complaints about excessively noisy vehicles from local residents and have proactively worked to resolve the issue.
Rubery	The site is considered representative of an urban location in a mixed-use area due to the presence of shops and residential properties at the trial site. Speeding, anti-social driving and excessively noisy vehicles have been reported in this area. The site is adjacent to a traffic light controlled junction and has a more complex road layout, providing a challenging environment for the noise camera.

Detailed descriptions of each of the four trial sites are provided in the following subsections.

3.3. Site 1: Keighley, Bradford

Site 1 is located at an edge-of-town location in Keighley, West Yorkshire. The site has predominantly residential land use to the south and predominantly agricultural land use to the north, with some residential use. The site is on Fell Lane, an unclassified road leading out from central Keighley to the surrounding rural area. The location of the noise camera covered both sides of the road, capturing vehicles travelling in both directions. At times throughout the trial, there were vehicles parked on the roadside in front of the camera. The width of the road meant that vehicles overtaking the parked cars were still captured by the noise camera.

The site is surrounded by minor unclassified residential roads with no significant noise sources in the vicinity. A map of the site location is shown in Figure 3-1 below.

Figure 3-1 Noise camera trial location at Keighley

Fell Lane itself was therefore noted to be the primary noise source within the immediate area. The surface of Fell Lane is asphalt that was in a generally good condition, with no visible imperfections along the section of the road chosen for the trial.

In between vehicle pass-bys, non-road related noise sources were more prominent such as rustling trees, birdsong and agricultural noise. Noise from these sources was however significantly lower than that experienced during vehicle pass-bys.

The noise camera itself was installed on lighting column number 35, on the eastbound side of the road. The lighting column is located between the junction with Low Fell Close and the “Fell Lane Prospect Mount” bus stop. The trial site was located on a reasonably straight part of a downwards sloping road for traffic heading eastbound, increasing the likelihood that sharp acceleration may occur at this location. The noise camera was deployed between Thursday 3rd November and Tuesday 8th November 2022. It was not cordoned off in any way but did include a notice at ground level explaining the purpose of the equipment and contact details in case of queries or an emergency. An image of the site set-up is included in Figure 3-2.

Figure 3-2 Noise camera installed at Fell Lane, Keighley

3.4. Site 2: A4174 Bristol Ring Road at Barrs Court

Site 2 is located adjacent to a dual-carriageway location on the A4174 Bristol Ring Road. The site is located on the northbound carriageway approximately 175 metres after the Kingsfield Roundabout. The noise camera was mounted to a pole located approximately 1 metre away from the nearside lane, and behind a safety barrier. The noise camera's detection zone was limited to both lanes of the northbound carriageway only. The site is in a narrow cutting with only one significant ambient noise source, the road traffic noise from the southbound carriageway. A map showing the site location is shown in Figure 3-3.

Figure 3-3 Noise camera trial location at the A4174 Bristol Ring Road

The road is surfaced in asphalt, which was in a generally good condition, with no visible imperfections along the section of the road chosen for the trial. The northbound and southbound carriageways of the road are separated by a central reservation approximately 1.5 metre wide with a metal central crash barrier.

In addition, the site is approximately 130 metre after a change in speed limit from 30 mph to 50 mph, further increasing the likelihood of sharp acceleration and anti-social driving occurring.

The noise camera was sited in a location not accessible to pedestrians, with no pavement or other dedicated pedestrian infrastructure. An image of the site set-up, taken from a nearby pedestrian bridge, is shown in Figure 3-4.

Figure 3-4 Noise camera installed at the A4174 Bristol Ring Road. Photo taken from nearby pedestrian bridge; noise camera highlighted in red box.

3.5. Site 3: Great Yarmouth

Site 3 is located in a seafront location at the eastern boundary of St Nicholas Car Park in Great Yarmouth, Norfolk. The site has the large South Beach Parade Car Park to the west, with South Beach Parade itself, leisure attractions and South Beach to the east of the trial site. Due to the road layout, the noise camera's detection zone was limited to the northbound carriageway of South Beach Parade. The road is classified as a C-road and is one of the main seafront roads in Great Yarmouth. South Beach Parade is a straight and flat road where sharp acceleration is possible.

The site is surrounded by public car parking and residential use to the west. St Nicholas Car Park and the adjacent leisure attractions to the east were closed during the trial. A map of the site location is shown in Figure 3-5 below.

Figure 3-5 Noise camera trial location at Great Yarmouth

South Beach Parade itself is therefore not the main source of noise in the immediate vicinity, however excessively noisy vehicles can cause it to become the main source of noise. The surface of South Beach Parade is asphalt that was in a generally good condition, with no visible imperfections along the section of the road chosen for the trial. The northbound and southbound carriageways of the road are separated by a central reservation approximately 1 metre wide containing planting, with hard kerbs on both sides. The added distance from the noise camera location resulting from this central reservation means that the noise camera is only able to monitor the northbound carriageway.

The noise camera itself was installed on a CCTV column located within South Beach Parade Car Park, but adjacent to the northbound carriageway of South Beach Parade. The CCTV column used was located approximately 3 metre from the edge of the northbound carriageway. It was not cordoned off in any way but did include a notice at ground level explaining the purpose of the equipment and contact details in case of queries or an emergency. Images of the site set-up are shown in Figure 3-6.

Figure 3-6 Noise camera installed at the Great Yarmouth trial site

3.6. Site 4: Rubery, Birmingham

Site 4 is a town centre location on New Road in Rubery, which acts as the neighbourhood centre of the local area. New Road contains retail, leisure, services and medical facilities but is not a significant through road, having been bypassed by the nearby A38 dual carriageway. It has a 30 mph speed restriction, some parking restrictions, and is classified as a C-road indicating that it is a more important minor road. New Road is long and straight and has potential for speeds in excess of the posted speed limit.

The site is in a busy location for both vehicles and pedestrians. This combined with the wide range of land uses near to the site means there is a diverse background noise. The effects of these background sources on the noise camera are minimal. There is also a small background noise level of traffic noise from the A38 dual carriageway, approximately 90m away from the trial location. This is only minor and is unnoticeable at the noise camera site, therefore not affecting the operation of or results from the noise camera. A map of the site location is shown in Figure 3-7.

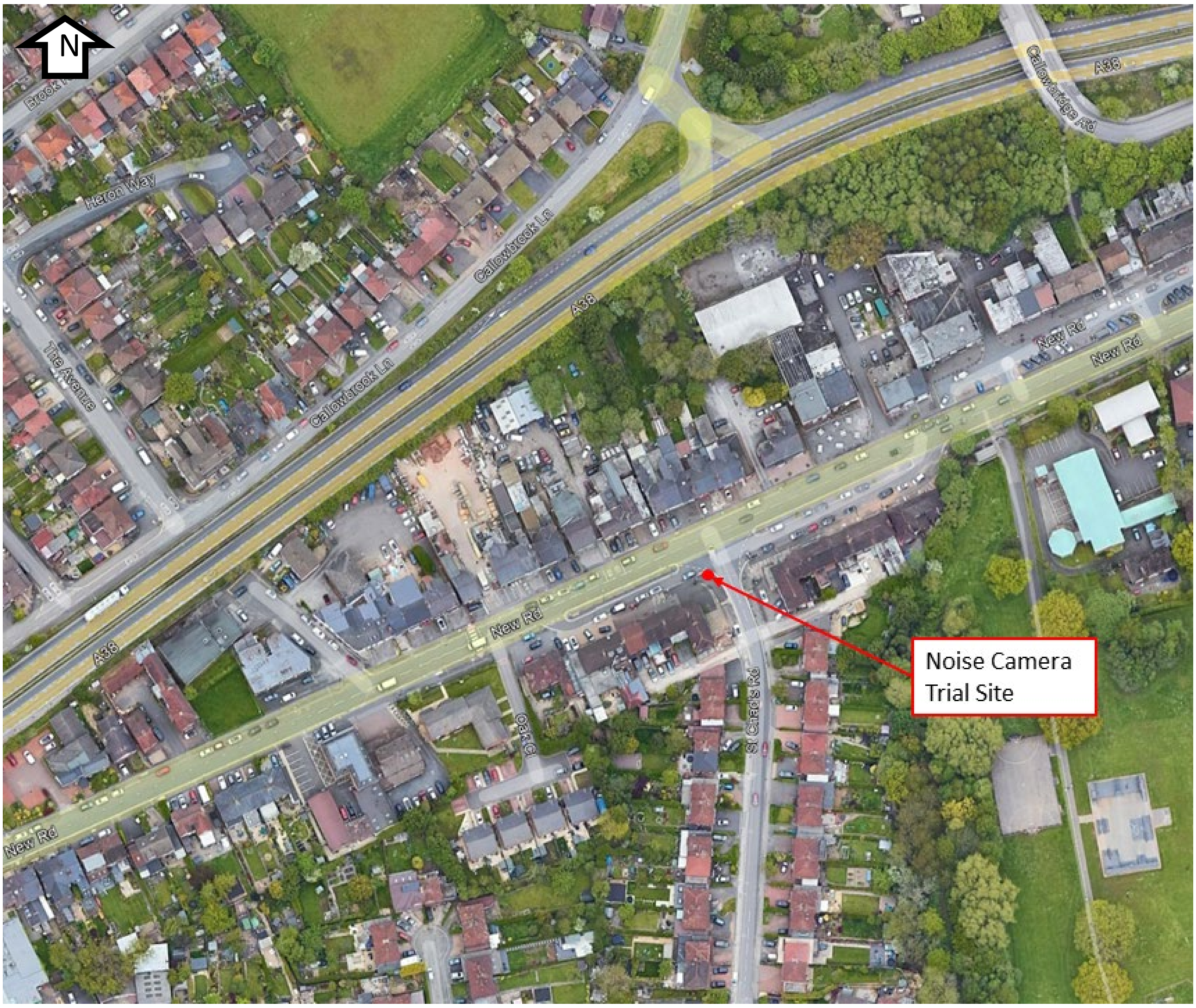

Figure 3-7 Noise camera trial location at Rubery

The noise camera itself was located on a CCTV column at the junction of New Road and St Chads Road. It was positioned to face towards New Road, therefore primarily picking up vehicles travelling along New Road; however, it was also able to detect some vehicles on St Chads Road at the point where it meets New Road. Regular vehicle parking on the side of New Road opposite the camera reduced the road width most of the time, resulting in the noise camera being able to pick up vehicles travelling both eastbound and westbound along New Road.

Although the noise camera and associated equipment was not cordoned off, it was located sufficiently high up on the CCTV column for it to not be at risk of vandalism. The CCTV camera associated with the column also helped to reduce the risk of the equipment being tampered with. The site set-up included a notice at ground level explaining the equipment and the trial. An image of the site set-up is shown in Figure 3-8 below.

Figure 3-8 Noise camera installed at Rubery trial site

4. Roadside Trial and Noise Camera Performance

4.1. Summary of trial dates and noise camera data

The sequence of events and data collection activities that took place during the trial is shown in Table 4-1.

Table 4-1 Key trial milestones and noise threshold triggers used

Site	Trial Dates	Threshold Start Time	Threshold end date	Noise Threshold Trigger Level at 7.5m (dB L_{Amax})
Site 1: Keighley	18 October 2022 to 8 November 2022	Installation	21 October 2022 at 13:00	70
		21 October 2022 at 13:00	End of trial	75
Site 2: A4174 Bristol Ring Road	9 November 2022 to 29 November 2022	Installation	11 November 2022 at 15:00	83
		11 November 2022 at 15:00	18 November 2022 at 15:00	88
		18 November 2022 at 15:00	End of trial	85
Site 3: Great Yarmouth	30 November 2022 to 17 January 2023	Installation	2 December 2022 at 14:00	78
		2 December 2022 at 14:00	9 December 2022 at 16:00	70
		9 December 2022 at 16:00	5 January 2023 at 15:00	72
		5 January 2023 at 15:00	End of trial	80
Site 4: Rubery	18 January 2023 to 1 February 2023	Installation	End of trial	78

As shown in Table 4-1, the noise camera was trialled between 18 October 2022 and 1 February 2023. The trial durations were 21 days at Site 1, 20 days at the Site 2, 49 days at Site 3 and 14 days at Site 4.

The number of noise threshold trigger levels tested at each trial site and the noise level selected for each were influenced by the trial duration and local conditions. For example, the highest threshold noise levels were tested at Site 2 due to higher ambient noise levels at its deployment site adjacent to a dual carriageway.

Table 4-2 shows the number of noise camera activations during the roadside trial at each site. The corresponding average daily traffic flows are also shown for each site to provide context and were estimated from traffic count data provided by the noise camera (successful activations and rejected vehicles). The row in the table showing activations from all vehicle types includes activations from cars, from motorbikes and from other types of vehicle which are not part of this study.

Table 4-2 Summary of Trial Data

	Site 1 - Keighley	**Site 2 – A4174 Bristol Ring Road**	**Site 3 – Great Yarmouth**	**Site 4 - Rubery**	**Total**
Estimated daily estimated traffic flow during trial period (all vehicle types)	1,970 vehicles/day	11,420 vehicles/day	1,815 vehicles/day	2,920 vehicles/day	18,125 vehicles/day
Number of verifiable noise camera activations (all vehicle types)	54	266	1,429	28	1,777
Noise camera activations from cars	14	197	1,134	19	1,364
Noise camera activations from motorcycles	6	35	55	3	99
Excessively noisy cars	5	43	0	2	50
Excessively noisy motorcycles	0	24	2	0	26

At Site 1, 54 vehicles activated the noise camera, where 20 of those were cars or motorcycles and the rest were false positives (further explanation can be found in Chapter 4.2.2). At Site 2, 266 vehicles activated the noise camera, where 197 were cars and 35 were motorcycles. At Site 3, 1,429 vehicles activated the noise camera, where 1,134 were cars and 55 were motorcycles. Lastly, at Site 4, 28 vehicles activated the noise camera, where 19 of those were cars and 3 were motorcycles, with 6 false positives.

