The perceived environmental impacts of traffic management schemes: a literature review

Prepared for Driver Information and Traffic Management Division, Department of the Environment, Transport and the Regions

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Executive Summary

The introduction of traffic management and traffic calming schemes has, in the past, caused a wide range of public reactions. Some schemes are generally popular and receive widespread acceptance, whilst others produce a hostile reaction leading to their abandonment. Often the popularity of a scheme depends greatly upon public perceptions of the environmental changes that have occurred. Consequently, it is important to have a clear understanding of the main environmental factors affecting public perception and acceptance, so that methods of prediction can be developed, and perceived impacts can be taken into account at the scheme design stage. This Report examines the most important factors affecting the perceived environmental impacts of different traffic management schemes.

The main methods of predicting public reactions to the environmental impacts of traffic management schemes include:

- The use of generalised relationships between subjective measures of community reaction and objective measures of pollution, noise, or vibration.
- The direct measurements of community reaction to specific schemes.

The first method assumes that generalised dose-response relationships can be applied to traffic management schemes irrespective of scheme design or location, whereas the second approach assumes that reactions to a scheme at one location can be applied to similar schemes located elsewhere. An objective of the Report was to examine the capabilities of these two approaches for predicting environmental nuisance resulting from traffic management schemes.

Quantitative evidence relating to dose-response relationships for air pollution is rather limited. Carbon monoxide (CO) is the only gaseous pollutant for which the relationships obtained in different studies can be compared. Even here there is some disagreement on the form of the relationship; at low CO concentrations the degree of reported nuisance due to air pollution appears to be independent of pollutant level, but there may well be an increase in nuisance where CO concentrations are particularly high. For black smoke, a weak correlation has been observed between measured concentrations and nuisance. However, the results from dose-response studies are likely to be quite variable since responses might be influenced by a number of personal, social and situational factors, and by the terminology employed to describe nuisance.

Dose-response relationships for road traffic noise have been established from various studies. Although the precise form of these relationships tends to vary between studies there is, as might be expected, a general tendency for annoyance to increase in a reasonably predictable way with an increase in traffic noise level. However, considerable differences in the dose-response relationships have been observed between populations who have been exposed to the same traffic noise level for some time (i.e. steady-state conditions) and those who have recently experienced a significant change in noise level. For the latter condition, annoyance changes have been shown to be significantly greater than would have been predicted from the steady-state dose-response relationships. Consequently, it was concluded that it would not be appropriate to predict the impact of noise changes resulting from traffic management schemes using steady-state dose-response relationships.

Previous studies have highlighted the importance of heavy vehicles as contributors to traffic noise annoyance. Generally, the degree of annoyance increases with increasing flows of these vehicles. However, one study has shown that when heavy vehicle flows exceed about 1500-2000 vehicles per day annoyance reactions tend to stabilise. This would indicate that traffic management schemes which reduce the numbers of heavy commercial vehicles are unlikely to have any major effect on noise annoyance unless the flow reductions achieved result in flows significantly less than 1500-2000 vehicles per day. Further work is needed to establish whether this result can be applied generally.

Community reactions to traffic vibration are summarised in Volume 11 of the Design Manual for Roads and Bridges (DMRB), the Government’s advice on the assessment required at stages in the development of a trunk road, and the requirements for reporting the effects on the environment. For a given level of noise exposure and average traffic flow conditions, the DMRB assumes that the percentage of people bothered by vibration is 10% lower than the corresponding figure for noise nuisance.

Information on the public response to traffic management schemes is limited in the UK. Almost all the relevant literature relates to traffic calming schemes, which are arguably the ones best suited to the task of surveying public opinion since they are predominantly installed in residential areas where any changes in environmental conditions will affect people in, or near, their homes. In addition, there are potentially a wide range of impacts with which people can associate. Attitude surveys generally ascertain the general level of acceptance of a scheme. For example, a previous TRL study showed that, on average, 65% of the people living alongside a traffic calming scheme approved of it. These surveys have tended to focus on the perceived effects on traffic speed and safety rather than perceived changes in the environment. It is therefore not clearly understood to what degree traffic calming affects perceptions of specific components of the environment such as air pollution, noise, and vibration.

It would appear that most respondents to questionnaires do not generally consider that traffic calming schemes affect local levels of air pollution. In studies where respondents have reported changes in nuisance due to air pollution they have tended to be divided in their perceptions of the change, and little or no evidence has been provided to suggest what it was about the schemes...
that influenced the respondents’ feelings. The effects of traffic calming on nuisance due to road traffic noise have received slightly more attention than the perceived effects on air pollution. This may be because noise is easier to detect, or it might be due to a better understanding on the part of the respondents of the concept of noise. There is some evidence to suggest that residents with traffic calming measures positioned close to their homes are more annoyed by noise than other residents. However, on account of the lack of information, no attempt was made in this Review to formulate relationships that relate changes in community annoyance to any aspect of traffic calming. For both air pollution and noise, existing studies currently appear to indicate that the effects of traffic calming on changes in annoyance show a large amount of variation between sites.

It is evident from this Review that current understanding of the dose-response relationships for air pollution and noise, and knowledge of the perceived environmental impacts of traffic management schemes, are inadequate for the task of predicting community reaction to future traffic management and traffic calming schemes. More work is therefore required before decisions about the design of a scheme can be aided by methods for anticipating public perception of the scheme’s environmental impacts.
1 Introduction

1.1 Background

Although the physical measurement of environmental pollution is important to quantify levels of public exposure, environmental problems are about how people react to stimuli, and measurements have limited value until they can be related to the human reaction (Watkins, 1981). Large sections of the public are annoyed by the environmental impacts of traffic, and the success or failure of any measures to reduce these environmental impacts will depend ultimately on how public perception of the environment is affected.

The introduction of traffic management and traffic calming schemes has, in the past, caused a wide range of public reactions. Some schemes are generally popular and receive widespread acceptance, whilst others produce a hostile reaction leading to their abandonment. Often the popularity of a scheme depends greatly upon public perceptions of the environmental changes that have occurred. Consequently, it is important to have a clear understanding of the main environmental factors affecting public perception and acceptance, so that methods of prediction can be developed, and perceived impacts can be taken into account at the scheme design stage.

The main methods of predicting public reactions to the environmental impacts of traffic management schemes include:

- The use of generalised relationships between subjective measures of community reaction and objective measures of pollution, noise or vibration.
- The direct measurements of community reaction to specific schemes.

The first method assumes that generalised dose-response relationships can be applied to traffic management schemes irrespective of scheme design or location, whereas the second approach assumes that reactions to a scheme at one location can be applied to similar schemes located elsewhere.

The overall objective of the work described in this Report was to produce a review summarising the current capabilities of the two methods in the prediction of nuisance. This was achieved by examining the most important factors that influence the perceived environmental impacts of different traffic management schemes. The Review has been commissioned by the Driver Information and Traffic Management Division (DITM) of the Department of the Environment, Transport and the Regions (DETR) as part of a programme of work to investigate the environmental impacts of traffic management schemes.

Before continuing, a mention should be made of the terminology employed in the material reviewed. The terms annoyance, nuisance, dissatisfaction, bother, and disturbance are often used in the literature to describe peoples’ reactions. Although these terms do have different meanings they are often used interchangeably and without qualification. Annoyance for example, suggests a more strident form of response than bother or dissatisfaction, whereas disturbance implies that the reaction is associated with a particular activity.

The approach adopted in this Report is to use the term nuisance to describe the overall effect (or combination of reactions), and the generic term annoyance to describe community or individual reaction where possible. However, where specific reference is made to review material the descriptors used in the referenced work will be used.

1.2 Environmental impacts of traffic management

The ultimate aims of traffic management are to reduce congestion in urban town centres, to improve safety in residential areas, or both. Congestion reduction schemes are employed to improve the flow of traffic and minimise queuing and stop/start driving. Typical schemes are urban traffic control (UTC) systems which optimise the timing of traffic signals, and bus priority on urban routes which can reduce journey times for public transport. Safety improvement schemes aim to reduce accidents on main, distributor, and residential roads in urban areas outside town centres. Typical measures include road closures, banned turns, mini-roundabouts, road narrowings, refuges, one-way streets and pedestrian crossing improvements. Area-wide traffic safety management may also include traffic-calmed areas which are intended to reduce the occurrence of road traffic accidents by reducing speeds. Residential traffic calming measures include road humps, narrowings, chicane.s, surface markings, pinch-points, and changed priorities.

The potential environmental impacts of road traffic are listed in Volume 11 of the Design Manual for Roads and Bridges (DMRB) (Department of Transport et al., 1994). The Manual presents eleven discrete categories which may need to be considered when assessing the environmental impact of a road scheme. The categories of environmental impact are:

- Air quality
- Traffic noise and vibration
- Cultural heritage
- Disruption due to construction
- Pedestrians, cyclists, equestrians and community effects
- Ecology and nature conservation
- Vehicle travellers
- Landscape effects
- Water quality and drainage
- Land use
- Geology and soils

Of these, the most important impacts that may be influenced following the introduction of a traffic management scheme are air quality, noise and vibration. This is partly because opinion surveys have shown them to be major sources of public nuisance, and also because they are directly affected by changes in parameters that are themselves influenced by traffic management. For example, both the exhaust emissions and noise produced by road vehicles are dependent upon the composition, volume and speed of traffic, mode of vehicle operation,
and driver behaviour, all of which may be affected by traffic management schemes.

Effects on pedestrians, communities, vehicle travellers, and land use could also become apparent after the introduction of a scheme, but these effects will not be considered in this Review.

1.2.1 Exhaust Emissions

In general, traffic management schemes which reduce the total volume of traffic in an area will tend to be associated with reduced emissions in that area. However, where such changes cause a redistribution of traffic, then environmental disbenefits can also be expected. In addition, trip generation caused by relief of congestion can also mitigate against improved environmental benefits. Schemes which encourage a change from private car use to public transport should produce net benefits environmentally although, in each case, the environmental changes produced by, say, increased flows of public transport vehicles, need to be assessed in order to obtain the overall impact of the scheme. Schemes which reduce congestion tend to reduce fuel consumption and emissions due to the reduction of stop/start operations. Restrictions and stopping controls on major urban routes can reduce congestion, increase average speeds and hence reduce vehicle emissions, and selective restrictions to vehicle access can modify traffic composition. An individual vehicle of a particular type will display wide variations in emissions depending on the way it is being used, and much of the variability in emission rates will be accounted for by the operational variables: average speed, rates of acceleration and deceleration, engine temperature and state of maintenance. Traffic calming schemes will change the mode of operation; parking management schemes may affect the numbers of vehicles operating with cold engines (Abbott et al., 1995).

1.2.2 Noise

According to Abbott et al. (1995), schemes designed to reduce the volume of traffic may reduce traffic noise. On the other hand, if the reduction in traffic volume were to lead to an increase in vehicle speeds, then the overall effect may be an increase in noise levels. If a traffic management scheme were introduced which caused a few vehicles to transfer from a heavily-trafficked road to a minor road where the pre-existing flows were low, then it is likely that there would be only a very small reduction in noise alongside the heavily-trafficked road but a large increase in noise alongside the minor road.

The introduction of a speed-reduction measure, such as a road hump or speed cushion, can influence traffic noise levels in a number of ways. For example, lowering the speed of vehicles may mean that vehicle noise emission levels are lowered. In addition, after the measures are installed traffic flows may be reduced, leading to further reductions in noise levels. However, vehicle noise emissions may also depend upon the way the vehicles are driven: a passive style of driving, at a lower but constant speed, may contribute to lower noise levels, whereas an aggressive style, with excessive braking and acceleration between speed control devices, gives rise to a high fluctuating noise level which can contribute to noise disturbance to residents. In addition, the use of road humps and cushions to reduce traffic speed may give rise to vehicle body noise (e.g. body rattles, suspension noise, etc.) which may be a cause of noise disturbance (Abbott et al., 1997).

There may also be a number of non-traffic parameters that influence traffic noise levels. These include the type of road surface and site layout features which affect the propagation of noise. For example, rough surfaces can cause more noise through tyre/road interaction than smooth ones; some asphaltic surfaces such as porous asphalt, and thin surfacings such as Stone Mastic Asphalt, tend to generate less noise than conventional surfaces. A new bus lane may alter the distribution of traffic across the carriageway and effectively move the noise source nearer or further away (Abbott et al., 1995).

1.2.3 Vibration

When assessing the environmental impact of traffic vibration it is important to consider the main mechanisms which operate when traffic vibrations are experienced. Vibrations can be transmitted through the ground, or through air as low frequency sound. Therefore, a number of different parameters need to be considered in the assessment.

