Road design measures to reduce drivers' speed via 'psychological' processes: A literature review

Prepared for Charging and Local Transport Division, Department for Transport

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TRL Report TRL564

First Published 2003
ISSN 0968-4107

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Executive Summary

Excessive driving speed is a major concern for road safety, with speed having an adverse affect on the number and severity of road traffic accidents and on a number of measures associated with quality of life. Traditional traffic engineering measures are examples of extrinsic forms of control (i.e. safety interventions that work to influence driver behaviour by placing external constraints on the driver). Such interventions (e.g. speed humps, chicanes, and other physical measures built on the carriageway) can substantially reduce drivers' mean travelling speeds. However, the main problems with these physical measures are as follows:

- They do not control how fast people drive between the measures, often inducing a style of driving involving repeated acceleration and deceleration, which in turn can result in increased vehicle emissions.
- They can be costly, which limits their application.
- They can be visually intrusive.
- Some measures (e.g. those based on vertical deflections) can cause some vehicles to generate increased noise and vibration, which may be a source of nuisance to local residents.
- Measures based on vertical deflection can generate discomfort to vehicle occupants. There is also the possibility that they might cause damage to vehicles and injury to vehicle occupants if crossed at inappropriate speed.

TRL has been commissioned by the Department for Transport (DfT) to carry out research into 'drivers and traffic calming'. One aspect of this project is the investigation of engineering measures which aim to reduce drivers' speed via intrinsic (or 'psychological') means of control. This report presents a review of the effectiveness of such measures.

The aims of this review were to:

- Identify relevant psychological theories to provide an insight into how specific road design measures might reduce driving speeds and to aid the development of new road design innovations to reduce speed; and to
- Assess, based on previous research findings, the evidence for the effectiveness of different road design measures to reduce driving speed.

The main findings were:

- Psychological measures investigated in this review have generally produced smaller speed reductions than those from physical measures, although psychological measures may be more acceptable to drivers. Their effects may lessen over time.
- The more successful non-physical measures tend to be visually intrusive and may therefore be considered out of place in rural areas.
- In general, more complex environments tend to be associated with slower driving speeds, the likely mechanisms being increases in cognitive load and perceived risk.
- Many aspects of the driving environment interact to influence speed. In particular, roadside activity tends to reduce speeds. Thus the presence of pedestrians may influence drivers to reduce their speeds and bus or cycle lanes are more likely to reduce speeds when they are in use. On-street parking not only narrows the carriageway, it may increase perceived risk because of the possibility of people getting out of their cars, or of pedestrians concealed by the cars, or the cars themselves moving off.
- Combinations of features tend to be more effective than individual measures. This will increase their alerting effect and will also make it more likely that different psychological effects are induced. For example, the positioning of trees should be such as to increase peripheral streaming and also limit forward visibility.
- Natural traffic calming (e.g. hump back bridges and winding roads with poor forward visibility) can be very effective and scores highly in terms of acceptability. Schemes based on natural traffic calming will need to be designed holistically and contextually to achieve a similar effect. Existing natural features should be enhanced by any traffic calming measures.
- As a general rule, reductions in speed can be presumed to result in increased safety. However, care is needed to ensure that measures that reduce speeds by increasing perceived risk do not increase actual risk.

1 Introduction

Excessive driving speed is a major concern for road safety. Although it is recognised that the speed-accident relationship is a complex one (Taylor *et al*., 2000), research has shown that fast driving, or speeding, is an important factor in influencing the frequency of road traffic accidents (e.g. Carsten *et al*., 1989; Finch *et al*., 1994; Stradling, 2000; Taylor *et al*., 2000). Moreover, the basic dynamics of an impact means that the severity of an accident increases with vehicle speed. In addition to these safety concerns, other important issues concerning high speed driving have been identified, such as the impact on quality of life (e.g. Ward, 1999). For instance, increased noise and vibration can result from high vehicle speeds. Fast moving traffic can also be seen by people as a barrier to walking and cycling because of the perceived danger it generates. Therefore, considerable benefits for safety and quality of life are likely to be obtained by reducing vehicle speeds.

In establishing how to reduce vehicle speeds (and maintain speed reductions), it is useful to consider the types of methods available for controlling people's driving behaviour. There are a number of methods available to reduce driving speeds, and these typically fall into one of three categories: enforcement, engineering or education/ publicity. The enforcement of road and traffic laws is one way of *extrinsically* controlling how fast people drive (i.e. by placing an external kind of constraint on the driver). Enforcement is regarded as one of the most influential ways to control drivers' behaviour, and it seems to be the most effective deterrent for speeding drivers (Corbett and Simon, 1992). However, the effectiveness of enforcement is dependent on the resources available and in many instances people can exceed legal speed limits without being punished by the law.

Engineering has also traditionally been thought of as being an extrinsic form of control. Speed humps, chicanes, and other physical measures built on the carriageway are external constraints on the driver, and can substantially reduce drivers' mean travelling speeds. However, the main problems with these physical measures are as follows:

- They do not control how fast people drive between the measures, often inducing a style of driving involving repeated acceleration and deceleration, which in turn can result in increased vehicle emissions (Cloke *et al*., 1999, Boulter *et al*., 2001).
- They can be costly, which limits their application.
- They can be visually intrusive.
- Some measures (e.g. those based on vertical deflections) can cause some vehicles to generate increased noise and vibration, which may be a source of nuisance to local residents (e.g. Abbott *et al*., 1997, Harris *et al*., 1999).
- Measures based on vertical deflection can generate discomfort to vehicle occupants. There is also the possibility that they might cause damage to vehicles and injury to vehicle occupants, if crossed at inappropriate speed.

Given these problems, it would be highly beneficial to find ways to encourage drivers to voluntarily adopt slower travelling speeds. To accomplish this, *intrinsic* forms of control are needed (i.e. ways of making drivers want to, or feel they ought to, reduce their driving speed, and which allow them to adopt slower speeds via the self-regulation of their own behaviour).

Traditionally, the job of encouraging intrinsic control has been through driver education. Interventions designed to change people's attitudes, via persuasive messages, have typically been used, but these interventions have had little observed impact on driving speeds (e.g. Parker *et al*., 1996). Therefore, finding other ways to persuade people to adopt slower driving speeds may be appropriate, and, in recent years, attention has been given to the development of engineering measures to encourage intrinsic control, by using the visual scene as a way of psychologically influencing drivers' speed choice (e.g. Chinn and Elliott, 2002); Scottish Executive Development Department - SEDD, 1999).

The Department for Transport (DfT) has now commissioned TRL to carry out research into 'drivers and traffic calming', with one aspect of this project being the investigation of measures which aim to reduce drivers' speed via intrinsic (or psychological) means of control. This report presents a review of the effectiveness of such measures. It is presented in 5 sections. The next section (2) outlines the aims of the review. Section 3 describes the psychological theories that provide an insight into how road design measures might reduce driving speeds and which can be used to aid the development of new or modified road design innovations to reduce speed. Section 4 outlines the interventions that have been used in the past to control drivers' speed by using the visual scene as a way to influence speed choice, and assesses the research evidence for their effectiveness. Finally, Section 5 summarises the main findings of the review.

2 Aims

The aims of this review were to:

- Identify relevant psychological theories to provide an insight into how specific road design measures might reduce driving speeds and to aid the development of new road design innovations to reduce speed; and to
- Assess, based on previous research findings, the evidence for the effectiveness of different road design measures in reducing driving speed.

3 Reducing driving speeds: Psychological principles

Theoretical approaches to understanding how road design measures might work to reduce drivers' travelling speeds are important, not only because they provide knowledge about how specific measures might work, but also because they provide a theoretical basis to aid the development of new road design innovations to reduce speed. In addition, knowledge of the reasons drivers often give for fast driving or speeding can be used to develop predictions about how design elements might influence drivers' speed choice. A number of relevant theoretical approaches to reduce speed are briefly described below:

3.1 Increasing cognitive load

Cognitive load refers to the amount of mental effort, or information processing, which is required to perform a task, and it is related to task complexity. As the complexity of a task increases, the amount of information processing required from an individual must also increase to sustain task performance at the same level. If an individual's level of information processing does not increase to match the increase in task complexity, then his or her level of task performance decreases. In the present context, the speed at which a driver is travelling can be seen as an aspect of task performance. Increasing the complexity of the driving task will result in an increase in the cognitive load on a driver, with the theoretical prediction being that the driver will then choose to drive at a slower speed to compensate for the increase in information processing required of him/her. This could be seen as a sub-conscious process, or as a consciously chosen response to increasing task difficulty. However, if the driver chooses to continue at the same speed, the increased load may mean s/he is driving less safely. A number of studies using an instrumented car have shown that drivers experiencing increased levels of cognitive load reduce their driving speeds (De Waard *et al*., 1995; Fusinato, 1977; Harms, 1986, 1991).

3.2 Utility: Decreasing the perceived profit of an individual to speed

Utility refers to an individual's choice to perform a behaviour based on a rationalised weighing up of the positive and negative aspects associated with that behaviour. Individuals are thought to choose an option which maximises their perceived profit. In other words, people will choose to drive fast if they perceive that it will lead to a positive, rather than a negative, outcome for them. As a theoretical prediction, design measures to reduce the amount of profit that individuals perceive for driving fast, may result in the adoption of slower driving speeds. To reduce the perceived profit for fast driving, design measures could be used which increase physical discomfort, stress, perceived accident risk, or risk of enforcement.

3.3 Enhancing perceived danger/risk

Risk tolerance is known to influence driving speed (Quimby *et al*., 1998) and drivers who tolerate a higher level of risk drive faster than drivers who tolerate a lower level of risk. Road surroundings can be manipulated to enhance a driver's perception of the danger associated with a particular road environment or situation, and this could be used to control drivers' speed. Interventions that increase perceived danger might be successful in reducing speed because drivers may compensate for the increase in perceived risk by slowing down to maintain their accepted level of risk tolerance. This effect might occur through a sub-conscious process. Alternatively, drivers might make a conscious decision to reduce their driving speed when their perception of danger or risk increases, and this concept is closely linked to utility theory (see above). Perceived risk could refer to a number of factors. It could be the perceived risk of causing damage to the vehicle, to oneself (i.e. the driver), or to other road users (e.g. pedestrians). More generally, it could refer to the perceived risk of a road traffic accident.

