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VEHICLE OPERATION AND ROAD TRAFFIC NOISE REDUCTION

P G Abbott Transport Research Laboratory, Crowthorne, Berkshire
S M Phillips Transport Research Laboratory, Crowthorne, Berkshire
P M Nelson Transport Research Laboratory, Crowthorne, Berkshire

1. Introduction

Of all the sources of noise nuisance in London, traffic is the most pervasive. Whether the noise is caused by the actions of individual vehicles or by the drone of the volume of traffic, well considered actions are required to reduce both the level and the annoyance of noise.

The ability of relevant authorities to influence traffic and vehicle noise are wide ranging although rarely exercised. This is largely because the most effective methods are frequently the responsibility of departments with no explicit responsibility for noise. With the greater acknowledgement of noise, various bodies are looking at how it can be reduced. Examples of potential noise reduction measures available range from improved infrastructure, traffic management and controls and specifications for vehicles, either through charging schemes or those directly controlled such as London's buses and its 19,000 taxis.

In general, the methods of controlling traffic noise have divided the problem into three components. These methods deal with controls aimed at reducing noise emission at source, controls along the propagation path, such as highway alignment and the use of barriers, and controls at the receiver which include better insulation of dwellings. Which method or combination of methods is used depends to a large extent on the degree and nature of the noise problem and upon the influence of both economical and operational constraints. In urban areas, for example, the use of barriers and other forms of screening are often not appropriate or create other problems such as severance.

Controlling noise at source is clearly the most obvious starting point since the success or failure of this strategy ultimately affects the other two courses of action. Source controls involve a consideration of technological solutions aimed at reducing emission through design changes principally to the vehicle. However, the design of the road surface also influences the generation of vehicle noise via tyre/surface interaction mechanisms and also needs to be considered here. Secondly there is a growing realisation that source noise can be controlled through a better understanding of the role of traffic management and calming techniques. Finally, encouraging changes to the way in which vehicles are driven can potentially control noise at source.

One key ingredient that appears to pervade each of the above approaches is the role of vehicle speed as it is widely known that noise levels and speed are strongly related. Unfortunately speed controls do not always provide the benefits expected and it is vitally important therefore to understand these relationships when considering speed control as a strategy in reducing noise impact.

This paper examines some of these issues. It presents the results of studies showing how road surface and tyre designs can affect the relationship between noise generation and speed and indicates where improvements in their design can help to reduce both the overall noise level and the dependency on speed. It reviews the research done to examine the effects of traffic calming on noise generation. Finally it briefly examines some issues associated with driver behaviour and what scope there is for reducing noise, in the future, by encouraging less aggressive, 'quieter' driving styles.

2. Relationships between speed and traffic noise

Figure 1 illustrates the relationship established between traffic noise and mean traffic speed. It also shows the relationship is dependent on traffic composition. The figure is taken from the statutory prediction method 'Calculation of Road Traffic Noise, CRTN' [1] which was revised at TRL in 1988.

In the near future, the change from L_{10} to L_{eq}, as a result of the need for greater harmonisation in noise models, will allow more sophisticated use of traffic speeds in noise models. Initially the speeds of different classes of vehicles will be able to be taken into account. Further refinements could allow the distribution of traffic speeds to be taken into account. Models are already available which can show, for example, the effect of noise on stricter enforcement of the speed limits.