Airborne vibration from traffic can be produced by the low-frequency noise emissions from the engine and exhaust of vehicles, and normally dominates the frequency range 50-100 Hz. This type of noise can cause light, flexible structures such as doors and windows to vibrate. This can, in turn, generate secondary noise effects which are perceived as ‘vibration’. These effects can be particularly noticeable for older types of ‘sash’ window. Modern, well-fitting double-glazed windows are, by comparison, much less prone to producing perceptible vibration effects.

The main contributors to low-frequency noise are commercial vehicles, particularly where traffic is congested in built-up areas. Some buses pulling away from bus stops can also produce high levels of low-frequency noise. Control measures include the re-fitting of windows which may be caused to vibrate by low-frequency noise, and reducing the flows of vehicles in the traffic which are the main emitters of low-frequency noise. Re-location of bus stops away from residential buildings, and measures taken to reduce the number of stop/start operations by commercial vehicles in residential areas, will help to reduce vibration effects.

Vehicles running on smooth surfaces do not normally cause perceptible ground vibrations, but high levels have been found at building foundations where the underlying soil is soft and houses are close to surface irregularities. In these situations serious nuisance and anxieties about building damage are likely to arise.

The main parameters influencing the levels of vibration that need to be considered in the assessment are the gross vehicle weight, the existence of significant road surface irregularities, the speed of traffic, and the soil conditions between the road and the receptor position. If ground-
borne vibrations are a major concern, then there are a number of remedial measures that can be taken. The simplest approach would be to remove significant surface irregularities in the road surface near the affected properties. Other approaches are to reduce the speed of heavy goods vehicles near the properties, to re-route HGVs to less sensitive roads, and to introduce a limit on gross vehicle weights of about 7.5 tonnes. However, decreasing the load carried by a particular HGV does not necessarily reduce the vibration level, and in some cases an empty lorry can produce higher levels of vibration than when fully laden (Watts, 1990).

1.3 Public perception of the environmental impacts of traffic

It is desirable that the members of a society are comfortable with their local environment in terms of, amongst other things, air quality and noise levels. While physical measures of air pollution levels are available, they rarely give a clear indication of the impact of the problems caused by the pollution. Although some of the impacts on, for example, health, flora and fauna, and building materials are readily identifiable, most impacts are experienced in terms of annoyance, disturbance, or fear by those affected.

It has been reported that such psychological reactions to air pollution are difficult to assess, and it is even more difficult to compare them with quantifiable impacts (May, 1988). More success has been achieved when measurements of traffic noise have been compared with the associated nuisance.

Information about public attitudes and opinions to traffic nuisance is usually obtained from questionnaire surveys involving personal interviews. Surveys have shown that large sections of the public are annoyed to some extent by the environmental impacts of traffic (e.g. Morton-Williams et al., 1978; Aas et al., 1991), although McCrae & Williams (1994) suggested that environmental issues usually become more important once people have first satisfied other social priorities.

However, the exact sources of nuisance are not always clear. The public’s perception of the environmental impacts of traffic may be influenced by factors other than the actual levels of air and noise pollution, including location, social status, the media, traffic parameters, and general environmental awareness. The general feeling of an improved traffic environment may therefore influence the perception of air pollution, noise and vibration.

Chapter 2 of this Review summarises the relationships between nuisance due to air pollution from traffic and actual pollutant concentrations. Attitudes to road traffic noise have been studied in greater detail, and extensive coverage of this work would require a larger review. The effects of traffic management schemes on noise annoyance are likely to be complex, and potentially important areas, such as the effects of sudden changes in mean noise levels, have only been addressed comparatively recently. Chapter 3 therefore investigates particular aspects of noise perception that could be important when assessing the impacts of schemes. Perception of traffic vibration is reviewed in Chapter 4. Those surveys of attitudes to traffic management schemes which have revealed information relating to noise, vibration, and air pollution are identified in Chapter 5. The findings of the Review are summarised in Chapter 6.

2 Nuisance from traffic derived air pollution

Graedel et al. (1986) listed several hundred compounds that are emitted by petrol and diesel vehicle exhausts, and are contained within evaporative emissions. By comparing their source strengths and toxicities, Ball et al. (1991) narrowed the list down to the components which represented the greatest risk to public health near roads, namely: nitrogen dioxide (NO\textsubscript{2}), carbon monoxide (CO), sulphur dioxide (SO\textsubscript{2}), lead, formaldehyde, acrolein, benzene, toluene, and a range of polycyclic aromatic hydrocarbons including benzo-a-pyrene. These pollutants vary in their impact on health from irritant to carcinogen, and some of them may also react to form secondary pollutants which can also represent a health hazard. In recent years, concern has also been mounting about the effects on public health of vehicle-derived particulate matter, particularly the respirable PM\textsubscript{10} and PM\textsubscript{2.5} fractions\textsuperscript{1}.

It has been suggested that increased concern about the public nuisance generated by air pollution from road traffic has resulted from the combined effects of the increased prominence of the motor vehicle as a source of pollution and the greater environmental awareness of the public (McCrae and Williams, 1994). However, although people are evidently concerned about pollutant emissions from road traffic, it is often difficult or impossible for the senses to detect their presence in the atmosphere; even at the concentrations experienced at roadside, the gaseous pollutants listed above are usually below human detection limits.

On the other hand, smoke emissions from road vehicles have been widely perceived by the general population to be a major nuisance in terms of soiling effects both inside and outside the home (Ball et al., 1991). This was confirmed by the findings of a DoE survey highlighting the public’s concern about the relationship between vehicle-derived pollution, especially particulate matter, and human irritant/health effects. In urban areas particulates, black smoke and unpleasant odours were often associated with the exhaust emissions from diesel vehicles (Department of the Environment, 1994).

The relationship between exposure to a source of nuisance and community reaction is termed the dose-response relationship. Only limited attempts have been made to link the degree of public nuisance to measured (or calculated) levels of pollutants, possibly because the situation is complex; ambient air pollutants are derived from a number of sources, all of which make a contribution to nuisance effects. This clearly makes it difficult to state that a particular pollutant derived from a single source is

\textsuperscript{1}PM\textsubscript{10} and PM\textsubscript{2.5} are fractions of particulate matter with aerodynamic diameter of less than 10\textmu m and 2.5\textmu m respectively.
the sole cause of a nuisance effect (Williams, 1994).

Survey data relating to how air pollution from traffic has been perceived by the public has often been categorised according to the terminology employed to describe nuisance. The major types of public nuisance arising from vehicle emissions include:

- dust and dirt;
- smoke, fumes and odour;
- reduced visibility;
- urban soiling;
- irritation of eyes and mucous membranes.

The vehicle-derived pollutants contributing to these different types of nuisance are listed in Table 1.

Table 1 Vehicle-derived pollutants contributing to nuisance effects

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<th>Nuisance</th>
<th>Pollutant</th>
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<tr>
<td>Fumes/smoke/odour</td>
<td>Particulates/volatile organic compounds/hydrocarbons</td>
</tr>
<tr>
<td>Visibility reduction</td>
<td>Particulates/hydrocarbons/secondary pollutants (e.g. ( \text{O}_3 ), ( \text{NO}_2 ))</td>
</tr>
<tr>
<td>Soiling</td>
<td>Particulates</td>
</tr>
<tr>
<td>Physical irritation</td>
<td>Particulates/hydrocarbons/secondary pollutants/volatile organic compounds</td>
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The review of public nuisance due to traffic-related air pollution presented in the thesis by Williams (1994) is probably the most comprehensive to date. The author covered existing attitude survey data relating separately to each of the nuisance effects listed. The following sections are designed to give only an overview of the relationships between measured levels of air pollution and nuisance expressed using this terminology, and for a more detailed assessment the thesis by Williams should be consulted. Nuisance due to soiling by vehicle pollutants is encompassed by the sections on dust/dirt and smoke/fumes/odour. Visibility reduction does not appear to be a major public concern, and there is insufficient data to state whether the public consider physical irritation from vehicle-derived air pollution to be a nuisance (Williams, 1994).

2.1 Dust and dirt

Social and Community Planning Research (SCPR) (Morton-Williams et al., 1978) described an extensive survey of England conducted in 1972 which showed that, for people at home, dust and dirt ranked a close second to noise as a traffic-derived nuisance. It also showed that many people believed that traffic was responsible for much of the dust and dirt in their houses; this sentiment was echoed several years later in the review of London Assessment Studies by Smith & Gurney (1992), in which pedestrians ranked dust and dirt third behind danger and noise/fumes as a disturbance from traffic.

The SCPR study also revealed a relationship between public disturbance from vehicle-derived dust/dirt and vehicle flow. The relationship is shown in Figure 1. The degree of disturbance encountered for such modest traffic flows implies that a large number of people must be disturbed by traffic pollution in the UK.

When considering the environmental effects of traffic changes in nine British towns, Mackie and Davies (1981) found that dust and dirt are of greatest nuisance to the public when they are indoors, rather than when they are pedestrians. It was also observed that significant reductions in nuisance from dust and dirt as a result of traffic changes only occurred where there was a substantial reduction in the total traffic flow, or where lorries had been re-routed.

![Figure 1](source: Moreton-Williams et al., 1978)
In spite of the general consensus that dust and dirt constitute a public nuisance, there have only been limited attempts to determine the correlation between physical measurements and the degree of nuisance caused.

Aas et al. (1991) described a health survey of 1025 people in the Vålerenga/Gamblebyen district of Oslo. The survey showed that a substantial part of the population in this district were seriously annoyed by dust/grime from traffic. Information regarding annoyance was compared with an index of estimated 8-hour average CO concentrations for an individual respondent’s home over the survey period. The results, shown in Figure 2, appear to indicate that the relationship between annoyance and calculated CO concentrations is approximately linear.

This concurs to some extent with the results of Smith & Gurney (1992), who found that levels of CO (98th percentile peak hourly concentration) were seen to reflect changes in perceptions of pollution, as measured by the number of comments on air pollution in questionnaire surveys. Although CO is colourless and odourless, Smith and Gurney asserted that in most situations the factors that produce variations in CO levels also affect to the same degree the more easily perceived aspects of pollution (dust, dirt, smell, etc.). However, Williams (1994) has noted that the 8-hour average CO values obtained by Aas et al. (1991) were far in excess of those regularly encountered in the UK at urban background locations (3-4 ppm).

To identify any relationships between the disturbance score for a specific nuisance and individual pollutant concentrations, Williams (1994) combined data from opinion surveys and air pollution monitoring performed in a number of cities. For selected pollutants (CO, NO₂, SO₂, O₃, and black smoke) the mean pollutant concentrations recorded over the sampling period were plotted against the mean disturbance scores for each site and respondent type. The outdoor disturbance scores for dust/dirt and concentrations of the pollutants CO and NO₂ are illustrated in Figures 3 and 4.

From the data Williams concluded that moderate-to-high outdoor disturbance from vehicle-derived dust and dirt was generally recorded at pollutant concentrations which are usual for urban background locations in the UK. This was considered to be important due to the amount of time that the public would be exposed to such conditions. No correlation between outdoor disturbance from dust and dirt and gaseous pollutant concentrations was apparent from the information.

The data obtained by Williams relating outdoor disturbance scores for dust and dirt to black smoke concentrations are shown in Figure 5. Although there is considerable scatter in the data there is some evidence to suggest that disturbance scores increase with increases in black smoke concentration.

### 2.2 Smoke, fumes and odour

A major stumbling block to the evaluation of public nuisance is the difference between the public’s understanding of the word(s) used to describe a nuisance and the strict definitions employed by scientists. For example, people often express annoyance with the fumes produced by vehicles. The word ‘fumes’ is particularly imprecise—it is not always clear whether respondents to questionnaires are thinking of odours or visible smoke, and this makes it difficult to identify the exact source of annoyance. There may also be some degree of confusion relating to perception of air quality in terms of smoke levels. When people think about smoke emissions from vehicles they may tend to visualise the moment of emission on a very localised scale, and they may relate this to recent experiences of particularly polluting vehicles. Once the smoke has dissipated it may no longer be perceived as a nuisance at all.

It is not possible to separate the subject of odour nuisance from the assessment of nuisance from smoke and fumes on account of the perceptual difficulties mentioned.

![Figure 2](image-url) **Figure 2** Percentage annoyed by exhaust emissions or dust/grime inside and outside their home as a function of 8h average CO concentration (source: Aas et al., 1991).
Figure 3 Scatterplot showing outdoor disturbance scores for vehicle-derived dust and dirt and mean CO concentrations (source: Williams, 1994).