3.4 Retinal streaming

The term retinal streaming refers to the cues for speed perception (Gibson, 1950; 1958; 1960). Briefly, when an individual moves forward, he or she perceives a visual scene with a stationary image at the point of fixation. Elements of the visual image are perceived to move with increasing speed as the distance increases from the point of fixation to the peripheral visual field. Early psychological research showed that images in the peripheral field could be manipulated to influence peoples' perceptions of speed. For example, vertical contrast in the visual periphery gives the perception of moving at speed whereas horizontal contrast does not, and increasing the level of vertical contrast and density in the visual periphery increases the speed at which an individual perceives to be moving. In the domain of driving, research has shown that drivers use the information in the visual periphery to estimate their travelling speed (e.g. Salvatore, 1968). Therefore, using design elements to manipulate vertical contrast in drivers' peripheral vision could create the 'illusion' of travelling faster than is actually the case. Drivers may then compensate for any perceived increase in speed by reducing their actual speed. Again, this might be a sub-conscious process, or might occur because of a conscious decision based on utility (see above). Research in this area suggests that optical flow which exceeds 2 radians per second induces a retinal streaming effect which is a discomfort for drivers (Yamanaka and Kobayashi, 1970), and that drivers tend to adopt travelling speeds which do not cause the speed of objects in the visual periphery to exceed this value (Van der Horst and Riemersma, 1984).

3.5 Driver stress

It has been suggested that increasing driver stress may be a way of controlling drivers' speed. However, stress is a complex and multidimensional phenomenon, as is its relation to task performance. In addition, little is known about the effects of stress on specific driving behaviours. Theory does indicate, however, that the effects of stress may be quite different for different individuals. This is in line with a *transactional approach* to stress, in which stress is seen as a condition that results when *person-environment* 'transactions' lead to a *perceived* discrepancy between the demands of a situation and the resources available to cope with those demands (Lazarus, 1966). Thus, it is not the magnitude of the demands which determines stress, but the *perceived* demands of the situation together with the *perceived* ability to cope. Therefore, when faced with the same demands, there may be significant individual differences between people because of differences in the ability to cope. Some individuals might, for example, cope with a 'stressful' driving situation by decreasing their driving speed. However, others might actually increase their driving speed in response to a stressor.

Support for this argument comes from the work of Matthews and colleagues (Matthews, 1993; Matthews *et al.*, 1998). They used a transactional approach to stress in the study of driver behaviour and investigated three aspects of driver stress: aggression, dislike of driving, and hazard monitoring. They found that people vulnerable to stress-related aggression tended to see other drivers as hostile, and cope with stressful driving situations by frequent overtaking and other risky behaviours (such as the adoption of faster travelling speeds). People whose response to over-demanding driving situations was dominated by 'dislike of driving' perceived themselves as poor drivers, and adopted self-criticism and other 'emotion-focused' coping strategies involving thoughts that interfere with attention and car-control. People whose primary goal was concerned with safety coped with demanding driving situations by trying to improve their hazard monitoring. Thus it would seem that any intervention that might seek to control drivers' speed, via increasing driving stress, would only be beneficial for certain types of people. In addition, even though it is possible that certain types of people might reduce their travelling speed in response to 'stress-evoking' driving situations, it must be noted that other 'undesirable' driving responses might accompany the speed reduction. For example, it might lead to a reduction in the ability to make 'safe' driving decisions and an increase in the frequency of driving errors.

3.6 Fear of enforcement

Enforcement of speeding laws is seen as the most effective deterrent for speeding drivers (Corbett and Simon, 1992). Resources for enforcement are limited meaning that drivers often go unpunished for exceeding legal speed limits. However, it is known that when drivers believe it is possible that they might be punished for speeding (e.g. when they see a police car or a speed camera) they slow down to a speed which is within the legal limit. Therefore, if road design measures could be found which induce a fear of possible enforcement for speeding, they might be effective in slowing down vehicle speeds. Measures that produce a similar effect, and are already in use, are speed camera signs in the absence of speed cameras (Corbett and Simon, 1999). Such measures, however, may lose their effectiveness over time unless mobile cameras are used, since the potential for being caught and punished does not manifest itself in actual enforcement.

3.7 Better knowledge of posted speed limits

One reason people often give for driving faster than posted speed limits is that they were not aware of the posted speed limit, and therefore did not know the appropriate speed at which they should have been travelling (Cameron, 1978, 1980; Corbett and Simon, 1992; AA Foundation, 2001). Therefore, road design elements to provide drivers with a better knowledge of the posted speed limit may be successful in reducing driving speed for certain types of driver (e.g. people who are motivated to keep within legal speed limits). A concept which supports this is that of Self-Explaining Roads (e.g. Kaptein and Classens, 1998; Kaptein *et al*., 1998; Theeuwes, 1991; Theeuwes, 1998; Theeuwes and Godthelp, 1992). A self-explaining road is one where the features which identify the class of road are easily distinguished and where those features support safe driving behaviour and appropriate speed choice. Therefore, drivers can immediately identify, via top down driven search strategies, the type of road they are driving on, and they immediately associate that road with a legal speed limit which they must not exceed.

3.8 Better knowledge of own travelling speed

Modern vehicles are capable of travelling at speeds far greater than the posted legal limits, and many drivers state that it is easy to exceed legal speed limits without realising it (AA Foundation, 2001). As a counter-measure to this problem, in-vehicle technologies have been developed to warn drivers when they are exceeding the speed limit (e.g. see Carsten, 2001). However, road design measures such as vehicle activated warning signs (see Section 4.2.9) might also be an appropriate way to do this and these might help people who are motivated to keep within the speed limit to do so.

3.9 A note on safety

It should be noted that although interventions which may influence vehicle speeds via the psychological mechanisms described above might have the desired effect on drivers' speed choice, it does not necessarily follow that desirable improvements in safety will be achieved. Interventions may reduce drivers' travelling speeds because of increases in cognitive load, perceived risk or stress, for example, but the speed reduction will not necessarily be sufficient to compensate for the increased demands, which may compromise safety. Research studies reported by Harms highlight this issue. Harms (1986) found that more complex driving environments were associated with increased amounts of cognitive load, which were accompanied by lower driving speeds. However, those same areas where cognitive load was high (and driving speeds were lower) had significantly higher accident rates compared with areas where cognitive load was low (and speeds were faster). Furthermore, Harms (1991) found that drivers' error rates and reaction times were poorer when cognitive load was high compared with when it was low.

For example, frequent junctions, the presence of parked cars, and interventions that encourage increased levels of pedestrian and cyclist activity might reduce vehicle speeds. However, this type of intervention should not be used purely as a traffic calming measure. For example, if driving speeds are not sufficiently reduced, these interventions might actually decrease safety because of the additional hazards that accompany them and because of the extra demands they place on the driver.

4 Reducing driving speeds: Road design features

There is a large volume of literature on road design interventions and their effects on vehicle speeds. Many of the results have been summarised in the DfT Road Safety Good Practice Guide (Barker and Baguley, 2001). Enforcement measures such as speed cameras can have an important effect on the faster drivers (Winnett, 1994) and have been shown to reduce casualties (PA Consulting Group, 2001). Physical measures such as road humps, speed cushions and chicanes can reduce mean vehicle speeds in urban areas by up to 12 mile/h (Webster and Layfield, 1996, Layfield and Parry, 1998, and Sayer *et al.*, 1998), although traffic may speed up between individual measures unless they are closely spaced.

As well as research into these 'traditional' forms of traffic calming, there are examples in the literature of research into the effectiveness of other road design measures that might control drivers' speed choice via the psychological mechanisms outlined above. The literature contained in the annotated bibliography, presented in Appendix A, outlines research studies that have been carried out into this issue and provides many examples of interventions that might control speeds via psychological means.

A brief assessment of these individual interventions is given in Section 4.2.

4.1 Holistic approach

In addition to the research on individual features, a number of recent studies have considered a more holistic approach to traffic calming, aimed at using measures that are appropriate to the context. Key examples are:

- DfT Village Speed Reduction (VISP) initiative (e.g. Wheeler *et al.*, 1993, 1994, Wheeler and Taylor, 1999).
- DfT / English Historic Towns Forum study of traffic calming in Historic Core Zones (e.g. Wheeler, 1997, 1999A and 1999B).
- DfT / Countryside Traffic Measures Group (CTMG) study of measures designed with sensitivity to the rural environment (e.g. Kennedy and Wheeler, 2001A).
- Research for the Countryside Agency (2000) to address the design issues in rural traffic management.
- Research by the Scottish Executive (SEDD, 1999) into how naturally occurring features reduce drivers' speeds – see Section 4.1.1.
- Highways Agency study of the effect of road appearance on perceived safe travel speed (Chinn and Elliott, 2002) – see Section 4.1.2.

4.1.1 The Scottish Executive study

The Scottish Executive study (SEDD, 1999) attempted to identify the underlying principles behind natural traffic calming. Ten small or medium towns on through routes in Scotland that appeared to be naturally traffic-calmed were selected as case studies. Psychometric work was also undertaken, designed to highlight the relative importance of different features or situations. The research suggested that traffic calming should be defined as a process of helping drivers adjust to the environment. It was concluded that examples of natural traffic calming tend not to rely on a small number of key features but that drivers are influenced by a large number of different cues. The main components were identified as follows:

- the road corridor as a whole should be considered;
- measures should fit the local environment;
- location of measures should be matched to natural; transitions (e.g. from rural to urban);
- measures should be matched to speed.

4.1.2 TRL research for the Highways Agency

The research by TRL for the Highways Agency on the effect of road appearance on perceived safe travel speed (Chinn and Elliott, 2002) suggests that the following design elements should be considered when developing traffic calming schemes:

- Context e.g. roadside type.
- Scale e.g. road width and complexity.
- Proportion (height of enclosing features such as buildings or trees).
- Horizontal and vertical alignment.
- Activity e.g. presence of pedestrians, parked cars.
- Objects in the road corridor e.g. street furniture, landscape.
- Colour and material of surfacing.
- Historic character.