In total, the noise camera was activated 1,777 times. The total noise camera activations consist of approximately 82% vehicle detections and the other 18% represents the false positives. The number of verifiable noise camera activations were split between 77% cars and 6% motorcycles. The remaining 17% of verifiable activations were from vehicles that were not cars or motorcycles, such as lorries, construction vehicles or buses.

4.2. Dummy enforcement – data validation

4.2.1. Comparison with ground truth data

As set out in Chapter 2.3.2, a site visit was conducted at each roadside trial location where noise monitoring was undertaken by the AJJV alongside the noise camera. The data collected from the site visit were distance corrected to 7.5 metres distance to allow comparisons with the normalised data from the noise camera, and make comparisons with the noise camera activations and rejected vehicle records. Table 4-3 shows when the AJJV site visits occurred at each trial site.

Table 4-3 Dates and times of ground truth data collection

Trial site	Date	Time Period
Site 1	Tuesday 25 October 2022	17:00 – 21:00
	Wednesday 26 October 2022	07:00 – 09:00
Site 2	Tuesday 22 November 2022	08:00 – 10:30
Site 3	Sunday 11 December 2022	18:00 – 19:30
	Monday 12 December 2022	07:00 – 09:00
Site 4	Thursday 26 January 2023	18:00 – 22:00

There were several instances during the site visits where the noise camera did not detect a noisy vehicle. Two vehicles monitored at the Site 2 were subjectively assessed to be excessively noisy, this was confirmed when comparing the site notes with the noise monitoring data analysis. Table 4-4 shows a sample of the vehicles observed from the ground truth data collected from the monitoring visits with the corresponding noise camera datasets. The full dataset can be found in Appendix D.

Table 4-4 AJJV attended site visits noise monitoring and noise camera noise level comparison

Site	Date	Time (hh:mm:ss)	Vehicle Type	Measured Noise Level (dB L_{AFmax}, 50 Hz to 20 kHz)	
				Ground truth	Noise camera
1	25/10/2022	18:19:47	Car	76.6	65.1
	26/10/2022	07:42:08	Car	85.3	66.3
2	22/11/2022	08:47:32	Motorcycle	83.8	93.4
		09:43:52	Modified car (with pops and bangs)	88.6	90.4

3	11/12/2022	18:34:32	Car	74.7	66.7
	12/12/2022	07:50:04	Modified car	76.9	68.4
		07:38:11	Van	78.9	No data
		08:20:46	Modified car	82.3	No data
4	26/01/2023	19:05:28	Car	85.1	73.5
		20:03:29	Car	72.8	72.9
		20:04:54	Car	77.6	76.8

At Site 4 there were two instances where the noise camera's vehicle noise data correlated with the ground truth data, as seen in Table 4-4 on 26 October (20:03 and 20:04).

Table 4-4 shows several instances where the ground truth vehicle noise levels were higher than the values reported by the noise camera. An example of this is on 12 December at 07:50, where the ground truth vehicle noise level was 76.9 dB L_{AFmax} and the noise camera measured 66.7 dB L_{AFmax}. This occurrence at Site 3 should have activated the noise camera but did not. The difference between the ground truth level and noise camera level may be due to an inaccuracy of the noise level in the rejected vehicle files from the synchronisation of rejected data in the noise camera.

At Site 2 there were two instances of validated excessively noisy vehicle activations occurring at the time of the AJJV site visit. An example of this is shown in Table 4-4 on 22 November at 08:47:32 where the noise camera noise level is 93.4 dB L_{AFmax}. Also at Site 2, a modified vehicle with a noticeable pops and bangs engine remap was observed, the noise camera measured a noise level of 90.4 dB L_{AFmax} whilst the noise monitoring data showed a noise level of 88.6 dB L_{AFmax}, shown in Table 4-4. Due to accessibility restrictions at Site 2, monitoring was conducted on the pedestrian bridge above the noise camera location. This can account for the level difference between the noise camera and ground truth noise level for both vehicles at Site 2 due to factors including the directivity of sound from the vehicles.

At the Site 3 two vehicles (modified car and van) were observed to exceed the noise camera threshold at the time of pass-by, however, there was no data recorded by the noise camera either validating or rejecting the vehicles at the time of these pass-bys. These instances occurred under freezing weather conditions, this may have altered the noise cameras capabilities as frost was visible on images from other noise camera activations near the time of the site visit. The noise camera has a 90% success rate for capturing cars and a 75% success rate for motorcycles, this capture rate may explain both these vehicles not being captured.

4.2.2. False positives

Some of the noise camera activations were identified as false positives once the evidence packages were reviewed. The following noise camera activations were considered to be false positives:

- A vehicle other than a car or motorcycle activated the noise camera, such as a construction vehicle, bus or lorry;
- An unnecessary noise camera activation due to how it was set-up;
- Sirens from a passing emergency services vehicle;
- The noise camera incorrectly identified the vehicle that activated it; and

- Other, such as someone shouting out of a vehicle or construction work being undertaken in the vicinity of the noise camera causing it to activate.

According to the data obtained, 34 false positives observed at Site 1, 34 at Site 2, 240 at Site 3 and 6 at Site 4. As seen in Figure 4-1 the most common cause of false positives across all the sites was the vehicle detected by the noise camera not being a car or motorcycle. No false positives were attributed to heavy goods vehicles passing the noise camera as the tested product is able to screen them out.

Another prominent cause of false positives from the tested system occurred when a vehicle exceeding the noise trigger level activated the noise camera and an incorrect vehicle was identified as the cause of the activation. An example of this is when a motorcycle and standard vehicle passed the noise camera at the same time. When this occurred the offending vehicle, in this case the motorcycle, was identified and analysed for excessively noisy characteristics whilst the standard vehicle labelled as a false positive. Similar situations to this occurred and both Site 2 and 3.

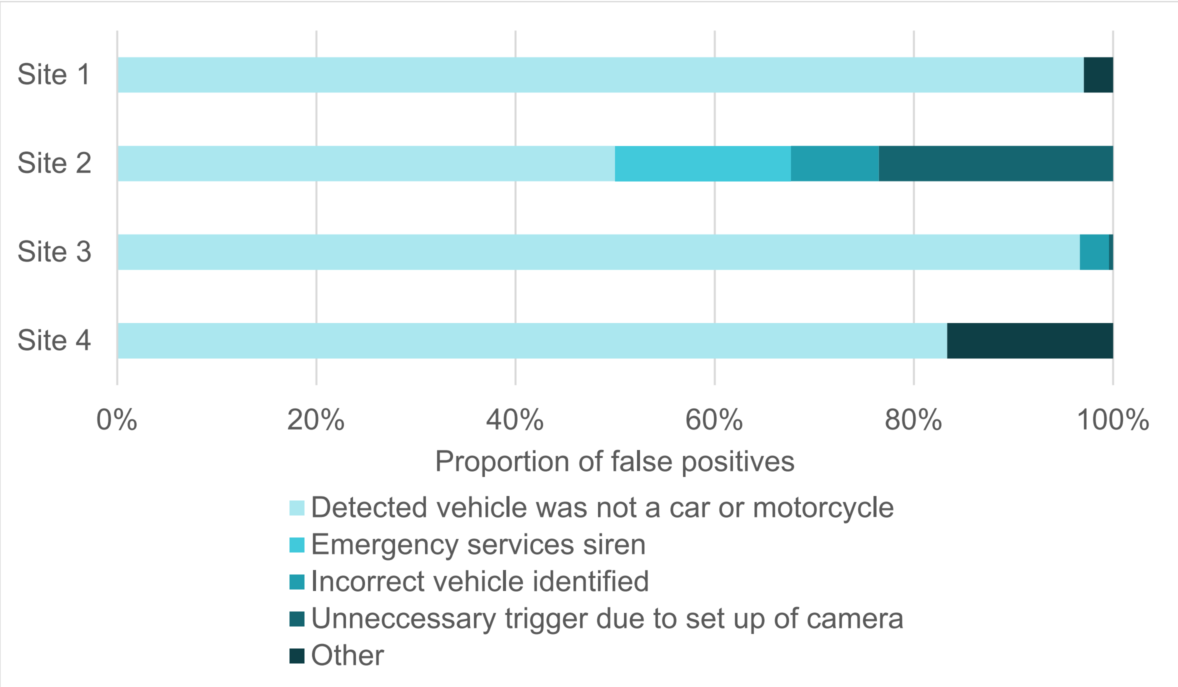

Figure 4-1 Causes of false positives

Another example of this type of false positive occurred at Site 2 when an emergency vehicle on the opposite side of the dual carriageway activated the noise camera and assigned the noise emissions from the emergency vehicle's siren to a standard vehicle. This occurred six times during the trial at Site 2. Similar false positives occurred at Site 4 when noise emissions from nearby construction works activated the noise camera and assigned the noise levels to a passing compliant vehicle.

As the noise camera's detection zone comprised two traffic lanes at most of the trial sites, the noise camera activations from each lane have been assessed to determine whether the lane type or site layout may have influenced the generation of false positives. The two traffic lanes are referred to as the nearside and offside lanes, where the nearside lane is the one that is closest to the noise camera. Owing to the site layout, the traffic on the nearside and offside lanes at Site 2 were travelling in the same direction, whereby the offside lane is the lane closest to the central reservation of the carriageway. Also, Table

4-5 shows the number of noise camera activations by lane type, to establish whether the noise camera performs consistently within its detection zone.

Table 4-5 Summary of Vehicle Type Data

		Site 1	Site 2	Site 3	Site 4
Number of Nearside Lane Noise Camera Activations	Cars	9	91	1,134	6
	Motorcycles	2	19	55	3
	Total	**11**	**110**	**1,189**	**9**
	Excessively noisy	3	30	2	-
Number of Offside Lane Noise Camera Activations (1)	Cars	5	106	-	13
	Motorcycles	4	16	-	-
	Total	**9**	**122**	**-**	**13**
	Excessively noisy	2	37	-	2

(1) For Site 2 the offside lane is the lane closest to the central reservation of the dual carriageway.

In Site 1 and Site 2, the number of vehicles that activated the noise camera were almost equally distributed between nearside and offside lanes. The number of cars and subclasses were significantly higher than the motorcycles and subclasses.

At Site 1 the road was single way carriageway, there were 13 vehicles travelling upstream and 9 travelling downstream on the road. Site 2 saw an equal split between noise camera activations and excessively noisy vehicles on the nearside and offside lane (lane closest to the central reservation on the dual carriageway). Due to the nature of Site 3 only one lane was monitored. Site 4 had 100% of the excessively noisy vehicles travelling in the offside lane.

4.2.3. False negatives

The noise camera has a number of settings available to optimise the detection of excessively noisy vehicles and reduce false positives and false negatives. These settings allowed the system to automatically reject noise camera activations if:

- Vehicles pass the noise camera simultaneously in opposite directions (such as a single carriageway);
- Vehicles pass the noise camera simultaneously in the same direction (for example, dual carriageways or overtaking);
- There are high wind speeds that can increase the measured noise levels; and
- The existing ambient noise level is high and above the noise threshold for noise camera activations.

For the first few days of the trial at Site 1, temporary traffic management was in place nearby for utility works unrelated to the trial. This resulted in queuing traffic on the offside lane. Any excessive noise generated by individual vehicles, such as revving, would not have resulted in a successful noise camera activation based on the current limitations of noise camera technologies identified during Part B [11].

No other false negatives were identified at any of the trial sites other than those observed from the ground truth monitoring visits, which are discussed in Chapter 4.2.1.

4.3. Dummy enforcement – evidence package and contravention record review

4.3.1. Quality of evidence package

The evidence package collated by the noise camera for each validated activation comprised audio and video clips, noise level data, still images of the top and rear of the detected vehicle and number plate information from the ANPR camera for each vehicle.

It was possible to determine the vehicle type using the evidence package contents for all vehicles activating the noise camera during all time periods. When the noise camera was in 'night-mode', vehicle colour could be distinguished. Sometimes images were blurry but the overall quality of the evidence package allowed for vehicle types and the excessively noisy vehicle to be identifiable.

The audio files provided in the evidence packages are of sufficient quality to be able to determine which vehicle activated the noise camera and what vehicle noise characteristics are present. The audio was normalised, so it was not possible to validate the noise level of the vehicle aurally from the evidence package. Wind speeds of up to and including 10 m/s occurred during the trial and were not found to affect the quality of the audio files.

Video files can vary in length from 15 seconds to over a minute and it was not always obvious which vehicle activated the noise camera. Video files with durations exceeding one minute collate several shorter video clips from various points in the day, finishing with a video clip with the relevant vehicle displayed. This tends to occur mostly at night-time. The overall quality of the video file means that it is not always possible to identify the key visual characteristics of a vehicle. This includes instances where a still image from another video is overlaid on a video.

The contextual image files provide a red polygon around the offending vehicle, as seen in Figure 4-2. This can be cross-referenced with the video file and ANPR data to ensure the correct vehicle registration has been identified.

Figure 4-2 Images from the noise camera in night-time conditions top view (left) and rear view (right) at Site 1.

The addition of an ANPR camera since the Part B track trial has improved the system's ability to identify excessively noisy vehicles and has automated this aspect of vehicle identification. When the ANPR system works successfully the vehicle registration plate is included within in the filename within the evidence package. This level of automation simplifies and shortens the data review process.

