5. LABORATORY VALIDATION STUDY - CLOSE FOLLOWING

The need for further research into the relationship between following distance and road crashes was discussed in the introduction. While traveling too close to the vehicle in front appears to be a particularly dangerous action on the road, very little is known about why drivers adopt such practices. As a preliminary step towards better understanding, it would be useful to undertake a study of drivers' perceptions of what constitutes a safe following distance for a variety of different roads, environments and speeds.

The laboratory environment would be a convienent means of testing following distance without endangering subjects unnecessarily. The speed perception technique might be a suitable candidate for assessing drivers' perceptions of following distance on the road. However, a validation study would be required first to assess its suitability for this task.

5.1 STIMULUS MATERIALS

Twelve rural road sites on the outskirts of the Melbourne metropolitan area were located that encompassed a range of road and environment factors. Details of each road site are shown in Appendix A-10 and in Figure 5.1, while Figure 5.2 shows some typical sites used in the close following validation study.

The independent variables included three road types (divided, 2-lane undivided and gravel), two roadside environments (walled and spacious), and two following distances (half-sec and two-sec). In total, there were twelve road scenes in a fully crossed factorial design experiment.

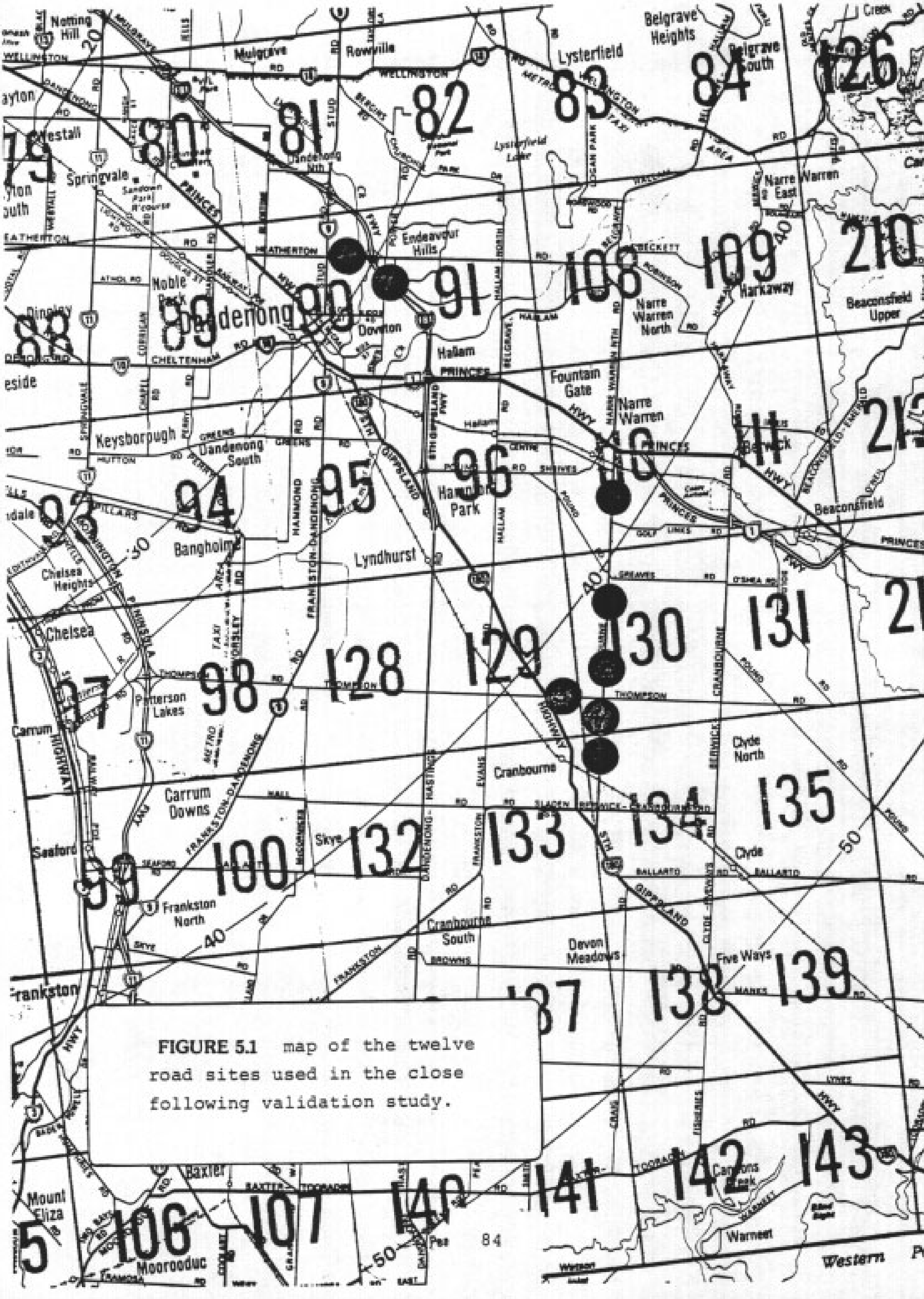


FIGURE 5.1 map of the twelve road sites used in the close following validation study.

Site 2 — Divided, 2-lane, walled urban freeway (speed limit 110k)

Site 4 — Undivided, 2-lane, spacious gravel road.

FIGURE 5.2 — Typical road sites used in the close following validation study.

First, it was necessary to develop a method of maintaining a one-half and a two second following distance between two experimental vehicles travelling at 75km/h and 100km/h. **A "following distance" indicator was developed** comprising a 24cm long vertical steel rod, approximately 0.5cm in diameter, along which there were four different coloured markings calibrated to represent the two following distances at both speed levels (see Figure 5.3 showing the rod and following distance scale).

The scale was mounted vertically on the rear test vehicle in the driver's line of sight to the lead vehicle. **As a test site** approached, the driver of the lead vehicle adjusted his speed to the posted speed limit (75km/h or 100km/h). **The driver of the** second vehicle then selected the appropriate coloured mark on the scale corresponding to the desired following distance and lined up this marker on the rear bumper of the lead vehicle at the appropriate speed. **This rather simple procedure ensured that the** correct following distance was achieved at each test site.

A suitable road segment was identified at each of the 12 selected sites that guaranteed a minimum of 5sec film time with specified sight distance requirements. The entrance point for these sites was marked and noted.

For the laboratory trials, each site was filmed once using the Bolex H16 reflex movie camera with 16mm Kodak colour negative 100 ASA film. **Films were processed into workprints and edited into** 5sec film segments. **A single experimental film was produced,** comprising the 12 road scenes in a fixed presentation order with 3 additional and novel practice sites. **Each road scene was of** 5sec duration and was followed by 10sec of blank film as before.

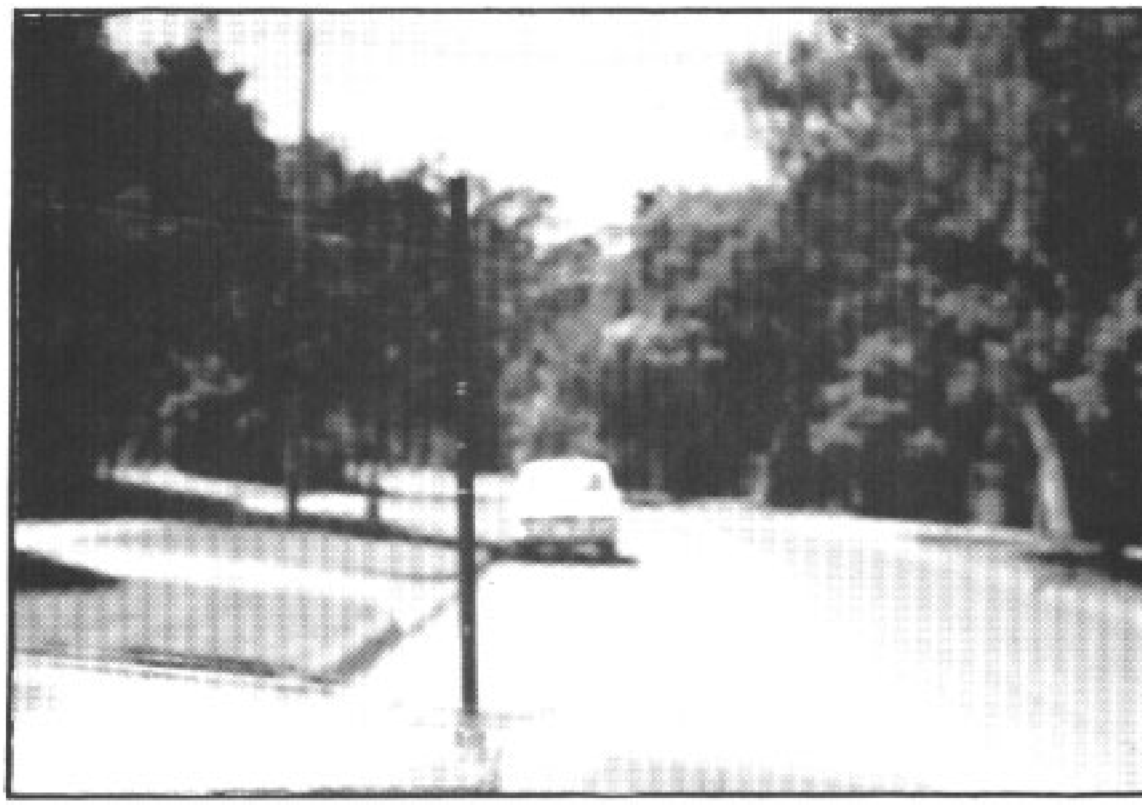


FIGURE 5.3 — The "following distance scale" in place on the trailing research vehicle. The driver of this vehicle aligned the correct graduation mark on the scale with the bumper bar of the leading vehicle with both cars stabilised at the same travel speed. This ensured that the two vehicles were correctly spaced apart during a particular road trial.

A response booklet, similar to those used in the day/night and curvature experiments, was employed for recording the subjects' speed and safety estimates on the road and in the laboratory. The endpoints of the slash-line response scale for this task were labeled "very safe" and "very unsafe". The subjects indicated how safe they perceived the distance to be between their vehicle and the vehicle in front by slashing across the response line.

A Kustom HR4 hand held radar gun was used to measure the free speed of 100 vehicles at the 12 road sites. Measurements were again taken by an observer seated in an unmarked vehicle at the side of the road.

5.2 ROAD TRIALS

Twelve subjects (three male and three female, first year drivers, and three male and three female full licence holders) were recruited. Each subject was driven individually along the pre-determined course encompassing three practice sites and the 12 chosen road sites. All road trials were conducted during off-peak traffic conditions, on dry roads and in good light and weather conditions.

Two experimenters were assigned to drive the first and second experimental vehicles. Both drivers underwent considerable training at maintaining following distances and how to avoid dangerous situations on the road. In addition, a third experimenter sat in the rear seat of the following vehicle to control the experimental procedure.

Each subject was given a response booklet and sat in the front passenger seat of the second (trailing) vehicle. Prior to arriving at the course, the subject listened to the pre-recorded experimental instructions (see appendix B-3) and any doubts about the task were clarified. The driver then shielded the car speedometer from the subject's view by placing a cloth over the dashboard and played white noise through the car's stereo system.

Upon reaching a site, the subject was asked to look down at the response booklet on his or her lap, while the drivers of both vehicles adjusted their speed to the posted speed limit for that site (either 100km/h or 75km/h). The driver of the second vehicle maintained the pre-chosen following distance as described previously in Section 5.2. When the vehicle entered the site, the subject was asked to look up and view straight ahead. After 5sec of viewing time, the subject looked down and made his or her assessments of safety and travel speed.

The experimenter stressed that subjects should try and make their responses as spontaneously as possible. After each trial, the experimenter engaged the subject in casual conversation to distract attention from the road and task. In between sites, both drivers varied their speeds and following distances to reduce familiarization and ensure that speed was sometimes increased or decreased on the approach to each site.

5.3 LABORATORY TRIALS

A further twelve subjects, consisting of three male and three female first year drivers and three male and three female experienced drivers, were recruited for the laboratory trials. The procedure used was similar to that used for the road and previous laboratory trials.

Each subject was seated in front of the back-projection screen and listened to the recorded instructions (see Appendix B-4). The subject was then shown the first part of the film comprising three practice sites and any doubts about the task were clarified. The film was then re-started and the 12 test sites were presented in the same order as the road trials. Subjects made their assessments of safety and speed during the 10sec of blank film between each 5sec test sequence.