This research study included a representative survey of 350 drivers which was used to assess the effect of a number of road design interventions on respondents' ratings of speed. Respondents were interviewed in their own homes by a trained interviewer and were presented with a number of sketches of existing roads from around England. There was one sketch of each road scene in which the road appeared as it was in reality (i.e. the untreated scene). There were also a number of sketches of each road scene depicting different possible design interventions (i.e. treated scenes). For each sketch, respondents had to rate how fast they would drive on the road depicted (estimated own travelling speed), and also had to rate how annoyed and how tense/relaxed they would feel driving in that situation. This research is discussed where appropriate in the following sections of this report.

4.2 An assessment of individual road design measures: The findings of previous research

Generally, research has shown that roads with 'filled' roadside spaces (e.g. roadsides containing buildings, trees and hedges for example) are associated with slower driving speeds than are roads with more open areas. A good general example of this can be found in a study by Cairney (1986). He found that drivers gave higher estimates of posted speed limit, perceived safe travelling speed, and the average speed that traffic would be travelling at for roads in recreational areas (with more open roadside environments) compared with roads in commercial areas (with more filled roadside environments).

One explanation for this effect is that, in general, the more ‘filled’ a roadside space is, the more urban an area one is likely to be driving in, and urban areas are generally associated with slower speed limits than more open/rural areas. Filled roadside space also creates a more detailed, or ‘busy’, environment in which more visual information is present than in open roadside spaces. Theoretically, increased information processing will be required by the driver in response to the increased amounts of visual stimuli in his/her visual periphery when driving on roads in filled roadside spaces compared with when driving on roads in more spacious environments. This might result in drivers experiencing increased levels of cognitive load, which has been shown to decrease driving speeds (see Section 3.1).

More specifically, roadside space could be ‘filled’ using interventions that might affect speeds via the psychological mechanisms outlined in Section 3 of this report. Examples of such relevant interventions, which have been assessed by researchers in the past, are given in the following section of this report.

4.2.1 Trees and overgrowth

A number of research studies have found that tree-lined roads are associated with slower driving speeds (e.g. De Waard *et al.*, 1995; Shinar *et al*., 1974). Estimates vary but the results of some studies suggest that 12-14% reductions in mean speed could be obtained by lining roads with trees (see Slangen, 1983). However, in the TRL research into road appearance and perceived safe travel speed for the Highways Agency (Section 4.1.2), it was found that street trees in the urban environment had little effect on speed ratings, leading on average to less than a 1 mile/h reduction in estimated own travelling speed.

Theoretically, the presence of trees on the roadside might lead to speed reductions because of increased driver cognitive load, or because of a compensation effect which might occur because of vertical contrast in the visual periphery which may create the impression of travelling faster than is actually the case (i.e. because of an increased amount of flow in the visual periphery). Consistent with findings reported by Fildes *et al*. (1987), this effect might occur in various types of ‘walled’ environments, which could be created by using interventions such as trees or buildings (see Section 4.2.2).

If the trees are used to reduce forward visibility, then perceived danger or uncertainty about the presence of potential hazards ahead may be increased, which could be expected to reduce speeds. Reductions in forward visibility could also be accomplished by other interventions such as some of those described below. However, as discussed in Section 3.9 of this report, the potential impact on safety of reducing drivers’ forward visibility must be considered before any intervention is implemented. An additional safety consideration is that a collision with a tree is a potential source of injury to the vehicle occupants.

Overgrowth by the side of the road has also been found to be associated with slower mean driving speeds (Van de Kerkhof, 1987). The amount of overgrowth may influence driving speed in a similar way to trees, by increasing the amount of flow in the visual periphery or by increasing cognitive load due to increased amounts of information in the visual field which would require increased attentional and processing resources from the driver.

4.2.2 Buildings

Research shows that buildings down the side of the road have an effect on travelling speeds. The frequency of houses in residential areas, for example, has been found to be negatively associated with vehicle speed (e.g. Van de Kerkhof, 1987; Van de Kerkof and Berénos, 1989). In addition, the distance from the buildings to the side of the road has an effect on speed - with decreasing distance from the roadside to the buildings resulting in a decrease in speed (e.g. Smith and Appleyard, 1981). The results of the TRL research into road appearance and perceived safe travel speed for the Highways Agency (see Section 4.1.2) are in support of these findings, with additional buildings at the roadside being found to reduce average estimated own travel speed by between 1 and 3 mile/h. In addition, the TRL research investigated the effect of building height and architectural detail. It was found that building height did not influence assessed speeds, although this was only investigated in one setting and to be able to draw reliable conclusions, building height needs to be investigated in a number of different settings. Architectural detail was found to be strongly correlated with assessed speeds generally (Pearson correlation = -0.61). The addition of detail to buildings at individual locations only resulted in average reductions of around 1 mile/h in assessed speed, but architectural detail was also correlated with building extent, which has a strong effect on speed.

As with the presence of trees or overgrowth at the roadside, the frequency, or extent, of buildings could be expected to reduce speeds because it is likely to be positively associated with the amount of cognitive load experienced by drivers, or to influence the amount of flow experienced by drivers in the visual periphery. Furthermore, it is likely that drivers will experience increased levels of peripheral flow because of decreasing distance from the buildings to the side of the road. It is also a possibility that drivers could make a conscious decision to reduce speed based on utility, perhaps because with an increasing frequency of buildings, perceived risk is enhanced (e.g. there is a greater likelihood of pedestrians (Section 4.2.4) and other hazards being present). The presence of roadside buildings may also indicate to the driver the speed limit for the area. Built-up environments are generally subject to lower posted speed limits than more open environments and this general association is likely to influence speed choice. With respect to architectural detail on the buildings, one could hypothesise that with increasing architectural detail, increased levels of information processing are required by the driver to perceive the information in the visual field. To compensate for this increased level of processing, drivers might reduce their travelling speed. Finally, although building height was not found to be particularly effective in the TRL research into road appearance and perceived safe travel speed for the Highways Agency (see Section 4.1.2), it has been suggested that the combined effects of building height and road width might be important. Taller buildings combined with narrower roads might create a sense of enclosure and result in slower speeds, while shorter buildings in combination with wider roads might create a sense of openness and result in faster travelling speeds. This effect could also be created with more natural interventions such as trees. However, the impact on vehicle speeds requires empirical assessment.

4.2.3 Statues, monuments, and other interesting structures

It has been suggested that the presence of interesting landmarks or architecture at the roadside might cause drivers to reduce travelling speed in order to give them time to perceive them. This idea was tested in the TRL research into road appearance and perceived safe travel speed for the Highways Agency (Section 4.1.2). The results indicated that such interventions had little or no effect on estimated travelling speeds. The addition of a statue at the roadside for example was not found to have any effect on estimated speeds. However, this may be a consequence of the method adopted, since with sketches, there is time to study the structure without the need to concentrate on the driving task. On the other hand, when a structure was located in the centre of the road, average estimated speeds were reduced by 5 mile/h). This is unsurprising since drivers would have to slow down to physically negotiate the structure, and forward visibility could be reduced, perhaps leading to increased perceived risk.

4.2.4 The presence of pedestrians

It is known that the presence of pedestrians influences drivers to reduce their travelling speeds e.g. The Scottish Executive study (SEDD, 1999). Psychologically, the presence of pedestrians may influence drivers to reduce their travelling speeds by increasing perceived danger or risk (e.g. a pedestrian may step out into the carriageway). It could also be argued that the complexity of the driving task increases when driving in areas with many pedestrians and thus, drivers may be influenced to reduce their travelling speeds because of increases in cognitive load. Another concept that may be a potentially useful explanation here is the concept of shared space. It has been suggested by many landscape architects and road planners that if, through road design, drivers could be made to perceive the road on which they are driving as being shared by other road users (e.g. pedestrians, cyclists, and so on), they might respond by decreasing their travelling speed. This might be expected for drivers with a strong moral conscience, but interventions that work through this mechanism alone could be expected to have little influence on speed.

Clearly it is not possible to use pedestrians as permanent roadside features to reduce vehicle speeds, although it is possible to build roadside environments that have the potential to facilitate pedestrian activity (e.g. the use of shops or cafes, or the use of footpaths in rural areas). Given that pedestrians are not permanent roadside interventions, their influence on vehicle speeds is limited by a number of factors that influence their presence. Such factors might be time of day, or weather conditions.

4.2.5 Carriageway width

In the TRL research into road appearance and perceived safe travel speed for the Highways Agency (Section 4.1.2), carriageway narrowing was found to reduce mean estimated driving speeds by as much as 7 mile/h in one location. Other research projects in which reported speed has been measured (e.g. Fildes *et al*., 1987), and in which actual vehicle speeds have been measured (e.g. Kolsrud, 1985; Vey and Ferreri, 1968; Yagar and Van Aerde, 1983) support this finding. Lane width can be expected to influence driving speeds through a number of psychological mechanisms. The extra effort required to negotiate a vehicle down a narrower carriageway compared with a wider one could result in increased cognitive load for example. In addition, wider roads provide more time and space to deal with hazards. Depending on other treatments to the roadside space, narrowing of a carriageway could also result in increased flow in the visual periphery.

Number of traffic lanes

A number of research studies report that roads with fewer traffic lanes are associated with lower driving speeds. Cairney (1986) for example found that participants' estimates of safe travelling speed, and their estimates of the speed limit, were lower for 2-lane roads compared with 4-lane roads. This finding is unsurprising given that roads with fewer traffic lanes are associated with lower speed limits. In addition, the width of a road (and drivers' perceptions of how wide a road is) is likely to be lower with fewer traffic lanes, and thus speeds should also be expected to be lower.

Build-outs

Build-outs, for example at village gateways, narrow the carriageway by building out the kerbline over a short distance. They can range from pinch-points, where the narrowing is only slight, but drivers may slow down slightly because of the perceived reduction in width, to full chicanes, where the effect is physical.