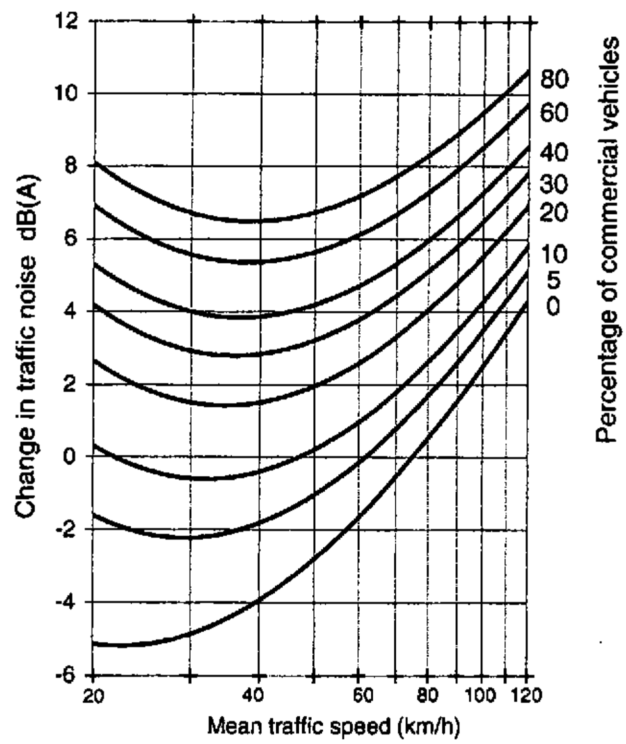


Figure 1. Change in traffic noise with mean speed and composition, relative to 75 km/h and 0% commercial vehicles [1]

The influence of traffic speed on traffic noise is perhaps easiest to discuss by identifying two speed regions. Above 50 km/h, where the traffic tends to flow relatively freely with drivers engaging top gear, and below this speed, where non-free flow conditions will tend to prevail. Above about 40 - 50 km/h, most of the noise sources on a vehicle vary proportionately with the logarithm of road speed or engine speed. It is not surprising therefore that that for free flow conditions traffic noise is also logarithmically related to vehicle speed. The slope of the speed function depends on a number of factors including the types of vehicles in the traffic stream and the type of road surface and tyres.

At lower speeds, driving conditions often dictate that gear changing occurs with the result that traffic noise levels become less dependent on vehicle speed. The figure illustrates this point where the slope of the speed functions reduce with speed eventually reaching the horizontal. It should be noted that for flows containing heavy vehicles the slope of the speed function can become negative at lower speeds, i.e. the noise increases as the speed is reduced further.

This example shows that dramatic reductions in vehicle noise can be achieved by reducing road speed although this is not a general panacea that applies to all speeds. Clearly, at relatively low speeds the reductions in vehicle speed may not always produce the reduction in traffic noise levels required.

One aspect of speed control to be considered is the reduction of speed for specific time periods. Recent studies have examined systems such as the M25 controlled motorway scheme where variable speed limits are determined by the volume of traffic and weather conditions. Alternative systems have been examined where lower speed limits are enforced during times, for example, when children are entering or leaving school. In other countries, reductions in speed limits during the night have been considered for reducing noise. Such systems would need to be examined carefully, but, particularly with the concomitant improvements in safety, could provide useful reductions in noise and associated disturbance.

3. Traffic management and calming

Traffic management is a multi-faceted subject embracing aspects as diverse as parking restrictions, economic policy, public transport, traffic signal control, training and education, highway design and many others. Although individual aspects of traffic management have been studied for many years, the principal aim of this research has rarely been environmental control. In fact the prime objectives have been to reduce congestion and, for calming techniques in particular, to reduce accidents.

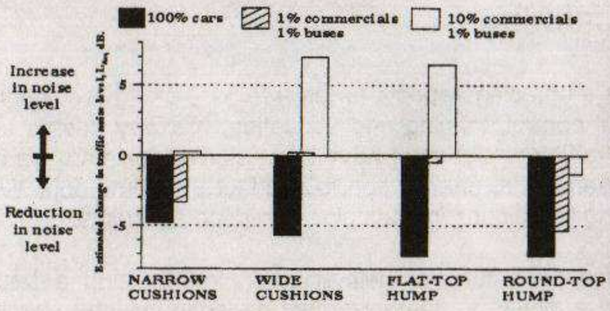
For several years now TRL researchers have been turning their attention to obtaining a better understanding of the environmental benefits/disbenefits of different traffic management and calming strategies. These studies have included a comprehensive examination of the effects on noise and vibration of different traffic calming methods and a wide range of case studies have examined the influence of traffic management on environmental impact. This work includes investigating the environmental impact of various urban management and safety schemes.

