inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 5.2

TRAFFIC CALMING IN GLOUCESTER, INFLUENCE ON NOISE AND GROUND-BORNE VIBRATION

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Keywords:
TRAFFIC CALMING, SPEED HUMPS, SPEED CUSHIONS, TRAFFIC VIBRATION

ABSTRACT
The Gloucester Safer City Project seeks to reduce road casualties in the city by one third by the year 2002. As part of more general research into the environmental impact of urban traffic management and safety schemes, the Charging and Local Transport Division (CLT) of the Department of Environment Transport and the Regions (DETR) has commissioned the Transport Research Laboratory (TRL) to monitor the environmental effects of the Gloucester Safer City Project. Surveys were carried out to investigate the effect of the Longlevens Area Wide Traffic Safety Scheme on traffic speeds and flows, vehicle emissions, local air quality, noise, ground-borne vibration and public perceptions. This paper describes the results from the vehicle and traffic noise surveys together with the measurements of ground-borne vibration.

1 - INTRODUCTION
TRL have carried out noise and ground-borne vibration surveys alongside traffic calming schemes in the City of Gloucester in the UK as part of the "Safer City" initiative financed by the Charging and Local Transport Division (CLT) of the Department of Environment Transport and the Regions (DETR) to investigate the environmental impact of urban traffic management and safety schemes. Measurements of vehicle and traffic noise together with ground-borne vibration were taken at selected sites in the Longlevens area before and after the installation of the traffic calming scheme. Previous work has shown that the level of noise from roads is directly proportional to the volume and speed of the traffic and the proportion of heavy vehicles [1]. It was anticipated that reductions in traffic flow and mean vehicle speeds resulting from the traffic calming measures would cause decreases in overall traffic noise levels. However, earlier studies have shown that the presence of vertical deflections can cause changes in the level or character of the noise from some vehicles [2]. This is most likely to occur as a result of changes in driver behaviour, or because of the excitation of sources of heavy vehicle body noise (heavy vehicle body noise is caused by impacts between parts of the vehicle body or between components of steel suspension systems; this can occur when heavy vehicles travel over a raised profile which causes vertical forces to be transmitted through the vehicle body via the suspension).

2 - NOISE AND VIBRATION SURVEYS

2.1 - Vehicle noise
Measurements of vehicle noise were taken at various roadside positions before and after the installation of the traffic calming scheme, see Fig 1. The purpose of this was to assess the change in maximum noise levels generated by vehicles passing through different points of the scheme. The traffic calming features studied were:

Speed cushions (N1): nominal 75 mm high, 3.5 m long, 1.6 m wide, with on/off ramp gradients of 1:10 and side ramp gradients of 1:4, the narrow width allows straddling by larger vehicles;

Junction tables (N3 and N6): nominal 75 mm high with ramp gradients of 1:13.5, length varying from 21 m to 39 m. The crossing points at the kerbs are flush with the raised plateau with tactile surfaces to assist visually impaired pedestrians;

Flat-top road hump (N7): nominal 75 mm high with ramp gradients of 1:13.5 with the length varying from 4 m to 12 m. Tactile surfaces on the pedestrian approaches are provided at locations where the humps are likely to be used as crossing places;
Between speed cushions (N4): A level site for comparative measurements.
The Statistical Pass-by (SPB) method was used to measure vehicle noise before and after the installation of traffic calming measures [3]. At each site a microphone was located 1.2 m above the road surface and 5 m from the centre of the nearside lane. The microphone was connected to a noise analyser configured to record the maximum A-weighted sound level during individual vehicle pass-bys. Vehicles were selected for measurement if they were judged to be sufficiently separated in the traffic stream so that other vehicles did not influence their noise characteristics. Each selected vehicle was subsequently classified as either "light" (i.e. all cars and vans with an unladen weight less than 1.5 tonnes) or "heavy" (goods vehicles with an unladen weight more than 1.5 tonnes). Vehicle speed was measured concurrently using a radar speed sensor. This was positioned to be as unobtrusive as possible, in order to reduce the likelihood of altering driver behaviour. Where possible during the after survey, tape recordings of noise from selected heavy vehicles were taken directly alongside the feature, and alongside a level section of road a short distance in front of the feature. It was intended that the analysis of the recordings would show any change in the level or character of the noise from individual heavy vehicles as they passed over the features compared to that alongside the level surface.
The analysis showed that the correlation between light vehicle noise and the logarithm of vehicle speed was significant at the 1% level for all of the sites. A statistical analysis showed that the before and after noise/speed relationships were significantly different at the 5% level for all sites. As a before survey was not carried out alongside the hump (N7) the after data has been compared with that obtained from the before data at site N3 where the road layout was similar.
The sample sizes for heavy vehicles at all of the sites were relatively small compared with the light vehicle data. To increase the sample size the heavy vehicle pass-by events on the far-side carriageway were also included. To account for the greater propagation distance, the noise levels were adjusted using the inverse square law assuming point source propagation. This method was verified in a previous study where the noise from heavy vehicles on both sides of the road had been measured at a similar site [4]. An analysis of the data from each site showed that the relationships between noise level and heavy vehicle speed were not statistically significant. Therefore, instead of regression lines, the mean noise level and standard deviation together with the mean speed for each sample was calculated. As for the light vehicles, the after survey data for site N7 (hump) is compared with that from the before survey at site N3.