Width of pavement (footway)

The TRL research for the Highways Agency (Section 4.1.2) suggested that wider pavements (footways) are associated with higher speeds. However, there may be some circumstances when wider pavements might have the opposite effect. Generally speaking, road environments with wider pavements are more spacious than those with narrower pavements (e.g. the buildings at the side of the road, for example, might be perceived by the driver to be further away). Widening pavements, therefore, might increase driving speeds by decreasing the amount of flow in the visual periphery. However, widening pavements can also be done in such a way that the carriageway becomes narrower, which can be expected to reduce speeds (see above). Whether pavement width increases or decreases driving speeds is likely to depend upon what other treatments to the road environment are carried out. For example, if pavements are widened (and in doing so the carriageway is narrowed) and interventions are used to make drivers perceive similar levels of spaciousness as in the original environment (i.e. before the pavements were widened), then driving speeds could be expected to slow. This argument is consistent with research findings which demonstrate that in the relationship between carriageway width and speed, it is the perceived width that is important (e.g. Smith and Appleyard, 1981; Von Mörner, 1984). Further research is required to investigate this issue.

4.2.6 Central median

Dual carriageways

Cairney (1986) found that drivers' estimates of safe travelling speed, posted speed and average travelling speed were affected by the presence of a median on a road, and by the width of the median. Drivers' speed assessments were found to be lower for roads without medians than for roads with them, but roads with wide medians were associated with lower speed assessments than roads with narrow medians. A psychological explanation for these findings could be that drivers perceive less danger when driving on roads with a median than they do on roads without one, because the opposing traffic is separated. Roads with wider medians may be associated with lower speeds than roads with narrower medians because they might reduce carriageway width.

Central island

Forbes and Gill (2000) investigated the effect of wide short landscaped median islands which diverted traffic with no loss of lane width. They observed a reduction in mean speed of 4.7 km/h. Similarly, in the TRL research for the Highways Agency (Section 4.1.2), a structure in the centre of the carriageway reduced estimated speeds by 5 mile/h on average. In both cases, there was a physical effect and forward visibility was reduced, possibly increasing perceived risk.

4.2.7 Parked cars

Research indicates that the presence of parked cars down the side of a road will have an effect on speed. Van de Kerkof and Berénos (1989), for example, found that parked cars on both sides of the road, or on the driver's side only, resulted in speed reductions compared with the same road with no parked cars present. Parked cars were also found to be important in the TRL research for the Highways Agency (Section 4.1.2). The addition of street parking with the vehicles parallel to the road was found to reduce estimated travelling speeds by 5 mile/h on average. Street parking with the vehicles at right angles to the road was associated with a 7 mile/h reduction in average estimated travelling speed.

Street parking may affect speed due to a narrowing of the carriageway, which may affect the amount of flow in the visual periphery as well as reducing the amount of useable road space in which a vehicle can travel. Parking may also enhance the perceived danger of the driving task (e.g. a pedestrian may step out from behind the stationary vehicles), and thus the presence of parked cars may slow speeds because drivers perceive a potentially more hazardous driving environment. This could, in turn, lead to an increase in cognitive load or 'stress', or it may indicate to drivers the appropriate driving speed for the road.

4.2.8 Rough road surface

Rough road surfaces could include roughness caused by road surface materials (e.g. a brick or cobbled road) or simply 'pot-holes' in the road surface. The rougher the road surface, the greater the noise and vibration, and thus driver discomfort, caused. Drivers can be expected to make a rational decision to reduce speed based on utility when exposed to such discomfort when driving. However, care needs to be taken to ensure that road surfaces are not so rough that they result in damage to vehicles or decreased levels of safety due to too much of an adverse effect on the driver. In addition, rough road surfaces can cause problems for cyclists, and increased noise.

Research evidence shows that rough road surfaces are effective in reducing speeds (e.g. De Waard *et al*., 1995; Slangen, 1983; Te Velde, 1985; Van de Kerkhof, 1987, Kennedy and Wheeler, 2001A, Wheeler *et al.*, 1997). Slangen (1983) suggested that as much as a 14-23% reduction in mean speed can be obtained due to rough road surfaces, whilst Van de Kerkhof (1987) stated that roughness of a road surface is the most influential factor in determining mean speed. Wheeler *et al.* (1997) found a large reduction in mean speed when imprinted surfacing was combined with prominent visual measures at a gateway. Kennedy and Wheeler (2001A) reported a reduction of about 4 mile/h in mean speed with imprinted surfacing; there was a change in character of the noise generated by vehicles on the imprinted surfacing compared with tarmac.

4.2.9 Road signs

Speed camera housings and/or signs

Speed camera housings and/or signs have been shown to reduce drivers travelling speeds, even in the absence of speed cameras themselves (Corbett and Simon, 1999). These measures are likely to influence drivers' speed by increasing perceived likelihood of enforcement. However, the deterrent effect of housings and/or signs is less than that of cameras.

Vehicle-activated signs

Vehicle-activated signs light up only for drivers exceeding a pre-set speed. They may display a speed limit or advance warning of a hazard. Reductions of up to 7 mile/h in mean speed have been observed following the introduction of such signs on the approaches to bends, junctions or a speed-limit change (Barker, 1997, Farmer *et al*., 1998, Webster, 1995, Winnett *et al.*, 1999, Winnett and Wheeler, 2002), depending on the traffic flows and 'before' speeds. Winnett and Wheeler (2002) reported that the signs trialled maintained their effectiveness even after 3 years. Psychologically, these interventions may influence drivers to reduce their travelling speed because they provide a better knowledge of the posted limit.

Warning signs

Warning signs generally serve to warn the driver to slow down in advance of a hazard such as a bend or junction. There is evidence to suggest that they are more effective when the message they give is reinforced by other measures and when they are visually intrusive.

Countdown signs

Barker (1997) found that countdown signs did not affect mean on road speeds. However, Pyne *et al*. (1995A and B) using a driving simulator, found they were more effective than a speed limit sign alone. Wheeler and Taylor (1999) recorded large reductions in mean speed when countdown signs were used in conjunction with other measures having a high visual impact at a village gateway (Section 4.2.13). Similar results were found by Taylor *et al.* (2002) using the TRL driving simulator.

4.2.10 Road markings

Roundels

Roundels on the road surface can be used to provide the driver with a better knowledge of the speed limit. They are usually adopted in conjunction with other measures, for example at a gateway (see Section 4.2.13). In the absence of other measures, 30 mile/h roundels were not found to have any effect, but 40 mile/h roundels reduced average speeds by 3 mile/h (Barker, 1997, Barker and Helliar-Symons, 1996).

Centre white lines and channelization

Centre lines are used for hazard marking (e.g. use of double white lines at bends). They may be used with hatching for channelization, in order to reduce lane width and increase the separation between the two directions of traffic, which may be particularly desirable on bends. The increased segregation does not necessarily reduce speeds however (e.g. Kennedy and Wheeler, 2001A).

The absence of centre white lining can increase uncertainty for drivers and removal of the white lining on moderately narrow rural roads has therefore been suggested as a means of reducing vehicle speed. Results for the village of Stiffkey in Norfolk, where speeds were already low, indicated a slight reduction in mean speed when the centre white line was removed (Kennedy and Wheeler, 2001A). Unpublished research indicated a reduction of 7 mile/h in mean speed in Starston, another Norfolk village, when the centre white line was removed. Yagar and Van Aerde (1983) found that the addition of a centre line had little effect on driving speeds.

Edge treatment

White edge lining is recommended to delineate the edge of the road and to provide a hardstrip on major roads. Its use may lead to higher speeds at night because it is easier for drivers to see the line of the road ahead. Hatching can also be used at the edges of the road to reduce lane width. Longitudinal red strips with hatching on the edges and centre of a rural single-carriageway road were found to be effective in reducing mean speeds on a driving simulator by up to 5.6 mile/h (Taylor *et al*., 2002).

An idea tested in Drenthe in Holland (De Waard *et al.*, 1995) combined a novel edge treatment with other measures. It was intended to reduce speed variance on rural roads with a lot of slow-moving farm traffic. The road was effectively narrowed by making it uncomfortable for car occupants when driving at over 50 mile/h unless they kept to the centre of the lane, whilst larger vehicles were not affected. The white edge lines were replaced by 4m long rectangles of rough surface (chippings) interspersed by 4m gaps where the road surface remained unchanged. Rough surfacing was also used between the white dashes in the widened centre line. The mean speed of subjects in an instrumented car was reduced by up to 3 km/h.

Transverse markings

Transverse yellow bar markings with reducing spacing in a reverse exponential pattern have been used on the approaches to dual-carriageway roundabouts and were shown to reduce accidents by about 50% relative to control roads (Helliar-Symons, 1981). On high-speed roads, drivers become adapted to the speed at which they are travelling and find it difficult to slow down to a safe speed to negotiate a hazard such as a roundabout. The aim was to increase peripheral flow to make drivers think they are travelling faster than they really are, and Denton (1973) recorded a reduction of 13 km/h in mean observed speed. However, Jarvis (1989) concluded that although the markings do reduce approach speeds, they appear to act as a hazard warning device rather than through manipulation of drivers' visual fields. Barker (1997) found little change in mean observed speed at 100m from the junction at sites with coloured bars on the minor arms of rural crossroads, whilst Meyer (2001) obtained reductions of up to 4 km/h on a high speed road in the US with white painted bars of different widths and patterns. Haynes *et al*. (1993) found a reduction in accidents of 15% when yellow bar markings were tested on motorway off-slips at grade-separated roundabouts, but the result was not statistically significant. It was anticipated that the effect would be less than that found by Helliar-Symons (1981) for at-grade roundabouts since drivers would already have made a conscious decision to leave the motorway.

Various studies have tested transverse lines using driving simulators. In Australia, Godley *et al.* (1999) found that transverse lines on the approach to a hazard reduced mean speed by 11 km/h. In the UK, Pyne *et al.* (1995) reported that yellow or white transverse lines were effective in reducing mean speed in a village scene and on a bend, whilst Taylor et el (2002) found that transverse bands intended to give the appearance of cobbles reduced mean speed at a village gateway by 3 mile/h.