5.4 RESULTS

While a full factorial analysis of the data was possible in this study with the structured format adopted, there were, however, only three subjects employed in each driver condition and the presentation order was the same for each subject. This was quite appropriate as the study was only intended to be for validation of the technique. Thus, a simple two factor analysis was undertaken, including type of experiment and road site, similar to that adopted in the previous validation study. The stricter design format, however, enabled a more thorough examination of the effects of the factors of interest than before. Free speed measures were collected once more to compare the perceptual responses with on-road driver behaviour at the 12 sites.

5.4.1 Safe Operating Distance Responses

Appendix C-7 lists the statistical summary table of these data and Figure 5.4 shows the effects of interest in this experiment.

The main effect for road site shown in Figure 5.4a was significant ($F(11,242)=54.2$, $p<.001$, $w^2=.6235$). Subjects' responses across the 12 road sites used in this study were quite

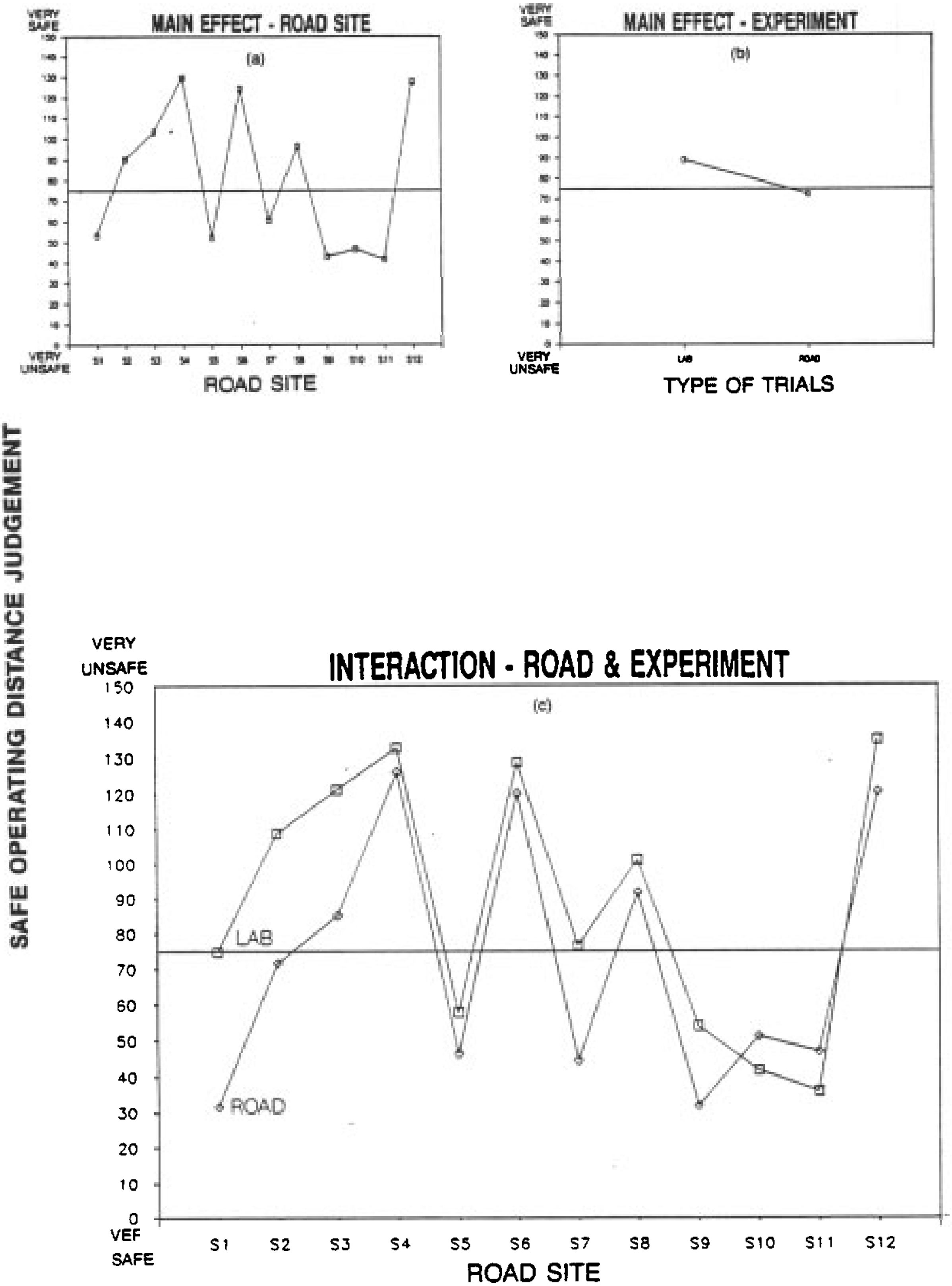


FIGURE 5.4 — Safe operating distance effects of interest in the close following validation study.

different and distributed quite evenly around the centre of the scale. **This variable manipulation accounted for more than 90 per** cent of the total treatment variance.

There was also a significant main effect for experiment, shown in Figure 5.4b ($F(1,22)=4.9$, $p<.05$, $w^2=.0315$). Subjects' following distance responses in the laboratory were less safe overall than those collected on the road. This variable, however, only accounted for 5 per cent of the total treatment variance and was considerably less powerful than road site.

There was also a significant interaction observed between road site and experiment in Figure 5.4c ($F(11,242)=3.5$, $p<.001$, $w^2.0290$). **The source of this interaction appears to be the** cross-over in the level of responding between the laboratory and road trials for sites 10 and 11. Apart from this discrepancy, the pattern of responses is quite similar for all other sites. This interaction attracted 4 per cent of the treatment variance.

5.4.2 **Speed Estimation Errors**

These results are listed in Appendix C-8 and are shown graphically in Figure 5.5. **Road site in Figure 5.5a was again** the strongest, significant effect observed in this analysis ($F(11,242)=74.0$, $p<.001$, $w^2=.5581$). **Errors in estimating travel** speed were noticeably different across the 12 sites and in most cases were under-estimates of travel speed. This variable accounted for 87 per cent of the total treatment variance.

The main effect for experiment in Figure 5.5b was significant ($F(1,22)=8.7$, $p<.01$, $w^2=.0564$). **Vehicle speed was under-**estimated much more in the laboratory than on the road. **This** effect accounted for 9 per cent of the treatment variance.

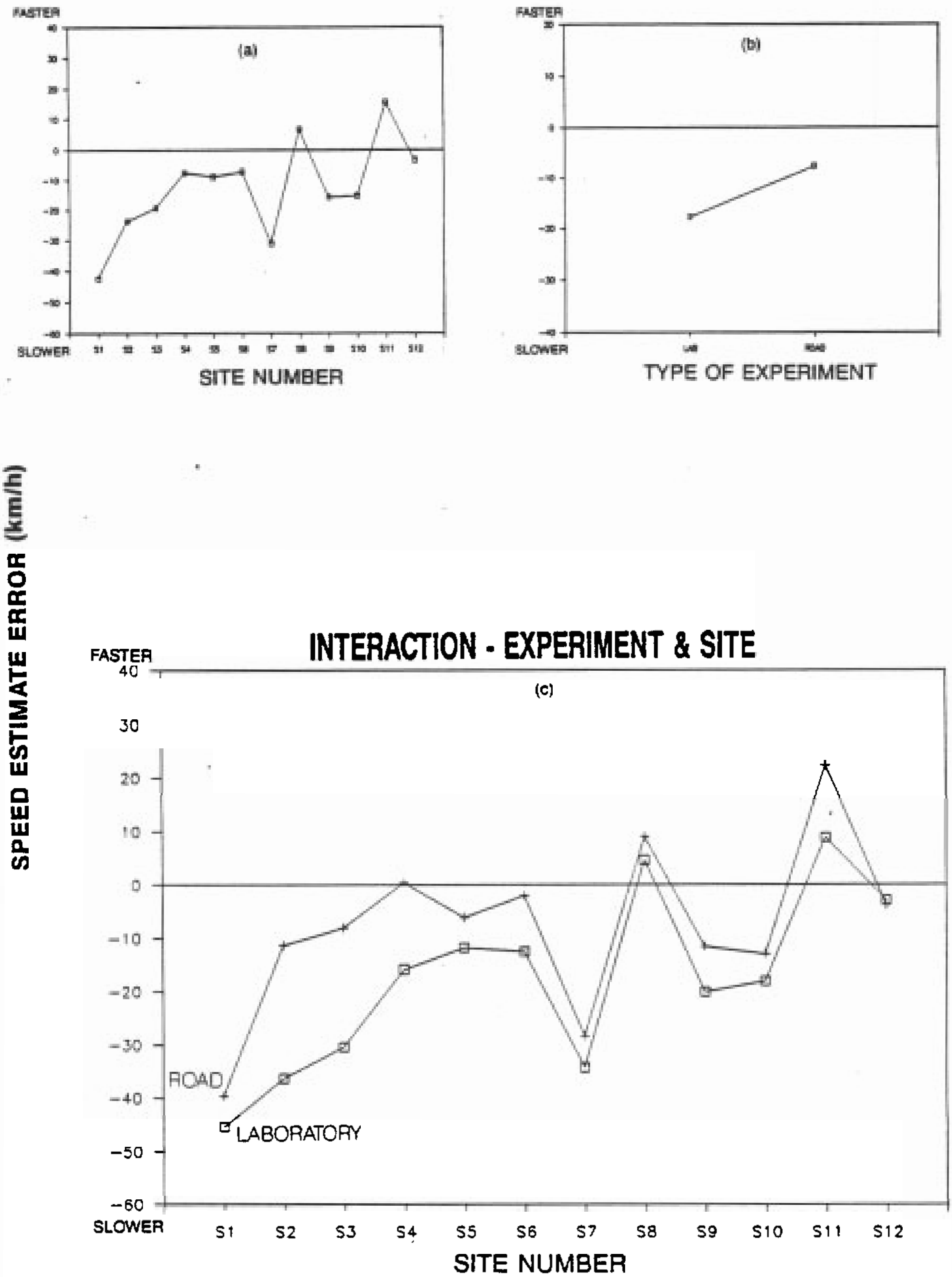


FIGURE 5.5 — Speed estimate error effects of interest in the close following validation study.

The interaction between experiment and road site in Figure 5.5c was also significant ($F(11,242)=4.4$, $p<.001$, $w^2=.0262$). **The** divergent trends in speed estimates taken in the laboratory to those collected on the road for sites 2 to 6 would be sufficient to generate this result. This variable combination, however, only captured 5 per cent of the treatment variance in the experiment.

5.4.3 **Free Speed Data**

For consistency, free speed measurements were collected at each of the 12 sites used in the close following study. Appendix Table A-10 lists the actual results, while Figure 5.6 shows the plot for road site and other variable combinations of interest. These data, however, were of less interest in this study because of the nature of the task (close following does not necessarily translate directly to speed behaviour on the road). **Thus,** apparent differences by type of road and roadside environment are not described any further here.

5.4.4 **Other Variable Effects**

The factorial design adopted in this study enabled a preliminary evaluation of the road, roadside environment and driver effects. These factors were not tested statistically for reasons previously explained and care should be taken not to interpret too much from these data. Figure 5.7 shows the main effects observed for these factors.