However, manual reading of the number plates from contextual images was required when the system provided no number plate or an incomplete number plate. The images were not always of high enough quality to identify the vehicle's number plate, and it was not possible to identify the vehicle's number plate from the video due to very poor quality. Both of these factors could prevent enforcement action from being pursued. The quality of images gradually improved throughout the trial due to image resolution upgrades. This resulted in clearer images during the daytime, low light conditions and at night, as alphanumeric characters on number plates were clearly readable on most images. By the time the trial started at Site 4 it was possible to verify the ANPR outputs using the images.

Some false positives were generated at Sites 1 and 2 because the ANPR data did not correspond to the noisy vehicle. An example of this occurred at Site 2, where an excessively noisy motorcycle activated the noise camera and the ANPR returned the number plate of a car passing the noise camera in another lane, as shown in Figure 4-3. This error was rectified for Sites 3 and 4, where it accounted for less than 1% of noise camera activations. It should be noted that an alternative configuration (utlisation of overtaking and contraflow automatic rejection setting) of the tested noise camera product would have rejected instances where there is more than one vehicle in the detection zone to reduce false positives.

Figure 4-3 Noise Camera, Contextual Image of Overtake Pass-by

Low temperatures also caused the formation of frost on the lenses of the ANPR camera, resulting in blurred images affecting the identification of alphanumeric characters.

Overall, the quality of the evidence packages were generally sufficient to confirm that the detected vehicle is an offending vehicle. This meets the requirements of the second step of dummy enforcement, noting that the ability to take enforcement action is dependent on the ANPR camera's performance and whether the vehicle's number plate is legible from other files within the evidence package.

The evidence package for each noise camera activation was transmitted as a zip file, which could act as a contravention record if the vehicle is confirmed to be excessively noisy. However, the evidence package does not provide a summary document that collates together the image, number plate and measured noise level that could further simplify the data review and issue of an enforcement letter to the vehicle's owner.

4.3.2. Efficiency

The time taken to review the evidence package from a noise camera activation is up to 10 minutes, which encompasses the following activities:

- Verifying that the noise camera has successfully identified the correct vehicle;

- Playback of audio and video files to confirm what vehicle noise characteristics were audible and if the vehicle was subjectively excessively noisy; and
- Logging key information from the evidence package into a datasheet.

The review time can be reduced to 5 minutes if the cause of the noise camera activation was easily identifiable and the ANPR camera retrieved the correct number plate.

4.4. System reliability

The noise camera deployed for the roadside trial was a prototype system and experienced periods of down-time during the trial. Table 4-6 details the time period when the noise camera was not fully operational.

Table 4-6 Details of when the noise camera was not working

Site	Duration	Reason
1	3 November 2022 15:00 to 4 November 2022 11:00	Vehicle identification trigger operation failure.
2	14 November 2022 20:00 until 17 November 2022 14:00	System operational but evidence packages did not include audio and photos.
3	14 December 2022 21:00 until 22 December 10:00	Noise camera system shut down due to cold weather. Noise trigger failure after the system rebooted on 19 December 2022.
	19 December 09:30 to end of site	Fewer images in the evidence package.
4	27 January 2023 18:00 until 30 January 2023 09:00	Vehicle identification trigger operation failure.

Table 4-6 shows that cumulative period of system down-time was approximately 25 days, excluding time periods associated with evidence package quality. The noise camera was therefore online for 77% of the trial duration, which included autumnal and winter weather conditions.

The air temperature ranged from -2°C to 18°C during the trial as a whole and did not affect the operation of the noise camera except at freezing temperatures, which caused frost formation on the noise camera and ANPR lens. This affected the quality of camera images and ultimately led to the system shutting down until it was rebooted by the local authority. No other meteorological factors affected the operation of the noise camera. It can therefore be inferred that if the trial had taken place during the summer months, when weather would have less influence on system operation, the noise camera would have been online approximately 84% of the time.

When the system was operational, the noise camera's microphone array, reference microphone and contextual cameras were found to have good stability and work well during all time periods. At Site1, 2 and 3, some vehicles activated the noise camera more than once during the trial period. The measured noise levels for the same vehicle were reasonably consistent and generally within 2-3 dB L_{Amax} of each other during the same weather conditions regardless of which traffic lane the vehicle was detected in. This provides high levels of confidence in the repeatability of the noise measurement component of the system and that excessively noisy vehicles can be identified anywhere within the noise camera’s detection zone.

The ANPR is a new component to this noise camera and performed inconsistently. This is attributable to the use of different ANPR cameras as the trial progressed. Further work is required on the integration of this component to improve its performance and stability.

5. Vehicle Noise Levels

The Part A report [10] recommended that a threshold noise level of 95 dB L_{AFmax} be adopted for excessively noisy cars and motorcycles at all speeds during the Part C roadside camera trials. This noise threshold was recommended based on the findings of the of Phase 3 track trials [10] [11] and by the responses of those who participated in the subjective assessment undertaken during the track trials. To ensure a variety of data was collected and that the threshold determined in Part A is valid for use in a roadside environment a lower threshold was used throughout the roadside trials, as seen in Table 4-1.

The subjective assessment showed that only two tests were considered excessively noisy, which corresponded to noise levels of 105 and 107 dB L_{AFmax}. Both tests were undertaken using a car fitted with aftermarket modifications in a test environment, where no other vehicles were present impacting perspective of standard vehicle noise levels. None of the motorcycle tests were considered excessively noisy as the measured levels were not as high as that from the car. 91% of vehicles (both car and motorcyle) with noise levels above 95 dB L_{AFmax} were considered noisy or excessively noisy.

5.1. Measured vehicle noise levels during the roadside trial

The total number of noise camera activations for each trial site and the percentage of those where the detected vehicle is considered to be excessively noisy are presented in Table 5-1. The term 'noise trigger' is used to define the decibel setting that was used to activate the noise camera to measure and record the individual vehicle passage.

Table 5-1 Noise bands of vehicles at each trial site with the percentage of vehicles which were considered to be excessively noisy

Maximum vehicle noise level band (dB L_{AFmax})	**Number of cars (% of excessively noisy cars)**				**No. of motorcycles (% of excessively noisy motorcycles)**			
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
< 80.0 (1)	6 (0%)	-	1,107 (0%)	2 (0%)	3 (0%)	-	40 (0%)	-
80.0 to 84.9	3 (0%)	21 (0%)	25 (0%)	11 (0%)	3 (0%)	-	10 (0%)	-
85.0 to 89.9	1 (100%)	107 (0%)	2 (0%)	4 (0%)	-	5 (20%)	4 (25%)	2 (0%)
90.0 to 94.9	-	53 (53%)	-	2 (100%)	-	16 (56%)	1 (100%)	1 (0%)
95.0 to 99.9	1 (100%)	12 (100%)	-	-	-	12 (100%)	-	-
≥ 100.0	3 (100%)	3 (100%)	-	-	-	2 (100%)	-	-
Total	**14 (36%)**	**196 (22%)**	**1134 (0%)**	**19 (11%)**	**7 (0%)**	**35 (69%)**	**55 (4%)**	**3 (0%)**

Maximum vehicle noise level band (dB L_{AFmax})	Number of cars (% of excessively noisy cars)				No. of motorcycles (% of excessively noisy motorcycles)			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
(1) A noise trigger of <80.0 was used at some of the sites but this did vary between sites and did change during the trial at individual sites. Details of how this noise trigger was assigned at each site are set out in Chapter 2.2.6.								

Table 5-1 shows that no excessively noisy cars or motorcycles were identified below a noise level of 85 dB L_{AFmax}. The majority (73%) of motorcycles recorded at ≥ 90 dB L_{AFmax} were considered excessively noisy, compared to 66% of cars. All cars and motorcycles measured at greater than 95 dB L_{AFmax} were considered excessively noisy. Table 5-1 shows that there are some vehicles considered to be excessively noisy with a lower noise level than some that are not considered excessively noisy. This demonstrates that the derivation of a vehicle being excessively noisy is not based solely on noise level and contains an element of subjectivity.

Across all four trial sites there were 76 vehicles considered to be excessively noisy, of which 50 were cars and 26 were motorcycles.

The data presented in Table 5-1 is also presented graphically in Figure 5-1, showing the total number of cars and motorcycles recorded at or above the trigger levels.

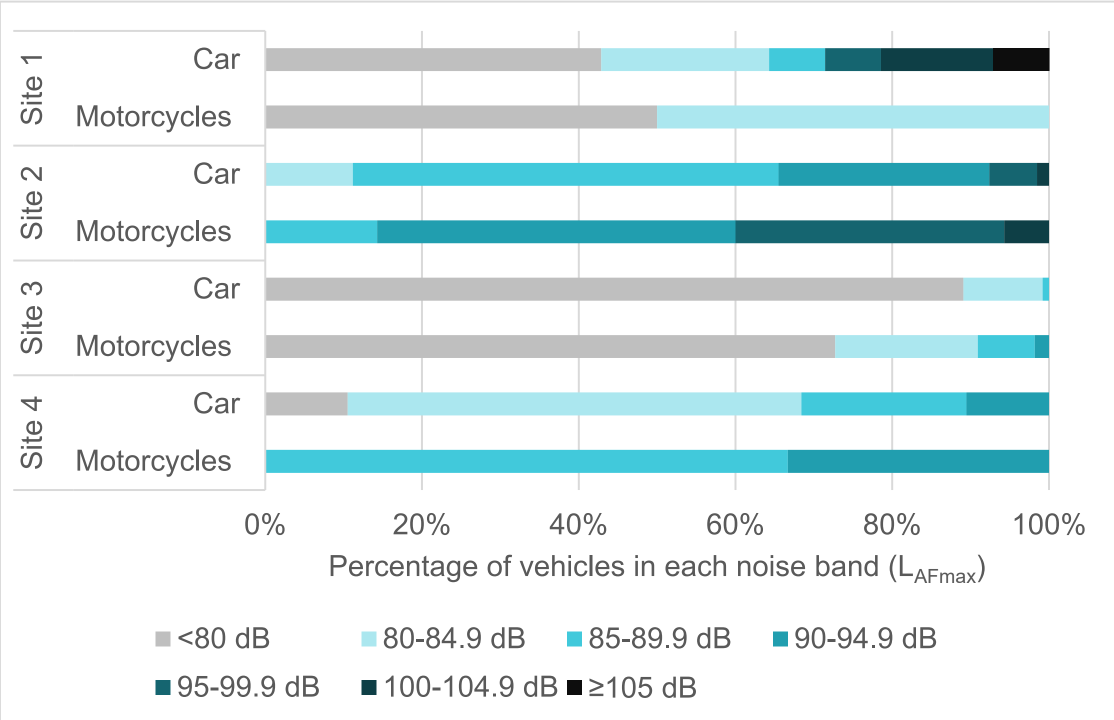

Figure 5-1 The distribution of cars and motorcycles at each site within 5 dB noise bands

5.2. Definition of an excessively noisy vehicle

In order to understand the definition of an excessively noisy vehicle, the noise level data gathered during the trial has been analysed to identify the percentage of excessively noisy vehicles at each site alongside the percentage of excessively noisy cars and motorcycles within 5 dB and 1 dB noise bands. The number of excessively noisy vehicles on 30 and 50 mph speed limit roads, during day and night periods, and the audio characteristics of excessively noisy vehicles are also presented.

Figure 5-2 presents the percentage of vehicles at each trial site in 5 dB noise bands and the percentage of vehicles considered to be excessively noisy. Site 2 had the highest percentage of excessively noisy vehicles (29% of all activations). Site 1 had 25%, Site 4 had 9%, and Site 3 had only 1%.

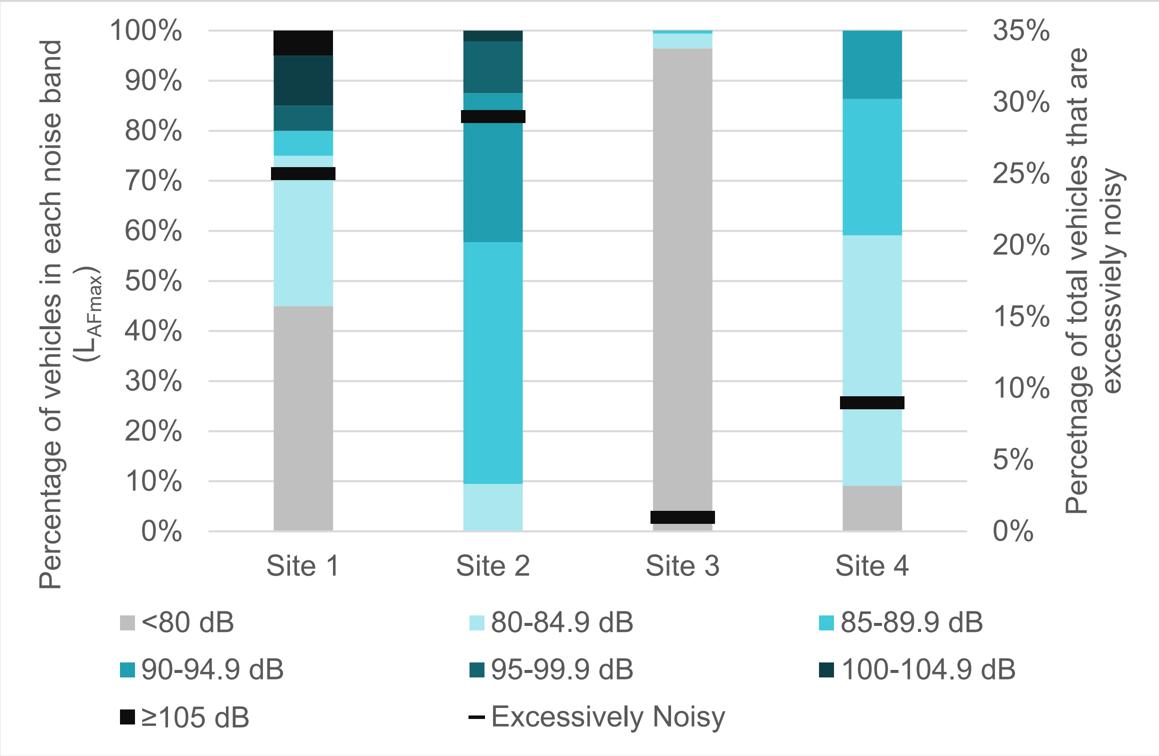

Figure 5-2 Distribution of vehicles at each site within 5 dB noise bands and the percentage of excessively noisy vehicles

Figure 5-3 expands upon the dataset of excessively noisy vehicles to show the percentage of vehicles in each noise band which were cars and motorcycles. The highest measured noise level recorded across all sites was 116.6 dB L_{AFmax} from a modified car at Site 1.