The influence of traffic management on noise levels may depend upon a number of inter-related factors. For example, a scheme designed to reduce traffic volume may appear to reduce traffic noise but only if the removal of some of the traffic does not encourage an increase in speed from the remaining traffic. This a particular concern when bypasses are used to relieve congestion. Generally the bypasses should also be accompanied by further measures to discourage speed increases in the roads where traffic volumes decrease as a result of the bypass. Overall traffic noise levels will decrease by about 3 dB(A) each time the flow is halved. However, for flows below about 200 vehicles per hour greater changes in noise level can occur when the traffic flow is changed. This observation is particularly important for areas where the flow is relatively low since the noise can rise rapidly with relatively small increases in overall flow rates.

Removing a proportion of commercial vehicles from residential areas is also a valuable management tool that can improve amenity and reduce noise levels. Figure 1 illustrates the significant effect commercial vehicles have on traffic noise levels. In particular, at low road speeds, where introducing just 10% commercial vehicles into the traffic stream can increase noise levels by more than 5 dB(A).

TRL's environmental work on traffic calming has mainly focussed on examining the noise and vibration issues associated with modifications to both the vertical and horizontal alignment of road surfaces. Vertical deflections (i.e. humps and cushions) in particular are known to be very effective in reducing speeds and accidents [2]. However, there has been some concern that the gains might have been at the expense of increased traffic noise and vibration. The work has involved both field trials where different designs of traffic calming measures had been installed and test track work where the principal objective was to establish the most appropriate designs for humps and cushions. Further details of this and other relevant work can be obtained by consulting the bibliography of publications produced by the Driver Information and Traffic Management Division of the Department of the Environment Transport and Regions [3].

Overall, the research has shown that after the installation of road humps and cushions, the maximum noise levels from cars are reduced. So to is the overall traffic noise level where light vehicles form most of the traffic stream. For example, daytime traffic noise levels were reduced by about 3dB(A) alongside the road humps installed in Slough and by about 4dB(A) alongside speed cushions installed at a site in York. However, the effect of road humps and speed cushions on noise from large vehicles is more complex. Whilst there are some decreases in maximum noise levels from large commercial vehicles, due to reductions in their speeds, this can be offset by increases in noise from the bodywork of such vehicles as they pass over the humps and cushions. The net effect of these vertical deflection measures on overall traffic noise depends on the proportion of large commercial vehicles in the traffic stream, and on the type of road hump installed.



Typical reductions in vehicle speeds (km/h) after installing each type of profile

Cars	15	23	23	23
Buses/commercials	4	14	20	20

Figure 2(a) Estimated change in traffic noise level after installing different types of speed control measures for a range of traffic scenarios; (b) a typical set of speed cushions

Figure 2(a) shows the estimated change in traffic noise levels for different designs of speed cushions, see Figure 2(b), and road humps. A range of traffic scenarios is included with increasing proportion of large commercial vehicles and buses in the traffic stream. The average reduction in speeds expected for each type of installation are also shown. The estimated changes in traffic noise levels shown in the figure were obtained from measurements of noise from vehicles driven over the profiles laid on the TRL test track. It has been assumed that the total flow remains unchanged between the before and after installation situations.

It can be seen that the narrower cushions offer a better overall acoustic performance than the wider cushions as the proportion of large commercial vehicles in the traffic stream increases. The performance of round top humps is notable in that traffic noise levels reduce even when the proportion of commercial vehicles is 10%.

A better understanding of this result can be seen from Figure 3(a) which shows how the average maximum noise level for large commercial vehicles varies with speed for different road profiles. It can be seen that for the assumed speed of 24 km/h for wide cushions and 18 km/h for the flat topped hump, there was a substantial increase over the flat road noise levels (assumed speed 45km/h) of 7.9 dB(A) and 6.2 dB(A) respectively. For the narrow cushions there was an increase of about 2 dB(A) and for the round topped hump a decrease of about 2 dB(A). Again the importance of controlling speed can be seen from the figure since although the flat topped hump produced the best performance for the assumed target speed, any increase in speed above this point would rapidly reverse the benefits observed.