The Wundt illusion (see Figure 1a) is a series of oblique transverse lines across the road making a chevron pattern, intending to alert the driver that he is approaching a hazard. It reduced mean observed speeds by 5.3 km/h on a bend in the USA (Shinar *et al*., 1980), but Godley (2000) reported little effect using a driving simulator and Pyne *et al.* (1995) concluded that it would be better to install transverse lines than the Wundt illusion.

Oblique transverse lines (with the middle part of the chevron omitted, as shown in Figure 1b) were tested by Godley (2000) and were reported to reduce mean speeds by 6 km/h. The lines may increase peripheral streaming and give the impression of narrowing, though it is not clear why they should be more successful than Godley's tests of the Wundt illusion.

Rumble devices

Rumble devices are small raised areas across the carriageway with a vibratory, audible and visual effect. Rumble strips can be laid out in a single group or in a series of groups, usually with decreasing spacing between the groups. They act as alerting devices rather than causing discomfort and therefore speed reductions tend to be small relative to physical measures such as road humps, up to about 6 mile/h (Webster and Layfield, 1993, Barker, 1997). They are noisy and therefore unsuitable near to housing. Their effect tends to lessen over time, since there is less discomfort when they are traversed at higher speeds. They are often used in conjunction with other traffic calming measures.

Coloured surfacing

Coloured road surfacing is commonly used in two ways. The first is to emphasize a traffic calming feature. A series of buff-coloured bands incorporating a SLOW marking at an isolated development on a rural road was found to be effective in reducing mean speeds by 6 mile/h on a driving simulator (Taylor *et al.,* 2002). The second use of coloured surfacing is to delineate the road space (e.g. cycle or bus lanes – as follows).

Cycle lanes

The effect on assessed speeds of adding a cycle lane to a road scene was investigated in the TRL research for the Highways Agency (Section 4.1.2). In this research, cycle lanes were investigated in two different environments using sketches. In the first instance, the addition of a cycle lane on a straight urban road was not found to result in any reduction in estimated travelling speed. However, when a cyclist was riding on the cycle lane, there was a 1 mile/h reduction in mean estimated speed. The second scenario was a rural road. When the addition of a cycle lane that was segregated from the road was investigated, there was a 1 mile/h reduction in mean estimated speed. When a cyclist was present on the segregated cycle lane, mean estimated speed reduced by an additional 4 mile/h. The reason for the differences between the two scenarios could be because on an urban road, speed is already considered suitable for passing a cyclist.

Cycle lanes could be expected to result in a reduction in speed because they effectively narrow carriageway width and the presence of cyclists may increase perceived risk. Cycle lanes may be effective if they encourage more cycling.

Bus lanes

The TRL research for the Highways Agency also investigated the effect on assessed speeds of adding a bus lane to a road scene. A similar effect to that for cycle lanes was found. The addition of the bus lane itself did not affect estimated travelling speeds, but when a bus was present in the lane there was a reduction in estimated speeds of 4 mile/h on average.

As with a cycle lane on the carriageway, the addition of a bus lane might be expected to reduce speed because of a narrowing of useable road width. When a bus is present in the lane, speeds might reduce because of a perceived danger associated with the presence of a large vehicle, and the possibility of people alighting from the bus.

Taylor *et al*. (2002) using a driving simulator showed a reduction in mean speed of between 1 and 2 mile/h with a bus lane.

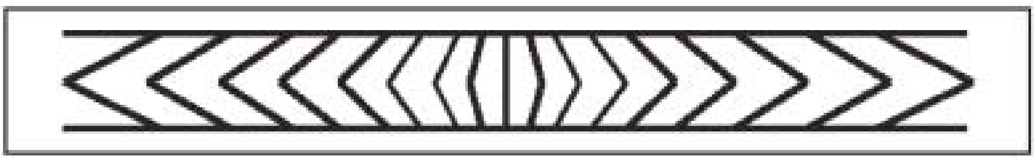

Figure 1a Plan view of Wundt illusion
(Reproduced by kind permission of S Godley)

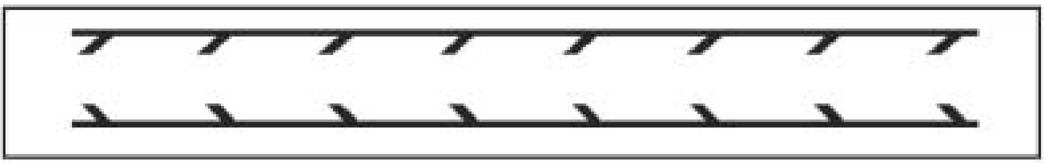

Figure 1b Plan view of oblique transverse lines
(Reproduced by kind permission of S Godley)

4.2.11 Frequency of road junctions

Increasing frequency of side road junctions has been found to be associated with lower travelling speeds (e.g. SEDD, 1999; Van de Kerkhof, 1987). The presence of side roads might be expected to reduce vehicle speeds because perceived danger may increase (e.g. the possibility of a vehicle pulling out from the side road into a small gap in mainstream traffic). Additional information processing might also be required of the driver due to the presence of side roads, thus perhaps increasing cognitive load or driving stress.

4.2.12 Village gateways

One way of informing drivers of a transition from one type of environment to another (where a different type of driving behaviour might be required) is through the use of a gateway. These are typically used in rural areas to indicate to a driver the entrance to (and departure from) a village. The design of a gateway involves using a variety of traffic calming measures to slow vehicle speeds (e.g. signs, emphasis of speed limit sign by use of yellow backing board, countdown signs, roundels, coloured road surfaces, dragon teeth to create a visual impression of narrowing, and physical road narrowings).

A number of TRL research studies have investigated the effect of different village gateway schemes on vehicle speeds (e.g. Wheeler, Taylor and Payne, 1993; Wheeler, Taylor and Barker, 1994, Wheeler and Taylor, 1999). The findings of this research have shown that gateways with simple signing and marking measures may reduce mean speeds by about 1-2 mile/h, whilst more comprehensive gateway measures with high visual impact (e.g. coloured road surfacing and dragon teeth) may reduce mean speeds by 5-7 mile/h. When physical measures (e.g. narrowing) have been used at gateways, even greater reductions in mean speeds have been found, up to about 10 mile/h. Measures need to be continued beyond the gateway in order to maintain speed reductions through the village itself. It should be pointed out that inhabitants of rural villages often object to the measures with the greatest visual impact as being too intrusive (e.g. red surfacing is often a source of complaint precisely because it is visually intrusive).

One could theorise that gateways influence drivers' speed choice via a number of different mechanisms depending on the traffic calming measures used. Drivers may be physically forced to reduce their speed to negotiate interventions such as chicanes and other interventions which cause vertical deflection. Measures such as roundels and countdown signs could influence drivers, who are motivated to keep within the speed limit, to reduce their speeds by making the posted speed more salient. A gateway might also comprise interventions that reduce speeds via other psychological means as outlined in Section 3 of this report. Finally, given that a gateway can be seen as a way of transforming a village from merely being an incident on the roadside to a place with a clear sense of arrival and departure, it might influence drivers to perceive the road on which they are driving as having a clear sense of ownership (i.e. ownership by the village). Some drivers might respond to such a perception by decreasing their travelling speed, particularly those drivers with a strong moral conscience.

4.2.13 Interventions using the concept of 'shared road space'

The concept of shared road space, whereby roads are designed to cater for pedestrians and cyclists as well as motorists, originated in the Netherlands (e.g. the 'woonerf') where large reductions in the number of accidents, particularly involving pedestrians and moped riders, have been reported following the implementation of such road environments (Alink, 1990).

Home Zones

Recently, this concept has been introduced to the UK as Home Zones. Legally, no one type of road user has priority in a Home Zone, but, through design, the road may be configured to make it more favourable to pedestrians and cyclists, and less favourable to motorists. Traffic calming features, parking areas, trees and bushes, benches, play areas, and different types of road and pavement surfaces can be introduced to open up the street for social use and make clear to drivers the appropriate speed for the area. Home Zones can be built by re-designing existing streets – i.e. they can be 'retrofitted' – or they can be built within new housing development – i.e. they can be 'new-build'.

The DfT has commissioned TRL (Layfield, 2000) to monitor pilot Home Zone schemes in England and Wales to measure the effect on drivers' speed, and also on traffic volume, street activity, the environment, and the attitudes of residents. To date, only 2 pilot Home Zone schemes have been completed. Interim results suggest that substantial speed reductions can be achieved.

Quiet Lanes

Quiet Lanes also use the concept of shared road space. They form a network of quiet, narrow, single track country lanes in a rural area and are intended to encourage shared use by vehicles, cyclists, pedestrians and equestrians. Traffic calming measures are kept to a minimum (and are non-existent over much of the network). The idea is to change the hearts and minds of local residents, persuading them to slow down and/or drive more carefully on the lanes, avoiding them as much as possible. The pilot areas are subject to the national speed limit for rural single-carriageway roads (60 mile/h).

TRL is monitoring traffic flows and speeds, numbers of non-motorised road users and public attitudes in 2 pilot areas (Kennedy and Wheeler, 2001 b and c). Preliminary findings are that there has been a small decrease in flow, but little change in mean speeds, which were already low because of the narrowness of the lanes and the limited forward visibility.

5 Summary

The main findings of the review were as follows:

- Psychological measures to date have generally produced smaller speed reductions than those from physical measures, although the measures may be more acceptable to drivers. Their effects may lessen over time.
- The more successful non-physical measures tend to be visually intrusive and may therefore be considered out of place in rural areas.
- In general, more complex environments tend to be associated with slower driving speeds, the likely mechanisms being increases in cognitive load and perceived risk.
- Many aspects of the driving environment interact to influence speed. In particular, roadside activity tends to reduce speeds. Thus the presence of pedestrians may influence drivers to reduce their speeds and bus or cycle lanes are more likely to reduce speeds when they are in use. On-street parking not only narrows the carriageway, it may increase perceived risk because of the possibility of people getting out of their cars, or of pedestrians concealed by the cars, or the cars themselves moving off.
- Combinations of features tend to be more effective than individual measures. This will increase their alerting effect and will also make it more likely that different psychological effects are induced. For example, the positioning of trees should be such as to increase peripheral streaming and also limit forward visibility.
- Natural traffic calming (e.g. hump back bridges and winding roads with poor forward visibility) can be very effective and scores highly in terms of acceptability. Schemes based on natural traffic calming will need to be designed holistically and contextually to achieve a similar effect. Existing natural features should be enhanced by any traffic calming measures.
- As a general rule, reductions in speed can be presumed to result in increased safety. However, care is needed to ensure that measures that reduce speeds by increasing perceived risk do not increase actual risk.