A review of the recordings shows that the highest recorded car not considered to be excessively noisy (e.g. through aftermarket modifications or driving style) was 93.5 dB L_{AFmax}, whilst the highest for a motorbike was 93.4 dB L_{AFmax}. The lowest noise level of a vehicle considered to be excessively noise was 85.5 dB L_{AFmax} for a car, the most dominant audio characteristics were pops and bangs from engine remapping and a low rumble from exhaust modifications. For a motorcycle, the lowest noise level was 88.6 dB L_{AFmax} where hard acceleration could be heard.

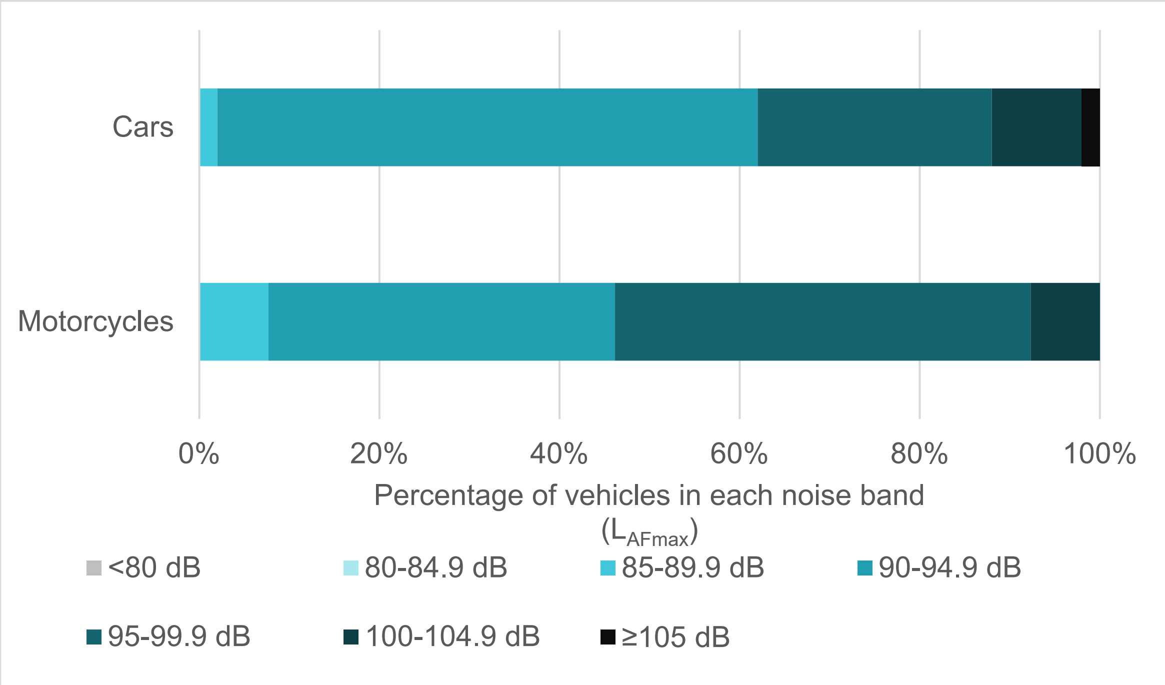

Figure 5-3 Percentage of excessively noisy vehicles in each noise band for cars and motorcycles

Table 5-2 presents the percentage of excessively noisy vehicles in 1 dB bands above 90 dB L_{AFmax}. A narrow 1 dB band (rather than the 5 dB bands used elsewhere) has been used to allow the prevalence of vehicles deemed excessively noisy to be more closely examined as the Part A recommended threshold noise level is approached (95 dB L_{AFmax}).

Table 5-2 Percentage of excessively noisy vehicles at or above 90 dB L_{AFmax}

Maximum vehicle noise level (dB L_{AFmax})	**Percentage of excessively vehicles**		
	Cars	**Motorcycles**	**All vehicles**
90.0 to 90.9	38%	25%	35%
91.0 to 91.9	64%	-	58%
92.0 to 92.9	47%	40%	45%
93.0 to 93.9	40%	100%	67%
94.0 to 94.9	83%	100%	89%
95.0 to 95.9	100%	100%	100%
≥ 96.0	100%	100%	100%

Table 5-2 shows that all vehicles with a measured noise level above 95 dB L_{AFmax} were considered excessively noisy. In terms of the split between vehicle type there was little difference, with all motorcycles with a measured noise level above 93 dB L_{AFmax} being considered excessively noisy as opposed to all above 95 dB L_{AFmax} for cars.

A separate breakdown of excessively noisy vehicles measured at the three sites that were subject to a 30 mph speed limit (i.e. Sites 1, 3 and 4) and the one site subject to a 50 mph speed limit (i.e. Site 2) is presented in Table 5-3.

Table 5-3 Number of excessively noisy vehicles in 5 dB noise bands for the 30 mph and 50 mph roadside trial roads

Noise level band (dB L_{AFmax})	**Excessively noisy vehicle type and speed limit of road**					
	Cars		**Motorcycles**		**All vehicles**	
	30 mph	**50 mph**	**30 mph**	**50 mph**	**30 mph**	**50 mph**
< 80.0	-	-	-	-	-	-
80.0 to 84.9	-	-	-	-	-	-
85.0 to 89.9	1	-	1	1	2	1
90.0 to 94.9	2	28	1	9	3	36
95.0 to 99.9	1	12	-	12	1	24
100.0 to 104.9	2	3	-	2	2	4
≥ 105.0	1	-	-	-	1	-
Total	**7**	**43**	**2**	**24**	**9**	**67**

Excessively noisy vehicles were first identified at noise levels of greater than 85 dB L_{AFmax} on both 30 and 50 mph speed roads. Examining the two different vehicle classes, the distribution between them on roads with a different speed limit is evident. For cars, 86% of those identified as being excessively noisy were on the road with a speed limit of 50 mph (Site 2). For motorcycles the corresponding figure is 92%.

As seen in Chapter 4.1, the total number of vehicles using all of the roads with a speed limit of 30 mph was less than half the flow on the road with a 50 mph speed limit. From the distribution of identified excessively noisy vehicles across the two types of road, it would appear that the speed limit of the road is not a factor where these instances occur.

Table 5-4 shows the number of vehicles measured above the noise trigger level at each site, broken down by site and whether considered to be excessively noisy.

The time periods chosen for day and night-time are the standard ones in environmental impact assessment. With the trials taking place during the late autumn of 2022 and winter of 2022/23, there would have been periods of darkness within the daytime period.

Table 5-4 Total number of vehicles at each site in daytime (07:00 – 23:00) and night-time (23:00 – 07:00) periods

Site		**1**	**2**	**3**	**4**	**Total**
Day	**Total vehicles (cars and motorcycles)**	18	211	1,123	20	**1,372**

	Excessively noisy vehicles	5	59	2	2	**68**
	Percentage of vehicles that are excessively noisy	28%	26%	0.10 %	10%	**5%**
Night	**Total vehicles (cars and motorcycles)**	2	20	66	2	**90**
	Excessively noisy vehicles	-	8	-	-	**8**
	Percentage of vehicles that are excessively noisy	0%	38%	0%	0%	**9%**

Table 5-4 shows there were eight vehicles identified that were considered to be excessively noisy during the night period, all of which were at Site 2.

It must be noted that the traffic flows during the night-time at each site would be expected to be lower than daytime, and so the split is not surprising. From the traffic flows available it is not possible to determine the day / night split of traffic at all sites.

The most prominent audio characteristics of excessively noisy vehicles observed during the roadside trials were exhaust and acceleration noise for both cars and motorcycles, as seen in Figure 5-4. Only a few instances of the other excessively noisy characteristics defined in Chapter 2.3.1 were observed during the analysis of the identified vehicle. It should be noted, as mentioned in Chapter 2.3.1, an excessively noisy vehicle may have more than one characteristic assigned to it, therefore, it is not possible to directly correlate the amount of excessively noisy vehicles as seen in Table 5-1 with the number of vehicles with each audio characteristic.

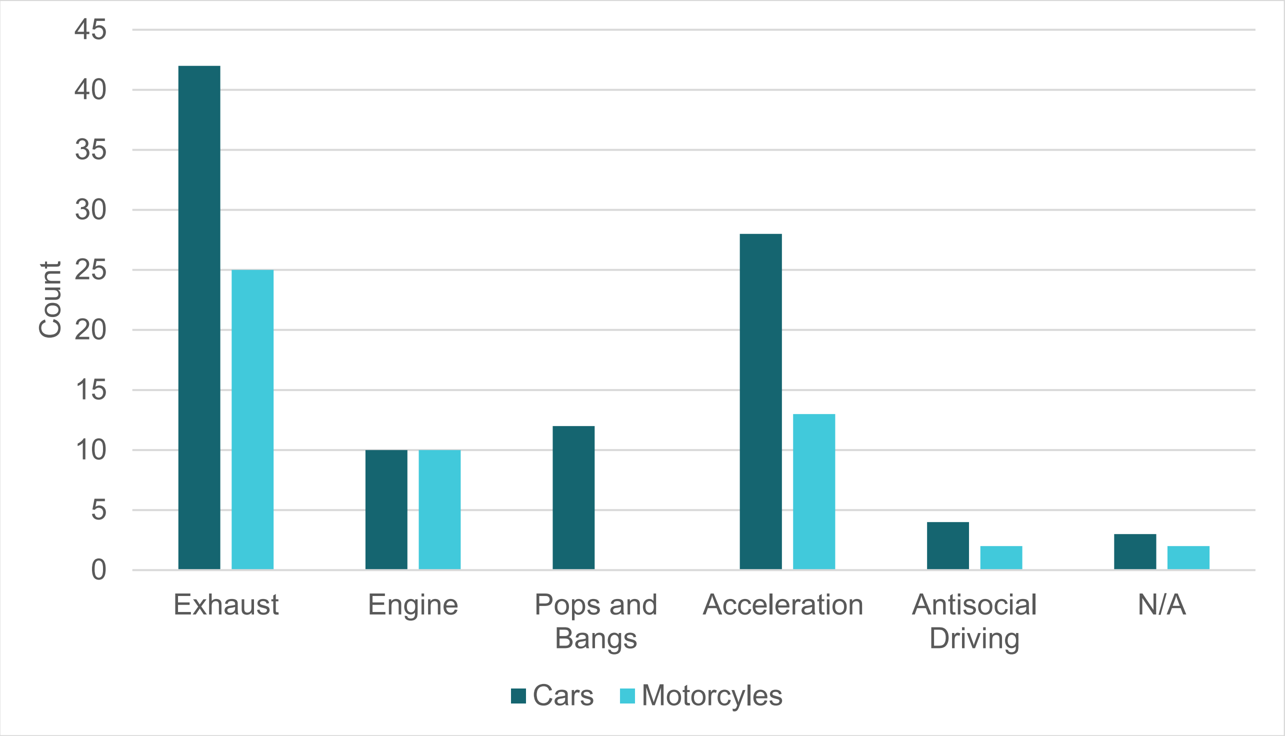

Figure 5-4 Audio characteristics of excessively noisy vehicles

6. Factors influencing the setting of a noise threshold limit

This section discusses the data presented in Chapter 5, and considers the findings and recommendations presented in Part A [10], where applicable, in the context of noise threshold limit setting and factors that may influence this. In setting an appropriate noise threshold limit for excessively noisy vehicles, it is necessary to consider the conditions under which measurements are taken. As such the conditions and sources of potential uncertainty, as discussed in Part A [10], are considered in the context of the data collected during the roadside trial study.

6.1. Road speed

There is no evidence to suggest that a lower noise threshold for excessively noisy vehicles would be appropriate on roads with a speed limit of 30 mph (when compared to 50 mph). This can be seen in Table 5-3. It should be noted there was a much greater traffic flow at the site with a 50 mph speed limit (Site 2), as seen in Table 4-1. However, the roadside trials did not include any roads with speed limits at 40 mph, so no conclusions can be made regarding appropriate noise thresholds for excessively noisy vehicles on such roads.

It should also be noted that the measurement location at Site 2 was positioned 150 metres from a roundabout and as such, would have included acceleration noise.

6.2. Road surface

The following recommendation was made in the Part A report:

'*It is initially recommended that noise cameras are not deployed alongside roads with concrete surface with speed limits of 50 mph or greater. The use of cameras in areas with a concrete road surface and speed limits less than 50 mph are expected to be minimal*'.