The figure also illustrates that the highest maximum noise levels from large commercial vehicles were generated when travelling over the profiles simulating poorly maintained surfaces, eg the 'trench' and 'ramp'. This type of situation has been the stimulus for complaints about vehicle body noise from the public the recognition by DETR that guidance was needed on both road maintenance and vehicle designs to reduce body noise in practice. As a result TRL, in association with commercial vehicle industry, have produced a 'Guide to good practice on the control of vehicle body noise' which should help both vehicle manufacturers and operators to minimise the occurrence of both vehicle body and suspension noise in the future [4]. Some examples of the body noise sources considered are shown in Figure 3(b)

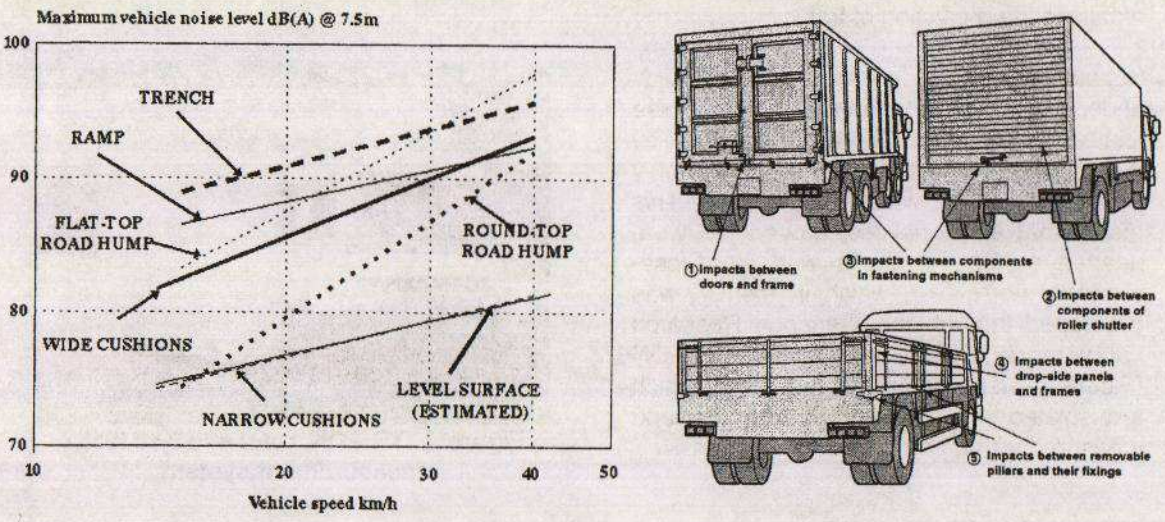


Figure 3(a) Comparison of average noise levels for commercial vehicles alongside different road profiles; and (b) examples of body noise sources

In association with the studies of noise, TRL have also carried out trials to assess the effect which road humps might have in generating ground-borne vibrations when commercial vehicles are driven over them [5]. The objective was to provide input to the development of guidance for local authorities to help avoid potential nuisance from vibration. Overall narrow cushions tended to produce the least vibration for a given crossing speed relative to other profiles. The slope of the leading ramp of a road hump can have a noticeable effect on vibration levels and advice has been provided on this design aspect. Vehicles that failed to straddle cushions produced about double the levels of vibration than when straddling. For this reason, narrower cushions might be preferred where there is a high proportion of commercial vehicles [6].

3. Influence of tyre and road surface design

Technological changes to vehicles have already led to substantial reductions in vehicle noise for certain types of vehicle operation. The introduction of vehicle noise type approval in Europe in the 1970's and the progressive reduction of limit values in the following years have helped to encourage the development of vehicles with substantially quieter power units. However, while limit values have reduced the maximum permitted noise from vehicles by as much as 11dB(A) the reductions in traffic noise have been more muted. This is partly due to the effects of traffic growth but also it is due to the influence of tyre noise that has not, hitherto, been addressed by the vehicle noise type-approval process. This is now being rectified by the introduction of tyre noise type approval.

The development of a range of quieter road surfaces has also progressed over the past few years, and, as a result of research, a much better understanding of the main factors and mechanisms affecting tyre/road surface noise has been developed. Again speed is an important ingredient affecting the generation of tyre noise.