2.2 - Traffic noise

Exposure to traffic noise was monitored outside residential properties before and after the installation of the traffic calming measures. In addition the number of individual noise events exceeding a selected noise level threshold in each hour together with the maximum noise level in each hour was also recorded. It was intended that these results would give some indication of the effect of the traffic calming measures on the generation of noisy events of short duration. A video camera was also set up whilst noise measurements were made of vehicles passing over a speed cushion. From this it was hoped that the types of vehicles generating high noise levels could be identified.

2.3 - Ground-borne vibration

Measurements of ground-borne vibration were also taken at properties close to selected traffic calming features to determine the levels generated by passing vehicles. Surveys were carried out before and after the installation of the junction table (N6) and during the after survey alongside the cushion (N1) and the hump (N7). Vibration was detected using geophone transducers which generate signals proportional to particle velocity. The geophones were positioned near to foundation level of the nearest house at the facade nearest to the road. The distance between the measurement position and the road was approximately 9 m at site N6 and approximately 14 m at sites N1 and N7.
The geophones were connected to a multi channel signal processor which amplified and then digitised the input signals at a sampling rate of 1 kHz. This device was connected via a data bus to a portable computer which scaled and recorded the digitised particle velocity signal using specialist software.
The system was configured to capture a 10 second time record of particle velocity during pass-bys of selected vehicles. The sampling period was commenced on the operation of a manual trigger switch which was activated as the vehicle approached the site. Following each pass-by, the peak particle velocity (PPV) value in each axis was recorded along with the type of vehicle and its passing speed. All heavy vehicle pass-bys during the monitoring period were recorded as these would be expected to produce the highest vibration levels. Prior to any vehicle measurements, levels of background vibration were recorded to