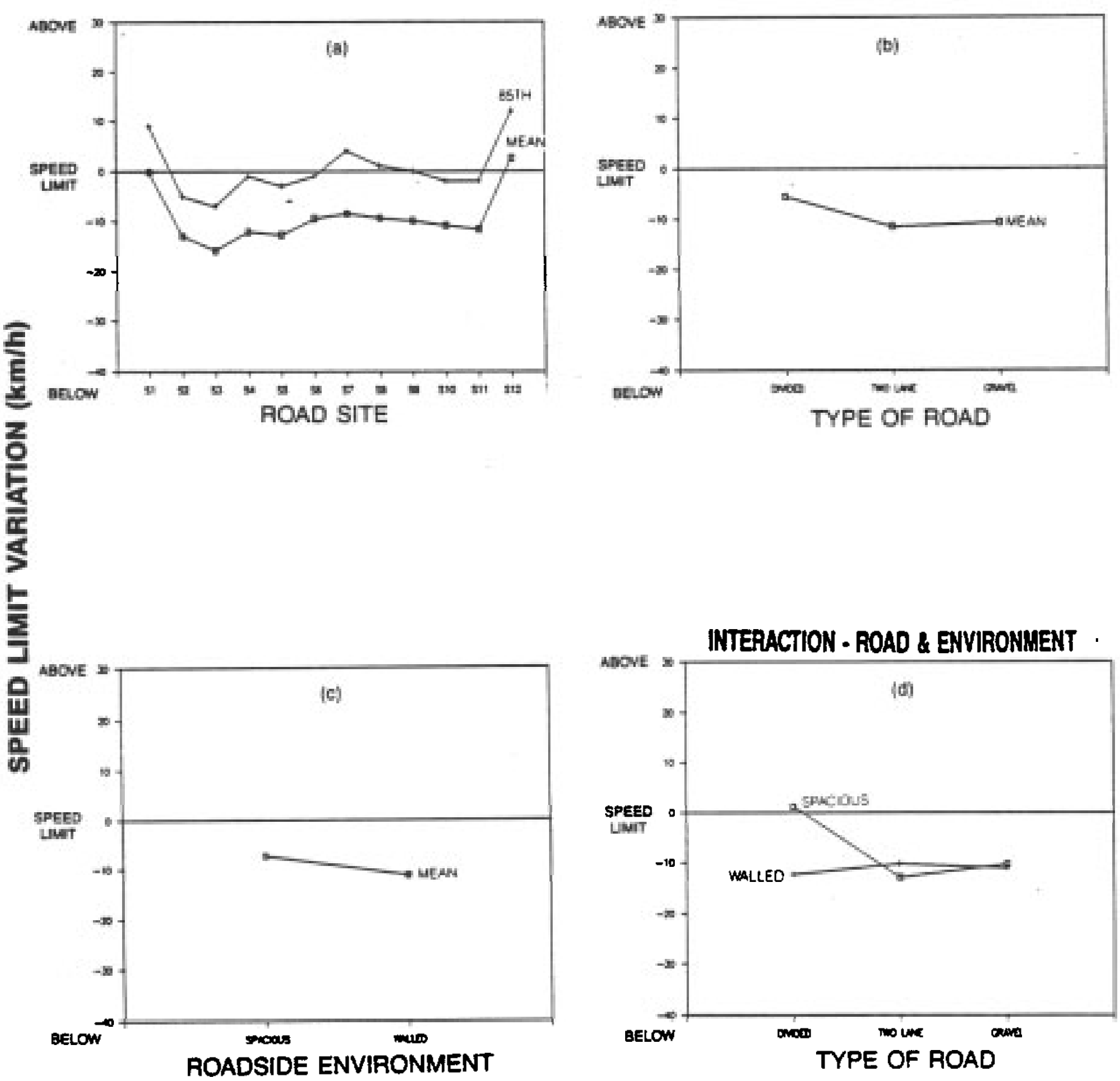


FIGURE 5.6 — Free speed variations around the speed limit in km/h for the variables of interest in the close following validation study.

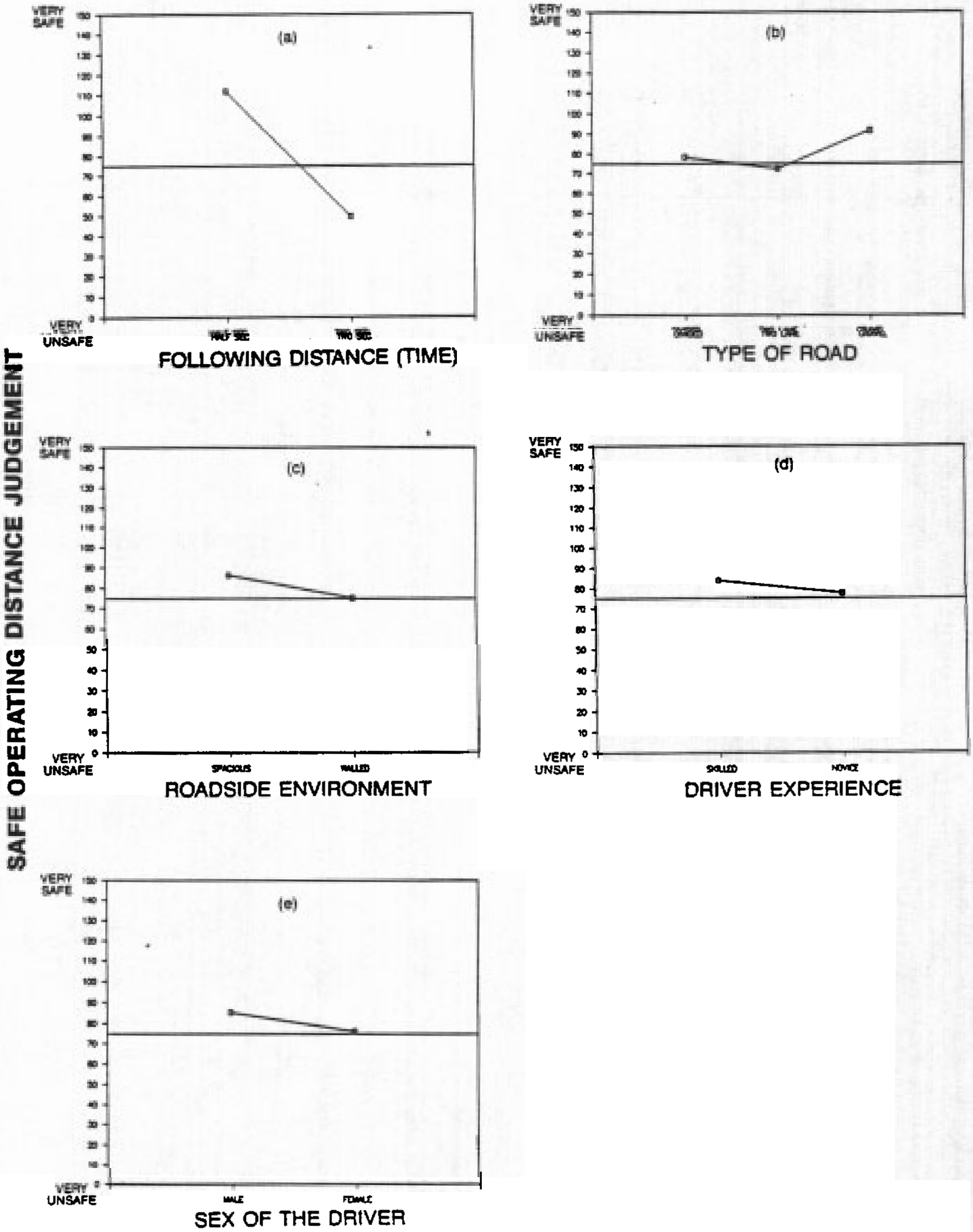


FIGURE 5.7 — Safe operating distance effects for a range of factors included in the close following validation study.

First, the results for following distance, shown in Figure 5.7a suggest that the one-half second distances were judged to be too close, while the two second distances were assessed very safe. This result suggests that a driver's ideal following distance on rural roads lies somewhere between these two values.

The type of road, shown in Figure 5.7b, indicates that perceptions of safe following distances can be influenced by the type of road surface. Gravel roads, in particular, seem to have evoked much less safe following distance responses than either divided or 2-lane undivided roads. Figure 5.7c also illustrates that following distances in walled environments were assessed to be safer than spacious road environments.

Two driver variables were included in the subject sample. The trend for driver experience in Figure 5.7d indicates that experienced drivers assessed the two following distances as safer overall than did the novice drivers. Furthermore, female drivers seem to have judged following distance to be more safe than male drivers did (Figure 5.7e).

5.5 DISCUSSION

The main purpose of the validation study was to assess the suitability of the laboratory for eliciting close following responses from the road. The results conclusively show that the laboratory method is suited for this task.

Figures 5.4c and 5.5c showed the interaction between experiment and road site for both sets of perceptual data and demonstrated a similar pattern of responses between the road and the laboratory trials. While these interactions were statistically significant effects in both analysis (the pattern for both the laboratory and road responses were not perfect mirror images of each other), the minor differences that appear to have caused these interactions do not really detract from experimental validity.

It could be that one or two sites used in this study may not have been particularly well chosen; the practicalities of conducting road studies means that sites are occasionally included because they are the best available in the area, rather than ideal choices. Moreover, the prevailing conditions for the 12 road trials may not have been perfectly consistent or similar to the laboratory trials and six subjects in each condition is not really sufficient. These are, of course, the very reasons for conducting laboratory experiments in perception and the consistency in form of both sets of responses is sufficient to support further laboratory testing.

The main effect observed for experiment in both data sets also suggests that the overall level of sensitivity was different in the laboratory to the road. This was also experienced in the speed perception research where it was argued that reductions in other information normally available to drivers (sound, gravitational forces, vibrations, lateral forces, etc.) decreased the subjects' perceptions of safety off-road. This decrease in safety, however, is of little consequence here where the relative effects of the independent variables are being tested, rather than their overall effects on the road. What must be stressed, however, is that subjects demonstrated considerable differences in their responses to the 12 sites and, for the most part, responded similarly in both the laboratory and road tests.

Without making too much of the other variable findings, it is worth noting that there appeared to be substantial differences in the level of safety for most of the factors included in the trials. The finding that subjects' ideal following distances appears to be somewhere between 0.5sec and 2.0sec on rural roads is especially interesting. If this is robust, it may help to explain some of the rear end crashes that occur on Australian roads. A 2.5sec following distance, as specified by the National Association of Australian State Road Authorities, (NAASRA, 1980) allows time for the driver to respond to a danger signal on the road and for the vehicle to come to a complete stop. With less than a 2.0sec gap between vehicles, the following vehicle could not avoid skidding, swerving, or colliding with the leading vehicle in the event of it stopping abruptly. This would be potentially dangerous in many driving situations.

In many instances, of course, the leading vehicle also has to brake in which case the gap between vehicles theoretically needs only to be equivalent to the time to respond. This assumes that the system is "perfectly calibrated" in that a driver's attention is not distracted, his response mechanisms are not dulled by drugs, tiredness, emotions or even old age, or that vehicle braking systems and road surfaces do not have different braking characteristics and effects. In short, the greater the following distance, the greater the margin for error on the road, vehicle and driver systems and the less likelihood there is of a crash. A following distance of less than two seconds does not seem to be an adequate margin for error in many circumstances.

It should be noted that the subject in this experiment was always the front seat passenger and not the driver. This was necessary to ensure that the subject's response was purely perceptual and free of any driving performance influence. Nevertheless, the results obtained may have been biased in that a passenger's perception of what constitutes a safe following distance may be quite different to that of a driver. The authors are not aware of any research that shows that a passenger's sensory perception on the road differs markedly from that of the driver. While it would be difficult to design an experiment to test solely for sensory perceptual effects between drivers and passengers, it is, nevertheless, an empirical question.

Further testing is clearly warranted here to test the robustness of these findings and to examine further the perceptual relationship between a driver's following distance, the road and environment influences, and the likely crash consequences.

6. GENERAL DISCUSSION AND FINDINGS

The findings from the road validation studies and the two laboratory experiments enable several conclusions and general principles to be drawn about the perception of speed in rural areas.

6.1 DAY AND NIGHT VISION

The first experiment conducted in this research programme was aimed at evaluating the effects of night vision on the previous findings of Fildes, Fletcher and Corrigan (1987) regarding drivers' judgements of safety and speed on rural straight roads during day-light hours. In addition, the time of testing during the day was also studied to see if biological cycles influence speed perception.

The results confirmed the previous day-light findings for presentation speed, type of road and roadside environment. However, the reduction in illumination to night-vision levels did influence the previous results.

Speeds at night were perceived to be less safe overall than speeds during the day and subjects made greater errors in estimating how fast they were travelling during night presentations. This was explained in terms of "perceptual narrowing" where the visual streaming patterns in the periphery of the eye of a driver during the day are markedly reduced at night. The speed estimation finding contrasted with that reported earlier by Triggs and Berenyi (1982) but this was explained by the differences in the amounts of night delineation treatments between the two studies.

Night vision interacted with the type of road and roadside environment. The perceptual advantage for walled sites during the day almost completely disappeared at night as roadside environment differences became less apparent. Unexpectedly though, speeds on walled, gravel, roads during the day were perceived to be much less safe than speeds at spacious gravel sites, suggesting that drivers seem to experience substantial reductions in perceived safety on these unsealed surfaces, even during day-light hours.

Night testing did not influence the results of the experiment. The only evidence of any night testing effect was an interaction between the sex of the driver when estimating travel speed (males made greater errors during the day than at night, and also made more errors than females did). It appears that this may have been a chance finding in the data.