The assessment of road surfaces is another important aspect of traffic noise reduction. In 2000, type approval for proprietary thin asphaltic surfacings was introduced through the Highway Authorities

Products Approval Scheme (HAPAS) [7]. This scheme included a noise test developed by TRL and based upon the internationally standardised Statistical Pass-by. This noise test provided UK authorities with the ability to specify and compare the acoustic performance of surfacings and use the results in the prediction of traffic noise.

Supplementary test methods were already under development when the HAPAS noise test was introduced. The Statistical Pass-by test had been acknowledged as having only limited application when used alone. This meant that additional test procedures were needed. One of these was the Close-proximity noise test, which in the UK was developed through the Transport Research Laboratory's TRITON test system. TRITON (Figure 4) uses dedicated test tyres, which are isolated in a sound-proof enclosure and measured with an array of microphones.

Figure 4. TRITON, road and tyre noise measurement system

Although the surfaces on high-speed roads are monitored by bodies such as the Highways Agencies, it is only recently that low-speed roads have started to come under the same degree of attention. TRL is working closely with researchers in other countries to develop suitable methods for testing road surfaces. The City of Paris is already beginning programmes to measure the noise of its road surfaces. The preferred method is close-proximity method as used with TRITON. This system was originally developed for use on high-speed roads but recent work for surfacing contractors has shown that testing can also be carried out at speeds of 50 km/h (30 mph).

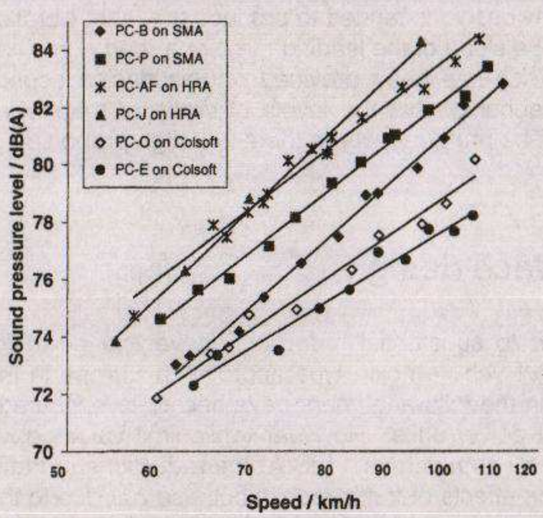


Figure 5. Speed/level relations for three different types of surfaces

Figure 5 shows some examples of the relationships derived from measurements taken of noise from different car tyres running on different road surfaces. The data shown in the Figure was taken as part of a recent study of tyre noise generation for DETR and the Highways Agency. The study examined over 170 different tyre and road surface combinations. The surfaces included in Figure 5 are the conventional Hot Rolled Asphalt (HRA), Stone Mastic Asphalt (SMA) which is now more widely used and a proprietary low-noise surfacing under examination at TRL.

It can be seen from the figure that the noise level versus speed functions for the different tyres and surfaces cover a wide range. For a given speed the differences in noise between the quietest and noisiest tyre/surface combination examined ranges from about 6 dB(A) at a speed of about 70km/h to over 8 dB(A) at the higher speed of 100km/h. Generally it is found that the quieter tyre/road surface combinations tend to produce noise level versus speed functions with the shallowest slopes.

These results indicate that noise levels can be reduced for both moderate and high-speed roads by surfacing the road with one of the growing range of new types of low noise road surface. Additionally by encouraging the greater use of tyres designed to produce lower noise, which should be an outcome the forthcoming legislation on tyre noise type approval, lower noise levels will result. German authorities have already introduced environmental labelling scheme for passenger car tyres. This includes a noise test and the intention is that all public bodies will be required to use the greenest tyres on their fleets.

4. Behaviour and driving style

The noise emission from road vehicles is dependent on the driving style adopted. Generally introducing less aggressive driving styles will reduce noise emissions. In addition changes to driving style that promotes 'quieter driving' will also tend to improve fuel economy, reduce emissions, reduce accident risk and probably also reduce driver stress. An analysis of accidents and speed reductions to affect 20 mph zones indicates, for example, that there is a 6.2% reduction in accidents for each 1mph reduction in vehicle speed [2].