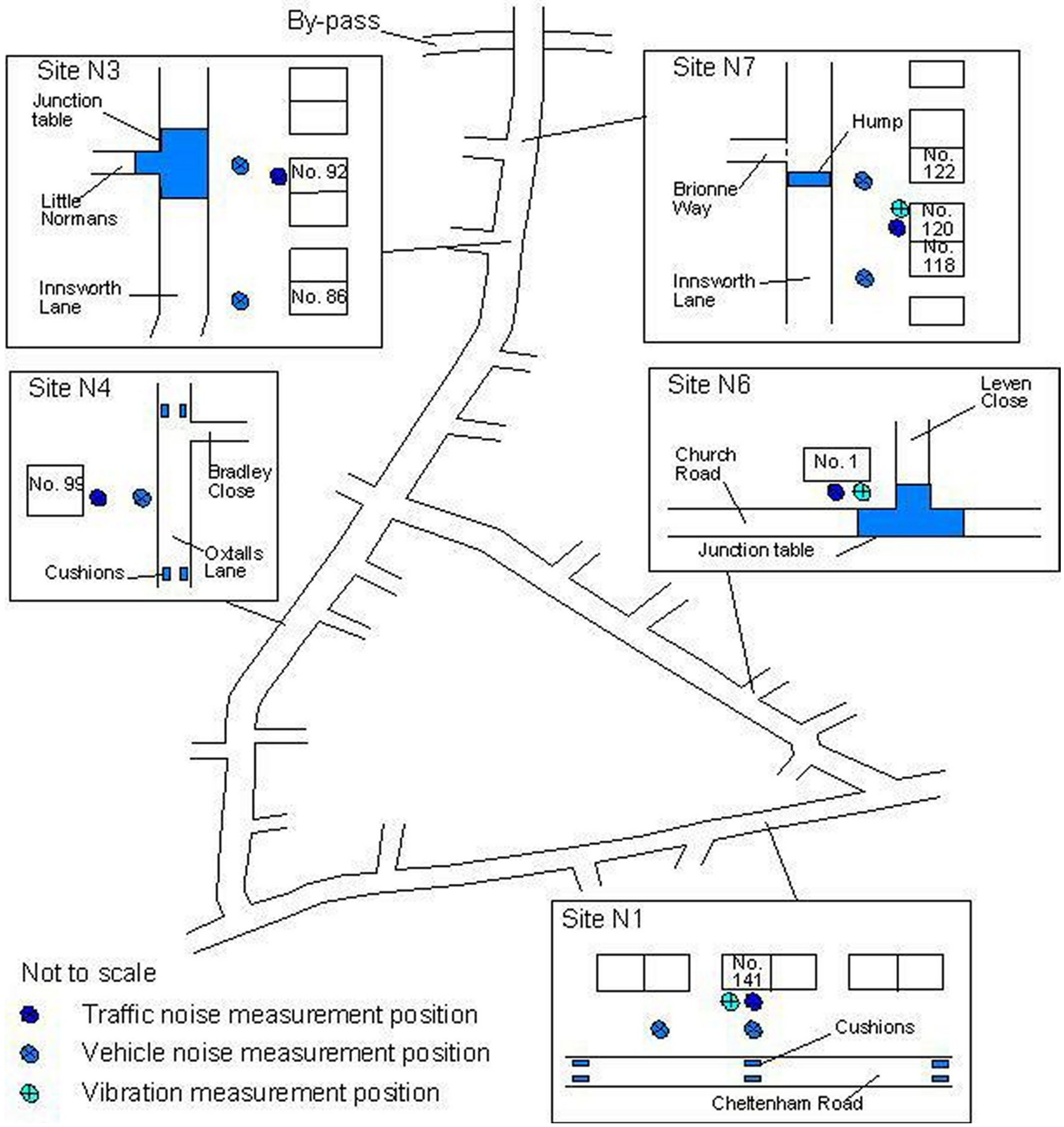

Figure 1: Site details showing type and location of surveys.

determine the lowest possible levels of vehicle generated vibration that would be discernible during any given measurement session.

To assess vibration exposure at the property, vibration levels were recorded for 15 minute periods in each hour of the survey. At the end of each logging period the software calculated the number of PPV events exceeding standard thresholds of 0.14, 0.3 and 1.0 mm/s in the vertical direction. These levels correspond to different thresholds in relation to human exposure to vibration [5].

3 - RESULTS AND CONCLUSIONS

3.1 - Light vehicles

The noise from light vehicles was reduced at each of the monitoring sites following the installation of the various traffic calming measures. The average noise reductions at the vertical deflections were 5.2 dB(A) alongside the cushion (N1), 5.3 dB(A) alongside the hump (N7), and 6.6 dB(A) alongside the junction table (N3). The reduction in mean speed was greatest alongside the junction table (N3). The reduction in noise on the level between cushions (N4) was only 2.7 dB(A). With the exception of the results obtained alongside the cushion (N1), the decreases were slightly less than would have been expected given the mean speed reductions that occurred. This can be partly explained by drivers selecting lower gear ratios whilst travelling at the lower speeds, resulting in higher engine speeds and therefore relatively higher noise levels than expected.

3.2 - Heavy vehicles

Mean heavy vehicle noise increased slightly at all of the monitoring sites, except alongside the cushion (N1), despite decreases in mean vehicle speeds generally comparable with those for light vehicles. The decrease in mean noise level at site N1 was 0.7 dB(A). At the other sites mean noise level increased by between 0.2 and 1.5 dB(A). These changes in noise level were not found to be statistically significant. A reduction in vehicle speed would normally be associated with a decrease in engine speed and hence a reduction in power train noise. In this case heavy vehicle engine speeds may have been relatively unchanged or even increased during the after survey as a result of drivers selecting low gear settings to negotiate the traffic calming measures. This might explain the absence of a reduction in mean heavy vehicle noise.

For some vehicles, increased body noise may also have contributed to the maximum pass-by noise level. The time histories of noise generation demonstrate how body noise from heavy vehicles affect the maximum A-weighted noise level. The time histories show distinct, multiple noise peaks. In some cases it is clear that the maximum noise level is not substantially increased by the occurrence of body noise. However, the impulsive nature would be expected to make the pass-by noise more noticeable and therefore potentially disturbing to nearby residents [6]. In one case, the body noise produced during the vehicle pass-by contained dominant tonal components: strong tonal characteristics also tend to make the sound more distinct to the listener [6]. Simply measuring the maximum A-weighted noise level may not, therefore, fully reflect the degree of disturbance experienced by some residents in response to body noise caused by some heavy vehicles.