If this is true, then it would appear that different biological cycles do not have much influence on a driver's perception of speed. Thus, differences in speed performance between day and night driving are more likely the result of fatigue or adaptation effects at night, rather than a fundamental difference in biological ability at this time. It could be argued that this result was a function of the relatively short testing times that applied to the trials and that the effects of fatigue or adaptation were not tested thoroughly in this experiment. Furthermore, there is reason to expect sensory perceptions to change with the level of alertness. Hence, it would be worth examining the effects of day and night testing further in any future perceptual studies, particularly those involving continuous testing over long periods of time.

6.2 THE VALIDITY OF CURVATURE TESTING

A study was undertaken to assess the validity of testing horizontal and vertical curvature effects in speed perception in the laboratory. A previous study by Fildes et al (1987) had shown that speed perception on rural straight roads could be tested in a laboratory using moving stimulus materials with controlled visual images.

Responses collected on the road were compared with those collected in a laboratory for a range of different curved road and environment conditions. The results confirmed the validity of using laboratory simulation for eliciting road speed perceptions for **horizontal** curves. However, the vertical curve results were ambiguous, suggesting that non-visual cues (gravitational force, sound, car movement and other forces) play a much larger role in speed perception in these undulating environments. Further testing is required to establish the effectiveness and degree of simulation necessary for testing **vertical** curvature effects off-road.

6.3 HORIZONTAL CURVES

A factorial experiment was undertaken to test the effects of a range of road, environment and driver factors on the perception of speed at horizontal rural curves.

While speed of presentation was still a strong effect in the subjects' judgements of safety and travel speed, the road and environment effects had considerably more influence here than previously reported for straight rural roads (Fildes et al, 1987). It was argued that the combined effects of type of road, curve radius, and roadside environment indicated that available sight distance was a crucial factor in curve perception.

Differences were noted between the sex of the driver and the amount of driving experience in this experiment. **Male subjects** assessed travel speeds on rural curves to be generally more safe than females, while male inexperienced drivers under-estimated travel speed much more than either the experienced males or all females. It was argued that these differences may have been a function of the different exposure rates between these groups of drivers on the road. The inexperience effect between novice and experienced drivers was only marginal and care should be taken not to infer too much from this result.

Curve direction had practically no effect on the subjects' judgements of safety and speed. This suggests that perceptual asymmetries previously reported for bends in the road by Gordon (1966), Stewart (1977), Fildes (1979), Triggs and Fildes (1986) and Fildes (1986) are essentially a static perceptual phenomenon. The introduction of motion appears to alleviate these effects.

The free speed results suggested that motorists' behaviour on 2-lane rural road curves under certain circumstances involves other factors apart from the sensory perception of speed. Further research is warranted here to investigate possible reasons why drivers negotiate small radius, 2-lane, undivided, road curves much faster than similar large radius curves.

6.3.1 Implications For Curve Safety

The results obtained here and elsewhere (Fildes 1986) suggest that there are several critical geometric aspects that should be addressed to improve road safety on rural curves:

1. Hazardous road curves should be upgraded to improve the quality of the road surface and increase the curve radius (the results here suggest that curve radii below 500 metres are undesirable for safe speed perception on rural road curves).

2. Trees and shrubs close to the edge of the curve should be cleared back from the road sufficiently far enough to ensure adequate vision around the curve. Fildes (1986) found that a curve angle of 30deg was a minimum requirement for veridical curve perception. Moreover, on some spacious curves, tall grass on the side of the road can be as detrimental for the safe perception of curvature as other major visual restrictions such as cliffs, trees and shrubs.

3. Road delineation treatments need to emphasize the change in direction of the road surface. Road markings, reflectorized guide posts and reflectorized pavement markers have all been shown to be efficient treatments for improving a driver's perception of an approaching road curve (Triggs, Harris & Fildes, 1979; Triggs, Meehan & Harris, 1982; Johnston, 1982, 1983; Jackson, 1983; Nemeth, Rockwell & Smith, 1985).

4. Speed zoning at hazardous curve locations may also be required in difficult geometric locations. However, advisory speed signs are often disregarded by motorists because they are inconsistent and unreliable (advisory speed signing really needs to be in terms of driver perceptions, rather than geometric parameters).

6.4 CLOSE FOLLOWING

Driving too close to the vehicle in front (not providing sufficient headway) has been shown to be a particularly dangerous action on the road (Cairney 1981; Quimby 1987; Royalauto 1988).

To test whether the speed perception technique would be suitable for studying the perceptual effects of these aspects of driving, a validation study was performed on drivers' perceptions of safe following distance. Subjects were asked to judge how safe they felt about the distance between them and the vehicle in front for a range of different road, environment, speed, and headway conditions, involving both on-road and laboratory trials.

The results demonstrated that close following responses can be simulated effectively in the laboratory. The pattern of responses on the road was similar to that collected in the laboratory, confirming the suitability of the technique for assessing the relative effects of the likely factors of interest. Moreover, subjects appeared sensitive to these factors as there were considerable differences expressed in safe following distance for the range of road, environment and driver factors employed in this study.

The data also suggested that a driver's safe following distance from the vehicle in front lies somewhere between 0.5sec and 2.0 sec. It was argued that this is less than ideal to avoid road crashes. Further research is warranted to establish safe following distances precisely for a range of road and roadside conditions, as well as its role in road crashes.

6.5 SPEED BEHAVIOUR IN RURAL AREAS

Free speed measurements were collected at 58 straight and curved rural road sites during the course of this research. **Overall,** these data show that the majority of motorists tend to travel at speeds close to or below the posted speed limits on rural roads in this state. In addition, while 85th percentile values were generally slightly above the posted speed limits, they were not excessively so. While there was a tendency for divided straight roads during the day to be perceived as extremely safe, this effect disappeared on curves and after dark.

It is difficult to argue that speed perceptions alone are responsible for motorists' speed behaviour on the road. The previous project (Fildes et al 1987) demonstrated a direct link between observed speed and **unsafe** speed perceptions (vehicle speeds reduced proportionally when unsafe speed perceptions in particular areas became more unsafe). However, the reverse was not true when safe speed perceptions became more safe; the authors claimed that other factors (eg, enforcement) seemed to set a ceiling limit on maximum speeds that most motorists were willing to travel at. The data collected here appeared to confirm this hypothesis.

What this means for perceptual countermeasures against speeding is taken up further in the next section of this report. However, on the evidence collected here for free speeds, it would be difficult to argue that the current speed limits in Victoria (100km/h on 2-lane rural highways and 110km/h on rural freeways) are in need of review.

6.6 FUTURE RESEARCH IN SPEED PERCEPTION

The results from this project and the previous speed perception research (Fildes et al 1987) have thrown considerable light on the role of a number of road, environment and driver variables in a driver's perception of speed. However, there a number of research questions raised during the course of this research program that still need to be answered in this area. These are listed below:

. What are the effect of travel lane on speed perception for multi-lane divided and undivided roads.

. What influence does different grades of road delineation have on speed perception at night (this is currently unknown and potentially useful for highway design and maintenance).

. Why were speeds on small radius, 2-lane, 2-way road curves relatively faster than on much larger divided road curves.

. What is the relationship between small radius, small visible angle road curves and rural crashes.

. What effects do driver experience and sex of the driver have on vehicle free speeds for straight and curved rural highways in Australia.

6.6.1 **Variables Not Tested To Date**

While these two projects evaluated many of the factors identified from a review of the literature as likely to be important for speed perception (Fildes et al 1987), a number of other variables could not be evaluated for a number of reasons, namely:

. Traffic density and mix (these factors are likely to have considerable influence on speed perception, although it would be difficult to test the effects of these variables using the method adopted here).

. Weather, too, would be expected to play a major role in speed perception but it is extremely difficult to simulate different weather conditions accurately on film.

. The effect of parked vehicles and pedestrians on speed perception is potentially testable using the laboratory technique. However, these effects tend not to have the same impact on a driver off-road and it would be difficult to nominate perceptual countermeasures likely to offset these influences.

Vertical curvature influences, however, are potentially manageable using perceptual countermeasures. However, the lack of a robust finding in the validation study in Chapter 3 suggests that this variable may also be difficult to test using the laboratory technique.

It would seem important, therefore, that an alternative method of evaluating the perception of speed on the road be developed before many of these other variables can be properly tested.

5.6.2 **The Next Step**

The long-term aim of this research programme was to discover perceptual countermeasures against speeding that could be applied to suitable locations to reduce road crashes. The last Chapter in this report lists a number of particular road and roadside treatments that may have potential benefits. However, many of these treatments need to be evaluated first to establish their potential costs and benefits.

In the first instance, a laboratory test of these countermeasures would be desirable to demonstrate their effectiveness and to identify any undesirable side effects. If these results were encouraging, performance testing could then be undertaken at specific hazardous road locations to assess their potential crash benefits. Finally, a detailed cost-benefit analysis should be carried out to rank these treatments in order of their potential road safety effectiveness.

6.6.3 **New Directions**

The close following validation study showed that the film and laboratory simulation technique could be used for evaluating the effects of the road and environment on particular driver actions on the road. Given the relative lack of knowledge about what constitutes unsafe driving actions on the road, research into drivers' perceptions of road user behaviours (in association with the risk of crash involvement) would be useful and ultimately lead to countermeasures against unsafe driving actions.

7. PERCEPTUAL COUNTERMEASURES

The project objectives outlined in Chapter 1 required a discussion of perceptual countermeasures against excessive speeding in hazardous rural locations. That is, treatments to the road or its surrounds that will influence a driver's perception of speed without introducing physical barriers or restrictions. These are sometimes referred to as perceptual illusion or trickery effects.

The results from both this study and the earlier study of speed perception on urban and rural straight roads (Fildes, Fletcher and Corrigan, 1987) showed that there is potential for manipulating the environment to produce changes in speed behaviour. In particular, it was argued that changes to the road surface have the greatest potential for influencing a driver's perception of speed, although roadside environment effects can also influence speed perception. The effectiveness of the treatment, however, is likely to be a function of the overall level of safety in a driver's perception of speed for a particular road and environment location.

This chapter is structured into 4 sections. First, it includes a brief discussion of traditional approaches to speed control and their successes and failures. Second, it proposes perceptual countermeasures as a viable alternative (or additional) approach to speed control and argues why these measures are likely to influence vehicle speed, drawing from the limited amount of evidence and theory available in this area. Third, an inventory of potential perceptual countermeasures is presented from a range of relevant sources (including literature reviews in this area, other studies that have evaluated the effectiveness of particular perceptual treatments on speed or driving performance, and local knowledge of measures that have been or are being contemplated for use in this country). The chapter concludes with a discussion of the need for a full evaluation of these treatments so that their black spot effectiveness (including their potential cost effectiveness at reducing road crashes) can be established.

7.1 TRADITIONAL APPROACHES TO SPEED CONTROL

Traditional approaches to speed control have emphasized the role of police enforcement (McMenomy, 1984; Vulcan, 1986; Road Traffic Authority, 1987). While this will always be an important and necessary approach to controlling vehicle speed in hazardous locations, the fact that a large number of motorists continually drive above the current speed limit suggests that it is not a totally sufficient means of speed control (cf., Mostyn and Sheppard, 1980; Cowley, 1980; Elliot, 1981; Sanderson and Corrigan, 1984; 1986; and Stiebel 1986). Moreover, findings by Hauer, Ahlin and Bowser (1982), Armour (1986) and Shinar and Stiebel (1986) have questioned the extent to which police enforcement generalizes much beyond the area of police presence.

Other researchers, therefore, have argued for alternative forms of speed enforcement (Klein and Waller, 1971; McLean, 1977; Hogg, 1977; Sabey, 1980; Elliot, 1981). Engineering the road and its immediate environment has been shown to have long-term effects on changing driving behaviour (Russam, 1979; Silcock and Walker, 1982; Parker and Tsuchiyama, 1985; Wright and Boyle, 1987). Thus, engineering countermeasures too have been introduced to make drivers slow down in particular hazardous locations.

7.1.1 **Local Area Traffic Management**

Engineering countermeasures against speed in residential streets and heavy traffic areas have tended to focus on Local Area Traffic Management devices (LATM). These measures usually employ a physical restriction on the road or in the travel path to force motorists to slow down or adopt a more desirable track. Examples of LATM devices include road humps, roundabouts, deviations and "neckings" in the travel lane, planter boxes, etc.

In many situations, these countermeasures have met with a degree of success. Webster and Schnerring (1986), for instance, reported a significant reduction in mean speed of 5km/h compared to a control precinct after installation of LATM devices on two residential streets in New South Wales.