Since all roadside trials were on roads where the surfacing appeared to be Hot Rolled Asphalt (HRA), the findings do not provide any evidence to suggest that the initial recommendation made in Part A [10] should be changed.

6.3. Night-time noise

The following recommendation was made in the Part A report:

'Due of this lack of evidence, it is considered that the same suggested noise enforcement level should initially be used for day and night periods'.

The findings of the roadside trial do not provide any evidence to suggest that the initial recommendation made in Part A [10] should be changed. As seen in Table 5-4, the percentage of excessively noisy vehicles that occurred during the daytime (5%) and night-time (8%) across all sites were similar.

6.4. Weather

6.4.1. Wind

The Part A report stated the following in relation to the effect of wind direction:

'this influence would be negligible and a tolerance would not be required'.

The Part A report stated the following in relation to the effect of wind speed:

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

The wind speeds recorded during the roadside trials were all 10 m/s or below. From the analysis of the audio files there was no apparent buffeting of the microphone and the effect of wind on measured levels was not considered to contribute to measured L_{AFmax} levels or the determination of whether the noise was excessive. As such, the recommendations made in the Part A report remain.

6.4.2. Rain

The Part A report stated the following in relation to the effect of rain:

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

An analysis of the wet and dry road noise from the data obtained from the roadside trial is an increase in maximum noise levels up to 5dB. However, it was found that the noise from tyres on a wet road could easily be distinguished over that from other components of the vehicle (e.g. exhaust, engine) and that an enforcement officer could judge whether rain is contributing to measured noise levels. As such, the recommendations made in the Part A report remain.

6.4.3. Road temperature

The Part A report stated the following in relation to the effect of road temperature:

'Any influence from the temperature of the road surface is considered negligible and no tolerance is required'.

The trials at all four sites were undertaken in conditions with varied road temperatures due to air temperatures between -2 °C and 18 °C. There was no evidence to suggest that the temperature of the surface had any influence on the measured noise level or the determination of whether the vehicle was excessively noisy. Therefore, the findings of the roadside trial do not alter the recommendation made within the Part A report.

Air temperature: no tolerance for air temperature would be recommended. Air temperature was not observed to have influenced the measured noise levels during the roadside trials.

6.5. Sound level meter

The Part A report stated the following in relation to the effect of the sound level meter:

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

The roadside trial study was undertaken using a single noise camera system that used a class 2 microphone. Since other devices have not been tested alongside this system, there is therefore no evidence to suggest a change to the recommendation made in the Part A report.

6.6. Equipment location

The Part A report stated the following in relation to equipment location:

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

The locations chosen for the roadside trials were identified to provide maximum opportunity for data gathering and no attempt was made to examine locations that could require tolerances to be considered. Therefore, the data collected during the roadside trial cannot be used to determine any possible restrictions or tolerances for equipment location beyond those advised by the supplier. Some information on requirements for a suitable monitoring location are set out in installation and deployment guide.

7. Cost and benefits of noise camera deployment

Although noise cameras are intended to be implemented to bring about a social benefit, it is important to justify the cost of funding it, as there will be competing uses for this public money. Furthermore, if a system of hypothecation or netting off were to be used, as has been the case with several other automated enforcement systems, then the implementation of noise cameras may only be possible where the fine revenue covers the cost of purchase and operation, giving a neutral or positive return on investment over its lifetime.

This chapter explains the high-level costs for implementing the system and the revenue that can be expected through the payment of penalties/fines. All values refer to one ‘site’ which covers both sides of the road and all lanes, and a one-year period (except where otherwise stated).

7.1. Costs

Among the costs for implementing the system, the **Capital Expenditure (CAPEX)** comprises the cost of noise cameras, power and communications supplies, installation pole if existing street furniture (e.g. street lighting column) is not available, civil engineering, traffic management and any other incidental infrastructure. The CAPEX costs have been assumed to be one-off and depreciated over a 10-year period.

The **Operational Expenditure (OPEX)** is the cost paid annually to the system supplier and would comprise the noise camera running costs, including maintenance, servicing/calibration, updates, communications costs, access to dashboards or file storage by the supplier.

Since noise cameras are at the prototype stage, there is no standard or off-the-shelf pricing available. Figures from the installation of noise cameras at four roadside trial sites have indicated the CAPEX and OPEX to be of the order of £4,800 and £8,400 respectively, per site, per year, i.e. an annual total expenditure of £13,200. This has been compared to the costs of the nearest equivalent devices – speed, red light and bus lane cameras - and seems reasonable, considering that the civil enforcement devices may be assumed to be substantially less expensive than the criminal enforcement devices due to the higher scrutiny and testing standards for criminal evidence gathering.

Another significant cost category is the Processing Charge per violation or offence. This is the marginal cost associated with processing staff, back-office systems, courts costs, police assistance, staffing for enquiries from the public, appeals process, bailiffs etc, i.e. the cost to issue a fine, follow it up, receive and process the payment.

Based upon experience of other large scale processing operations for existing camera enforcement schemes in the UK, this is estimated to be around £40-£50 per violation. This is backed up by revenue costs across multiple police force areas and years in the National Safety Camera Programme [13], adjusted for inflation.

7.2. Revenues

The revenue or income has been quantified by estimating the collection of fines from a proportion of the passing traffic which is excessively noisy at the locations where the noise cameras are to be implemented. The overall traffic is essentially the **Average Annual Daily Flow (AADF)** that can be expected at the roads where the cameras will be installed.

The road traffic estimates for Great Britain document for 2021 has listed the AADF for the strategic and local road networks [14]. The AADF for the **Strategic Road Network** (SRN), **Local Major Road Network** and **Local Minor Road Network** in 2021 were 50,200, 13,700 and 1,600 vehicles/day respectively.

The results for the **proportion of the excessively noisy vehicles** from the roadside trials have been implemented as the proportion of passing traffic that is excessively noisy. The trials were carried out for varying traffic and road conditions. Site 1 represents local minor roads whereas Site 2 is an example of a local major road. Overall, the proportion of excessively noisy vehicles was lower for Site 1 than Site 2. The results from the trials showed that 1 in 6,700 vehicles passing through Site 1 were excessively noisy.

The trials carried out at Site 2, which is a local major road predict the number of excessively noisy vehicles to be 1 in 3,400 vehicles. This estimate is from a large sample size of excessively noisy vehicles that were obtained for Site 2.

Therefore, two different road traffic scenarios that are backed up by statistics/experimentation have been simulated:

1. Local major road network with a proportion of excessively noisy traffic of 1 in 3,400.
2. Local minor road network with a proportion of excessively noisy traffic of 1 in 6,700.

Since the idea behind introducing noise cameras is to bring about social benefits to residential areas, no estimates were forecast for the third class of road, the SRN, as the 50,200 AADF figure typically suggests a 6/8 lane motorway, which are less likely to have residential frontages.

At the outset, it is clear that the likelihood of achieving financial benefits for scenario 1 will be higher than scenario 2 due to there being more vehicles that would be fined (higher traffic flows at the site as well as higher proportion of traffic that is excessively noisy).

This knowledge of traffic flows and the proportion of excessively noisy vehicles for the 2 scenarios can help estimate the number of vehicles that could be fined for being excessively noisy.

However, the number of vehicles that could be fined will reduce because of the following factors:

1. **Vehicles that back off:** If the presence and positioning of the noise camera is known, then there is a high risk that drivers of excessively noisy vehicles will drive in a way to avoid triggering the threshold limit. It was the intention to apply this factor to a generic traffic level of all vehicles that are capable of excessive noise, such as the total percentage of modified cars and bikes in the UK. However, since such global figures are not known, and the numbers of actual offending vehicles per day from two of our trial sites is being used, the concept of backing off / evasion is already baked into the numbers, so n/a appears in the tables which follow.
2. **Lost violations due to high threshold:** The results from the trials to date tell us the number of excessively noisy events which will be missed at any set threshold. It is assumed in these calculations that a threshold of 95 dB L_{Amax} will be used in order to minimise false positives. The roadside trials indicate that at this level, 56% of offending vehicles may be missed. This figure has been used for all scenarios.
3. **Violators who do not pay:** There is also the risk of violators not paying the appropriate fine. In order to keep the forecasting permutations to a minimum, a single value of 25% has been selected. These offences will no doubt be pursued via the courts system or some escalated mechanism such as civil enforcement / bailiffs,

but the eventual revenue may not come back to the scheme operator in these cases.

4. **Unidentifiable or untraceable vehicles:** There will also be a proportion of offending vehicles that cannot be identified sufficiently well to prosecute. This would include those where the licence plate is not visible / clean / legible, where the identity has been concealed (cloned plates) or where the registered keeper is not updated or not contactable. Collectively for all these categories, an assumption of 10% has been made for all scenarios.

The fine income that can be recovered from the remaining vehicles will then help estimate the overall revenue. The **Public Space Protection Order (PSPO)** regulations used in London and other UK trials to date result in a penalty/fine of up to £100. Several other relevant pieces of legislation under which noise offences could be enforced are listed in Table 7-1 along with the corresponding penalties. This is an important consideration that will reasonably impact the collected revenue and was thus sensitivity-tested. Three values of £50, £100 and £150 were selected based on the suitable regulations highlighted in Table 7-1.

Table 7-1 Relevant regulations and fine levels/endorsement.

Act	Offence type	Fine level / Endorsement
Crime and Policing Act 2014, section 68	Anti-social Behaviour- Breach of a Public Spaces Protection Order	Up to £100
Police Reform Act 2002, section 59	Vehicles used in manner causing alarm, distress or annoyance	(Vehicle may be seized by the police) £100 / 3 points
Road Traffic Act 1988, section 40A	Using vehicle in dangerous condition	£100 / 3 points
Road Traffic Act 1988, section 42	Breach of other construction and use requirements	£100-£200 [15]
Noise Act 1996, section 8	Noise exceeding permitted level, Domestic premises: Designed for buildings	£60-£100

There will be little variation in the processing charges and is expected to be between £40 and £50. The lower rate will be applied to lower penalties and the higher rate to higher penalties for modelling purposes.

The expected annual cost and benefits for the implementation of noise cameras on a typical local major road has been shown in Table 7-2. On implementing the value obtained from the trials for the proportion of excessively noisy traffic and the standard value for the AADF, a surplus is obtained only for the implementation of medium and high settings in the model.

Break-even point: Further fine-tuning of the forecasting model showed that a value of **1 in 1,125 vehicles** for the proportion of excessively noisy traffic would start showing the revenue surpassing the cost the under the ‘Low’ setting. For the ‘medium’ and ‘high’ settings, the same value would need to be **1 in 6,185 and 1 in 21,250 vehicles respectively**.

Table 7-2 Return on investment calculations for Local Major Road Networks or Scenario 1

Scenario 1- Local Major Road Network			
Prospect of revenue collection	**Low**	**Medium**	**High**
Proportion of passing traffic which is excessively noisy	1 in 3,400 (0.03%)		
Average Annual Daily Flow (AADF)	13,700 (so 4 offences per day)		
Vehicles that ‘back off’ (%)	n/a	n/a	n/a
Lost violations due to high threshold (%)	56		
Violators who do not pay (%)	25		
Untraceable vehicles (%)	10		
Revenue per violation (£)	50	100	150
Processing charge per violation (£)	40	45	50
Contribution per site (£/year)	9,729	53,509	97,289
CAPEX + OPEX per year (£/year)	13,200	13,200	13,200
Surplus (loss) per camera per year	(8831)	10,825	30,480

The forecasts for the local minor road network that have been shown in Table 7-3 do not show an adequate level of contribution even for the least conservative set of values. Since the AADF on local minor roads is rather low, the proportion of passing traffic that is excessively noisy would need to be much higher.

Break-even point: Further fine-tuning of the forecasting model showed that a value of **1 in 130 vehicles** for the proportion of excessively noisy traffic would start showing the revenue surpassing the cost the under the ‘Low’ setting. For the ‘’medium’ and ‘high’ settings, the same value would need to be **1 in 720 and 1 in 1,310 vehicles respectively**.

Table 7-3 Return on investment calculations for Local Minor Road Networks or Scenario 2

Scenario 2- Local Minor Road Network			
Prospect of revenue collection	**Low**	**Medium**	**High**
Proportion of passing traffic which is excessively noisy	1 in 6,700 (0.015%)		

Scenario 2- Local Minor Road Network			
Prospect of revenue collection	**Low**	**Medium**	**High**
Average Annual Daily Flow (AADF)	1,600 (so 0.23 offences per day)		
Vehicles that 'back off' (%)	n/a	n/a	n/a
Lost violations due to high threshold (%)	56		
Violators who do not pay (%)	25		
Untraceable vehicles (%)	10		
Revenue per violation (£)	50	100	150
Processing charge per violation (£)	40	45	50
Contribution per site (£/year)	577	3,171	5,766
CAPEX + OPEX per year (£/year)	13,200	13,200	13,200
Surplus (loss) per camera per year	(12,941)	(11,776)	(10,611)

7.3. Rising compliance and breakeven flow

The above calculations show in effect a 'Day 1' scenario, with the current 2023 number of noisy/modified/anti-socially driven vehicles on the roads. However, over time following the introduction of noise cameras in live enforcement mode, it is hoped that drivers would modify their driving to be less noisy and un-modify their vehicles, as well as detering future modifications by other drivers. This rising compliance is an important fifth reduction factor that will be time-dependent. In that case, the proportion of excessively noisy vehicles on the network would need to be more than or equal to the 'break even' proportion figures that are being suggested for the scheme to continue to self-fund.