High level peaks of impulsive body noise were recorded, for example, the pass-by noise measured alongside the hump at site N7 from an unladen articulated tipper truck, rapidly reached a maximum level over 11 dB(A) higher than that generated as the vehicle travelled over a level surface. The disturbance experienced by residents in response to these body noise events is likely to be dependent on the time of day, their activity, and the associated background noise levels. For example, distinctive body noise from a vehicle passing at midnight, when many residents are trying to sleep, is likely to be more disturbing than the same noise event occurring at midday.

3.3 - High level noise events

High level noise events (i.e. >80 dB(A)) were logged outside properties near to the speed cushion (N1) and the junction table (N6). At the cushion the number of noisy events over the 24-hour period was reduced from 32 to 21 following the installation of the cushions. A video analysis showed that many of the noisy events before calming were caused by buses accelerating through the site. The cushions were successful in reducing this particular noise problem, but it was also clear from the video analysis that some of the noisy events in the after survey were caused by body noise.

At the junction table (N6) the number of noisy events was reduced from 13 to 0. As a video monitoring survey was not conducted at this site the source of the noisy events during the before survey is not known. However, the result at least demonstrates that there was an improvement in this respect rather than an increase in high noise level events following the installation of the junction table.

3.4 - Traffic noise exposure

Daytime traffic noise exposure ($L_{A10,18h}$) was reduced at all of the monitoring sites following the installation of the traffic calming measures. Reductions in $L_{A10,18h}$ were between 5.8 and 2.8 dB(A). The hourly data also show that noise was consistently lower throughout the daytime period at all sites. The smallest decrease of 2.8 dB(A) was at the hump (N7), although as the before noise level was estimated it is possible that this reduction would actually have been greater. Also the after noise level may have been affected by traffic on the nearby A40 By-pass making it difficult to assess the effect of the traffic calming measure on the local traffic noise.

When the effects of changes in traffic flow and composition were taken into account the estimated changes in noise exposure were between 6 and 2.4 dB(A). The reductions obtained at the cushion (N1), junction table (N3) and between cushions (N4) sites were within 1 dB(A) of each other (i.e. between 3.1 and 4 dB(A)). The largest reduction of 6 dB(A) at site N6 was almost 3 dB(A) greater than that at site N3 although both sites were alongside an equivalent feature (junction table). This cannot be explained by speed change as the mean speed change was in fact considerably less at site N6 than at site N3. The larger noise reduction at site N6 might have been be a result of the more constricted road layout at this site. To the east was a mini-roundabout junction and to the west there were often cars parked at the kerbside restricting the flow of traffic. It is possible that these constrictions near the junction table

may have caused drivers to accelerate away from the feature more gradually than at site N3, resulting in greater noise reductions.
There was no notable change in daytime C-weighted noise levels at either of the sites where $L_{C10,18h}$ was measured (sites N1 and N6) indicating that low frequency traffic noise levels were generally unchanged. Night-time noise levels at most sites were reduced by nearly 6 dB(A) ($L_{A10,6h}$) except at the junction table at site N3 where the noise level was little changed. This was a result of the nearby A40 By-pass tending to dominate night-time noise levels, hence diminishing any benefit in reduction in local traffic noise. The influence of the by-pass on the local noise climate at site N3 is also shown by the absence of change in $L_{A90,18h}$ level. At other sites, background (L_{A90}) noise levels were generally controlled by local traffic noise at other sites and therefore tended to reduce following the installation of the scheme along with the L_{A10} levels.

3.5 - Ground-borne vibration

Levels of ground-borne vibration at one of the junction tables (N6) were not found to have increased significantly. The maximum levels recorded were unlikely to have been perceptible at the property either before or after installation of the feature (i.e. <0.3 mm/s). Levels alongside the hump (N1) and cushion (N7) prior to installation were not recorded, so it is not known if levels increased or decreased following installation. However, alongside the cushion (N1), levels were generally higher than at the junction table (N6) and several events were recorded which may well have caused perceptible vibration and therefore nuisance inside the property. Alongside the hump (N7), at least one event was recorded which could have been perceptible

ACKNOWLEDGEMENTS

The authors are grateful to Eric Wyatt from the Charging and Local Transport Division of the Department of the Environment, Transport and the Regions for his support and guidance.

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