Figure 4 Scatterplot showing outdoor disturbance scores for vehicle-derived dust and dirt and mean NO\textsubscript{2} concentrations (source: Williams, 1994).

Figure 5 Scatterplots showing the relationship between outdoor disturbance from vehicle-derived dust and dirt and mean black smoke concentrations (source: Williams, 1994).
The environmental impact of exhaust odours is difficult to quantify since odourants are poorly characterised, rapidly dispersed into the atmosphere, and only present in low concentrations. Consequently, short-lived and localised odours may be the cause of much of the disturbance from odour. However, Williams (1994) found that these odours do not appear to represent a significant public nuisance.

McCrave & Williams (1994) argued that the issues of smoke, fumes and odour were more difficult to quantify than dust/dirt as the public finds it difficult to decide whether they are more disturbed by visual intrusion (smoke), an unpleasant smell (fumes, odour), a general feeling of discomfort, or concerns about health (smoke, fumes, odour). They concluded that although people believe that traffic pollution may damage their health, they actually complain more about dust and dirt, and this may indicate that total suspended particulate (TSP) concentrations are a better indicator of nuisance effects than concentrations of gaseous pollutants.

Williams (1994) determined values of outdoor disturbance scores for smoke, fumes and odour in relation to pollutant concentrations. The results were similar to those shown in Figures 3-5, although the disturbance scores were slightly higher. Again, no correlation between outdoor disturbance from smoke/fumes/odour and gaseous pollutant concentrations was apparent from the information presented, and only a slight increase in disturbance score was seen with increases in black smoke concentration.

Williams considered that his own findings, for both dust/dirt and smoke/fumes/odour, were lacking in precision because they were based on lower ambient concentrations alone. He recorded no extreme concentrations at the urban background sites, and observed that the concentrations measured were below the levels suspected to cause irritant effects to the public. Secondly, interviewing at roadside did not appear to alter the results. This appeared to reinforce the common belief that the public tend to base their annoyance upon their experience of typical local air quality rather than exposure to elevated concentrations, and that respondents assess nuisance in relation to a particular environment (e.g. people expect to encounter pollution at the roadside, and so less nuisance is generated).

Williams did observe a weak correlation between black smoke concentrations and disturbance scores. However, the suggestion of a linear relationship was viewed with considerable uncertainty, and regression equations calculated by the author were determined to be unreliable predictors of nuisance. However, by assuming a linear relationship the author estimated a disturbance score of 3 (moderate) for a black smoke concentration of 0 \( \mu g/m^3 \), and suggested that this may indicate that at typical urban concentrations, factors other than actual air pollution levels had a strong influence on public nuisance from smoke, fumes and odour. Williams identified a need for similar work to be performed in an area where smoke concentrations were abnormally high. This would enable the regression equations derived to be tested. In addition, regular social surveys of public attitudes towards vehicle-derived pollution would have to be repeated in urban areas so that changes in public opinion could be monitored alongside changes in urban air quality.

The links between traffic exposure and nuisance from air pollution are poorly understood at present. Williams has suggested that the factors which contribute to a person’s annoyance from vehicle-derived pollution are highly personal, numerous, and exceptionally difficult to quantify, making predictions of the magnitude of nuisance from pollutant concentrations unreliable. Aas et al. (1991) indicated that there is some evidence to suggest that the amount of annoyance is affected by personal actions, habits, socio-economic factors, and the media as well as pollutant levels.

2.3 Summary
In summary, knowledge of the dose-response relationships for atmospheric pollutants is rather limited. The only gaseous pollutant for which the dose-response relationships from different studies can be compared is carbon monoxide. Even here, there is some disagreement on the form of the relationship, although this may be partly due to differences in the terminology employed to describe nuisance. By including relatively high concentrations, Aas et al. (1991) indicated that the relationship between annoyance and calculated CO concentrations was a linear one. At the lower, and more typical, CO concentrations measured by Williams (1994), the degree of reported disturbance appears to be independent of pollutant level.

Williams’ result might be expected. It is often difficult or impossible for the senses to detect the presence of gaseous pollutants in the atmosphere; even at the concentrations experienced at the roadside, the gaseous pollutants are usually below human detection limits. However, the factors that produce variations in CO levels also affect the more easily-perceived aspects of pollution. Smoke emissions from road vehicles have been widely perceived by the general population to be a major nuisance in terms of soiling effects both inside and outside the home, and there may be a weak correlation between
black smoke concentrations and disturbance scores.

Little or no work has been performed which would show how the studies described could be employed to help improve public acceptance of traffic management schemes. Schemes may alter people’s perception through changes they produce in other aspects of traffic behaviour, and research in this area may prove more fruitful in terms of assessment of perceived nuisance from traffic management schemes.

3 Nuisance from road traffic noise

Large proportions of the people interviewed in national surveys have reported that they are annoyed by noise. Appleyard (1981) observed that in the 1973 US Housing Survey, based on interviews with 53,800 households, 45.5% of respondents reported ‘street noise’ as an undesirable characteristic of their neighbourhood. In central cities, 51% complained of street noise. Road traffic is clearly the most important source of noise annoyance (Morton-Williams et al., 1978; Smith & Gurney, 1992), and noise has generally been seen to be the most annoying aspect of road traffic. Hede & Bullen (1982) surmised that around half of the population in Australian urban residential areas was annoyed by traffic noise, and in the three site survey performed in Norway (Aas et al., 1991), road traffic noise ranked first ahead of fumes and dirt/dust as a traffic-related nuisance.

Road traffic noise affects both users (motorists) and non-users (pedestrians and residents) of the transportation process. It can have a significant effect on the environment and the quality of life enjoyed by individuals and communities (Department of the Environment, 1994). The main impacts have been identified as:

- Speech/communication interference: disruption of conversation (both indoors and outdoors), television, radio or music.
- Task interference: distraction from reading and writing.
- Rest/sleep interruption: delay in the onset of sleep, waking, disruption of sleeping pattern.
- Startle reactions.
- General annoyance.

Lambert et al. (1984) found that traffic noise also leads to a significant increase in behavioural responses such as closing windows, transferring activities to quieter rooms, and sound-proofing the house.

3.1 Noise level and annoyance

An important objective of traffic noise studies is to relate human response to certain physical descriptors of noise exposure (i.e. the formulation of dose-response relationships). The level of nuisance and the effects of noise in the community are determined from questionnaire surveys that use a variety of measurement scales relating to, for example, ‘annoyance’, ‘dissatisfaction’ or ‘bother’.

Noise from road traffic can be considered as a virtually continuous sound which fluctuates almost regularly with passing vehicles. The sound is dependent upon several factors, including distance from the road, type of traffic flow (free-flow or congested), traffic speed, traffic composition, and the type of road surface. Because road traffic noise is usually composed of a complex acoustical pattern, exposure to noise is rated by indices. The main indices that have been developed for assessing traffic noise are $L_{Aeq}$, $L_{A10,15}$, the Traffic Noise Index (TNI), the Day and Night Average Sound Level ($L_{D,N}$) and the Noise Pollution Level ($L_{np}$). The definition of each of these indices is provided in Appendix A.

The correlations between noise level and individual annoyance scores are usually quite low. Surveys have revealed that individuals vary considerably in their sensitivity to noise and this is reflected in their ratings of traffic noise nuisance (Department of Transport et al., 1994).

It is often stated (e.g. Hede, 1984; Job, 1991) that the best exposure indices can only explain up to around 20% of the variation in subjective annoyance among individuals. However, it is common to find that the correlation between noise level and the average of the annoyance scores in a neighbourhood is relatively high, and this indicates that the individual non-noise differences tend to average out. Noise level is therefore a good predictor of the average annoyance response of a community.

The dose-response functions from several social surveys of transportation noise were synthesized into a single function by Shultz (1978), and this has become the standard and most widely-adopted description of the relationship between community annoyance and noise level. By introducing a relatively high cut-off point for annoyance (i.e. only considering the percentage of respondents found to be ‘highly annoyed’ at different noise levels), it was shown that annoyance generally increased with traffic noise level in the way shown in Figure 6. The relationship is generally linear over a wide range of noise levels.

The variation in individual responses around the community average may be partly random, partly due to the failings of the chosen exposure index, and partly due to the fact that people’s tolerance to noise levels and different types of noise varies considerably. People tend to be annoyed or disturbed by, and react differently to, different types of noise. Some may find occasional loud noises intrusive, whilst others may object to a moderate, constant noise. Attitudes to traffic noise may also be related to a number of other factors, including general satisfaction with the neighbourhood (Jonah et al., 1981), and community size (Bradley and Jonah, 1979). In addition, respondents may interpret questions in different ways.

Fields and Hall (1987) noted that a number of hypotheses have been proposed as explanations for the scatter of individual annoyance responses around the community average. These include differences in daytime and night-time annoyance, reaction to multiple noise sources, and variations in individual exposure. An important factor in terms of the potential impact of a traffic management scheme could be a measure of the number of noisy events in a given time period. This topic is explored further in Section 3.2.
Much of the published data on dose-response curves relates to fairly static situations in which the noise level has not changed for several years. Section 3.3 deals with the findings of research conducted at locations where the noise level has changed suddenly.

### 3.2 Number of noisy events

Most of the methods for describing a varying noise have been based on an average of the total sound energy over time. However, several studies have pointed out that this may not be the optimal acoustical concept for expressing the relationship between noise exposure and the extent of annoyance (e.g. Björkman, 1991), and annoyance has been shown to correlate well with non-acoustical factors related to the composition of the traffic flow.

Heavy goods vehicles (HGVs) appear to be a major factor in producing environmental problems. For example, Morton-Williams et al. (1978) reported that 66% of respondents in the national survey claimed to hear lorry noise when they were indoors. Langdon (1976) concluded that in areas in which a congested traffic flow is prevalent, a measure of the heavy vehicle component was a better predictor of noise nuisance than the $L_{Aeq}$ and $L_{A10}$ indices.

Yeowart et al. (1977) investigated community reactions to noise from free-flowing, motorway, and congested traffic at 27 sites. The results showed that no existing traffic noise index (i.e. $L_{Aeq}$, $L_{A10}$, $L_{DN}$, $L_{NP}$ or TNI) could predict reaction adequately under all the traffic flow conditions. It was suggested that sleep disturbance caused by heavy vehicles during the night could be a missing factor, and when indices were combined with measures of traffic volume between midnight and 6 a.m., a marked improvement in their predictive ability was noted under all traffic flow conditions.

The question of the relative importance of individually noisy vehicles versus the ‘bulk flow’ noise of traffic as determinants of community annoyance was addressed by Hede (1984). The author suggested that with exposure indices relating to bulk flow, the variation in subjective annoyance among individuals may be partly due to psycho-social factors such as sensitivity or general attitude, and partly due to the annoyance caused by individually noisy vehicles. Residents who are regularly disturbed by noisy vehicles may rate themselves as ‘highly annoyed’ even though their overall noise exposure is quite low. Indices which uniquely represent noisy or heavy vehicles (such as log%HGV - the logarithm of the percentage of heavy goods vehicles in the traffic flow) have been found to correlate with community reaction. There is evidence that log%HGV is a better predictor in congested traffic conditions. Hede assumed that the reason for this was that free-flowing traffic is relatively constant in noise level, whereas congested traffic is more intermittent and has more perceptible peaks from gear changing in noisy vehicles. He found that the

\[
\%HA = 0.8553 L_{DN} - 0.0401 L_{DN}^2 + 0.00047 L_{DN}^3
\]

![Figure 6 Relationship between noise level and annoyance averaged over 11 surveys (Shultz, 1978).](image)

\[
\%HA = 0.8553 L_{DN} - 0.0401 L_{DN}^2 + 0.00047 L_{DN}^3
\]
correlation between annoyance and log HGV was almost unchanged when overall exposure was held constant, indicating that the percentage of heavy vehicles has an effect on annoyance that is virtually independent of overall noise level. In the converse situation, with log HGV constant, it was suggested that overall exposure to traffic noise also causes annoyance independently of the effect of heavy vehicles. Hede therefore concluded that heavy or noisy vehicles cause annoyance in excess of that accounted for by an index based on overall noise level.

The reasons for the log HGV index being a good predictor of annoyance in congested traffic were also identified by Björkman (1991). The noise level from HGVs is about 10 dB(A) higher than that of light vehicles, and the frequency spectrum is dominated by lower frequencies which are particularly annoying. Hede (1984) had previously argued that the peak noise levels associated with gear changing in noisy vehicles were particularly perceptible, and had also suggested that because noisy vehicles often exceed the threshold level for awakening, they are primarily responsible for the sleep disturbance resulting from traffic noise.