Under the proposed assumptions, for the most conservative/ low revenue prospect scenario, the lowest proportion of passing traffic that would need to be excessively noisy for there to be a surplus revenue on implementing noise cameras is **1 in 130 (12 vehicles/day) and 1 in 1,125 vehicles (12 vehicles/day)** for local minor and major roads respectively.

Under the proposed assumptions, for the medium revenue prospect scenario, the lowest proportion of passing traffic that would need to be excessively noisy for there to be a surplus revenue on implementing noise cameras is **1 in 720 (2 vehicles/day) and 1 in 6,185 vehicles (2 vehicles/day)** for local minor and major roads respectively.

Under the proposed assumptions, for the least conservative/high revenue prospect scenario, the lowest proportion of passing traffic that would need to be excessively noisy for there to be a surplus revenue on implementing noise cameras is **1 in 1,310 (1 vehicle/day)** and **1 in 11,250 (1 vehicle/day)** for local minor and major roads respectively.

Note that rising compliance, if it occurs at cameras sites and away from them also, is a sign of success: the objective is not to raise revenue but to deter antisocial levels of noise, and any early signs of rising compliance can be factored into a plan to eventually ramp down enforcement. However, if drivers only comply at noise camera sites, then this is a very strong argument for mobile devices to give a random deterrent everywhere.

7.4. Statistical sense check

In considering which of these widely varying numbers of offending vehicles are realistic, the original objective of the scheme must be remembered: to tackle a noise nuisance which is reported as highly problematic in specific locations across the UK. To be highly problematic, and to warrant the civil engineering and equipment associated with a noise camera installation, this might be taken to mean multiple noisy vehicles a day rather than one every few days. This is of course subjective, but it seems reasonable to assume that the cameras would be deployed in the worst areas for noise offences, and anecdotally it is a frequent problem at the worst locations. For minor roads, the road type on which most residents live, the AADF flow is 1,600 vehicles per day, so if there were approximately 5 noisy vehicles per day, that would be **1 in 320**. Similarly, on a major road, 10 noisy vehicles per day would equate to **1 in 1,300** vehicles. Both of these figures are considerably higher than the offending numbers seen at the roadside trial sites. There are many factors which could explain or contribute toward the apparently low numbers of excessively noisy vehicles at the trial sites as discussed in other parts of this report, including site selection issues, deliberate evasion from very prominent and publicised camera installations and the winter months over which data were collected.

Putting these ratios back into the Medium scenarios above (£45 processing cost, £100 fine), gives an annual contribution per site (before deduction of the £13,200 annual camera cost) of **£30,000 and £62,800** for minor and major roads, respectively, so a surplus per camera per year of **£16,600 to £49,600** depending on the road type.

7.5. Sensitivity of inputs: Recommendations to firm up a bottom-line value

According to these calculations, the factor which has the greatest effect upon the financial viability of noise cameras is the number of offending vehicles passing the camera site. As the estimates and surveyed values vary so widely, it is recommended that more data be gathered (this can be with simple surveys, a noise camera is not needed) at reported locations and times of noise nuisance problems.

Policy discussions around the disposal route (civil/criminal, which act and offence to use) will then narrow down the likely fine amount. It is recommended to roll into this debate some robust social science research to ensure that the penalty level carries public support, especially when compared to fines and penalties for other driving offences.

The third factor which affects breakeven is the processing cost per violation. This can be reduced substantially by automation (ANPR of licence place, automated DVLA lookup of keeper detail and image processing to verify vehicle type and colour match, secondary check of audio file threshold, automated mailing, self-service portal for customer queries / appeals and automated receipt of payment etc). It is recommended that pricing up of some or all of this functionality, and the scope to ‘piggyback’ onto other existing back-office systems such as those used for bus lane infringements, should be investigated before any wide-scale rollout.

7.6. Electric and hybrid vehicles

It is also worth noting the increase in the sale and use of electric vehicles (pure and hybrid) which do not typically produce antisocial levels of noise. Bearing in mind that internal combustion cars can be sold in the UK until 2030 and internal combustion hybrid until 2035, and the average age of UK cars being 8 years (so taken off the road at 16 years), it is clear that there will be a substantial albeit reducing number of potentially offending vehicles for at least 10 years, which is the assumed lifetime of a camera system and its payback period in the above calculations.

8. Discussion

8.1. Enforceable traffic scenarios for noise cameras

The most enforceable traffic scenario is where single vehicles pass the noise camera in isolation. These can occur on single carriageway, dual carriageway and high-speed roads. When the noise camera was located in urban or suburban environments on single carriageway roads (Sites 1, 3 and 4), the evidence package review process was quicker as vehicles passed the camera in isolation more often. However, the number of noise camera activations was significantly lower than when the noise camera was located on a dual carriageway due to the lower rate of traffic flow.

Excessively noisy vehicles that overtake another vehicle within the detection zone or are part of a traffic stream or convoy are also enforceable using noise cameras, with shorter review times when there is a headway of 1.5 to 2 seconds. The same is true of vehicles passing the noise camera simultaneously from opposite directions. The noise camera tested during the roadside trials is capable of automatically rejecting these scenarios to reduce false positives if the enforcement officer considers this to be desirable.

The trials during Parts B and C found that noise cameras have performance limitations where there is stationary or slow-moving traffic. This is because there are multiple vehicles in the detection zone, making it more difficult to attribute noise levels to a specific vehicle without manual review. When vehicles are close together, the vehicle’s registration plates may not be visible, preventing enforcement action from being undertaken if the excessively noisy vehicle is otherwise identifiable. Installation of noise cameras in environments where stationary and/or slow-moving traffic is regularly expected (for example at traffic light controlled junctions) should have a lower priority unless multiple units are installed to overcome these issues or the technology is further improved.

Noise cameras are capable of being deployed at other junctions, roundabouts and interchanges but evidence packages may require longer review times to compensate for decreased ANPR reliability and photo quality due to the number plate orientation changing as vehicles turn into and from junctions. There is also an increased likelihood of vehicles queuing within the detection zone while an excessively noisy vehicle turns into or passes a junction. A further consideration from placing cameras in these areas is that vehicles typically accelerate from a junction, roundabout or interchange and this can result in accidental driving errors that cause an increase in noise. Examples of this include grinding gears, missed gears and false neutrals. This increases the risk of enforcement action upon drivers who made a genuine error when accelerating away from the junction, roundabout or interchange and subsequent challenges to enforcement.

The deployment of noise cameras in locations with high noise levels is also possible, particularly for array-based products. For the environmental noise level to not have a significant effect on the noise camera’s performance, the typical noise maxima that occur due to extraneous environmental noise (i.e. any other environmental noise source other than the road traffic along the noise camera is monitoring) would need to be 10 dB lower than the noise emissions from an excessively noisy vehicle. As the lowest noise level attributed to an excessively noisy vehicle during the roadside trial was 86 dB L_{AFmax}, typical extraneous environmental noise maxima that occur near to the camera would need to be ≤76 dB L_{AFmax}. Such environmental noise maxima typically occur due to transport noise sources (road, rail, air, pedestrian crossing alarms, level crossing alarms), construction or heavy industry. Strategic noise maps or baseline noise survey data could be used to identify high noise sites and investigate whether noise maxima from extraneous environmental noise sources will cause an increase of the noise maxima which may be enforceable.

Table 8-1 summarises the potential enforceability excessively noisy vehicles in a selection of live traffic scenarios based on the outcomes of the roadside trials and the track trial undertaken during Part B [11].

Table 8-1 Enforceable scenarios

Scenario	Comments
Single carriageway	Assignment of noise levels to individual vehicles is easily achievable. This is also possible when vehicles are overtaking, in a convoy or traffic stream, and vehicles pass the noise camera from opposing directions. Limited manual review is required when vehicles have an approximate headway of 1.5 to 2 seconds.
Dual carriageway or high-speed road	A noise camera unit would be required for each direction of travel. Products with high levels of automation are well-suited to these roads. Manual review may be required for some noise camera technologies to separate vehicles travelling in opposite directions.
Junctions, roundabouts and interchanges, including those that are traffic signal controlled	Complicated layouts may require higher levels of manual review to confirm the source of noise depending on the noise camera technology selected. Higher risk of false positives from unintentional driving errors.
Environments/situations with high ambient noise levels	May require manual review to confirm the source of noise depending on context and level of automation provided by the noise camera.
Stationary or slow-moving traffic	Lengthy manual review required to confirm the noise source as limited automation currently available. Not cost-effective to deploy a noise camera at locations where this is an issue. Further technological improvements or the installation of additional noise camera units may be required to improve the enforceability excessive vehicle noise in this scenario.

There is therefore a balance to be struck between locating a noise camera where there is a suitable flow of vehicles to obtain sufficient legitimate noise camera activations, but also in a location where there is an increased chance of an offending vehicle passing the noise camera in isolation. This balance could be determined on a site-by-site basis via the installation of a noise camera on a temporary basis to gauge the number of noise camera activations alongside the ease of enforceability.

8.2. Limitations of noise camera technologies

8.2.1. Constraints

Each of the noise camera technologies identified or tested during Part B [11] has specific installation requirements that must be met to ensure that the technologies perform as intended. Noise cameras are installed several metres above street level to ensure that the dimensions of the detection zone are suitable and to prevent vandalism, and are often mounted to existing street furniture. The weight of noise cameras varies between products and can influence site selection, as fewer site options are available for those with weights in excess of 20 kg. Many local authorities approached during the site selection stage stated that existing heritage lighting columns and aged lighting assets were unsuitable for noise camera deployment. This may result in the need to install suitable street furniture specifically for the noise camera or the selection of sites that place limitations on the noise camera's detection zone. The use of a mobile asset that is suitable for mounting and powering the noise camera could provide a more flexible approach and reduce constraints.

The installation and removal process for the noise camera systems requires the use of a mobile elevated work platform or cherry picker, which can also influence the selection of deployment sites if there are access restrictions. Full or partial traffic management may also be required depending on the site context, for example, the installation works at Site 2 required a temporary lane closure on a two-lane dual carriageway. The costs associated with these may further influence decisions on where a fixed noise camera can be deployed.

8.2.2. Avoidance of enforcement locations

Selection of an appropriate enforcement site requires full consideration of the surrounding area and local knowledge. The presence of a noise camera in one problem area may cause noisy vehicles to frequent another nearby area instead. This avoidance behaviour was observed during site visits and reported to the AJJV by local residents at Keighley and Rubery, where drivers of excessively noisy vehicles used alternate roads in the local area. Care needs to be taken to not inadvertently encourage anti-social driving on neighbouring streets, which could be achieved through the deployment of additional noise cameras or using a mobile approach.

The deterrent effect of the noise camera was also noted to benefit the local residents living closest to deployment sites who noticed lower noise levels and less disturbance from excessively noisy vehicles. At Keighley, Great Yarmouth and Rubery, drivers often slowed down on approach to the noise camera to avoid detection. The change in driver behaviour achieved the desired effect of reducing noise pollution in the affected areas.

8.2.3. False positives

Noise camera activations from vehicles other than cars or motorcycles were the most common cause of false positives from the noise camera product tested in the roadside trials. Reducing the occurrence of false positives is key to ensuring confidence in the technology and minimising the workload of enforcement officers.

The roadside trial results show that the tested system successfully screened out heavy goods vehicles throughout the trial, meaning that no false positives were generated due to this particular type of road user. This demonstrates that noise camera technologies can be further developed to reject activations caused by other irrelevant vehicle types, such as buses and construction vehicles.

Integration and accurate operation of an ANPR component is also an important requirement for an efficient review of the evidence package. This continues to be the weakest component of noise camera technologies to date, taking into account the outcomes of Phase 2 [3] and Phase 3 Part B [11]. However, this is resolvable with further development.

8.2.4. Enforcement operator review time

The Part A research [10] and roadside trial have shown that the review time for each noise camera activation is between five and ten minutes depending on the level of automation offered and achieved by current noise camera products. Further automation is required to screen out false positives, retrieve the number plate of the detected vehicle and prepare a contravention record. This is required to achieve a review time of up to two minutes per noise camera activation to improve the economic viability of the technology.

8.3. Noise limits

Table 8-2 discusses the options for the suggested noise threshold level. The final row of the table, which discusses the possibility of a different noise threshold level for cars and motorcycles, could be combined with any of options 1 to 4. The options discussed in Table 8-2 have been considered in setting the noise threshold level presented in Chapter 9.2.

Table 8-2 Options for enforcement noise levels

Option	Description	Discussion
1	Single noise threshold level – 95 dB L_{AFmax} (as recommended in Part A [10])	Table 5-2 shows that above 95 dB L_{AFmax}, 100% of vehicles were deemed excessively noisy. The recommended threshold noise level from Part A report is supported by evidence from roadside trials. A level of 95 dB L_{AFmax} excludes 57% of subjectively excessively noisy vehicles captured at the roadside trials.
2	Single noise threshold level – <95 dB L_{AFmax}	Examining the noise bands directly below 95 dB L_{AFmax}, 45% of vehicles between 92.0 to 92.9 dB L_{AFmax} were deemed as excessively noisy, with the figure rising to 67% of vehicles with a noise level between 93.0 to 93.9 dB L_{AFmax}. Setting a noise threshold below 95 dB L_{AFmax} is more likely to generate false positives from vehicles with high noise levels that are not subjectively considered to be excessively noisy.
3	Single noise threshold level – >95 dB L_{AFmax}	All of the vehicles measured above 95 dB L_{AFmax} were considered excessively noisy. Therefore, a threshold level higher than 95 dB L_{AFmax} could lead to a proportion of excessively noisy vehicles being unidentified. A level above 95 dB L_{AFmax} maybe viewed by some authorities as too cautious.
4	Split noise threshold level depending on speed limit of road	The onset of vehicles deemed excessively noisy was at 85 dB L_{AFmax} for roads with speed limits of 30 mph and 50 mph. There is therefore considered to be insufficient evidence to suggest a separate noise threshold trigger level at different speed limits.