6 Acknowledgements

The work described in this report forms part of the programme of research undertaken by TRL for Charging and Local Transport Division, DfT.

The authors would like to thank Marie Taylor, Roger Layfield, Linda Chinn and Chris Baughan of TRL for their comments and editorial advice.

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Appendix A: Annotated bibliography of road design measures

Reference	**Alink G M M (1990)**. Road safety policy in the Netherlands and the effects of the infrastructure on the success of the policy. *Proceedings of the 1990 Actes du Congres, Living and Moving in Cities*, Paris.
Interventions tested	● Woonerfs.
Method of Assessment	On road measurements.
Description	The 'woonerf' is a traffic calmed environment used in the Netherlands in shopping and residential areas using different types of paving, winding vehicle paths and various types of physical and perceptual treatments. It is designed to make the appropriate speed (20km/h) clear to drivers. The study reported that this has resulted in striking reductions in accidents, particularly those involving mopeds riders and pedestrians.

Reference	**Barker J (1997)**. *Trials of rural safety measures*. TRL Report TRL202. Crowthorne: TRL Limited
Interventions tested	● Coloured bar markings. ● Rumble strips. ● Vehicle activated signs. ● Channelisation at bends. ● Roundels and countdown signs.
Method of Assessment	On road speed measurements. Channelisation using driving simulator.
Description	Coloured bar markings on minor road approaches to priority junctions reduced mean speeds by 1.2 mile/h. Rumble strips reduced mean speeds by 3 mile/h on a bend and by up to 6 mile/h in villages. Vehicle-activated signs reduced mean speeds by up to 6 mile/h. Countdown signs and 30 mile/h roundels had no effect on speeds. 40 mile/h roundels reduced mean speeds by 3 mile/h.

Reference	**Cairney P (1986)**. *The influence of cues from the road and the roadside environment on estimates of operating speeds and speed limits*. Research Report ARR143. Australian Road Research Board.
Interventions tested	● Recreational/commercial land-use. ● Road type (2 lane undivided, 4 lane undivided, divided with narrow median and divided with wide median).
Method of Assessment	Colour photographic slides.
Description	Recreational (more open) land use led to higher estimates of posted speed, perceived safe speed and average speed of other traffic compared with commercial land use. The average speed of other traffic with recreational land use was estimated to be above the perceived safe speed. Two lane roads had lower estimated safe speeds than 4 lane roads, whilst roads with medians had higher estimated safe speed than undivided roads.

Reference	**Denton G G (1973)**. *The influence of visual pattern on perceived speed at Newbridge M8 Midlothian*. Laboratory Report LR531. Crowthorne: TRL Limited
Interventions tested	● Yellow transverse lines on the approaches to a roundabout on the M8.
Method of Assessment	On road speed measurements
Description	A 13 km/h reduction in mean speed, from 57.0 to 44.1km/h, was measured at 45m from the roundabout.

Reference	**De Waard D, Jessurun M, Steyvers F J J M, Raggatt P T F and Brookhuis K A (1995)**. Effect of road layout and road environment on drivers' performance, drivers' physiology and road appreciation. *Ergonomics, 38, 7*, pp 1395-1407.
Interventions tested	● Road environment (a woodland and a moorland road in Dutch province of Drenthe). ● Drenthe treatment (white edge-lining replaced with 4m long rectangles of rough-surfacing with 4m gaps; gaps in centre white line replaced by rectangles of rough surfacing to reduce width of smooth driving surface to 2.25m). The rectangle and gap sizes were selected such that car occupants were uncomfortable driving over the rough surfacing at speeds above 80 km/h. Larger vehicles were not affected.
Method of Assessment	Participants driving an instrumented car (before and after Drenthe treatment). Effect on heart rate etc also measured.
Description	Participants drove more slowly on the woodland road, which had greater curvature, than on the moorland road. They avoided driving over the rough surface since this induced discomfort in the form of increased noise and vibration. With the Drenthe edging, therefore, speeds were lower by 3 km/h for the woodland road and by 1.5 km/h for the moorland road and participants were more likely to keep to a fixed lateral position. The narrowing of the available smooth road surface increased cognitive load.
Comments	The effect of woodland compared to moorland was confounded with curvature; that of the Drenthe treatment was compounded with the change in road width and removal of the white edge-lining.

Reference	**Fildes B N, Fletcher M R and Corrigan J (1987)**. *Speed perception 1: Drivers' judgements of safety and speed on urban and rural straight roads*. Report CR54 Federal Office for Road Safety, DoT and Communications, Canberra, Australia.
Interventions tested	● Type of road and road width (divided-wide, divided-narrow, 4-lane, 2-lane-wide and 2-lane-narrow) in rural, semi-rural and urban environments. ● Walled and spacious roadside environment.
Method of Assessment	Participants' estimates of travel speed from 5 second film clips.
Description	In both rural and urban areas, perceived safe speed was lower on less major and narrower roads and actual speeds were less likely to exceed the speed limit. Drivers were more likely to underestimate their travel speed on more major roads. In urban areas, 'walled' environments might be housing whereas in rural areas they might be trees. Overall the study concluded that walled roadsides had lower actual speeds compared to spacious roadsides for all road types (except for 2-lane narrow roads). Road type accounted for nearly five times as much variance as roadside development.
Comments	Speed reductions appeared to result from increased perceived risk in a given road environment.

Reference	**Forbes G and Gill T (2000)**. *Arterial speed calming, a Mohawk Road case study*. TRB Circular E-C019: Urban Street Symposium. Transport Research Board of the National Academy of Sciences.
Interventions tested	● Wide short landscaped median islands.
Method of Assessment	On road speed measurements.
Description	The case study examined ways of reducing speed on Mohawk Road in Ancaster, Canada, a 50 km/h arterial road with 85^{th} percentile speeds of up to 70 km/h. Public consultations were carried out to identify speed-reducing measures. Medians were proposed as a possible solution to the speeding problem. The medians were between 3 and 4m in width and divided the 8.6m road into two 4.3m pieces. Trees were placed in the median and on either side of the road adjacent to the median. Mean speeds were reduced by 4.7 km/h. The proportion of drivers exceeding the speed limit was reduced from 67% to 47%.

Reference	**Gattis J L (2000)**. *Urban street cross section and speed Issues*. TRB Circular EC019: Urban Street Symposium. Transport Research Board of the National Academy of Sciences.
Interventions tested	● Carriageway width. ● Parked vehicles. ● Setback of roadside objects from kerb.
Method of Assessment	On road speed measurements.
Description	Speed and width relationships on a number of major and minor streets in Fayetteville, Arkansas were examined. It was found that traffic function (whether local or through traffic) was a more important indicator of speed than carriageway width for the examples studied. An attempt to quantify the speed selection cues a driver receives from the environment of a particular street was inconclusive. The effect of roadside objects located close to the carriageway was considered. It was noted that utility poles and trees often show signs of damage. Trees or hedging planted too close to the roadside may obscure road signs and reduce forward visibility, thereby contributing to safety problems.
Comments	Differences in road layout and driver behaviour between the USA and the UK need to be taken into consideration.

Reference | **Godley S, Fildes B, Triggs T and Brown L (1999)**. *Perceptual countermeasures: experimental research*. Australian Transport Safety Bureau, Monash University Accident Research Centre CR182.

Godley S (2000). *A driving simulator investigation of perceptual countermeasures to speeding*. Ph D Thesis. Australia: Monash University.

Interventions tested

- Transverse lines (60cm wide over 400m on approach to a hazard).
- Peripheral transverse lines.
- Drenthe treatment (see De Waard *et al.*).
- Centre line treatments.
- Walled and open environments.
- Enhanced curvature treatments, including roadside posts.

Method of Assessment Driving simulator with a number of scenarios, including treated and untreated locations.

Description The most effective measure was transverse lines, which reduced speed by up to 11 km/h both immediately after entering the treatment zone (alerting effect) and throughout the treatment area (perceptual effect).

Peripheral transverse lines and the herringbone pattern (oblique peripheral transverse lines) gave a speed reduction of 6 km/h. The Drenthe treatment reduced speeds by up to 2 km/h, but it is not clear whether there was any vibration or whether the effect was purely visual.

Hatched median lines also reduced travel speed slightly by 3km/h. Further reductions were obtained with narrow lanes (< 3m).

Curve treatments were intended to over-state the amount of curvature and included the use of roadside posts (both constant height and ascending patterns), which was found to reduce speed.

Reference **Harms L (1986)**. Drivers' additional responses to variations: A dual task real traffic study. In A G Gale, M H Freeman, C M Haslegrave, P Smith and S P Taylor. (Eds.). *Vision in Vehicles*, North-Holland (Netherlands).

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Interventions tested

- Highway / village environment

Method of Assessment Driving simulator and on road using instrumented car.

Description The study investigated the effects of altered environments on driving. It was hypothesised that driving in a more complex environment such as a village demanded more attention than driving in a simple environment such as a highway. A secondary reaction time task was used to record attentional demand.

The study concluded that speeds were reduced in village environments compared to highway environments where there was less filled land use. There were intermediate speeds at village / highway transition areas.

Reference	**Jarvis J R (1989)**. *The effect of yellow bar markings on driver braking behaviour*. Research Report. Australian Road Research Board
Interventions tested	● Yellow bar markings on the approach to isolated rural intersections.
Method of Assessment	On road measurements of speed profile over 450m.
Description	The study examined the braking behaviour of drivers on the approach to isolated rural intersections in order to determine the effectiveness of yellow bar markings as a speed reducing device. It was found that although the markings do reduce approach speeds, they appear to act as a hazard warning device rather than manipulating drivers' visual fields.