It was later suggested by Hede (1985) that the predictive ability of a traffic noise exposure index would therefore be increased if it included a term for noisy vehicles, although he recognised that this had already been proposed by several investigators (Langdon, 1976; Yeowart et al., 1977). Hede proposed that the most suitable basis for such an ‘extended’ index should be chosen from those which have been consistently found to be reasonable predictors of reaction. He argued that the two most suitable basic indies were $L_{A\text{eq}}$ and $L_{A10(18\text{h})}$, with preference given to the former because the $L_{A10(18\text{h})}$ index ignores the ‘critical’ night-time period, when he felt that the number of heavy vehicles was particularly important. Using the data from the Australian survey by Brown (1978), the most suitable form of the extended index for predicting the percentage of respondents in the top two categories on Brown’s 7-point scale (i.e. those highly annoyed) was determined by Hede to be:

$$L_{A\text{eq}} + (0.1 \text{MNV})$$

where $\text{MNV} = \text{mean number of heavy vehicles per hour, between 10 p.m. and 7 a.m.}$.

Hede also suggested that the coefficient of the MNV term should be limited to 0.1 so that the increase in the overall noise level was limited to 15 dB. The use of ‘0.1MNV’ as the noisy vehicle term in the extended index was due to the higher correlation with community reaction (0.62) than either log NHV (number of heavy vehicles) or log HGV, both of which had correlations of 0.46. He added that continued use of an unextended index would result in gross underestimation of traffic noise impact on residents along roads carrying noisy heavy-duty vehicles at night.

Brown (1981) argued that a person inside a house may perceive the peak noises from cars and motorcycles in the same way as the peaks from heavy vehicles, and suggested that the acoustic variable that might correlate best with annoyance may be a more general measure such as the number of noisy events in the traffic stream. The ‘threshold’ above which a noise event becomes discernible varies according to the situation of the listener, including background noise level. The suggestion was therefore put forward that the effects of traffic noise on people may be determined more by the number of ‘interruptions’ that they experience than by some time-averaged noise level.

Björkman (1991) assessed the effects of the number of noise events (indicated by the number of heavy vehicles in a 24-hour period) on community annoyance in fourteen areas of Gothenburg. Figure 7 shows that the extent of

![Figure 7](image-url)
noise annoyance increased with an increasing number of heavy vehicles up to around 1500-2000. After this point the dose-response curve levelled out.

However, Björkman also found that an increase in the maximum noise level from the noisiest event would lead to more extensive annoyance independent of the number of events. He suggested that from the point of view of human perception, the traffic will be interpreted as a continuous noise under heavy flow conditions, which explains the observed plateau on the curve. Therefore after the ‘breakpoint’ there was considered to be no need to measure the number of events in order to estimate annoyance reactions.

3.3 ‘Steady-state’ and changing traffic noise levels

The relationship between noise level and annoyance in a particular community is only applicable to situations where the noise level has been fairly steady for some time. Recent research has indicated that the relationship does not hold in situations where a sudden change in traffic noise level has occurred.

Most of the information on the relationship between nuisance and exposure comes from studies in which exposure has been approximately steady (e.g. Langdon & Griffiths, 1982; Harland, 1977; Shultz, 1978). This has generally been taken to mean no change in the noise environment for a number of years, and stable populations with low inward and outward migration rates (Brown et al., 1985).

The Design Manual for Roads and Bridges (Department of Transport et al., 1994) uses a steady-state relationship, comparable to that obtained by Shultz (Figure 6), between noise exposure (L_{A10,18h}) and nuisance to estimate current nuisance, and to estimate future nuisance where only gradual changes in noise exposure are likely.

Since the development of the steady-state relationships, workers have found that where a comparatively sudden change in traffic volume has occurred, accompanied by a change in noise level, the changes in dissatisfaction with the noise are considerably greater than would have been predicted on the basis of findings under steady-state conditions (Griffiths & Raw, 1986; Mackie & Davies, 1981; Brown et al., 1985). For example, where a decrease in noise exposure occurs, residents’ dissatisfaction with traffic noise decreases to an extent which is greater than that predicted from the steady-state findings. Where an increase in noise occurs the increase in dissatisfaction is, similarly, greater than that predicted. Therefore, changes in dissatisfaction predicted from the steady-state relationships can represent an underestimate. According to Griffiths and Raw (1986), the difference between the predicted and observed dissatisfaction is equivalent to a difference in noise level of at least 10 dB(A). Griffiths & Raw (1989) suggested that responses to upward and downward changes in noise levels follow significantly different rules from those applicable to the steady-state condition.

Baughan & Huddart (1992) also investigated this phenomenon. They conducted attitude surveys at sites where traffic levels were predicted to change. Nine sites were selected where a decrease in traffic was expected, and five where an increase was expected. Two control sites, where no sudden changes in traffic levels were expected, were also included. Interviews were conducted one or two months before and after the expected change using seven point scales, with mean ratings being used as the index of nuisance.

In order to establish a relationship between changes in noise and changes in respondent dissatisfaction, Baughan & Huddart derived a linear regression equation from their data and that of Griffiths & Raw (1989). This was symmetrical for increases and decreases in traffic noise:

\[ \text{Change in dissatisfaction} = 1.06 + 0.19 \times (\text{change in } L_{A10,18h}) (r=0.76) \]

The authors recognised that because this linear model gave an intercept on the y-axis, an anomaly was created whereby a change in noise nuisance was predicted even when there is no measured change in L_{A10,18h}. This anomaly was avoided by using a cubic curve passing through the origin, with equation:

\[ \text{Change in dissatisfaction} = 1.30 \times (\text{change in } L_{A10,18h})^3 (r=0.94) \]

This relationship (now used in the Design Manual for Roads and Bridges) is shown in Figure 8, along with the steady-state relationship derived by TRL from 35 sites.

As data from sites where traffic levels increased were rather limited (hence the dashed line in Figure 8), the authors were unsure whether ‘increase’ sites should be treated as the mirror image of ‘decrease’ sites, or whether separate equations would need to be derived. It was also noted that the derived equations applied to noise changes brought about by changes in traffic flow, and may not be good predictors of the effects of noise changes brought about in other ways.

It is now accepted that people are more sensitive to abrupt changes in traffic noise than would be predicted from the steady-state evidence. In the period following a change in traffic flow, people may find benefits or disbenefits when the noise changes are as small as 1 dB(A) (Department of Transport et al., 1994). Abbott et al. (1995) pointed out that further problems are thought to exist where the introduction of a new noise source results in previous ambient levels of traffic noise being greatly exceeded, such as when a new road is opened near a rural community.

Baughan & Huddart (1992) also discussed several theories that have been advanced to explain the differences between annoyance ratings associated with changing noise levels and steady-state ratings. These theories included measurement bias, adaption, changes in site character, and changes in respondent character. The theories are reviewed briefly in the following paragraphs.

**Measurement Bias**

Ratings depend not just on the magnitude of whatever is being rated, but also on how the respondent interprets the various positions along the rating scale. It was suggested by Brown (1987) that such an effect may account for ratings differences.
**Adaptation**

It is possible that people take time to adapt to new conditions. The excess change in nuisance observed would therefore be a real but transient effect. The effects of a change in noise level on perceived annoyance may last for a number of years, and in the longer term, perceived noise nuisance may tend towards the steady-state level associated with the new noise exposure (Department of Transport *et al.*, 1994). Griffiths & Raw (1989) investigated adaptation to changes in traffic noise exposure. The effect of change was recognised as a long-term phenomenon, being persistent over a period of at least two years (a major part of it still being apparent after 7-9 years).

Brown *et al.* (1985) found that ratings of ‘before change’ conditions made retrospectively during an ‘after change’ survey differed from the actual before responses and suggested adaptation as one possible explanation. It was hypothesised that respondents had adapted to their new conditions and were evaluating their previous level of exposure against this new level of adaptation.

Alternatively, Job (1988) has argued that there is little evidence to support adaptation. He suggested that the effect may be created by cues given to respondents which reveal the hypothesis and expectations of the interviewer. Subjects who are asked about their reaction to road noise before and after noise-reducing changes are likely to feel that the interviewer is expecting or demanding a substantially reduced reaction. Another possible explanation lies in the residents’ possible awareness of the use of these studies in decisions regarding alleviation of noise levels. Residents may reward the relevant authorities for reduced noise levels or punish decisions leading to increased noise by showing a greatly increased reaction.

**Changes in site character**

‘After-change’ sites may not be typical of steady-state sites at the same level of exposure. For example, sites that have experienced a decrease in exposure may tend to have a lower exposure than is typical for the type of road, area, and housing. This implies that before and after surveys measure a real change in nuisance.

**Changes in respondent character**

After a change in noise levels, respondents’ sensitivity to exposure may not be typical of people living at steady-state sites with the same level of exposure.

### 3.4 Summary

Road traffic is generally the most important source of noise annoyance in urban communities. Noise level is a good predictor of the average annoyance response of a community, but there is a large amount of variation in the individual measured responses at a given noise level. Some studies have indicated that the number of noisy events is probably as good an indicator of community annoyance as noise level, and perhaps a better indicator in congested conditions. The relationships between noise level and community annoyance are only applicable to situations where the noise level has been fairly steady for some time, and recent research has indicated that they do not hold in situations where a recent or large change in traffic noise level has occurred. Consequently it would not be appropriate to predict the impact of noise changes resulting from traffic management schemes using steady-state dose-response relationships.

There appear to be inconsistencies in the literature concerning the relationship between traffic flow and reaction to noise. There is general agreement that increases in commercial vehicle flows are associated with increased annoyance. However, one study suggests that once the flow reaches 1500 commercial vehicles per day there is no significant further increase in annoyance at higher flows. Although this result does have clear implications for traffic management schemes, further work is needed to establish whether it can be applied generally.

The heavy vehicle component may be particularly
important to residents of an area where traffic calming measures are to be introduced, and Abbott et al. (1997) have shown that the noise benefits resulting from speed reductions can be eroded if heavy vehicles are involved. Fluctuating noise levels may give rise to disturbance, particularly where the background noise levels are low and noise from individual vehicles are the dominant noise source. However, conventional methods of measuring traffic noise do not readily expose annoyance factors associated with the changes in the variability of that noise (Abbott et al., 1995).

The body of research on perception of traffic noise is much larger than that relating to air pollution, and this permits some discussion on links between factors affected by traffic management schemes and perceived noise. However, the full extent of the relationship between noise exposure and nuisance is far from being fully understood, and it is currently not possible to accurately assess the perceived noise impact of schemes which alter, for example, traffic flow, speed and composition. Further work is required to examine the links between traffic characteristics and noise exposure, and the effects that these may have on perceived annoyance.

4 Nuisance from traffic-derived vibration

The DMRB defines traffic vibration as a low frequency disturbance producing physical movement in buildings and their occupants. Traffic-induced vibration in buildings can result from ground vibration which is coupled into the structure via the foundations, and from low frequency airborne noise which affects light components such as doors and windows.

Groundborne vibrations are generally in the 8-20 Hz frequency range and are produced mainly from the interaction between the rolling wheels of vehicles and rough road surfaces. According to Watts (1990), vehicles running on smooth road surfaces do not normally cause perceptible ground vibrations at the roadside or in buildings.

Airborne vibration (low frequency noise) from traffic is mainly produced by the engines or exhausts of heavy-duty road vehicles, and is predominantly in the frequency range 50-100 Hz (Leventhall, 1987). High levels are often produced by vehicles operating under full engine loads, such as on gradients or when accelerating from rest. Vehicles idling in queues, or buses waiting at stops can also act as sources. Noise in the 50-100 Hz frequency range is not only audible, but can cause doors and windows to vibrate and generate secondary noise effects which contribute to the disturbance felt by residents. Low frequency noise can be heard at considerable distances from its source, owing to poor attenuation in the air, barriers or windows (Persson & Rylander, 1988). Certain levels and frequencies can be particularly annoying because they affect the body directly. The most notable effect is chest resonance, occurring in the 30-90 Hz frequency range. This is perceived as a fluttering feeling in the chest cavity, and can also affect speech.

Traffic vibrations are generally experienced by fewer people than traffic noise. However, once vibration is experienced, it is more likely to cause a high degree of disturbance or annoyance (Baughan and Martin, 1981; Watts, 1985). The DMRB suggests that two effects of traffic vibration need to be considered: the effects on buildings and the disturbance to occupants. It is clear that these two effects are linked, since disturbance due to traffic-induced vibration can often be associated with concern over damage to an individual’s property caused by traffic vibration (Watts, 1990). Extensive research by Watts (1990) failed to find any conclusive evidence that traffic-induced vibrations can cause significant building damage. However, minor cracking to wall plaster may occur in heavily trafficked locations with particular soil conditions. Nevertheless, these cracks are generally indistinguishable from those resulting from other causes such as minor subsidence, thermal effects and domestic activities such as slamming doors.