The exact nature of the success of LATM devices, however, is not always immediately apparent. While measurements may reveal a drop in mean speed or an increase in travel time for a particular location after installation, they do not show the real reason for this effect. It may have occurred because of an overall reduction in speed by all vehicle users, or simply because the previous high speed deviant vehicles chose to use another route through that neighborhood after LATM was introduced (i.e., in statistical terms, a truncation rather than a downward shift in the overall speed distribution).

Some would argue that it really doesn't matter what caused the speed reduction at a particular location as the hazard has been eliminated for whatever reason. From a road system perspective, however, it is important to know whether the treatment has been effective or whether "accident migration" has occurred (where the problem at one hazardous location is shifted somewhere else in the road network). Moreover, the installation of physical barriers on the road can introduce an additional road hazards, where one type of crash is traded for another.

The introduction of any countermeasure can only be beneficial if it can be shown that there has been a resultant reduction in injury or damage for the total road network. Unfortunately, this evaluation procedure is often overlooked once the LATM device is installed.

7.2 PERCEPTUAL COUNTERMEASURES

More recently, there has been interest in developing road treatments aimed at changing undesirable travel behaviour that do not require building obstructions or barriers. These measures attempt to create perceptual conditions that will induce a particular desired change in behaviour by the driver (i.e., a speed reduction in this context), and are referred to as "perceptual countermeasures".

7.2.1 The Unobtrusive Nature of Perceptual Countermeasures

Unlike either of the other two methods of speed control discussed previously, perceptual countermeasures attempt to bring about a change in behaviour unobtrusively (i.e., without the driver being aware necessarily of any change in his or her behaviour).

This more subtle approach to speed control has several advantages over the traditional methods. First, by influencing the visual information on display to the driver, it is attempting to address the root of the problem. If drivers subconsciously perceive a particular road situation to be safe, then cognitive restrictions (involving conscious thought processes) are only likely to have a marginal effect on their behaviour. This is evident from the fact that police enforcement is only effective in "safe environments", for the most part, as long as the deterrent is obvious to the driver.

In addition, modifying the perceptual environment is less likely to annoy or frustrate the driver and, therefore, is more likely to be a long-term benefit. A change in the visual input to create an illusion of "less safe" will probably go by unnoticed and, therefore, not lead to "accident migration" by forcing speed deviants onto other roads. It could be argued that subtle changes to the road or the environment may be the only effective long-term means of influencing drivers who blatantly refuse to obey the law by driving at excessive speeds. In any event, removing restraints which people believe to be unnecessary should result in safer driving for the total driving population.

Finally, perceptual countermeasures, by definition, do not involve introducing additional hazards on the roads in the same way as LATM devices have in the past. Most of these treatments simply involve painted lines or additional plastic or gravel surfaces applied to the road surface to create the desired effect. Apart from the obvious road safety benefit, perceptual countermeasures are also likely to be relatively inexpensive, may be easier to justify in terms of cost/benefit effectiveness, and enable more treatments per budget than other methods.

7.2.2 **The Effectiveness of Perceptual Countermeasures**

It was argued that perceptual countermeasures are likely to be effective because they are aimed at modifying the relatively subconscious visual information arriving at the driver's eyes. While the evidence about visual perception processes is far from complete, it is worthwhile reviewing what is known about the perception of speed in humans.

There are only a limited number of studies that have attempted to explain how drivers perceive sensory information about speed from their environment. Early studies by Gibson (1950, 1958, 1968) and Calvert (1954) argued that a moving environment is coded on the retina of the eye as a pattern of blurred images, varying from zero blurring at the fovea (area of visual fixation) to maximum blurring at the extremities of the eye. The perception of speed, they claimed, is interpreted from analyzing the differences in relative velocity across the surface of the retina.

Other researchers, however, have criticized this rather simple direct account of speed perception (e.g., Johnston, White and Cummings, 1973; Regan and Beverley, 1978; 1982). These papers reported findings that could not be explained solely in terms of retinal streaming from a fixed point of expansion. They claimed that the visual processes associated with motion perception are more complex than those postulated earlier by Gibson.

Most authors reporting on visual perception in driving do agree that relative coding on the retinal surface of the eye is an extremely important cue for the perception of speed (Gibson and Crook, 1938; Gordon, 1966; Moore, 1968; Lee and Lishman, 1977; Harrington and Wilkins, 1980). It is the extent of the retinal streaming explanation, rather than the concept itself, that seems to be contentious.

Salvatore (1972) and Triggs (1986) suggested that the way velocity is sensed may be dependent upon the absolute level of speed. They proposed that slow speeds are perceived from successive static observations of changes in position, while fast speeds seem to be assessed relatively directly. This hypothesis is intuitively attractive but needs further development before it can be tested empirically. Moreover, a simple static/dynamic distinction has been criticized by other researchers interested in explaining the perception of movement in humans (Johansson, 1977; 1985; 1986; Warren & Shaw, 1985; Mace, 1985).

In any event, while retinal streaming may not be a totally sufficient explanation of the perception of speed, it does seem to explain many of the effects reported in this programme of research. In particular, it helps explain why the road surface is a primary cue for speed perception and how the immediate roadside environment can influence a driver's perception of speed.

7.2.3 **Limitations With Perceptual Countermeasures**

While perceptual countermeasures may have several advantages over other forms of speed control, it would be unrealistic to expect these treatments to solve all speeding problems on the road. The different findings between the perceptual results and the free speed measurements in Fildes et al (1987), as well as the study reported here, show the subtle relationships that exist between speed perception and behaviour and the likely limitations in the effectiveness of perceptual countermeasures. When drivers' perceptions of speed at particular road sites were in the "too slow" range of the response scale (i.e., drivers generally felt quite safe), free speeds at these road sites tended to be above the speed limit, but the pattern of the results was generally less sensitive to the effects of the independent variables. However, when perceptions were less safe (responses were in the "too fast" range of the scale), free speed differences almost mirrored the perceptual effects. This suggests that countermeasures aimed at reducing perception of safety may only be effective in reducing travel speed in environments that drivers' perceive to be unsafe.

7.3 SPEED PERCEPTION COUNTERMEASURES

In arriving at a list of potential perceptual countermeasures for speed, evidence was drawn from a range of sources including relevant literature reviews in this area, other studies that have evaluated the effectiveness of particular perceptual treatments on speed or driving performance, and local knowledge of measures that have been or are being contemplated for use in this country.

7.3.1 Transverse Road Markings

Perhaps the most well known and widely used perceptual road treatment to reduce vehicle speed at roundabouts and other intersections is the transverse line treatment used extensively in the U.K. Denton (1973) described the treatment as a series of contrasting lines painted across the road on the approach to a hazard that increase in frequency as the hazard approaches. The lines provide a systematic perceptual aid for drivers as they decelerate on approach to the roundabout or intersection (Denton, 1971). Figures 7.1 and 7.2 show some examples of this particular road treatment in the U.K. and more recently in Australia.

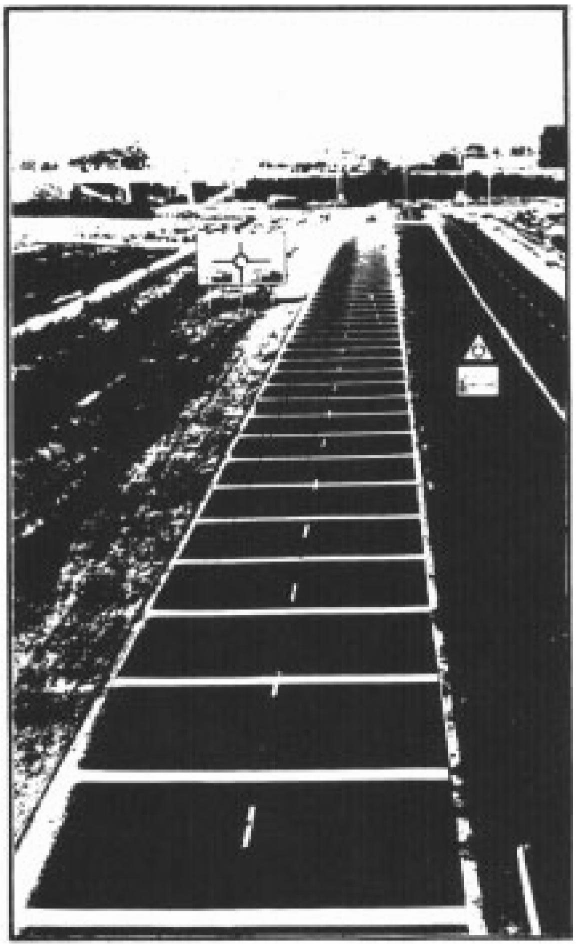


FIGURE 7.1 — Transverse line treatment at the approach to Windsor, England (Denton, 1973).

FIGURE 7.2 — Transverse line treatment using different road metal on the Northern Hwy., Victoria.

Several authors have attempted to evaluate the speed and crash consequences of these treatments. Denton (1973) reported reductions in mean travel speed of 23 percent and a 37 percent reduction in speed variance immediately after installation of the treatment. However, mean speed reductions subsequently fell to only 8 percent one year later, presumably because of a "novelty effect" with this treatment (Rutley, 1975).

Agent (1980) also found a large decrease in vehicle speed after transverse lines were installed at several hazardous locations in the USA, but he noted a subsequent increase in speed one year later (crashes, however, remained consistently lower, although he commented on interpretation problems due to central tendency effects and other statistical difficulties).

Havell (1983) reported a 10 percent reduction in mean vehicle speed one year after installation of transverse bars in the approach zone of a roundabout at Fountains Circle in Pretoria, South Africa. Unfortunately, though, none of these authors have followed up to test for speed reduction effects beyond 12 months.

Helliar-Symons (1981) examined the crash consequences of 42 transverse bar installations in the U.K. and claimed a decrease in speed related crashes of 57 percent over 4 years. Furthermore, he showed this treatment to be highly cost-beneficial. Silcock and Walker (1982) argued that crash reduction from bar markings was more apparent in the U.K. for access roads than in local streets. This finding, however, was deduced from other studies and did not involve collecting any new data.

7.3.2 **Transverse Markings with Rumble Bars**

More recently, visual treatments have been "enhanced" with rumble effects from the vehicles crossing these bars through the use of raised markers, varying grades of road metal, or road scoring procedures (Figure 7.2 shows one such combined treatment installation on the approach to a dangerous tee-intersection in rural Victoria).

Enustun (1972) evaluated a combination line and rumble bar installation on the approach to a freeway interchange in Michigan, USA. Using a series of contrasting plastic strips adhered to the road surface to provide the required visual and rumble effects, he reported an immediate drop in mean speed of 12km/h (-15%) which subsequently moderated to only 8km/h (-10%) one month after installation, without any change in before and after speed variation. He further claimed that this process was extremely durable to wear and tear (including snow plowing operations, with special precautions). Interestingly, though, when compared with the research reported earlier, this combination road treatment does not seem to have produced any additional speed reduction benefit over that of the lines alone.

7.3.3 **Lane Width Reductions**

If road surface has a primary role in drivers' perceptions of speed (as found in this programme of research), it seems logical to expect the width of the travel lane to have a strong influence on perception and travel speed. Indeed, the first stage of this speed perception research (Fildes, Fletcher and Corrigan, 1987) demonstrated that reduced lane width and number of lanes were generally associated with lower safe operating speed responses on urban and rural straight roads (and in some instances actual lower free speeds), although this result was often confounded with different classes of roads and varying speed limits.

McLean and Hoffman (1972) reported a change in driver steering behaviour from wide lanes (3.7m) at low speeds (42km/h) to narrow lanes (2.5m) at high speeds (80km/h) that they attributed to a perceptual difference in vehicle control for straight road driving for these different lane widths and vehicle speeds. In addition, they reported that shoulder width also influenced steering strategy (through perceptual differences apparently), although this was never evaluated in their research. There was some suggestion in Fildes et al (1987) that speed on wide divided urban and rural road pavements was perceived differently from that on equivalent narrow surfaces, although opposite to that predicted by McLean and Hoffman (1972).

Lum (1984) showed that duplicate longitudinal pavement markings with raised pavement markers set between them and the original lines to create an impression of a narrower residential street, had no effect on vehicle speed (see figure 7.3). They did, however, report a tendency for drivers to stay within narrow lanes (2.7m), but their conclusion that drivers' perceptions of road width remained unchanged was, at best, speculative using their methodology. It would be interesting to test this particular treatment more fully, especially its effect without a plain, wide verge area on the side of the road.