Reference	**Kennedy J V and Wheeler A (2001a)**. *Countryside Traffic Measures Group: demonstration schemes*. TRL Report TRL502. Crowthorne: TRL Limited.
Interventions tested	● Village gateways. ● Imprinted surfacing. ● Removal of centre white lining. ● Other minor measures.
Method of Assessment	Included Before and After on road speed measurements with Automatic Traffic Counters.
Description	The aim of the study was to investigate the effectiveness of non-visually intrusive measures. Small speed reductions were generally obtained at the gateways. Removal of the centre white-lining was intended to increase perceived risk; there was only a small reduction in speed, but speeds at this site were already low. There was a reduction of about 4 mile/h in mean speed on the imprinted surfacing, probably as a result of increased noise within the vehicle.

Reference	**Kolsrud B (1985)**. *Speeds in Rural Traffic. The influence of various factors on car speeds on straight level roads.* Meddelande, Sweden:VTI.
Interventions tested	● Road width.
Method of Assessment	On road speed measurements.
Description	The study investigated the effects of road width on driver behaviour. A positive correlation was found between road width and speed on rural roads when the speed limit was kept constant.

Reference	**Meyer E (2001).** *A new look at optical speed bars*. ITE Journal, November 2001.
Interventions tested	● White painted transverse lines ('optical speed bars'). Three consecutive patterns were used: 20 bars of constant width of 105cm, 16m apart, covering 332m (warning). 29 bars varying width, at decreasing spacing (16-9m apart) covering 279m (perceptual effect). 4 sets of 6 bars in work zone (6m apart, 152m between sets) over 747m (reminder).
Method of Assessment	On road speed measurements using Automatic Traffic Recorders.
Description	The study was carried out in 1999 by the University of Kansas on a busy straight rural road with no intersections. It examined the mechanism by which optical speed bars cause speed reductions and evaluated the utility of the technique for slowing traffic in highway work-zones. The painted bars maintained a high visibility for the three month period of the study. It was concluded that optical speed bars reduced mean and 85th percentile speeds, and also reduced variation in speeds.

Reference	**Pyne H C, Carsten O M J and Tight M R (1995a)**. Speed on rural arterial roads. *Proceedings of the conference, Road Safety in Europe Strategic Highway Research Program (SHRP)*, September 1994, Lille: France. **Pyne H C, Dougherty M S, Carsten O M J and Tight M R (1995b)**. *A simulator based evaluation of speed reduction measures for rural arterial roads*. Institute for Transport Studies, University of Leeds. Working Paper 434.
Interventions tested	● *Straight section of road:* Double centre line, central hatching, 6m carriageway & 2m shoulder, trees at roadside, broken edge line, unbroken edge line. ● *Village treatments:* Countdown signs, hazard marker posts, central transverse lines (creates illusion of acceleration), Wundt illusion (illusion of narrowing), chicane, transverse lines at edges, 'SLOW' sign on road, central and edge hatching, speed limit on road, street lights and trees at roadside, nearside parking. ● *Left hand bends:* Transverse lines at the curve mid-point, side hatching, trees at roadside, transverse lines on point of curve entry, Wundt illusion broken edge lines, nearside shoulder, central hatching, shoulder on both sides, hazard markers, transverse lines on both sides and central transverse lines. ● *Right hand bends:* Triangular speed sign on road, 'SLOW' sign on road, 'REDUCE SPEED NOW' plate, transverse lines at centre of curve, chevron signs on bend, warning sign 200m from curve, central hatching, bend warning sign on road and nearside shoulder.
Method of Assessment	Driving simulator.
Description	Repeated controlled trials for each participant allowed the measures tested to be ranked in order of their effectiveness at reducing speed. The study found that although trees at the side of the road would be expected to reduce speeds through perceptual illusions such as optical narrowing and increased optical flow, they were one of the least effective measures.
Comments	A simulator may not fully re-produce real world perceptual illusions.

Reference **Scottish Executive Development Department (1999)**. *Natural traffic calming – guidance and research report.* Prepared for The Scottish Executive by Land Use Consultants & JMP Consultants, Glasgow.

Interventions tested

- Various traffic calming schemes.

Method of Assessment Case studies, surveys and psychometric testing.

Description The study attempted to identify the underlying principles behind natural traffic calming. Ten small or medium towns on through routes in Scotland that appeared to be naturally traffic-calmed were selected as case studies. Psychometric work was also undertaken, designed to highlight the relative importance of different features or situations.

The written scenarios in the psychometric testing that produced the lowest average response speeds were: ‘pedestrians are crossing’ (20 mile/h); ‘there are children around’ (23 mile/h); ‘lorries are unloading (24 mile/h); ‘cars are parked on both sides of the road’ (26 mile/h); ‘the road surface is cobbled’ (26 mile/h); ‘traffic is heavy’ (27 mile/h); ‘there are several street intersections’ (28 mile/h) and ‘high buildings close to the road’ (29 mile/h).

The research suggested that traffic calming should be defined as a process of helping drivers adjust to the environment. To be successful, schemes should be based on a thorough understanding of a given situation. The components of such an approach are: consider the road corridor, not simply the point where a change in speed is required; develop measures that fit the environment in question; match the location of measures to natural transitions (e.g. from rural to urban); and match calming measures to speed.

It was concluded that rarely do examples of natural traffic calming rely on a small number of key features and that drivers are influenced by a large number of different cues.

Comments The study highlights the importance of activity in the road corridor in determining speed choice.

Reference **Shinar D, McDowell E D, Rockwell T H (1974)**. *Improving driver performance on curves in rural highways through perceptual changes*. Report Ohio-DOT-04-74, Columbus, OH: The Ohio State University, Dept. of Industrial Engineering.

Interventions tested

- Road curves.

Method of Assessment Driving simulator.

Description The study investigated driver response to road curvature. Participants were asked to make judgements on curve characteristics prior to using a driving simulator. It was concluded that subjective judgements of curve characteristics such as curve sharpness bore little relationship to the physical characteristics of curves.

Reference **Shinar D, Rockwell T H and Malecki J (1980)**. The effects of changes in driver perception on rural curve negotiation. *Ergonomics, 23(3),* 263-275.

Interventions tested

- Wundt illusion used on the approach to a curve and on the curve itself.

Method of Assessment Before and After on road speed measurements

Description A reduction of 5.3 km/h in mean observed speed (9.5 km/h in 85th percentile speed was found, mostly from the faster drivers.

Reference **Slangen B (1983)**. *Changes in road environment may lead to speed reduction.* Wegen, October, pp 312-319.

Interventions tested

- Built environment.
- Natural environment.

Method of Assessment On road speed measurements with radar gun.

Description The study investigated the differences in driver speed on roads lined with trees and houses and compared it to speed levels in areas without natural or built characteristics. It was concluded that sites with screening (trees and houses along the roadside) had speeds that were 12-14% lower than sites without.

Vehicle speeds reduced significantly (13-23%) upon transition from a smooth road surface to a rough road surface made from concrete clinkers.

Reference **Smith D T and Appleyard D (1981)**. *Improving the residential street environment: Final Report*. Report FWHA/RD-81/031. Washington DC: Federal Highway Administration.

Interventions tested

- Carriageway width and pavement.

Method of Assessment On road speed measurements.

Description The study investigated the relationship between speed and carriageway width. It was found that speeds at urban sites were lower where housing was closer to the road. The study concluded that the results were due to perceptual interpretation of geometric features.

Reference **Szplett D and Fuess M (1999)**. *Designing speed controlled subdivisions without road humps*. Washington DC: Institute of Transportation Engineers.

Interventions tested

- Carriageway width.
- Curvature.

Method of Assessment Traffic surveys.

Description The study investigated a three year local planning effort to integrate speed control into design. The designs implemented included: reduced street cross sections; curvilinear street alignments; shorter block lengths; and installation of chokers and islands.

Traffic surveys found curves with a 350ft radius were enough to reduce average speed by more than 10 mile/h below the recognised speed limits. Street cross sections were narrowed in some areas from 32ft to 29ft with two sided parking as standard, traffic surveys demonstrated that both streets had a similar average speed of 28 mile/h. Choker widths had little or no effect on the reduction of speed and proved problematic for civic amenity vehicles. Street alignments were found to be the most effective in changing driver behaviour.

Comments Differences between UK and USA road systems need to be taken into consideration.

Reference	**Taylor M C, Crinson L F and Osborn R E (2002)**. *An assessment of traffic calming for trunk roads using the TRL driving simulator*. TRL Report TRL539. Crowthorne: TRL Limited
Interventions tested	● *Bends:* Large single chevron sign on yellow backing board, four small chevron signs on yellow backing boards, symbol on road, buff lane on approach to bend. ● *Village gateway:* Cobbles, countdown signs with enlarged nameplate, narrowing, roundel, buff bands, 3D wedges, white triangles. ● *Within village:* Buff bands with SLOW marking. Pelican crossing. ● *Isolated developments:* Buff bands with SLOW marking. Longitudinal red strips with hatching along edges and centre of road. ● *Rural single-carriageway links:* Hatching in centre of road. Hatching/red surfacing along sides of road, and along centre and sides of road. ● *Urban dual-carriageway links:* Speed camera with symbol on road.
Method of Assessment	Driving simulator.
Description	The most successful measures were: the hatching/longitudinal red surfacing on the edges and centre of the road, which was more successful than hatching alone; the buff bands with SLOW marking at an isolated development; the speed camera with markings on an urban dual-carriageway link; the large bend chevron sign, which was more successful than the 4 small signs; and the pelican crossing within the village.

Reference	**Te Velde P J (1985)**. *De invloed van onvlakheid van wegverhardingen op de rijsnelheid van personenauto's [The influence of roughness of road pavement on driving speed of cars]*. ICW Nota, 1599, February, 1985.
Interventions tested	● Rough road surfaces.
Method of Assessment	On road speed measurements.
Description	The study examined the effects of road surfaces on driver behaviour. Large road differences, for example, 200m of rough road surface, were compared to 200m of smooth road surface. Speeds were found to be lower on the rough surfacing.