Watts (1985 and 1990) has suggested that disturbance ratings associated with the perception of traffic vibration correlate well with the L A10,18h and L Aeq,18h indices of traffic noise. The DMRB suggests that in situations with traffic noise levels (L A10,18h ) of 58 dB or less, there will be very few people who will be bothered by traffic vibration. For a given level of noise exposure, the DMRB assumes that the percentage of people bothered very much or quite a lot by vibration is 10% lower than the corresponding figure for noise nuisance.

Abbott et al. (1995) warned that these are general guidelines relating to average traffic flow conditions and have not been tested for traffic management schemes. Some schemes may alter the vibration effects generated by heavy vehicles which are not exposed by changes to the levels of traffic noise as measured using the L A10,18h index. Such conditions may exist, for example, where traffic management reduces the incidence of flow breakdown (i.e. where a reduction in vibration impact might result without a noticeable change in L A10,18h levels). Alternatively, where road humps are introduced, a rise in the number of accelerating vehicles may increase vibration disturbance. Again, this may not be reflected in changes to the overall levels of traffic noise.

It should be noted that it is very unlikely that even superficial building damage would be caused by vehicles running over road humps. However, if a road hump is installed where there are underlying soft soils, there may be a small risk of minor fatigue damage. With softer soils the vibrations are likely to be experienced over a longer distance from the source and, even though no damage is caused, the experience of the vibrations may be perceived as annoying by residence (Watts et al., 1997).

Clearly, in order to fully evaluate the environmental impact of different traffic management schemes it is important to be able to forecast the changes in traffic vibration effects that might occur. Current methods of assessment of vibration have not been tested in the context of traffic management and may well be inadequate in their ability to predict the perceived impact on vibration of different schemes (Abbott et al., 1995).
5 Perceived environmental impact of traffic management schemes

Traffic management schemes have generally been assessed in terms of their impact on journey time, traffic speed, traffic flow, and accident reduction. The attitudes of those affected by these changes have been obtained less frequently. The quantifiable environmental impacts of schemes have only recently been considered in detail. Accordingly, few workers have considered the perceived changes in the environment, such as changes in levels of air pollution and noise levels, that these schemes can provoke.

In studies of traffic management schemes where perceived changes in the environment have been investigated, questionnaires have often lacked detail and have seldom been employed in conjunction with the physical measurement of air pollution and/or noise. In some surveys the extent of the coverage received by the environment is often limited to a basic inquiry about contentment with the local environment in general.

However, local authorities obviously give high regard to the perceived environmental impact of schemes. The overall success of a particular scheme will ultimately be determined by the opinions of those who use it or live by it. Some measures - usually traffic calming devices - have occasionally been modified or removed as a result of complaints about environmental degradation, particularly increased noise levels. For example, in an assessment of the effects of rumble devices used at 35 locations in the UK, Webster & Layfield (1993) found that the noise generated by traffic passing over the devices was an important factor in deciding whether they should be installed at a particular location. The devices were removed from 7 locations because of complaints about the level of traffic noise generated.

Unfortunately, from the existing literature it is difficult to make comparisons between surveys of the effects of schemes in different locations on account of, for example, the different measures installed, the differences in the character of the areas and the survey groups, and the different surveying techniques employed. The net outcome is that survey results appear to be specific to the schemes with which they are associated, and are not necessarily a reliable indicator of how people might react to other schemes. It is also important to consider that the attitudes of the public concerning the impact of a scheme may well be tied to their preconceptions and expectations beforehand, including how importantly they rated the environment in general, as these expectations will undoubtedly influence their expressed views. For example, in relation to the installation of road humps, Van Every and Holmes (1992) argued that there are residents who support or oppose road humps for a variety of reasons, and these polarised views apply to any expressions of benefit or disbenefit.

In this Chapter, public reaction to environmental change has been collated for different types of traffic management scheme, although the existing studies show a strong bias towards traffic calming. No attempt has been made to formulate trends from these studies of traffic calming. Since it has been noted that the current understanding of the expression of public opinion concerning the environmental impacts of traffic is not particularly good, any apparent trends would have to be viewed with some caution. The results from these studies are also summarised in Appendix B.

5.1 Traffic calming and residential speed limits

Of the small amount of research on the perceived environmental impact of traffic management schemes (and indeed other impacts), most is to be found within the domain of traffic calming. Traffic calming is arguably better suited than other types of scheme to assessment by attitude survey, for reasons which probably include the following:

- Traffic calming has predominantly been installed in residential areas where any local changes in environmental conditions will directly affect a large number of people in or near their homes.
- Residents are often involved in the consultation process before the implementation of traffic calming schemes in their area, and surveys may be conducted to assess their sentiments as part of the consultation process.
- Traffic calming is multi-objective, and there are therefore a large number of potential impacts (e.g. speed, danger, amenity, and the environment) with which people can associate and on which attitude surveys can focus.

In the UK, surveys of residents have indicated that the majority of respondents approved of the traffic calming schemes that have been installed in their areas (Hass-Klau et al., 1992; Webster, 1998). Similarly, in an evaluation of 2000 residents of calmed areas in the Netherlands, 84% of respondents said that their street was more pleasant to live in than before (Pharaoh and Russell, 1989). However, it is not clearly known to what degree traffic calming affects residents’ perceptions of the specific components of the environment that are of interest, namely air pollution, noise and vibration. For these elements, residents’ opinions may well differ from the overall acceptance level, and may also differ from the results of the physical measurements used to evaluate schemes. Webster (1998) has therefore argued that, although public attitude surveys are useful in establishing overall approval levels and in identifying the relative popularity of individual measures, the usefulness of questionnaires relating to pollution appeared to be somewhat limited in reflecting physical changes.

5.1.1 Air pollution

From the few attitude surveys that have probed the issue, it appears that most respondents to questionnaires do not generally consider that traffic calming schemes affect local levels of air pollution. Those respondents who do feel that pollution levels have changed tend to be divided in their perceptions of the change.

For example, Stockport Metropolitan Borough Council (1995) sent brief questionnaires to residents at four locations where different traffic calming measures had
been installed. Residents were also invited to make brief comments. Of more than 300 respondents in total, only three specifically mentioned that air pollution resulting from vehicle emissions was a problem associated with the scheme about which they were questioned.

In a study by Windle & Mackie (1992), residents of four separate areas (around 160 in each case) were surveyed in order to ascertain their opinions of the traffic calming schemes that had been introduced in their localities (in Exeter, Sutton, Maidstone and Bridgewater). Each of the schemes was different in nature. Interviews were carried out with residents and local shopkeepers within a tightly defined area around the schemes. Although dirt and fumes from traffic in general were regarded as a serious problem by up to 25% of all respondents, the majority (more than two thirds in each instance) were of the opinion that there had been no change in dirt and fumes since the introduction of the traffic calming measures. When asked what was the best thing about the scheme, fewer than 1% cited less dirt. The percentage trends in perceived changes in dirt and fumes followed a similar pattern (that is to say, mainly ‘no change’) which, except perhaps at Bridgewater, was also similar to the trend in perceived changes in traffic volume. Ways in which schemes could be made more acceptable to those residents who did have criticisms included taking care that residents living close to a road agreed more frequently (55-60%) that dust/dirt and emissions had increased traffic fumes. On this point there was agreement, though only slight, that the overall traffic flow through Craven Arms, or the number of HGVs.

The Thorney scheme comprised gateway treatments, changes in surface colour, chicanes, mini-roundabouts, pedestrian crossings and refuges, and speed cameras. In Thorney, the social survey responses showed, however, that there was a fairly strong perception by the residents that the introduction of the measures had increased traffic fumes. Again, the scheme did not measurably affect the overall flow of traffic through Thorney, or the number of HGVs.

Esteves (1995) also found that, on balance though not conclusively, local residents considered that air pollution levels had increased as a result of a traffic calming scheme in Camden. When Taylor and Tight (1996) asked residents at a total of six traffic calming sites in Leicester, Brighton and York about their perceptions of the changes in the various environmental impacts of traffic, respondents at each of the three sites in York showed a net agreement with the suggestion that air pollution had worsened. Again, the level of agreement was not particularly high.

It has also been shown, however, that some schemes can be associated with perceived benefits in terms of air pollution. For example, respondents at the Leicester and Brighton sites examined by Taylor and Tight felt, on balance, that air pollution had improved. Before the introduction of a road hump scheme, 60% of residents along the B1040 at Gamlingay who responded to a questionnaire regarded traffic pollution (and noise) as unacceptable or highly unacceptable. After implementation, 72% of respondents regarded it as acceptable or were not concerned (Cambridgeshire County Council, 1991).

In the Austrian city of Graz, a general 30 km/h speed limit was introduced on the secondary road network. Public opinion polls were conducted at four different stages: shortly before the introduction of the speed limit (June 1992), shortly after introduction (October 1992), around six months after the introduction (March 1993), and around one and a half years after the introduction (June 1994). Before the introduction of the speed limit, 52% of the people surveyed thought that exhaust emissions would increase, but by June 1994 only 24% thought that emissions had actually increased (Wernsperger and Sammer, 1995).

The Graz study is of particular interest because it offers a chance to compare changes in public reaction with changes in vehicle emissions. The modelled changes in emissions of CO and HC were found to be relatively small on the 30 km/h roads. CO and HC were found to have increased by 3.8% and 0.5% respectively, while NO₂ emissions were reduced by 24%. However, the changes in emissions for the whole road network resulting from the introduction of the speed limit were negligible.

Where respondents to any of the cited studies have, on balance, reported either an increase or a decrease in annoyance due to air pollution, little or no evidence has been provided to suggest what it was about the schemes that influenced the respondents’ feelings. The results appear to indicate that the effects of traffic calming on annoyance due to air pollution show a large amount of variation from site to site.
5.1.2 Noise and vibration

Large changes in traffic volume or speed are usually required to give rise to a perceptible change in traffic noise (Chua and Fisher, 1991). Traffic calming does tend to produce large changes in traffic speed, but devices that result in the vertical deflection of vehicles can produce a variety of noisy events which are distinct from the overall noise level. Kent County Council has financed research investigating the public perception of traffic calming schemes. Brake noise from buses and HGVs has been identified as an important factor in determining public annoyance in the vicinity of road humps. It has been suggested that the loud, high-pitched sound resulting from the release of air is particularly noticeable because it has a frequency which is distinct from the ‘background’ of engine noise that people tend to expect in the vicinity of roads (Bulpitt, 1995). Wheeler et al. (1996) considered it important that the design of speed control measures is optimised so that average vehicle speeds are reduced whilst maintaining a fairly constant speed profile. This would minimise fluctuations in speed and consequently the fluctuations in noise emissions which may possibly cause annoyance to residents.

The effects of calming on annoyance due to traffic noise have received slightly more attention than the perceived effects on air pollution, and there have been more comparisons of the perceived changes with actual measured changes. This may be because respondents have a better understanding of the concept of noise, or can express more readily how they feel about it. It certainly appears that in relation to traffic calming, noise is the more prominent issue. Out of 300 respondents to the questionnaire sent out by Stockport MBC (1995), 17 people specifically mentioned the noise associated with vehicles as they passed over humps, whereas only three mentioned air pollution. However, as with air pollution the published studies appear to indicate that the effects of traffic calming on changes in noise annoyance show a large amount of variation between sites.

Sumner and Baguley (1979) conducted opinion surveys relating to the installation of road humps on five residential roads in Oxford, Norwich, Haringey, Kensington and Glasgow. A total of more than 400 residents of houses fronting the roads were asked for their opinions of the humps. Around 30% of residents were bothered ‘a lot’ or ‘very’ much by noise before the humps were installed. After installation, this had been reduced to 17%. Measurements of $L_{A10,18h}$ noise levels made close to the line of house fronts on the three roads in Oxford, Norwich, and Kensington showed a reduction of 2-6 dB(A) after calming. At all three sites noise was reduced, partly because of the lower traffic flow and partly because of the reduction in traffic speed.