A comprehensive review carried out as part of TRL's internally funded research found that there was considerable scope for reducing noise emission in urban areas by encouraging drivers to drive passively rather than aggressively. One study examined in the review showed that when drivers were told to drive an urban route in a passive rather than aggressive style, reductions of 5dB(A) in average noise levels and fuel savings of between 19 and 32% were achieved whilst journey times were lengthened by less than 5% [8].

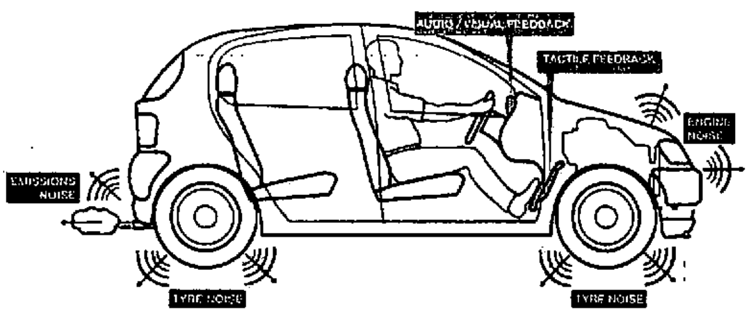


Figure 7. Driver feedback systems to encourage environmental conscious behaviour

How to secure the changes in behaviour needed, however, remains elusive. One promising approach is to make use of emerging technology to present drivers with feedback information on the consequences of their driving performance. Research is needed, however, to determine the most appropriate way of providing drivers with this information without risking overloading the driving task itself

There are many forms of feedback systems that could be used. Some operate in real time, where information on driving performance is relayed immediately back to the driver, and some types of feedback can be delayed as in training. A schematic diagram of how real time feedback might be used to affect driving style is shown in Figure 7. In the example, noise levels are determined from information supplied by the engine management system, which enables engine and exhaust noise to be computed. Average tyre noise levels are determined from the speed of the vehicle. This information is suitably processed in real time and fed back to the driver either through the use of visual or audible cues from the dashboard or through the use of tactile measures. The tactile measure shown in the example is an active throttle. This can be linked to vehicle operation and can be programmed to vary the resistance to the throttle pedal to help minimise rapid throttle opening. An assessment of the effectiveness of different real time feedback methods under controlled and safe conditions using TRL's driving simulator has been proposed.

5. Conclusions

The operation of both vehicles and traffic is clearly an important factor in reducing noise impacts. Of the many factors that contribute to operation, speed is perhaps the most important. Reducing speed makes a lot of sense not just for reducing noise emissions it also reduces the numbers and severity of accidents and can reduce fuel consumption and associated harmful emissions. Reducing the dependency of traffic noise on speed can provide one line of attack. Using some types of low noise road pavements and better designs of vehicle tyres will not only reduce overall noise levels but will offer the additional advantage of a lower dependency on speed which will provide additional benefits at the higher end of the speed range.

Getting drivers to reduce speed is another approach. Traffic calming techniques will help to encourage lower speeds, but they are not universally liked by the people they are designed to protect. Significant noise reductions are possible, consistent with the speed reductions achieved, but care has to be taken to ensure that the traffic using roads treated with humps and cushions, for example, do not contain significant proportions of commercial vehicles. Following research at TRL, advice is now available to local authorities on the most appropriate speed control designs to use and where to locate these treatments to avoid problems with both noise and ground vibration. Enforcement of existing speed limits can also be an effective measure in the some circumstances.

Apart from inducing speed changes and safer driving through road design changes, there needs to be general change in behaviour of drivers to adopt a more environmentally friendly driving style. Substantial noise reductions are achievable through quite modest changes in behaviour. Feedback systems could be used to both inform and to educate drivers in 'quieter' driving style although care must be taken to ensure that feedback encourages the changes required without overloading the driving task itself.

Such systems could be considered for a wide range of vehicles and may be used in conjunction with traffic management or road user charging systems to maximise the reduction of noise.

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