Vey and Ferreri (1968) reported lower speeds for 3m compared to 3.4m lane widths on two bridges in the USA. DeLuca (1985) also examined the effect of reducing lane width on an urban freeway in

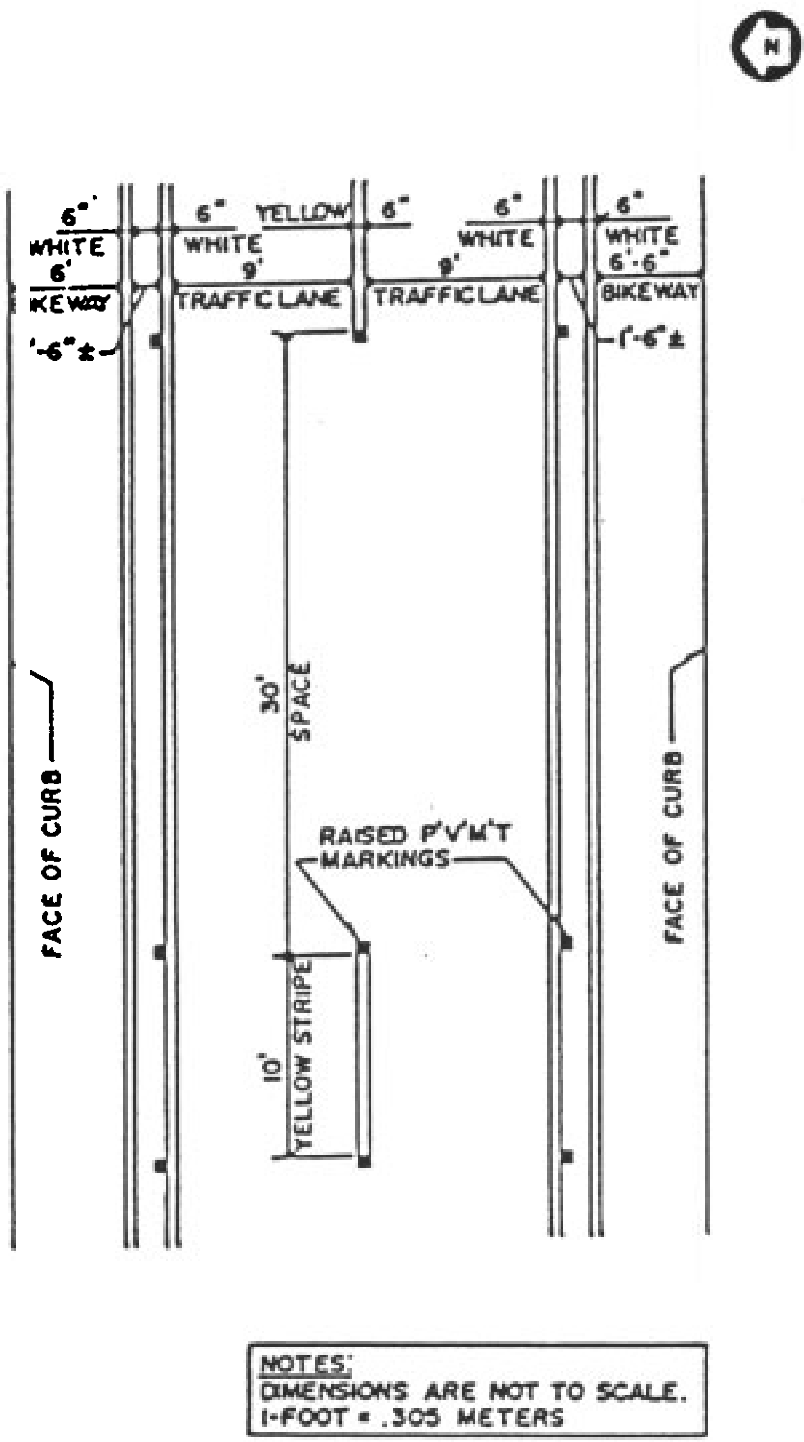


FIGURE 7.3 — Duplicate longitudinal pavement markings used at one residential road site by Lum (1984).

Miami from 3.7m to 3.4m. He reported no significant difference in vehicle capacity (presumably this meant similar vehicle speeds), but he did find subsequent crash improvements. Neither of these studies, though, assessed perceptual consequences directly.

7.3.4 Longitudinal Edgeline Treatments

Several studies have attempted to assess the effect of the presence or absence of standard edgeline treatments on the side of the road on vehicle speed, performance and road crashes. Witt and Hoyos (1976) found that edgelines in the approach zones of rural road curves resulted in drivers adopting a more suitable curve entry speed and travel path in a driving simulator. This difference, however, was dependent on the type of treatment, and the speed findings were not particularly robust. They noted that:

> "The question remains open as to whether the effect was due to the fact that the advance information directly influenced speed perception or whether the driver decoded the information and consciously selected a more appropriate speed."

Triggs and Wisdom (1979) and Triggs (1988) reported reliable differences in the pattern of lane-keeping and lateral position behaviour between matched road sections with and without centreline and edgeline treatments. Lines enabled drivers to maintain a more consistent travel path and safer travel strategy, especially at higher speeds. However, they did not test for observable differences in travel speeds across contrasting road conditions directly (travel speed was a control, rather than an independent, variable in this study).

Potter Industries (1981) argued that wide edgelines in the USA, W. Germany and England systematically reduced road crashes in these countries, particularly those crashes involving drinking drivers. However, most of their evidence was derived from other studies, some of which are unavailable. Johnston (1983) also reported a perceptual advantage for wide edgelines in conjunction with chevron signs on rural curves for drinking drivers. However, neither of these two studies reported specifically on the speed consequences of variable edgeline types.

Willis, Scott and Barnes (1984) applied solid and broken edgelines on two hazardous sections of roads in south-west England. They found a significant reduction in the number of single vehicle loss of control crashes (especially in dry weather) but less impressive reductions in other crash types. Unfortunately, they didn't evaluate the perceptual or performance effects of these treatments in their study either.

7.3.5 **Lateral Edgeline Treatments**

A number of investigators have examined the effects of novel painted treatments to the edges and shoulders of straight and curved roads.

Parker and Tsuchiyama (1985) reported on the effects of several edge-of-the-road treatment evaluations by other researchers. In particular, they noted the use of a herringbone pavement marking pattern of decreasing frequency in the approach to a roadside hazard which they claimed resulted in a reduction of mean travel speed (although no reduction in speed variance). Figure 7.4 illustrates the herringbone pavement marking system listed in this report (unfortunately, the reference to the original source of this treatment is not clear from this report).

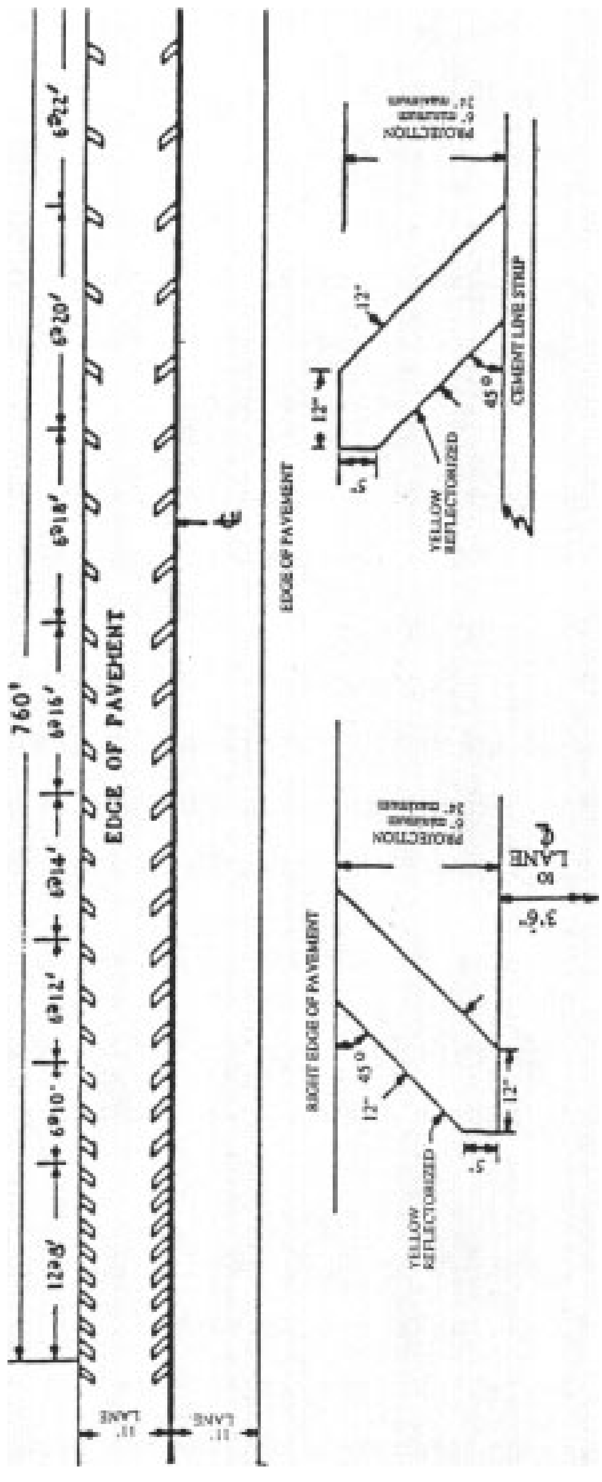


FIGURE 7.4 — Herringbone pavement markings used to create a more desirable deceleration pattern on the approach to a road, hazard (source reference not known).

Rockwell, Malecki and Shinar (1975) applied a painted line treatment to the inside edge of a rural road curve to increase apparent curvature by increasing the inside perspective angle presented to drivers on their approach to the curve (see Figure 7.5). This treatment resulted in speed reductions in the approach zone of the curve but not in the curve itself. However, they did note significant reductions in speed variance for all vehicles negotiating the curve as a result of this treatment. Their evaluation unfortunately did not extend beyond 30 days after the treatment was applied.

In a later report, Rockwell and Hungerford (1979) also reported the effects of applying a modified form of transverse striping to the outside lane only of a two-way rural road curve for up to 30 days after application (see Figure 7.6). They found that this treatment caused a marked reduction in approach speed and curve negotiation speed for the full evaluation period and attribute this to a modification in curve perception.

Emmerson and West (1985) applied shoulder rumble strips on the approach zone of a number of bridges on two Oklahoma turnpikes. This treatment consisted of 3m long, high contrast concrete bars, 15cm x 3cm sections, applied to the sealed shoulder region of the road surface to provide a visual and auditory warning for drivers as they approached these narrow bridges. They reported a reduction of up to 56 percent in the numbers of crashes at these sites over a 4 years before and 4 years after time period, which yielded an average benefit/cost ratio of between 29:1 and 73:1. Unfortunately, they failed to report speed differences before and after at these sites so it is difficult to know whether these crash improvements may have had a perceptual basis.

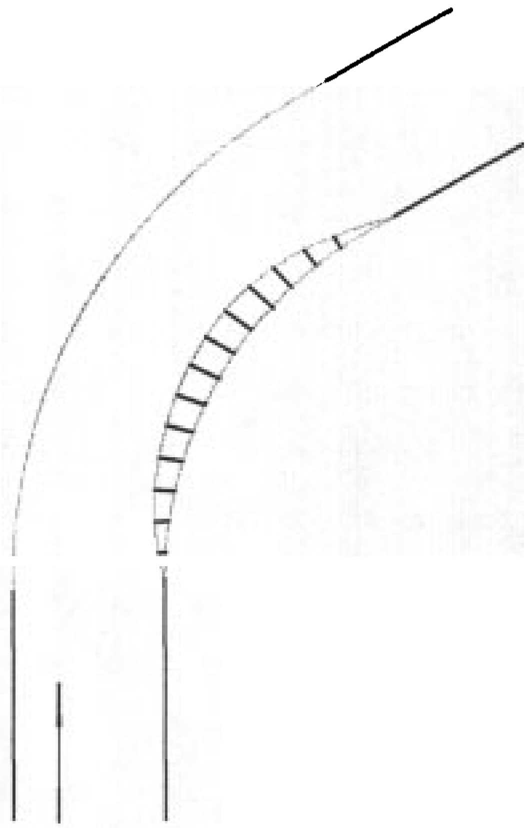


FIGURE 7.5 — Inside perspective angle treatment (Rockwell, Malecki and Shinar, 1975).