Option	Description	Discussion
-	Split noise threshold level for cars and motorcycles	The onset of whether a vehicle was considered to be excessively noisy was very similar for cars and motorcycles, so there appears to be no justification for assigning a separate threshold for different vehicle types. This is consistent with the recommendation from Part A [10].

The recommended single threshold noise level of 95 dB L_{AFmax} from Part A report for all road speed limits and all vehicle types is supported by evidence from roadside trials.

8.4. Trial limitations and uncertainties

The outcomes from the noise camera trial showed that 4% of the 1,777 noise camera activations were attributable to an excessively noisy car or motorcycle. The low ‘success’ rate is in part linked to the selection of threshold noise levels that were selected to ensure that the noise camera was operational and that there were some standard cars and motorcycles to compare against. Fewer noise camera activations would have occurred if higher threshold noise levels were selected.

The roadside trials took place during autumn and winter months, which also influenced the presence of excessively noisy vehicles and site conditions. The majority of the roadside trial applications indicated that the presence of excessively noisy vehicles is greater during the summer months. This suggests that there is a seasonal influence and that a higher number of excessively noisy vehicles may have been detected during a summer trial. However, the trial methodology and outcomes have removed uncertainties associated with weather-based tolerances for enforcement noise levels.

A further factor influencing the roadside trial outcomes is avoidance of the trial sites. The noise camera trial received significant media attention and some misleading reports suggested that offending vehicles would be fined. This encouraged drivers of these vehicles to use alternate routes or drive more carefully past the noise camera. For these reasons, the number of excessively noisy vehicles detected from the trial is not considered a representative indicator of the numbers of excessively noise vehicles on UK roads.

8.5. Enforcement routes

There are a number of possible pieces of legislation under which noise offences could be enforced using the equipment evaluated in this study. A selection of these are listed in Table 7-1, but the critical choice which divides their relative effectiveness and cost is whether to employ a disposal route which results in endorsed driving licences (criminal) as with speed cameras or just a fine (civil) as with bus lane cameras. Table 8-3 lists at a high level the key advantages (green) and disadvantages (red) of each, with areas requiring more consideration or investigation in yellow.

Table 8-3 Enforcement routes

Category		Civil Enforcement	Criminal Enforcement
Deterrent Effect	Penalty	Fine, circa £100	Fine, upwards of £100
	Re-education course option, e.g. NDORS/UKROEd	Possible	Possible
	Licence endorsement	No	Potentially (3 points tbc)
	Escalation route for non-payment	Civil recovery with added costs (e.g. Bailiff)	Magistrates court, increased fine, costs, Increased points, County Court Judgement, Disqualification (via totting up)
Timescale to implement	Legislation Change	No	TBC. Note also, driver at the time must be proven, not just vehicle keeper. 6 months time limit for summary only offences
	Private sector development of equipment	Fast, incentivised by faster route to market and lower accuracy requirements	Slow, disincentivised by unknowns and level of proof required
Cost	Capital cost	Lower	Higher (accuracy, proof burden). Annual recalibration
	Revenue cost (per offence processing)	Lower – simple, civilian staffed process	Higher – more checks, police officer involvement, requirement to identify driver not just vehicle keeper
Stakeholders needed		Local Authority	Local Authority, Police and Magistrates courts must all support/collaborate
Public support		Unknown – research needed	Unknown – research needed
Legal challenge		Less likely	More likely (due to greater penalty and scope for disqualification via totting up)

In summary, the higher penalty of an endorsable (criminal) offence has the potential to be a more effective deterrent to anti-socially noisy driving styles or the deliberate modification of vehicles to produce excessive noise. The fine based on civil route however avoids many of the delays, costs and risks which have frustrated the rollout of other automated enforcement (speed and red light cameras).

Not only will a criminal/endorsable system cost more and take longer to achieve, but the sunk costs of certification and years of delay before payback may deter suppliers from even offering a product in the UK market. Informal discussions with leading industry figures confirms this.

Once into the operating phase, the cost of processing each offence will be higher for a criminal system than for a civil one at every stage, meaning that public authorities may not be able to participate in a scheme due to the costs.

The final factor in deciding this, namely what is ‘reasonable’ as a penalty requires research into the attitudes of the public and other stakeholders as to the ‘equivalence’ of this offence against other motoring or related offences.

Subject to this public opinion/public interest test, the other factors suggest that overall a civil route is by far the more likely to come to fruition and tackle the noise problem, especially since time may be at a premium as vehicles shift to quieter electric powertrains.

9. Recommendations

9.1. Development of noise camera systems

9.1.1. Evidence package

The entire prosecution lifecycle should avoid ambiguity where possible to ensure that the required evidence burden for civil or criminal enforcement routes is met. It is therefore of paramount importance to ensure that the performance of the noise camera system and the evidence package are not compromised. It also follows that the contravention detection must include the vehicle's pass-by noise level and an audio file demonstrating the excessive noise as well as the corresponding ANPR record confirming the identity of the excessively noisy vehicle.

To improve the integrity of the evidence package and prevent GDPR breaches, it is recommended that where possible the video file contains one contravention only. In addition, the video file should contain an appropriate amount of time prior to and after the vehicle passing the noise camera. This would allow the enforcement officer to see and listen to the vehicle approaching and passing the noise camera when confirming the contravention. Long video files can be trimmed within the noise camera unit or in a back office, depending on factors such as the reliability of data transfer, cost of transmission, cyber security and data storage.

The evidence collected for each contravention must be packaged into a single coherent folder that can be verified as a complete evidence pack prior to being transmitted via a secured channel. If transmission is to take place over a secure private network, the evidence package will require authentication. On the other hand, if transmission is to be carried out on a network that can be accessed by a third party, both encryption and authentication along with a secure interface will be required.

9.1.2. System packaging and equipment distribution

A constraint of noise cameras is that they can be too heavy to install on many existing lighting columns, which can support a maximum additional weight of approximately 20 kg. As all components of the noise camera need to be mounted at height, the structural requirements from the upright infrastructure are high, especially under high wind conditions.

It is recommended that suppliers work towards a single-box solution that is light enough to be mounted to any existing upright structures, such as lighting columns and CCTV masts. Furthermore, a lighter system will mean it will be easier to manoeuvre and install.

If a single box solution is not achievable, it is recommended that a structural survey is undertaken of the lighting column, CCTV mast or other upright structure that the noise camera would be installed on to confirm its suitability. The installation design may require adjusting depending on the condition of the upright structure. For example, the microphone and cameras can be mounted at height while the rest of the system (such as the processing unit) can then be housed in a cabinet at a lower position. The security of the cabinet would require careful consideration. In the event of severe threats, such as unauthorised access, the system should suspend enforcement, stop any data recording and delete any encryption keys and unsecured evidence packages. A clear-text alarm message will need to be sent by the system, indicating that enforcement has been suspended and a ciphertext detailed status message describing the fault detected should also be sent to the back office.

To reduce potential risks from electromagnetic interference and fluid ingress, extra care will however be needed to ensure the system is immune to interference from a range of electromagnetic threats both in the surrounding and from other components within the system.

9.1.3. System configuration

At Site 1, it was found that residents tend to park their vehicles outside their homes during night-time. This affected the performance of the system as it altered the anticipated vehicle path until the noise camera was reconfigured to address this. An option for future developments is to consider the use of a timetable, where the noise camera system configurations change at scheduled times. In the case of Site 1, there could have been one configuration for daytime and another one for night-time. If a timetable is to be implemented, a mechanism and an associated notification system will have to be in place to confirm each configuration change-over. If there is a period when enforcement is not to be taken place, a mechanism within the system will have to ensure that no enforcement evidence will be gathered.

9.2. Noise threshold for enforcement

After evaluation of the data collected from the roadside trials and the Part A outcomes and recommendations, it is considered that a single figure noise threshold of 95 dB L_{AFmax} at 7.5m from the centreline of each traffic lane should be adopted for enforcement. This threshold would apply to both excessively noisy cars and motorcycles, for day and night periods, at all speed limits and for all weather conditions (subject to review by enforcement officer).

9.3. Enforcement route

After reviewing the civil and criminal/endorsable enforcement options, it is recommended that the project considers a civil enforcement route due to the lower risk of legal challenge and the lower burden on the evidence package as proof of the driver at the time is not required, only the vehicle. Due to the lower burden of proof, civil enforcement equipment is faster and less costly to build, approve and operate, meaning that a civil system is more likely to attract UK-spec products and to be feasible to deploy in a cost-neutral way, so bringing benefits to communities.

9.4. Next steps for the project

As noise cameras have been found to operate effectively at roadside environments, the next step for the project would be to progress to a live enforcement trial. The main focus of the live enforcement trial would be to work with key stakeholders, the police and the court system to integrate the enforcement component after the receipt of evidence packages from noise camera activations. This would ensure that enforcement processes run smoothly should a national rollout of the technology be pursued. The Traffic Management Act includes offences for moving traffic and bus lanes based on outcomes of automated technology, which provide a precedent for the integration of noise camera technologies.

A key factor in the eventual success of a live enforcement scheme will be to carry public support along with the technology, not just in the principle of noise enforcement but in the detail of how its implemented. This would answer the Public Interest Test and form a valuable next stage prior to any wide-spread rollout. Social research questions and techniques can provide evidence to support this and can assist with many decisions, not just a binary go/no-go but also with choices and policy setting over items such as reasonable threshold setting, where to place cameras for the greatest good and what the penalty should be. Members of the vehicle modification community and motoring enthusiasts can also be invited to participate in the social research. This can be undertaken using the following approaches:

- Evidence reviews to apply learnings from other sectors;
- Qualitative research through focus groups and interviews; and
- Quantitative research to gain results at scale and follow on from qualitative research.

To support the business case for using noise cameras as an enforcement tool, the cost-benefit assessment can be updated and refined if more data sources become available. Studies can be commissioned to fill knowledge gaps, leading to a more robust appraisal of the cost-neutrality of these systems.

The use of artificial intelligence can improve automation, reduce false positives and reduce human time costs for data review. A clear area to prioritise is the identification of different vehicle types so that vehicle types that are not relevant for enforcement can be screened out. This would benefit local authorities using PSPOs as an enforcement route, who may choose to use a lower noise threshold than recommended in this study. Similarly, an automation tool could be developed to review low frequency vehicle noise levels where this information is available to screen in vehicles that are more likely to be excessively noisy in subjective terms. Other applications can include screening for driving styles that generate excess noise or targeting false positive generation.

As noise cameras become further developed and ready for market, the need to implement a type approval process for noise cameras will become increasingly relevant. This will ensure that competing noise camera products meet the required technical, safety and regulatory standards. A defined data security standard is also required for protection of noise camera data and transmission to ensure that appropriate data encryption and authentication protocols are implemented. The Department for Transport's Certification of Approved Devices [16] can provide a useful starting point for developing this.

9.5. Summary of Phase 3C

The outcomes of Phase 3C are summarised in Table 9-1 with reference to the objectives specified for Phase 3C.

Table 9-1 Summary of Phase 3C outcomes

Description	Summary of outcome
To further test the performance of suitable noise camera products in real world driving environments, particularly in urban environments	• Roadside trials were undertaken at Keighley, A4174 Bristol Ring Road at Barrs Court, Great Yarmouth and Rubery for 2-6 weeks at each location. The selected sites represent a variety of suburban and urban contexts. • There were 1,777 noise camera activations during the roadside trial, of which 4% corresponded to excessively noisy cars or motorcycles. • The main causes of false positives during the trial were linked to vehicle type and the identification of incorrect vehicles. These are generally resolvable through setting the trigger noise level in line with our recommendation and implementing improvements to the tested system's ANPR capabilities.

	• Further work is needed to optimise the evidence package and contravention record for an efficient enforcement process. • A single figure noise threshold for enforcement of 95 dB L_{AFmax} should be adopted. This threshold would apply to both cars and motorcycles, for day and night periods, at all speed limits and for all weather conditions (subject to review by enforcement officer). • Enforcement using noise cameras is well-suited to single carriageways, dual carriageways and high-speed roads. Junctions, roundabouts and interchanges can also be suitable deployment sites but may require additional review time by an enforcement officer. Locations with stationary vehicles or queuing traffic should not be prioritised unless lengthier evidence review times are deemed acceptable. • Deployment of a noise camera at a fixed location is most cost-effective on major roads. The breakeven point can be as low as 1 excessively noisy vehicle per day depending on the legislation used for enforcement and the fine amount. A mobile noise camera may provide a better cost/benefit on local roads by tackling a wider area. • Rising compliance over time would improve noise pollution from excessively noisy vehicles (and reduce revenue) at the point of enforcement. A mobile noise camera would have a deterrent effect and bring noise pollution benefits over a greater area as drivers would not know its location. The increasing proportion of electric and hybrid vehicles will reduce the number of potential offending vehicles over time, but not until the end of life for the first noise cameras.

10. Conclusions

The noise camera trials undertaken in controlled conditions during Part B and in real-world settings in Part C demonstrate that noise camera technologies are capable of detecting and identifying excessively noisy vehicles in a number of traffic scenarios. The performance of MicrodB's array-based noise camera was good overall with noticeable improvements in image quality and automated vehicle identification since the Part B trial. Further developments to the newly added ANPR component are expected to result in improvements to the stability of the system and consistency in the quality of its evidence packages.