Baguley (1981) also investigated the effects of road humps on annoyance due to noise in residential areas of Lytham, Ventnor and Rotherhithe. The proportion of residents bothered by noise showed a general reduction (between 3-13%) after the humps had been introduced. Measurements of noise and vibration were taken at South Park, Lytham. Vibration levels produced by buses crossing the humps were only slightly above the human perception level at a frequency of around 10 Hz. The highest level measured was still well below that which is likely to cause damage to property. The $L_{A10,18h}$ noise measurement taken before and after hump installation was reduced from 60.3 to 45.9 dB(A). Baguley thought that this reduction was chiefly due to the reduction in traffic flow along South Park.

In the Craven Arms study by TRL (Wheeler et al., 1996), measurements were carried out of traffic noise and ground vibration before and after implementation of the scheme. Noise levels were measured at sites adjacent to, and between, the speed cushions, at one of the gateways, and at a site within the village away from any calming measures. Maximum noise levels were substantially reduced after the measures had been installed. At a site located alongside a speed cushion, vehicle noise levels were reduced by around 9 dB(A) for light vehicles, and around 8 dB(A) for heavy vehicles. Between the cushions light vehicle noise was reduced by around 7 dB(A), and heavy vehicle noise by around 5 dB(A). The reductions in noise levels were due to reductions in vehicle speeds. At the north gateway site, it was estimated that maximum noise levels for light and heavy vehicles may have been reduced by about 4 and 3 dB(A) respectively. At the site with cushions the ‘before’ and ‘after’ relationships between noise level and speed were similar. Therefore, allowing for the reduction in speed, the presence of the 1500 mm wide cushions had little, if any, effect on maximum vehicle noise levels.

Daytime traffic noise levels - $L_{A10,18h}$ (0600 to midnight) - measured adjacent to a cushion on the approach to a mini-roundabout fell by more than 3 dB(A). Ground-borne vibration exposure was found to be very low, with peak levels well the level at which complaints would be expected. The presence of the speed cushions increased vibration but the resulting levels were still very low.

In the attitude survey residents were asked to think back to any problems caused by the road before changes were made. Three per cent of respondents mentioned body rattle from HGVs encountering potholes. When respondents were prompted with a number of questions relating to problems caused by traffic on the main road before the installation of the scheme, 38% of all respondents identified noise and 25% mentioned ground vibration. However, compared with residents living elsewhere, those living on the main road agreed more frequently that traffic noise/vibration had been problems (50-60%). Respondents were asked whether or not they agreed about various statements regarding the changes. 48% of respondents believed that the alterations had increased noise and 27% thought that their homes shook when a lorry went past. For respondents living on the main road, these percentages increased to 57% and 68% respectively. There was slight agreement that the traffic calming measures had increased noise, despite measurements indicating the contrary. It was suggested that an isolated noise at night causing disturbance would bias residents opinions to the negative side. There was also slight agreement with the statement that houses were shaken by lorries, in spite of the fact that measurements of ground-
borne vibration showed an increase to levels that were still very low and unlikely to have been perceived.

A further assessment of the noise at the Craven Arms scheme was conducted to examine whether other physical measures of vehicle and traffic noise levels might explain the discrepancy between the dissatisfaction shown by many residents of the effect of the scheme on the noise climate, and the overall reductions in both vehicle and traffic noise levels (Abbott et al., 1997). One potential source of increased dissatisfaction was the variability of low frequency noise levels (50-125 Hz) from heavy vehicles travelling through the scheme. Changes in driver behaviour were also identified as potentially having an important effect on vehicle noise levels through the scheme in the initial study. Only vehicles passing unimpeded across the speed control cushions were considered during the original vehicle noise surveys. A comparison of noise levels from vehicles straddling the cushions unimpeded, and those not straddling the cushions was undertaken. For light vehicles there was found to be little difference between the maximum noise levels for straddling and non-straddling vehicles. For heavy vehicles, however, average noise levels were 5 dB(A) higher when not straddling compared with when straddling a cushion. Although the percentage of heavy vehicles not straddling the cushion was only around two per cent of the total traffic flow, the number of occurrences in a 24-hour period could be several hundred based on a typical flow of 10,000 vehicles. This effect may give rise to an increase in dissatisfaction for residents living alongside such schemes. Further work indicated that the number of noisy events had actually increased since the scheme had been introduced, particularly at the cushion site. However, from the information available it was not possible to determine whether these events were related to heavy vehicles not straddling the cushions.

In the Thorney study (Wheeler et al., 1997), ‘before’ and ‘after’ measurements were made of traffic noise. Monitoring of ground-borne vibration was carried out in the ‘after’ period only. Vehicle and traffic noise measurements were taken in Thorney to quantify the change in the noise climate after the introduction of the scheme. Vehicle noise measurements involved recording the noise from individual vehicles as they passed alongside such schemes. The survey entailed interviewing with 425 residents in their homes. The residents considered noise (and air pollution) to be minor traffic-
related problems prior to calming. High speeds were felt to be by far the most significant problem. Residents who felt that the effects of the calming schemes were beneficial or detrimental were asked why they held these views. Only four per cent of these people felt that the schemes were beneficial because they resulted in less noise, and none of the residents attributed the detrimental effects of the schemes to noise or air pollution.

Traffic calming measures in the village of Kennington were included in the Oxfordshire County Council 1990/91 Traffic Management Programme as a response to a significant number of injuries sustained as a result of road accidents (Oxfordshire County Council, 1992). The scheme comprised a series of road humps along the main road through the village. Mini-roundabouts were positioned at the entrances to the scheme. An unusual feature of the scheme was that the mini-roundabout islands were constructed on top of extended flat-top humps in order to provide a further reduction of speed. An additional raised mini-roundabout was provided mid-way along the scheme, and flat-top hump/zebra crossing combinations were placed in two side roads leading to Upper Road in an attempt to reduce the attractiveness of this route as a ‘rat-run’. A questionnaire survey was distributed to all households (1400) in the village one year after the scheme had been completed. More than 800 responses were received, presumably reflecting the high level of local interest in the scheme. In terms of the overall perception of traffic noise, 17% of respondents noted an increase, 29% no change, and 43% a decrease. No noise measurements were obtained. The 9% of total respondents that had a hump positioned outside their house showed a greater tendency to perceive an increase in noise as a result of the scheme than the other respondents, although even in this group the majority felt that noise levels were either unchanged or lower. There was some indication that those making a large number of trips by car, moped, or motorcycle were less likely to approve of the scheme than people whose trips were predominantly made by cycling or walking.

At the Camden scheme examined by Esteves (1995), the results suggested that local residents’ perceptions of noise had worsened after the implementation of the scheme. Taylor and Tight (1996) found that respondents at sites in Leicester and Brighton showed a net agreement with the suggestion that noise had improved, whereas respondents at sites in York felt that noise had worsened. Interestingly, the perceived changes in traffic noise mirrored those observed for air pollution at the same sites. One hundred people living or working within the area of a gateway installed at the village of Tavistock in Devon participated in an opinion survey concerning the measure. Most people (88.9%) did not think that the noise level had increased (Wheeler et al., 1993).

A few studies performed in Australia have also examined public attitudes in relation to traffic calming. Van Every and Holmes (1992) described a study undertaken in the City of Woodville in which residents of streets containing traffic calming measures were sent mail questionnaires. The respondents were split equally between those who thought that road humps had either no effect, little effect or a major effect on noise reduction. A greater proportion (46%) felt that roundabouts had no noise-reduction effect, with 36% being of the opinion that they had little effect. The results of a survey of residents of calmed streets in the city of Unley were also reported. Traffic noise was perceived to have decreased by 43% of respondents in the treated streets. However, a similar proportion of respondents living in nearby streets felt that noise had increased. Chua and Fisher (1991) received 339 replies to a questionnaire on the subject of an area-wide traffic calming scheme in the East Hornsby area of Sydney. Features within the scheme included roundabouts, road closures, horizontal deflections and road humps. Despite the fact that almost three quarters of all respondents thought that the amount of traffic had been reduced, opinions were divided on the change in noise.

Gennaoui and Smith (1987) performed surveys relating to the main speed-reducing devices used in traffic calming schemes at Willoughby, Canterbury, Mosman, and Sutherland in New South Wales. The surveys covered vehicle speeds, traffic volumes, traffic noise, and public attitudes regarding each device, and were conducted in areas where schemes had already been implemented. The devices selected for investigation were one- and two-way-working build outs (‘one and two-lane angled slow points’), T-junction treatments featuring horizontal deflections, flat-top road humps (‘mid-block thresholds’), entrance treatments combined with a road hump (‘entry threshold’) and a chicane (‘diamond slow point’). The attitude surveys were device-specific. The respondents were found to be most satisfied with the lack of noise associated with the single lane build-outs and T-junction treatments. The flat-top hump and the round-top road hump/two-lane build-outs combination rated worst. In the latter case, further analysis showed the road hump to be the device at fault, rather than the two-lane build-out. For the flat-top hump on its own, more residents saw a worsening noise situation than those seeing improvement.

In response to requests from residents for speed reduction without further use of physical measures, a trial 40 km/h limit was established in a residential area of Unley, South Australia. Speed cameras were used to enforce the limit. Cairney & Harwood (1994) investigated the attitudes of residents towards the scheme. Community opinions and perceptions were surveyed at three points in the trial: (1) immediately prior to the introduction of the trial (December 1991), (2) after three months of low-intensity enforcement (June 1991), and (3) at the conclusion of the trial (March 1993). Face-to-face interviews using a set questionnaire were used throughout. As the trial progressed, traffic replaced crime as the most frequently cited problem. The authors did not find this surprising, considering the repeated questioning relating to traffic issues. When asked how noisy residents considered their street to be, a shift was recorded in the proportion of ‘extremely noisy’ ratings to ‘moderately noisy’. In survey 2, only 20% of residents thought that noise had been reduced. This increased to 29% in survey 3. Rating of other aspects of the traffic, including the volume
and speed of traffic, were unchanged between the first survey and the last.

Before the introduction of the 30 km/h limit in Graz, less than one third of the respondents expected the noise level to drop, but by June 1994 the number of people who were concerned that noise had increased had risen to 34% (Wernsperger and Sammer, 1995). Noise measurements ($L_{Aeq}$ and the peak noise level) were taken before and after the introduction of the speed limit at two sites. At these sites the $L_{Aeq}$ value reduced by 0.9 and 1.9 dB, and the peak noise levels showed reductions of 0.9 and 2.5 dB. The reductions were attributed to the reduction in traffic speed, with drivers maintaining a steadier speed.

5.1.3 Summary
It appears that most respondents to questionnaires do not generally consider that traffic calming schemes affect local levels of air pollution. Those respondents who do feel that pollution levels have changed tend to be divided in their perceptions of the change, and little or no evidence has been provided to suggest what it was about the schemes that influenced the respondents’ feelings. The results appear to indicate that the effects of traffic calming on annoyance due to air pollution show a large amount of variation from site to site. There is also no available data to suggest any links between perceived and measured changes in air pollution.

In relation to the environmental impacts of traffic calming, survey results generally reveal noise to be a more prominent issue than air pollution. However, as with air pollution the published studies appear to indicate that the changes in noise annoyance associated with traffic calming show a large amount of variation between sites.

There is some evidence from the work by TRL at Thorney and Craven Arms, by Kent County Council in Sittingbourne, and by Oxfordshire County Council in Kennington to suggest that residents with certain traffic calming measures positioned close to their homes are more annoyed by noise than other residents.

5.2 Other schemes
Few studies have investigated the perceived environmental effects of traffic management schemes other than traffic calming schemes. The work that has been reviewed here relates to pedestrianisation, one-way streets and area licensing, but it does not offer a great deal of insight into the subject area.

The pedestrianisation scheme introduced in Cambridge city centre focused on narrow ‘canyon’ streets, and was devised to address the poor environment in these streets. The layout of the city centre was such that servicing had to be carried out from the street, and so the central area was only pedestrianised between 10 a.m. and 4 p.m.. As the pedestrian flows were high and the streets were narrow, the total exclusion of vehicles was considered to be essential. This led to some controversy, in particular over the changes that affected buses and cyclists. The area was controlled using manually operated gates and automatic rising bollards. The results of a public attitude survey indicated that the amenity of the area had been improved, with 83% of those asked saying that the centre was now more pleasant to walk around, and 72% considering that the environment had improved. It was not specified which aspects of the environment were under consideration. One of the concerns was that traffic may have been displaced onto other routes, but this did not happen (Cole, 1995).

Lünenburg in northern Germany is a town of 62,000 inhabitants whose local authority agreed to an overall transport strategy in 1991. This included the closure of the town centre to cars, the reduction of town centre car parking, an increase of cycle facilities, 30 km/h speed limits for all residential roads, and the promotion of public transport. A survey was carried out to obtain the view of people living in, and outside, the town, and to access the success of the road closure four months after it was implemented. A total of 2225 people were interviewed using a short questionnaire. When asked about improvements in the town centre, ‘better air’ was a minor factor, being mentioned by only around 4% of respondents (Dowland, 1994).