Reference	**Van der Kerkhoff W (1987)**. *The influence of road and environment characteristics on driving speed*. Afstudeerverslag HTO voor Planogie, Verkeerkunde en Vervoeskunde, Richting Verkeerskunde, Mei 1987. **Van der Kerkhoff W and Berenos M (1989)**. *Urban development factors affecting driving speed*. Verkeerskunde, 14 (1), pp 30-33.
Interventions tested	● Houses. ● Parked cars. ● Overgrowth. ● Rough surfaces.
Method of Assessment	On road speed measurements.
Description	The study found that the presence of houses in an urban environment reduced speeds, and that more parked cars, on both sides of the road, or on the driver's side only, reduced speeds. More extensive overgrowth along the side of the road also reduced vehicle speeds. Vehicle speeds were significantly lower when travelling on rough surfaces.
Comments	Speed reduction may be due to an increase in peripheral information and in perceived risk.

Reference	**Van Mörner (1984) cited in Martens, M H, Comte and Kaptein N A (1997)**. *The effects of road design of speed behaviour: A literature review*. TNO Report TM-97-BO21. Netherlands: TNO Human Factors Research Institute.
Interventions tested	● Trees. ● Lighting columns.
Method of Assessment	On road speed measurements.
Description	Speeds were reduced by using vertical elements, such as trees and lighting columns, at road narrowings.
Comments	Vertical contrast increases perceived speed.

Reference	**Vaniotou M (1990)**. *The perception of bend configuration*. Researché Transports Securité 7, pp 39-48.
Interventions tested	● Safety rails. ● Fences. ● Walls. ● Vegetation. ● Poles. ● Reflective posts. ● Overhead cables.
Method of Assessment	Video clips.
Description	The study investigated the effects of various roadside features or combinations of features on perceived safe speed on bends.

References	**Vey A H and Ferreri M G (1968)**. The Effect of Lane Width on Traffic Operation. *Traffic Engineering, 38 (8)*, 22-27.
Interventions tested	● Lane width.
Method of Assessment	On road speed measurements.
Description	The study compared traffic behaviour on two multi-lane bridges of equal total width in Philadelphia, USA. One bridge had eight narrow lanes of 9 feet and 8.75 inches (2.97 m) width, the other had seven wider lanes of 11 feet and 3.33 inches (3.44 m) width. The narrower lane bridge had free (mean) speeds that were 12 mile/h (19.3 km/h) slower. In addition, headway distances were longer on the narrower lane bridge (2.2 seconds) compared to the wider lane bridge (1.5 seconds).

References

Webster D C (1995). *Traffic calming – vehicle-activated speed limit reminder signs*. TRL Report TRL177. Crowthorne: TRL Limited

Interventions tested

- Vehicle activated speed limit reminder signs.

Method of Assessment

On road speed measurements using Automatic Traffic Counters.

Description

‘Secret’ vehicle activated speed limit reminder signs have been used as a means of warning drivers that they are travelling too fast by the activation of a sign triggered when the speed of the vehicle is above a pre-set level. This report reviews the published results from 13 of these ‘secret’ sign sites. The signs can lead to reductions in mean speeds of about 2 mile/h. Some of this reduction is maintained for some distance downstream. The effect was maintained over time.

References

Webster D C and Layfield R E (1993). *An assessment of rumble strips and rumble areas*. Project Report PR33. Crowthorne: TRL Limited

Interventions tested

- Rumble areas - bands of coarse surface texture.
- Rumble strips - narrow strips of material laid across the carriageway.

Method of Assessment

On road speed measurements using automatic traffic counters or radar guns.

Description

Rumble devices have been used in many countries as a means of alerting drivers to hazards such as junctions and bends. The report assesses the types of rumble strips and rumble areas which have been used at 35 sites in the UK, to ascertain which devices are the most effective. It covers the types of rumble devices used, the layouts and dimensions of the devices and the effects on speeds, accidents, driver behaviour, noise and vibration.

On average, the devices gave a small reduction in 85^{th} percentile speed of 3.1 mile/h and a slightly greater reduction in mean speed, suggesting that the faster drivers may maintain or increase their speed at some sites to lessen the ‘cattle-grid’ effect. It was found that the effect of rumble devices tends to diminish over time.

References | **Wheeler A H., Taylor M C and Payne A (1993)**. *The effectiveness of village gateways in Devon and Gloucestershire*. Project Report PR35. Crowthorne: TRL Limited

Wheeler A, Taylor M and Barker J (1994). *Speed reduction in 24 villages: details from the VISP study*. Project Report PR85. Crowthorne: TRL Limited

Wheeler A H and Taylor M C (1999). *Traffic calming in villages on major roads: Final report.* TRL Report TRL385. Crowthorne: TRL Limited.

Interventions tested

- Village gateways.
- Physical measures within villages.

Method of Assessment

Included Before and After on road speed measurements with radar guns or Automatic Traffic Counters.

Description

Village gateways with various designs were studied. Designs with countdown signs, 30 mile/h roundels, dragons teeth and contrasting red and white road surfaces resulted in significant decreases in mean speed, of the order of 10 mile/h where there were physical measures, such as a central island, or signing and marking with a strong visual impact.

The size of the speed reduction depended on the Before speeds and whether there was a change in the speed limit as well as the measures used.

The effects of gateways were found to be limited in extent. Additional measures are required to reduce speeds within the village itself. It was suggested that gateways are most effective on wider roads.

References

Wheeler A (1999). *Traffic calming in historic core zones: Bury St Edmonds*. TRL Report TRL388. Crowthorne: TRL Limited.

Wheeler A (1999). *Traffic calming in historic core zones: High Street route, Shrewsbury*. TRL Report TRL374. Crowthorne: TRL Limited.

Wheeler A (1997). *Traffic calming in historic core zones: Crossley Street, Halifax*. TRL Report TRL288. Crowthorne: TRL Limited.

Interventions tested

- Various traffic calming measures in historic town centres, including:

  Use of granite setts.
  20 mile/h zone.
  Signing less visually intrusive, yellow lines removed.
  Carriageway narrowing.

Method of Assessment

Included Before and After on road speed measurements with Automatic Traffic Counters.

Description

Results showed that non-visually intrusive measures can reduce speeds, but the studies could not assess whether more visually intrusive measures would have led to greater reductions in mean speed. In addition, the effect of individual measures could not be assessed separately. Public reaction to the schemes was favourable.

References	**Winnett M and Wheeler A (2002)**. *Vehicle-activated signs – a large scale evaluation*. TRL Report TRL548. Crowthorne: TRL Limited.
Interventions tested	● Vehicle-activated signs (speed limit reminder, bend and junction warning, safety camera repeater) at over 60 sites.
Method of Assessment	Before and After on road speed measurements using Automatic Traffic Counters.
Description	Vehicle-activated signing has been developed to encourage drivers to approach hazards such as bends and junctions at a safe speed, and to encourage them to comply with the speed limit, e.g. through villages. The signs display a message to just those drivers exceeding a set threshold speed. The effect of the signs on speed and injury accidents, and on drivers' understanding of the signs, was assessed. The signs appeared to be very effective at reducing speed, particularly of the faster drivers who contribute disproportionately to the accident risk, without the need for enforcement such as safety cameras. A substantial accident reduction was demonstrated.

References	**Winnett M, Woodgate E and Mayhew N (1999)**. *Interactive fibre-optic signing at a rural crossroad*. TRL Report TRL401. Crowthorne: TRL Limited
Interventions tested	● Interactive signs at a rural crossroad at Felthorpe in Norfolk.
Method of Assessment	On road speed measurement using Automatic Traffic Counters.
Description	The site had a history of 31 recorded personal injury accidents in a ten year period. Engineering remedial measures had been carried out but with little affect upon the accident problem, principally collisions between vehicles emerging from the minor arm with high speed vehicles on the major arm. The signs, showing the standard crossroad symbol with the message 'SLOW DOWN', were switched on when vehicles approaching the junction exceeded 46 mile/h. Although the drivers were not given an advisory speed, they did slow down, resulting in a safer approach speed to the junction. Additionally, time headways increased (avoiding tailgating).

References	**Yagar S and Van Aerde M (1983)**. Geometric and environmental effects on speeds on 2-lane rural roads. *Transportation Research Record*, *17A (4)*, 315.
Interventions tested	● Land use adjacent to the road. ● Speed limit. ● Gradient. ● Curvature. ● Junctions. ● Lane width. ● Presence of an extra lane. ● Centre line markings.
Method of Assessment	On road speed measurement.
Description	The study investigated traffic speeds on two-lane rural highways in Canada, comparing road sections. The roads had relatively high and uniform design standards, with gradients less than 3% and radius of curvature greater than 1400m. Multiple linear regression was used to relate measured speeds to geometric and environmental factors. Land use, speed limit, gradient, junctions and lane width together accounted for 85% of the variation. For every metre of reduction in lane width beyond four metres there was a reduction in speed of 5.7 km/h.

Abstract

Excessive driving speed is a major concern for road safety, with speed having an adverse effect on the number and severity of road traffic accidents and on a number of measures associated with quality of life. One potentially useful way to reduce drivers’ travelling speeds might be through the use of road design measures which influence drivers’ speed via intrinsic, or psychological, means of control. This report presents a review of such measures within the framework of relevant psychological theory and knowledge about driver behaviour. The research is funded by the Charging and Local Transport Division of the Department for Transport.

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TRL511 *The relationship between speed and accidents on rural single-carriageway* by M C Taylor, A Baruya and J V Kennedy. 2002 (price £25, code AX)

TRL322 *Road layout design standards and driver behaviour* by G Maycock, P J Brocklebank and R D Hall. 1998 (price £35, code H)

TRL326 *Drivers’ speed choice. An in-depth study* by A Quimby, G Maycock, C Palmer and G B Grayson. 1999 (price £25, code E)

TRL325 *The factors that influence a driver’s choice of speed - a questionnaire study* by A Quimby, G Maycock, C Palmer and S Buttress. 1999 (price £35, code H)

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