The outcomes of Part A and Part C provide an objective and subjective evidence base that 95 dB L_{Amax} at 7.5 metres is an appropriate noise level for enforcement against excessively noisy vehicles on roads with speed limits of 50mph or less. Setting the noise camera to activate at this noise level would eliminate false positives from irrelevant vehicle types, such as lorries and construction vehicles. Lower noise levels may be considered to enforce against vehicles that are noisy but not excessively noisy, however, this would risk increasing the number of false positives prior to review by an enforcement officer. The use of an artificial intelligence program to screen out irrelevant vehicle types would make this more achievable.

A key constraint of an array-based noise camera is its increased weight, which places limitations on the number of prospective deployment sites if use of existing infrastructure is desirable. Reducing the weight of the system to below 20 kg would provide more flexibility in where the noise camera can be sited and reduce installation costs for the local authority or police force.

The roadside trials sites are representative of a variety of suburban and urban contexts where excessively noisy vehicles can cause disturbance to local residents. Although at some locations not many excessively noisy vehicles were detected, the noise camera's deterrent effect resulted in changes to driver behaviour and avoidance of the installation site. While this achieved the ultimate aim of reducing noise pollution close to the installation site, further consideration is required to prevent the issue from being exacerbated in neighbouring areas. The installation of additional units on alternate routes or a mobile noise camera could achieve this and incentivise drivers to fit quieter aftermarket products to their vehicles.

The observed offence numbers at the three trial sites on local roads would not bring sufficient revenue to cover the cost of an end-to-end camera enforcement operation. However, a mobile noise camera could offer a more cost-effective solution by targeting compliance and behavioural change over a wider area. The breakeven point for a noise camera system would require at least two excessively noisy vehicles to pass by per day throughout its usable life, a proportion of which would be successfully detected and fined. Further information, for example though surveys, is required on the prevalence of excessively noisy vehicles without noise cameras present to validate the breakeven point. Rising compliance over time will gradually reduce revenue, but this is the objective of the technology and needs to be planned for. Social science research to determine the public acceptance of noise cameras and fine values that would carry public and political support would benefit future business case assessments and better inform operational decisions such as site selection.

A potential next step for this research is to progress to live enforcement trials, where enforcement officers would gain practical experience of using noise cameras. This would provide an opportunity to integrate the evidence packages from noise camera activations with back-office systems to ensure that the technology can be implemented smoothly if progressed to a national rollout. It is recommended that this is undertaken alongside a public perception study that could influence the selection of deployment scenarios and enforcement action decisions. The development of a type approval procedure and data security standard for noise cameras is also a priority to ensure that all products achieve the required performance standards and data encryption protocols.

11. References

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Appendix A. Glossary and Abbreviations

AADF	Average Annual Daily Flow.
Aftermarket exhaust	Replacement exhaust from a third-party company.
AI	Artificial Intelligence.
AJJV	Atkins Jacobs Joint Venture.
ANPR	Automatic Number Plate Reader.
A-weighting	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear. A-weighted sound is often denoted by ‘A’ in noise indices, for example L_{Aeq} and L_{Amax}.
CAPEX	Capital Expenditure.
dB, dBA	Decibel, A-weighted decibel.
Contraflow	Two-way traffic; a bidirectional road with one lane in each direction.
Decibel	The unit of measurement for sound.
Detection zone	The area on the road surface where a noise camera detects a vehicle exceeding the stated noise threshold and records an evidence pack. The detection zone has an entry and exit point dictated by the direction the vehicle is moving in. The centre point is positioned in the middle of the detection zone.
DfT	Department for Transport
DVLA	Driver and Vehicle Licencing Agency.
Engine Mapping	The process of tuning an engine via the vehicle’s electronic control unit to achieve a higher engine power output. This can potentially create ‘pops and bangs’.
Evidence package	Encrypted data outputs from the noise camera pertaining to a potential offence that are transmitted securely to an enforcement officer.
False positive	A test that wrongly indicates that a particular condition or attribute is present. In the context of this project, a false positive is a compliant vehicle being identified by a noise camera as excessively noisy.
False negative	A test that wrongly indicates that a particular condition or attribute is not present. In the context of this project, a false negative is an excessively noisy vehicle being identified by a noise camera as a complaint vehicle.
Fast response	Noise measurement with a 125 ms time constant, meaning that the sound pressure level is sampled every 125 ms. This is sometimes denoted in noise indices by ‘F’, such as L_{AFmax}.
Frequency	Rate at which sound wave crests reach a given point (cycles per second), measured in Hertz (Hz). Low frequency sounds have long wavelengths, resulting in a bass sounds (e.g. engines, thunder). High frequency sounds have short wavelengths and have a higher pitch (e.g.

	bird song, emergency vehicle siren). For this project low frequencies are 31.5 Hz to 250 Hz octave bands, mid frequencies are 250 Hz to 1 kHz octave bands, and high frequencies are 1 kHz to 8 kHz octave bands.
GDPR	General Data Protection Regulation.
Ground truth	The independent measurement of an event using calibrated instruments (e.g. a sound level meter).
Headway	The time (or distance) between the rear of the leading vehicle and the front of the following vehicle.
HGV	Heavy goods vehicle.
Hypothecation/ Netting Off	The ring-fencing of revenue from a system (in this case fines) to pay for operation of that system
ISO	International Organization for Standardization.
$L_{Aeq,T}$	The equivalent continuous A-weighted sound pressure level during time period T.
$L_{Amax,T}$	The maximum A-weighted sound pressure level measured during time period T.
MP	Member of Parliament.
NDORS	National Driver Offender Retraining Scheme.
Noise	Unwanted sound.
Noise camera	System typically comprising a sound level meter with one or more microphones, ANPR and video camera that can be used to identify vehicles producing excessive noise.
Noise camera activation	Instance where the noise camera is activated by a vehicle whose noise level exceeds the noise threshold trigger, resulting in the automatic generation of an evidence package.
Noise threshold trigger	The ‘noise trigger’ is the decibel level set in the noise camera. It is used to activate the noise camera to measure and record the individual vehicle passing the camera.
Octave Band	Standardised frequency bands for analysis of noise signals. Defined in BS 2045, each band having a centre frequency twice the previous one. The sequence includes 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz.
OPEX	Operational Expenditure.
Performance Map	Engine remapping which modifies the amount of fuel injected and the timing of its injection in order to achieve a higher power output or higher torque.
Pops and bangs	The effect where noise is generated on the vehicle overrun. Normally fuel is stopped when letting off the accelerator but the remapping changes this to continue to inject fuel and change the ignition timing so it is retarded to a point when it sparks the mixture very late in the engine combustion cycle and the igniting of the fuel happening in the exhaust rather than the engine.

PSPO	Public Spaces Protection Order.
Public Interest Test	An assessment of whether an intervention such as legislation or government intervention is in the overall interests of the public, and is supported by public opinion
Standard vehicle	A vehicle that passed the noise camera that was not modified or driven in a manner that generates excess noise.
SRN	Strategic Road Network.
Type approval	A procedure whereby a manufacturer can obtain certification from a competent authority that their product meets the requirements of a certain European Directive or Regulation.
UK	United Kingdom.
UKROEd	UK Road Offender Education.
Wavelength	The distance between the two peaks (or two troughs) of a sound wave, measured in metres.

Appendix B. Acoustic Instrumentation Information

The details of the acoustic instrumentation integrated with the noise camera or utilised on site visit are summarised in the tables below. Calibration certificates are available upon request.

Table 11-1 Sound Level Meter 1

Type	Frequency Meter	Microphone	External Pre Amplifier	Internal Pre Amplifier	Associated Calibrator
Manufacturer	01dB	GRAS	01dB	01dB	01dB
Model	FUSION	40CE	Pre No22	FUSION	CAL21
Serial Number	11199	233344	1605096	11199	34565046
Last calibration	15/04/2021	15/04/2021	15/04/2021	15/04/2021	14/04/2022

Table 11-2 Sound Level Meter 2

Type	Frequency Meter	Microphone	External Pre Amplifier	Internal Pre Amplifier	Associated Calibrator
Manufacturer	01dB	GRAS	01dB	01dB	01dB
Model	FUSION	40CE	Pre No22	FUSION	CAL21
Serial Number	11201	233351	1605099	11201	34565048
Last calibration	23/11/2022	23/11/2022	23/11/2022	23/11/2022	23/11/2022

Table 11-3 Sound Level Meter 3

Type	Frequency Meter	Microphone	Associated Calibrator
Manufacturer	Cirrus	Cirrus	Cirrus
Model	CR:171C	MK:224	Model 105
Serial Number	G061732	606473B	50719
Last calibration	02/02/2022	21/01/2022	02/02/2022

Appendix C. MP Application Form

Roadside Vehicle Noise Measurement – Phase 3 Application Form

Vehicle noise is recognised as a significant cause of noise pollution and excessively noisy vehicles often lead to annoyance and complaints. The Department for Transport has commissioned the Roadside Vehicle Noise Measurement – Phase 3 project to address this issue. An element of the project is to conduct roadside trials of noise camera technologies.

If you are interested in the noise camera trials taking place in your area, please complete this application form. This information will be reviewed by our contracted researchers at the Atkins-Jacobs Joint Venture to assess the suitability of sites for participation in the trials. Following initial screening, you may be approached for further information necessary to finalise decisions on appropriate sites.

We will assess all applications made, however please note that sites are more likely to be selected in situations where:

- The problem described occurs on the public highway, not on a private road or land adjacent to a public highway.
- There is existing street furniture such as streetlights, traffic lights or road signs where the camera can be safely mounted.
- The local highway authority is already aware of the issue described.

In addition, sites are less likely to be selected in situations where:

- There are other significant noise sources in addition to the problem described, such as the site being adjacent to a particularly noisy construction site.
- The visibility of the public highway is obstructed, preventing the camera from functioning properly.

Please note: Due to the limited number of trial sites available, applicants may submit one site for consideration only.

Answer boxes can be expanded to fit as necessary, and attachments may also be provided.

Applicant details	
Name:	
Email address:	
Phone number:	
Constituency:	

The limited amount of personal data that we collect for the noise camera trials will only be used for that purpose, in line with DfT's public task. To find out more about how DfT handles personal data and what your rights are under data protection legislation, see our Privacy Notice on GOV.UK

Description of noise issue	
Please describe the nature of the noise issue (for example, car cruises, motorcycle racing, anti-social behaviour, who is affected).	
What type(s) of vehicles are causing the issue?	
What if any measures have been taken to resolve the aforementioned issue?	
Frequency of occurrence of the noise issue (for example, weekly, monthly, certain time of day)	
Is the noise issue seasonal? If yes, please provide details.	
Are there periods where the noise issue is more frequent or disruptive? If yes, please provide details.	

Proposed site	
Is the proposed trial location in a rural or urban setting? What is the surrounding land use?	
Description of location (road name, town, post code, speed limit of road)	
Does the site have any road usage restrictions? For example, buses only or a vehicle weight limit.	
Map or link to Google Maps of proposed site	
Does the proposed site have any streetlight columns, traffic light columns, road signs, or any other street furniture suitable for attaching the noise camera equipment to? If yes, please provide details.	
Is the Local Highway Authority willing to allow us to power the cameras through a connection to their lighting column or other street furniture?	
Has the Police, Local Highway Authority and/or local council provided consent for the noise camera trial to take place at the proposed site? If yes, please provide contact details of relevant people at each organisation.	
Are there significant noise sources at or near the site in addition to the problem described above, for example a noisy construction site? If yes, please give details.	

Financial Matters	
Are the Police, Local Highway Authority and/or local council willing to subsidise or waive the installation costs?	
Miscellaneous	
Would any third-party approvals be required (for example, private landowners)?	
Please provide examples (if any) to show collaborative working between the Police, Local Authority and Local Highway Authority to address road vehicle noise.	

Appendix D. AJJV Ground Truth Data

Site	Date	Time (hh:mm:ss)	Vehicle Type	Measured Noise Level (dB L_{AFmax}, 50 Hz to 20 kHz)	
				Ground truth	Noise Camera
1	25/10/2022	18:19:44	Car	73.9	57.9
		18:19:47	Car	76.6	65.1
		18:47:37	Tractor	81.0	59.1
		19:29:17	Motorcycle	77.4	72.2
		19:59:50	Car	75.8	66.1
	26/10/2022	07:42:08	Van	85.3	66.3
		08:15:24	Van	77.6	71.9
		08:55:31	Large van	77.9	64.1
2	22/11/2022	08:42:26	Motorcycle	82.9	85.1
		08:47:32	Motorcycle	83.8	93.4
		08:48:55	Lorry	81.5	84.0
		08:55:00	Car	85.1	84.5
		09:02:15	Emergency vehicle	80.0	81.0
		09:19:43	Car	82.4	82.5
		09:38:36	Lorry	80.9	86.9
		09:39:05	Motorcycle	80.5	84.3
		09:43:52	Modified car (with pops and bangs)	88.6	90.4
3	11/12/2022	18:34:32	Car	74.7	66.7
		18:46:44	Car	75.7	64.3
		18:58:15	Car	76.1	67.7
		19:19:05	Car	73.6	62.7
	12/12/2022	07:50:04	Modified car	76.9	68.4
		07:38:11	Van	78.9	No data
		08:20:46	Modified car	82.3	No data
4	26/01/2023	18:47:29	Car	77.1	72.8
		18:50:49	Car	78.1	74.0
		19:05:28	Car	85.1	73.5
		19:16:17	Car	72.3	72.8
		19:20:32	Car	74.7	74.0
		20:03:29	Car	72.8	72.9
		20:04:54	Car	77.6	76.8
		20:21:21	Car	76.7	70.8

ATKINS Jacobs