Stannard (1972) described the results of a community survey conducted in Catford, South London, after the implementation of a one-way traffic scheme. Physical changes involved kerb realignments, additional traffic islands and signals at all major junctions, removal of two zebra crossings, and provision of a footbridge. The scheme also involved the extension of parking and loading restrictions. When people living in the area were asked whether they heard more, less, or the same amount of noise in the house as before the scheme, responses correlated closely with the changed pattern of traffic flows in the area. The author concluded that increased traffic noise seemed to have caused more concern to residents than any other change resulting from the traffic management scheme, although the majority of respondents (78%) thought that the scheme had been a good idea because it reduced congestion. In the case of air pollution, 65% of respondents had noticed no fumes in their home either before or after the one-way scheme.

During the 1970s the Government of Singapore introduced a traffic restraint scheme. This was based on area licensing supplemented by a 100% increase in parking fees, and combined with a park-and-ride scheme to provide motorists with an alternative mode of transport. The scheme, designed to reduce congestion during the peak hours, operated between 07:30 and 10:15. The scheme resulted in a reduction in the daily average CO levels, and a public opinion survey revealed that Singaporeans believed that it had relieved congestion and improved conditions in central Singapore. Central area residents reported that it was easier and safer to cross roads, that conditions in the restricted zone had improved, and that the amount of fumes had been reduced (Holland and Watson, 1977).
6 Summary and discussion

6.1 Background

Large sections of the public are annoyed by the environmental impacts of traffic, and the success or failure of any measure to reduce these environmental impacts will depend ultimately on how public perception of the environment is affected.

The introduction of traffic management and traffic calming schemes has, in the past, caused a wide range of public reactions. Some schemes are generally popular and receive widespread acceptance, while others produce a hostile reaction leading to their abandonment. Often the popularity of a scheme depends greatly upon the public’s perception of the environmental changes that have occurred. Consequently, it is important to have a clear understanding of the main environmental factors affecting public perception and acceptance, so that methods of prediction can be developed, and perceived impacts can be taken into account at the scheme design stage.

The main methods of predicting public reactions to traffic management schemes include:

- The use of generalised relationships between subjective measures of community reaction and objective measures of pollution, noise or vibration.
- The direct measurements of community reaction to specific schemes.

The first method assumes that generalised dose-response relationships can be applied to traffic management schemes irrespective of scheme design or location, whereas the second approach assumes that reactions to a scheme at one location can be applied to similar schemes located elsewhere. The objective of this Review was to examine both the dose-response relationships and existing surveys of schemes in order to assess current predictive capabilities.

6.2 Air pollution

The major disturbances arising from vehicle emissions include: dirt and dust; smoke, fumes and odour; reduced visibility; urban soiling; and irritation of eyes and mucous membranes. Existing attitude survey data relates mainly to disturbance from dust/dirt and smoke/fumes/odour (both these categories cover urban soiling). Visibility reduction does not appear to constitute a major public nuisance, and there is little data relating to the nuisance caused by physical irritation from vehicle-derived air pollution. Williams (1994) reported moderate-to-high outdoor disturbance from vehicle-derived dust/dirt and smoke/fumes/odour at pollutant concentrations which are usual for urban background locations in the UK.

Only a few attempts have been made to link the degree of public nuisance to measured (or calculated) levels of pollutants. Quantitative evidence on the nature of the dose-response relationships for various pollutants is therefore rather limited, and still inconclusive. However, the determination of these relationships is not a straightforward process, since ambient air pollutants are derived from a number of sources. As all of these sources contribute to the nuisance effect, it is difficult to pinpoint a particular pollutant derived from a single source as the sole agent of nuisance.

Carbon monoxide is the only gaseous pollutant for which the dose-response relationships obtained in different studies can be compared. Even here, there is some disagreement on the form of the relationship; at low CO concentrations the degree of reported nuisance appears to be independent of pollutant level, but there may well be an increase in nuisance were CO concentrations are particularly high. It has been suggested that although CO is colourless and odourless, the factors that produce variations in CO levels also affect the more easily-perceived aspects of pollution. Measurements have failed to reveal a link between concentrations of other gaseous pollutants and disturbance, but a weak correlation has been observed between black smoke concentrations and disturbance scores. The results from dose-response studies are likely to be quite variable since responses might be influenced by a number of personal, social, and situational factors.

6.3 Noise

Road traffic is generally the most important source of noise annoyance in urban communities. The correlations between noise level and individual annoyance scores are usually quite low. However, the correlation between noise level and the average of annoyance scores in a community is high, and it is not entirely clear what causes the variation in individual responses around the community average. A number of hypotheses have been proposed as explanations for the scatter of individual annoyance scores.

For example, one of the most important additional considerations is likely to be an indication of the number of noisy events in a given time period. Work conducted during the 1970s highlighted heavy goods vehicles as a major factor in the production of noise annoyance, especially in areas which a congested traffic flow is prevalent. Later work has focused on the relative importance of individually noisy vehicles versus the ‘bulk flow’ traffic noise as determinants of community annoyance. It appears that heavy or noisy vehicles cause annoyance in excess of that accounted for by an index based on overall noise level. This has led to the development of ‘extended’ indices that include terms for both individually noisy vehicles and the overall noise level. Hede (1985) argued that continued use of an unextended index would result in the underestimation of traffic noise impact on residents along roads carrying noisy heavy-duty vehicles.

The importance of the number of noisy events (indicated by the number of HGVs in a given time period) as a measure of community annoyance was addressed by Björkman (1991). Using the results from several areas, he found that increasing the number of HGVs in a 24-hour period to 1500-2000 led to an increase in annoyance, but after this point the dose-response curve levelled out. Although this result does have clear implications for traffic management schemes, further work is needed to establish whether this result can be applied generally.
Relationships between noise level and the extent of annoyance have been derived for communities where the noise level has been steady for some time. However, such relationships do not hold in situations where a sudden change in traffic noise level has occurred. Studies have shown that where a comparatively sudden change in traffic volume has occurred, accompanied by a change in noise level, the changes in dissatisfaction with the noise are greater than would have been predicted from the steady-state relationship. The current method used in the DMRB Volume 11 for predicting changes annoyance associated with changes in noise takes the form of a cubic function (Baughan and Huddart, 1992).

6.4 Vibration
Traffic vibrations are generally experienced by fewer people than traffic noise. However, once vibration is experienced, it is likely to cause a high level of nuisance. Nuisance ratings associated with the perception of traffic vibration correlate well with the $L_{A10,18h}$ and $L_{Aeq,18h}$ indices of traffic noise. In situations with traffic noise levels of 58 dB(A) or less, very few people will be bothered by traffic vibration. For a given level of noise exposure, the DMRB assumes that the percentage of people bothered very much or quite a lot by vibration is 10% lower than the corresponding figure for noise nuisance. These observations relate to average traffic flow conditions.

6.5 Traffic management and perceived environmental nuisance
Information relating to the public response to traffic management schemes is limited in the UK. The attitude surveys that have been conducted have tended to focus mainly on the perceived effects of the scheme on traffic speed and safety. Few workers have considered the perceived changes in the environment associated with the introduction of traffic management schemes. Rarer still are those studies that have evaluated both the measured and perceived changes in air pollution and/or noise.

This lack of information is not due to a lack of interest; many, if not all, local authorities give high regard to the opinions of residents and may even remove particular measures if there is a strong adverse public reaction to them.

An objective of this Review was to present the results of public attitude surveys of the environmental impacts of traffic management schemes, almost all of which relate to traffic calming. Traffic calming schemes are arguably the ones best suited to the task of surveying public opinion. They are predominantly installed in residential areas where any changes in environmental conditions will affect people in or near their homes, and there are potentially a wide range of impacts with which people can associate.

Reasonably high levels of public acceptance have generally been reported for traffic calming schemes. However, it is not clearly understood to what degree traffic calming affects perceptions of specific components of the environment such as air pollution, noise, and vibration.

It appears that most respondents to questionnaires do not generally consider that traffic calming schemes affect local levels of air pollution. Those respondents who do feel that pollution levels have changed tend to be divided in their perceptions of the change, and little or no evidence has been provided to suggest what it was about the schemes that influenced the respondents’ feelings.

The effects of traffic calming on nuisance due to road traffic noise have received slightly more attention than the perceived effects on air pollution. This may be because respondents have a better understanding of the concept of noise, or can express more readily how they feel about it. There is some evidence to suggest that residents with certain traffic calming measures positioned close to their homes are more annoyed by noise than other residents. However, on account of the lack of information, no attempt has been made in this Review to formulate relationships relating changes in community annoyance to any aspect of traffic calming. For both air pollution and noise existing studies currently appear to indicate that the effects of traffic calming on changes in annoyance show a large amount of variation between schemes.

6.6 Predicting the impacts of traffic management on annoyance
It has been shown in this Review that neither of the two predictive methods investigated is sufficiently developed to provide a reliable indication of the environmental impact of a future traffic management scheme, as perceived by those affected.

Dose-response relationships for air pollution are not sufficiently developed to allow an estimate of community reaction to the changes in pollution levels that may be predicted for future traffic management schemes. However, Abbott et al. (1995) suggested that if traffic operations can be controlled in a way that makes conditions more acceptable to local residents and other road users, it may be found that concern over pollution is influenced far more than the levels of pollution.

Much more work has been performed on perception of traffic noise, although the bulk of this has related to free-flowing traffic where the noise levels have shown little sudden variation. These conditions are likely to be different to those encountered during the implementation of a traffic management scheme, and more recent research into the effects of changing noise levels is likely to be more valuable in this respect.

Some research regarding perceived annoyance from traffic noise will be relevant to environmental considerations during the design phase of traffic management schemes. In order to assess the effects of changing the fraction of HGVs in the traffic flow on perceived annoyance, the work of Björkman (1991) appears to show that reducing the number of heavy vehicles along a given road each day will have little effect on annoyance unless it can be reduced to less than 1500-2000. Consequently, if the proportion of HGVs in the traffic flow is relatively large, a scheme that encourages a shift towards lighter vehicles may not reduce annoyance. However, perceived annoyance would appear to be very sensitive to changes in composition where the fraction of HGVs is lower.
Abbott et al. (1995) emphasised that the noise impact of a traffic management scheme will be determined by interdependencies between the various traffic parameters and their combined effect on the change in traffic noise levels. As a result, prediction of the effect of traffic management schemes on traffic noise levels and associated nuisance is a complex process. Current understanding of the extent of the relationship between noise exposure and nuisance is inadequate for this task. Therefore, although the introduction of a traffic management scheme may produce changes in noise levels, it is still not wholly clear how these changes are perceived by the public.

6.7 Further research

It is evident from this Review that current understanding of the dose-response relationships for air pollution and noise, and knowledge of the perceived environmental impacts of traffic management schemes are inadequate for the task of predicting community reaction to future schemes. A great deal more work is required before any decisions about choice of scheme design can be made on the grounds of changes in annoyance due to air pollution and noise.

It may be the case, as suggested by Abbott et al. (1995), that concern over air pollution is related to traffic parameters such as speed, volume and composition. As these parameters are likely to be affected by schemes, and therefore monitored during assessment, further comparisons could be made with the results from attitude surveys in an effort to determine which factors contribute most to changes in perceived annoyance. In the long term, this could lead to the development of new air and noise pollution indices, or even indices that are specific to particular types of traffic management scheme.

Where traffic management schemes are implemented, a variety of devices are often employed to obtain the desired effect. There is little information on the relative effects of these devices on perceived nuisance. Certain devices, such as road humps, may cause higher levels of disturbance due to noise in nearby properties. Therefore a distinction may be required between general street noise levels and levels in the vicinity of a measure. If a particular measure is the source of increased disturbance, it may also be of interest to determine the spatial extent of this increase. Eventually, a framework might be devised for expressing the impacts of different schemes on perceived nuisance alongside their impacts on, for example, speeds, accidents, noise, and air pollution.

Currently, the main barriers to achieving this are the lack of appropriate information and the variability of conditions under which attitude surveys operate. One way of increasing the rate at which information on public reactions to the environmental impact of schemes is accumulated might be to integrate appropriate questionnaire surveys into the consultation process. The viability of this option requires investigation. Additionally, if schemes are to be compared on the same basis, then a number of conditions would have to be standardised. For example, controls would be required on the questions asked in surveys and the terminology used to describe nuisance.