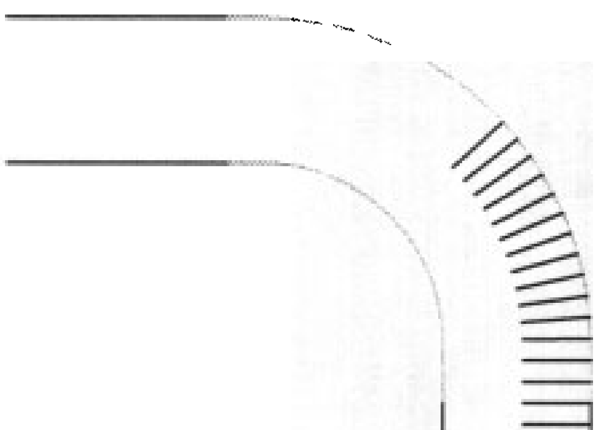


FIGURE 7.6 — Transverse striping of a rural road curve (Rockwell and Hungerford, 1979).

7.3.6 **Guideposts and Chevron Signs**

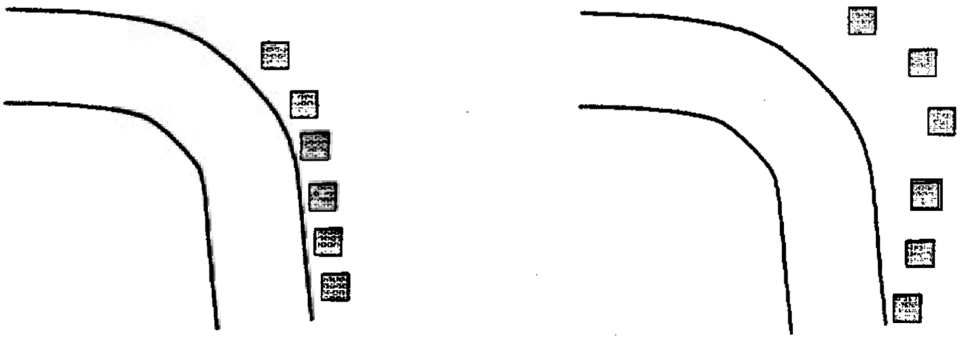
Hungerford and Rockwell (1980) attempted to modify drivers' behaviour at rural road curves by the use of novel guidepost and chevron sign delineation systems. At 2 rural road curves, they varied the height of post delineators from ground level to 10 feet high from the approach to the exit positions and also manipulated the perceived radius of the curve by relocating the guideposts to appear to give the appearance of a tighter radius road curve. Large chevrons were also applied at an additional 2 road curve sites (Figure 7.7 shows the various treatments adopted at these curves).

Their results showed reduced vehicle velocities (especially for high speed vehicles) for the the novel guidepost system at night immediately after installation, but there were no significant speed benefits for chevron signs. These speed differentials, however, were not apparent during the day and were not tested beyond 1 month after installation.

7.3.7 **Special Road Treatments**

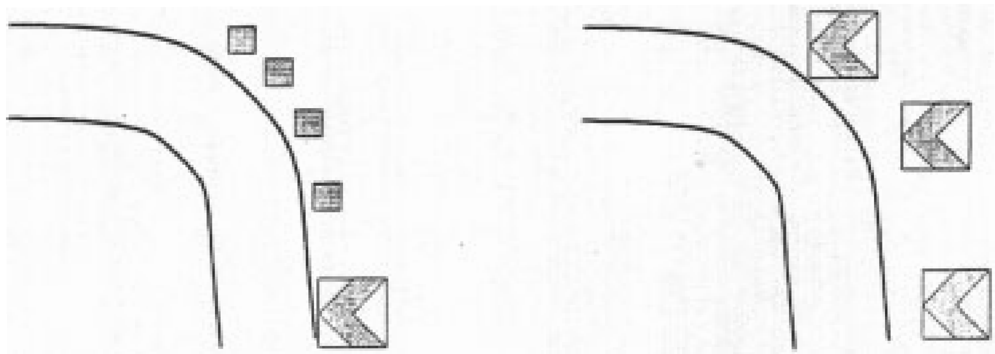
The South Melbourne City Council in Victoria have recently been experimenting with various perceptual road treatments as an alternative crash countermeasure to L.A.T.M. devices.

One measure that has been used in several locations, includes a road marking system comprising a white gravel median strip and a one metre hatched edgeline marking (in conjunction with solid edgelines) to create a perceptually narrow road surface and travel lane. Figure 7.8 shows an example of this particular treatment.



Six (6) standard delineators

Six (6) standard delineators arranged in increasing height & distance from berm



One (1) large chevron followed by four (4) carsonite delineators

Three (3) large chevron delineators

FIGURE 7.7 — Various guidepost and chevron arrangements evaluated by Hungerford and Rockwell (1980).

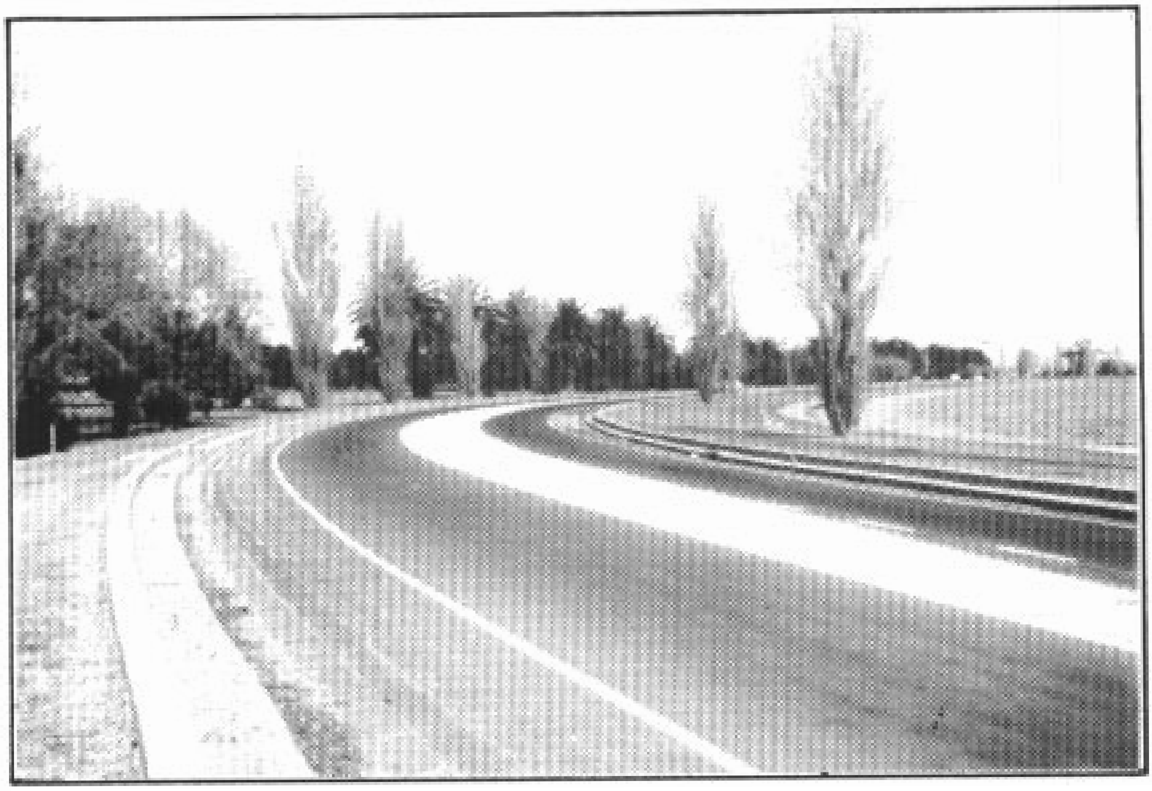


FIGURE 7.8 — Median and edge treatment on Lakeside Drive, Albert Park.

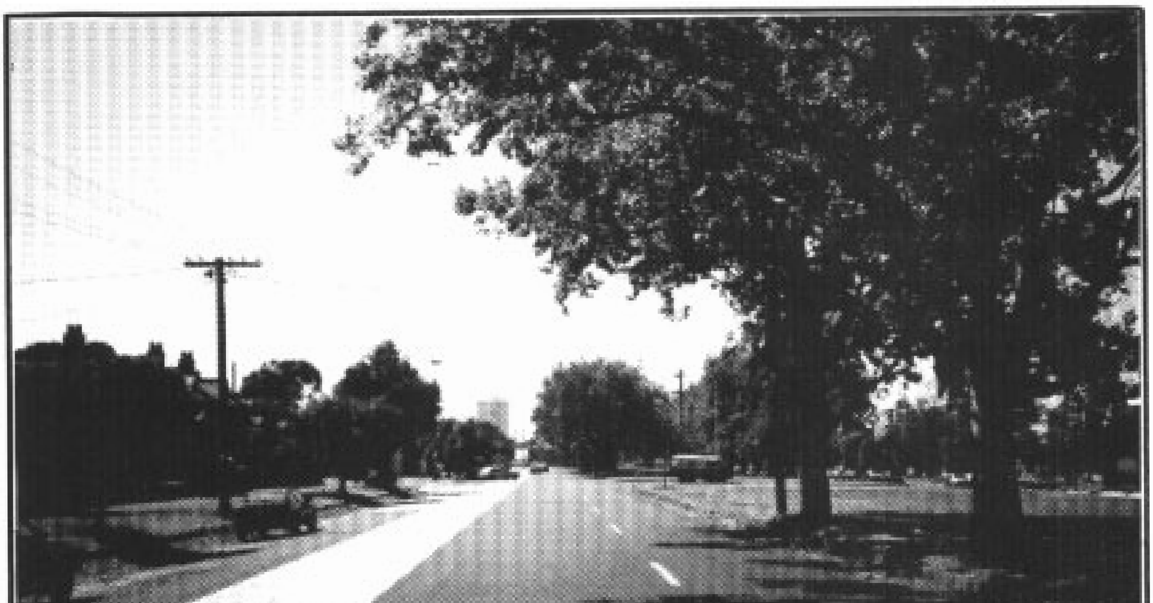


FIGURE 7.9 — Perceptual narrowing treatment applied on Kerford Road, South Melbourne.

As a part of this project in speed perception, a simple before and after speed study was performed recently at a new installation using a variation of this treatment on Kerford Road, South Melbourne, Victoria, and the results are listed in the Appendix D to this report. The treatment consisted of a white gravel perceptual separation strip and associated edgeline markings being applied between the moving and parked vehicles (which was also used as a bike path on occasions). This separation strip effectively reduced the travel lane width from 5.0m to 3.7m. Corner bollards and bluestone paving at the intersections were also added, subsequent to the after-installation speed observations (see Figure 7.9).

The major finding of this study was a reduction in free speeds of 3km/h after treatment installation with no appreciable change in traffic volume. Control sites had no reductions in free speeds over the same period. It was not possible to evaluate the perceptual effect of this road treatment on drivers' speed judgments, unfortunately, because of time constraints. This result, therefore, needs to be tested further to demonstrate its long-term speed perception and road crash effectiveness.

Nevertheless, this simple evaluation demonstrates the potential for this particular road treatment to reduce vehicle speed in these locations. Moreover, the results generally support many of the previous findings on lane width reductions and edge-of-the-road treatments. As the treatment cost is minimal compared to other physical speed management devices, it further suggests that reducing vehicle speeds through perceptual treatments at hazardous locations may be particularly cost-effective.

7.3.8 **Road Signs**

The final category of delineation treatments likely to induce a reduction in speed perception includes advisory speed signs and other dynamic sign systems. While some of these devices tend to require a deliberate conscious decision about travel speed rather than to influence speed perception automatically[1], they have been included here nevertheless for completeness.

Summala and Hietamaki (1984) reported on the speed consequences of an extensive experimental road curve sign programme, advising motorists of either impeding danger, children crossing, or an advisory speed limit of 30km/h. They found reliable speed reductions to all signs, depending to some degree on the position of observation before the curve. However, they noted greater speed reductions for danger and children signs than speed reduction signs which they classified as "more significant" to the drivers involved.

They argued that the effectiveness of road signs at reducing speed was dependent, therefore, upon motivational factors of the drivers involved (Summala and Naatanen, 1974; Summala and Hietamaki, 1984), a view shared by other researchers in sign perception (e.g., Hughes and Cole, 1984).

Koziol and Mengert (1978) conducted a before and after study to evaluate the effectiveness of "dynamic sign systems" to alert motorists to the presence of narrow bridges on two lane rural highways in the USA. Of the four sign systems tested, they found

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[1] This research programme here was confined to speed perception at a basic sensory level, excluding higher cognitive levels of human information processing (see Fildes et al 1987, pp 9-10).

that a strobe light sign combination reduced mean vehicle speed by 3km/h during the day while a flashing beacon sign combination had a similar effect on vehicle speeds at night. None of the other signs had a significant speed effect over the existing standard static sign and there were no appreciable differences in lateral position for any of the four signs tested.