7 Conclusions

The following main conclusions can be drawn from the results of this Review:

1 Relationships between atmospheric pollution and public reaction are not clearly established at the present time. This is partly because of the lack of appropriate data, and partly a result of the generally poor correlation between perceived effects and actual pollutant concentrations. Some studies have shown carbon monoxide concentrations and perceived nuisance to be related, but there has been no conclusive research demonstrating the nature of the relationship.

2 In comparison, there are well established relations between traffic noise and average community reaction responses. However, these dose-response relationships tend to relate to situations where populations have become accustomed to the level of noise (i.e. steady-state conditions). For situations where there has been a recent change in noise level the steady-state dose response relationships do not apply. Under these conditions, which would also apply for traffic management schemes, reactions to change have been found to be much greater than predicted from steady-state relationships.

3 There appear to be inconsistencies in the literature concerning the relationship between traffic flow and reaction to noise. There is general agreement that increases in commercial vehicle flows are associated with increased annoyance. However, one study suggests that once the flow reaches 1500 commercial vehicles per day then there is no significant further increase in annoyance at higher flows. Although this result does have clear implications for traffic management schemes, further work is needed to establish whether it can be applied generally.

4 Few studies have explored the perceived changes in levels of air pollution and noise levels that traffic management schemes can provoke. Almost all existing studies relate to traffic calming, but the effects of traffic calming on changes in annoyance due to air pollution and noise show a large amount of variation between sites.

5 Respondents to questionnaires do not generally consider that traffic calming schemes affect local levels of air pollution, and those respondents who do feel that levels have changed tend to be divided in their perceptions of the change.

6 In relation to traffic calming, noise appears to be a more prominent issue than air pollution. There is some evidence to suggest that residents with certain traffic calming measures positioned close to their homes are more annoyed by noise than other residents. It also appears that the perceived noise benefits resulting from the speed reductions associated with calming can be eroded where the flow includes a significant number of heavy goods vehicles.
Current understanding of the dose-response relationships for air pollution and noise, and knowledge of the perceived environmental impacts of traffic management schemes, are inadequate for the task of predicting community reaction to future schemes. A better understanding of the relationships between traffic management methods and perceived environmental changes would be achieved as a result of further investigations where both community effects and traffic changes were measured. Such studies could also investigate the use of different physical measures of noise or air pollution in order to obtain improved correlations with perceived impacts.

8 References


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Appendix A: Noise indices and ratings

The noise from a traffic stream is not constant, and it is necessary to use an index to arrive at a single-figure estimate of the overall noise level for assessment purposes.

$L_1$, $L_{10}$, $L_{50}$, $L_{90}$ and $L_{eq}$

The noise levels exceeded for 1, 10, 50, 90 and 99% of the measurement period, and the noise level equivalent to the average noise energy over the whole period. $L_{eq}$ is given by:

\[
L_{eq} = \frac{1}{T} \int_0^T L(t) dt
\]

where $T$ = the time period covered

$L_{A10}$, $L_{A90}$, $L_{Aeq}$ etc.

As $L_{10}$, $L_{90}$, $L_{eq}$, but the A in the subscript denotes that the sound levels have been ‘A’ weighted (i.e. the frequency response of the equipment for measuring noise is similar to that of the human ear).

$L_{A10,18h}$, $L_{A90,18h}$, $L_{Aeq,24h}$

The noise levels defined over a fixed time period (e.g. 1, 8, 18, 24 hours). It is important when quoting values that the time period is clearly stipulated.

Traffic Noise Index (TNI)

The Traffic Noise Index is based on the assumption that extensive noise level fluctuations over time are the dominant factor in traffic noise annoyance.

Traffic Noise Index = $4(L_{10} - L_{90}) + L_{90} - 30$

Noise Pollution Level ($L_{NP}$)

The Noise Pollution Level relies on annoyance due to noise being dependent on the mean acoustic energy ($L_{eq}$) and the range of its variation ($\sigma$).

Noise pollution level = $L_{eq} + k\sigma$

$L_{DN}$

The Day and Night Average Sound Level is based on the concept that the annoyance rating of a noise is greater during the night. The energy is averaged over 24 hours, but a 10 dB weighting is given to the night-time $L_{eq}$ over a 9 hour period (2200 to 0700):
Appendix B: Results from attitude surveys - traffic calming

B1 Air Pollution

Table B1 Percentage agreeing with a particular option

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Subject</th>
<th>Worse</th>
<th>Same</th>
<th>Better</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windle &amp; Mackie (1992)</td>
<td>Exeter</td>
<td>Fumes</td>
<td>2</td>
<td>73</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dirt</td>
<td>3</td>
<td>73</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Maidstone</td>
<td>Fumes</td>
<td>11</td>
<td>74</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dirt</td>
<td>8</td>
<td>74</td>
<td>14</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Bridgewater</td>
<td>Fumes</td>
<td>8</td>
<td>78</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dirt</td>
<td>8</td>
<td>81</td>
<td>4</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Sutton</td>
<td>Fumes</td>
<td>9</td>
<td>62</td>
<td>13</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dirt</td>
<td>9</td>
<td>65</td>
<td>12</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Table B2 Mean score showing level of agreement with a statement

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Statement</th>
<th>Rating scale</th>
<th>Period</th>
<th>Mean score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esteves (1995)</td>
<td>Camden</td>
<td>'What do you feel about the air quality in your neighbourhood?’</td>
<td>1=filthy,</td>
<td>Before calming</td>
<td>2.059</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7=clean</td>
<td>After calming</td>
<td>1.724</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(calmed area)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Before calming</td>
<td>2.471</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>After calming</td>
<td>2.688</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(control area)</td>
<td></td>
</tr>
<tr>
<td>Wheeler et al.(1996)</td>
<td>Craven Arms</td>
<td>'The changes have increased traffic fumes’.</td>
<td>5=agree a lot</td>
<td>After calming</td>
<td>3.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1=disagree a lot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeler et al.(1997)</td>
<td>Thorney</td>
<td>'The changes have increased traffic fumes’.</td>
<td>5=agree a lot</td>
<td>After calming</td>
<td>4.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1=disagree a lot</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B3 Net agreement with a statement

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Statement</th>
<th>Net agreement (approx. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor (1995)</td>
<td>York, Tang Hall</td>
<td>'Pollution has got better'</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>York, Muncaster</td>
<td></td>
<td>-12</td>
</tr>
<tr>
<td></td>
<td>York, Foxwood</td>
<td></td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td>Leicester</td>
<td></td>
<td>+9</td>
</tr>
<tr>
<td></td>
<td>Brighton, Rugby Rd</td>
<td></td>
<td>+18</td>
</tr>
<tr>
<td></td>
<td>Brighton, Hanover</td>
<td></td>
<td>+13</td>
</tr>
</tbody>
</table>

Table B4 Percentage agreeing with a statement

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Statement</th>
<th>Period</th>
<th>% agreeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wernsperger &amp; Sammer (1995)</td>
<td>Graz</td>
<td>'Pollution will increase(d)’</td>
<td>Just before</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Just after</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 months after</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18 months after</td>
<td>24</td>
</tr>
</tbody>
</table>
## B2 Noise

### Table B5 Percentage agreeing with a particular option

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Subject</th>
<th>Worse</th>
<th>Same</th>
<th>Better</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windle &amp; Mackie (1992)</td>
<td>Exeter</td>
<td>Noise</td>
<td>6</td>
<td>64</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Maidstone</td>
<td>Noise</td>
<td>15</td>
<td>61</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Bridgewater</td>
<td>Noise</td>
<td>7</td>
<td>79</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Sutton</td>
<td>Noise</td>
<td>12</td>
<td>61</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Oxfordshire C. C. (1992)</td>
<td>Kennington</td>
<td>Noise</td>
<td>17</td>
<td>29</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Van Every and Holmes (1992)</td>
<td>Woodville</td>
<td>Noise</td>
<td>32</td>
<td>68</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table B6 Mean score showing level of agreement with a statement

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Statement</th>
<th>Rating scale</th>
<th>Period</th>
<th>Mean score</th>
<th>Noise change ($L_{eq,10}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esteves (1995)</td>
<td>Camden</td>
<td>‘What do you feel about the noise level in your neighbourhood?’</td>
<td>1=high, 7=low</td>
<td>Before calming</td>
<td>2.341</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>After calming (calmed area)</td>
<td>1.724</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Before calming</td>
<td>3.657</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>After calming (control area)</td>
<td>4.222</td>
<td></td>
</tr>
<tr>
<td>Wheeler et al.</td>
<td>Craven Arms</td>
<td>‘The changes have increased traffic noise.’</td>
<td>5=agree a lot, 1=disagree a lot</td>
<td>After calming</td>
<td>3.51</td>
<td>-3.5 dB(A) (daytime)</td>
</tr>
<tr>
<td>Wheeler et al.</td>
<td>Thorney</td>
<td>‘The changes have increased traffic noise.’</td>
<td>5=agree a lot, 1=disagree a lot</td>
<td>After calming</td>
<td>4.21</td>
<td>-3.5 dB(A)</td>
</tr>
</tbody>
</table>

### Table B7 Net agreement with a statement

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Statement</th>
<th>Net agreement (approx. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>York, Muncaster</td>
<td></td>
<td>-27</td>
</tr>
<tr>
<td></td>
<td>York, Foxwood</td>
<td></td>
<td>-8</td>
</tr>
<tr>
<td></td>
<td>Leicester</td>
<td></td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>Brighton, Rugby Rd</td>
<td></td>
<td>+31</td>
</tr>
<tr>
<td></td>
<td>Brighton, Hanover</td>
<td></td>
<td>+13</td>
</tr>
</tbody>
</table>
Table B8 Percentage agreeing with a statement

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Location</th>
<th>Statement</th>
<th>Period</th>
<th>% agreeing</th>
<th>Noise change ($L_{eq}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wernsperger &amp; Sammer (1995)</td>
<td>Graz</td>
<td>‘Noise will/has increase(d)’</td>
<td>Just before</td>
<td>31</td>
<td>-0.9 dB and -1.9 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Just after</td>
<td>20</td>
<td>(measured at two points)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 months after</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18 months after</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Kent County Council (1992)</td>
<td>Sittingbourne</td>
<td>‘Noise has been reduced.’</td>
<td>After</td>
<td>62</td>
<td>N/A</td>
</tr>
<tr>
<td>Cairney &amp; Harwood (1994)</td>
<td>Unley</td>
<td>‘Has noise reduced?’</td>
<td>3 months after</td>
<td>20</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 years after</td>
<td>29</td>
<td></td>
</tr>
</tbody>
</table>

Table B9 Percentage bothered by noise

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Criteria</th>
<th>Location</th>
<th>% of sample</th>
<th>Noise change ($L_{10,18h}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baguley &amp; Sumner (1979)</td>
<td>Bothered ‘a lot’ or ‘very much’ by noise</td>
<td>Norwich</td>
<td>31</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxford</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kensington</td>
<td>42</td>
<td>17</td>
</tr>
<tr>
<td>Baguley (1981)</td>
<td>Bothered ‘a lot’ or ‘very much’ by noise</td>
<td>Lytham</td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventnor</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotherhithe</td>
<td>30</td>
<td>19</td>
</tr>
</tbody>
</table>
Abstract

The success of a traffic management scheme will depend ultimately on the acceptance by the general public of the scheme. This in turn will depend on how the various impacts of the scheme, including impacts on the environment, are perceived. The development of methods for predicting public reaction to the environmental impacts of schemes might therefore help planners to improve their popularity, and to reduce the need to alter or remove those that are particularly unpopular on environmental grounds. Potential predictive methods include the use of dose-response relationships and the analysis of existing attitude surveys conducted at schemes. This Review examines the current understanding of the dose-response relationships for three important components of environmental nuisance - air pollution, noise, and vibration - and records how subjective responses to these components have been influenced by traffic management schemes. Current predictive capabilities of both the methods considered are found to be inadequate for use with traffic management schemes. It is suggested that further work is required to determine the relationships between traffic parameters and perceived environmental nuisance.

Related publications

TRL311 Traffic calming - public attitude studies: a literature review by D C Webster. 1998 (price £30, code H)
TRL307 Traffic calming and vehicle emissions: a literature review by P G Boulter and D C Webster. 1997 (price £30, code H)
TRL235 Traffic calming; vehicle generated ground-borne vibration alongside speed control cushions and road humps by G R Watts, G J Harris and R E Layfield. 1997 (price £30, code H)
RR246 Traffic induced vibrations in buildings by G R Watts. 1990 (price £15, code C)

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