While the precise nature of the perceptual influence they were measuring is unclear, they noted that signs were not as effective on driver behaviour in their study as the presence of opposing vehicles or roadway geometry.

7.3.9 **Summary of Treatment Effects**

The review of the effects of potential speed perception countermeasures is summarized in Table 7.1 and the following discussion:

1. Transverse road markings appear to have had a significant long-lasting influence on driver's perceptions of speed and road crashes at hazardous intersections and roundabouts. The addition of rumble bar effects at these locations does not appear to have any additional perceptual or behavioral benefit over just the lines themselves.

2. There seems to be some evidence of speed and crash reductions benefits from reduced travel lane widths, but the effects may be dependent upon the lane widths and class of road involved. It seems that travel lanes of 3.0m or less are necessary to induce sufficient perceptual effects to ensure free speed reductions on the road.

TABLE 7.1
SUMMARY OF REPORTED EFFECTS
SPEED PERCEPTION COUNTERMEASURES

TREATMENT	INSTALLATIONS	REPORTED PERFORMANCE EFFECTS	REPORTED SAFETY EFFECTS
1. Transverse lines	urban & rural roundabouts, curves, dangerous bridges	speed reductions & improved lane travel	crash reductions
2. Trans. lines + bars	rural intersection and a freeway interchange	speed reduction	unknown
3. Lane width reductions	urban & rural straight roads, residential streets, bridges	speed reduction ? better lane keeping improved steering	crash reductions
4. Longitudinal edgelines	rural curves & straight roads	minor speed reductions better lane keeping	crash reductions (esp. drink drivers)
5. Lateral edgeline treat.	approaching road hazards, dangerous curves, bridges	speed reductions (before & during curve) bridges unknown	crash reductions at bridges.
6. Guideposts & chevrons	rural curves	speed reductions for posts at night but no effect for chevrons	unknown
7. Special treatments	urban residential streets and arterials	speed reductions	crash reductions ?
8. Road signs	residential streets, rural highways & bridges	some speed reductions	unknown

3. A slight perceptual advantage in speed perception may be gained from the presence of both centreline and edgeline treatments on the road. Standard edgelines, however, seem less likely to produce significant reductions in travel speed and road crashes than other kinds of road surface treatments.

4. Transverse striping on the edges and shoulder regions of the road may have a positive influence on vehicle speeds at specific hazardous locations. The approach zones of dangerous curves seem especially suited for this treatment. Rumble bars may have an added advantage in some cases, although their full effects need to be established further in the perception of speed on the road.

5. There seems to be potential for novel guidepost arrangements to influence speed perception and road crashes on rural curves that are particularly hazardous at night.

6. Special road treatments, such as the white gravel median with edgeline marking, have potential for reducing travel speed in some locations. The full perceptual effects of this treatment, however, need to be tested further.

7. While signs may have a marginal effect at reducing vehicle speeds in some locations, they seem dependent on a driver's motivation and expectation and the 'element of surprise'. These are hardly desirable characteristics for any long-term benefits in the perception of speed.

8. There was some evidence that reducing vehicle speeds through perceptual treatments at hazardous locations may be particularly cost-beneficial.

7.4 IMPLEMENTATION AND EVALUATION

So far, the discussion has centered on perceptual countermeasures as an alternative means of speed control. A range of countermeasures likely to influence speed perception in certain locations was also compiled. The final section in this chapter deals with the need for these treatments to be installed and tested, including the need for a full evaluation of their potential cost-effectiveness.

7.4.1 Countermeasure Selection

In discussing the identification of hazardous road locations, Sanderson, Cameron and Fildes (1985) pointed out that there is a general lack of definitive documents on how to treat hazardous locations. The reports that are currently available tend to be derivatives of each other and there is little evidence of a single accepted procedure for implementing and evaluating hazardous countermeasures in general.

Moreover, they found that many of the authorities in Australia responsible for implementing hazardous countermeasures, tend to rely on "professional judgment" and "past experience" in the selection of suitable countermeasures. This was not meant as a criticism of engineers responsible for reducing roadside hazards, but rather to highlight the lack of objective information available to them when making their judgments.

What is required then, they argued, is a formalized research programme, listing suitable countermeasures that are available for treating particular hazardous road situations, computations on the potential cost effectiveness of each countermeasure (in terms of benefit cost ratios), and a method for evaluating the effectiveness of countermeasures employed at various locations. In particular, evaluation criteria and implementation priorities would be most helpful for practitioners in the field.

7.4.2 The Next Step For Perceptual Countermeasures

To help satisfy this need and show the desirability of perceptual countermeasures for reducing speed and road crashes, a range of measures could be installed at suitable hazardous locations to test their potential for black spot improvement. These sites would need to be matched with control sites and several different before- and after-installation evaluations would need to be carried out to test these effects fully. A methodology for this research is detailed below.

1. **Perceptual Measurement** - an assessment of the perceptual consequences of these treatments at these sites would need to be carried out initially to ensure that the proposed measures do influence speed perception at the installations nominated and that there are no negative side effects from these treatment/site combinations. The method of testing drivers' perceptions developed in this program of research would be suitable for this first stage evaluation.

2. **Performance Measurement** - an assessment of the performance effects would also be required 'before' and 'after' installation. This should include a range of measures such as vehicle speeds and lateral position (at several critical site positions), and volumes and type of vehicles using the sites. Traffic movements throughout a particular region would also need to be monitored for changes in the pattern of vehicle movements, brought about by

the introduction of these measures. The evaluation period would need to be over 1 or 2 years with measurements immediately after installation, 1 month after, and then 12 months and 24 months later. Even longer effects would be desirable but not practical.

3. **Road Crash Consequences** - a 'before' and 'after' crash analysis would also be necessary to show the potential road safety benefits from the introduction of these measures. As there is a general tendency for "regression to the mean" at high accident locations, several control and experimental sites would be preferable and this analysis should extend over a considerably longer time period than that required for the other evaluations.

4. **Cost & Benefit Analysis** - a detailed cost/benefit analysis of the potential savings from the introduction of these treatments would be the final stage of the evaluation. The benefits could be determined from the potential savings in road crashes from the previous analysis, while costs would need to cover installation, maintenance, and any other intangible charges over the same period used to measure crash benefits.

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SITE NUMBER	SITE DESCRIPTION	AREA	ROAD CATEGORY	SPEED LIMIT	FREE SPEED (kph) (mean / 85%)	FREE SPEED (std dev)	SEAL WIDTH (m)	LANE WIDTH (m)	ROADSIDE ENVIRONMENT	SHOULDER WIDTH	SIGHT DISTANCE
1	Western Freeway, Ballan 255 D1*	rural	4-lane Divided, (Freeway)	110kph	107.2/ 112	9.3	7.4	3.7	spacious - open farming	4.0m	>800m
2	South Gippsland Hwy., Kooweerup 256 R7	rural	4-lane Divided	100kph	102.3/ 115	12.3	7.3	3.65	spacious - open farming	16.0m	>800m
3	Princes Freeway, (Geelong Rd.) Werribee 255 H4	rural	4-lane Divided, (Freeway)	110kph	105.8/ 116.8	10.6	7.5	3.75	walled - treed	3.0m	>800m
4	Western Freeway, Pykes Creek 255 E1	rural	4-lane Divided, (Freeway)	110kph	101.1/ 114	12.4	7.4	3.7	walled - cutting	3.0m	>800m
5	Calder Highway, Kyneton 253 F9	rural	2-lane Undivided	100kph	100.8/ 111	9.9	7.4	3.7	spacious - open farming	3.0m	>800m
6	Ballan-Daylesford Rd. Ballan 253 D12	rural	2-lane Undivided	100kph	98.0/ 111	13.2	7.4	3.7	spacious - open farming	4.0m	>800m
7	South Gippsland Hwy., The Gurdies 256 R9	rural	2-lane Undivided	100kph	96.7/ 108	10.8	7.4	3.7	walled - treed	4.5m	>800m
8	Trentham Road, Daylesford 253 D10	rural	2-lane Undivided	100kph	87.1/ 101	13.9	7.4	3.7	walled - forest	2.0m	>800m
9	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	spacious - open farming	3.0m	>600m
10	Hoppers Lane, Werribee 206 H5	rural	2-lane Gravel	75kph	67.2/ 80	11.8	7.5	3.75	spacious - open farming	6.0m	> 600m
11	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - treed	3.0m	> 600m
12	Reef Hills Road, Benalla 254 U1	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - forest	1.4m	>600m

*Map references from MELWAY - GREATER MELBOURNE, edition N°. 17, 1987.

APPENDIX A - 2

DAY/NIGHT STUDY - 12 RURAL STRAIGHT ROADS - NIGHT VISION.

SITE NUMBER	SITE DESCRIPTION	AREA	ROAD CATEGORY	SPEED LIMIT	FREE SPEED (kph) (mean / 85%)	FREE SPEED (std dev)	SEAL WIDTH (m)	LANE WIDTH (m)	ROADSIDE ENVIRONMENT	SHOULDER WIDTH	SIGHT DISTANCE
1	Western Freeway, Ballan 255 D1*	rural	4-lane Divided, (Freeway)	110kph	104.1/ 116	11.09	7.4	3.7	spacious - open farming	4.0m	
2	South Gippsland Hwy., Kooweerup 256 R7	rural	4-lane Divided	100kph	100.7/ 112	11.88	7.3	3.65	spacious - open farming	16.0m	
3	Princes Freeway, (Geelong Rd.) Werribee 255 H4	rural	4-lane Divided (Freeway)	110kph	104.7/ 111	9.69	7.5	3.75	walled - treed	3.0m	
4	Western Freeway, Pykes Creek 255 E1	rural	4-lane Divided, (Freeway)	110kph	109.3/ 123	14.27	7.4	3.7	walled - cutting	3.0m	
5	Calder Highway, Kyneton 253 F9	rural	2-lane Undivided	100kph	99.0/ 112	10.82	7.4	3.7	spacious - open farming	3.0m	
6	Ballan-Daylesford Rd. Ballan 253 D12	rural	2-lane Undivided	100kph	95.9/ 105	11.06	7.4	3.7	spacious - open farming	4.0m	
7	South Gippsland Hwy., The Gurdies 256 R9	rural	2-lane Undivided	100kph	93.7/ 104	8.66	7.4	3.7	walled - treed	4.5m	
8	Trentham Road, Daylesford 253 D10	rural	2-lane Undivided	100kph	89.6/ 103	13.03	7.4	3.7	walled - forest	2.0m	
9	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	spacious - open farming	3.0m	
10	Hoppers Lane, Werribee 206 H5	rural	2-lane Gravel	75kph	-	-	7.5	3.75	spacious - open farming	6.0m	
11	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - treed	3.0m	
12	Reef Hills Road, Benalla 254 U1	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - forest	1.4m	

*Map references from MELWAY - GREATER MELBOURNE, EDITION N^{o}. 17, 1987.

APPENDIX A - 3

RURAL SITES USED IN THE CURVATURE VALIDATION STUDY.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROAD/LANE CATEGORY	ROADSIDE GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH	ROAD LANE WIDTH	SHOULDER WIDTH	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE 5 SEC INTO CURVE.	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
1	2-lane	vertical curve (crest)	LYSTERFIELD Wellington Road Before Cornish Rd. 82 J3*	7.4m	3.7m	3m	walled (treed)	50m	100	84.36	94	9.55
2	2-lane	vertical curve (sag)	LYSTERFIELD Wellington Road After Lysterfield Rd. 83 F5	7.4m	3.7m	4m	walled (treed)	800m	100	87.66	98	10.23
3	2-lane	horiz. LH-curve (flat)	NARRE WARREN EAST Wellington Road After Edebohls Rd. 84 K12	7.4m	3.7m	3m	walled (treed)	120m	100	92.29	103	9.96
4	2-lane	horiz. LH-curve (flat)	CARDINIA Reservoir Wellington Road 126 C10	7.4m	3.7m	4m	spacious	500m	100	86.29	94	8.54
5	2-lane	horiz. LH-curve (flat)	CARDINIA RESERVOIR Wellington Road. 126 E6 After Aura Vale Rd.	7.4m	3.7m	4m	walled (cutting)	200m	100	93.62	103	9.12
6	2-lane	horiz. RH-curve (flat)	CARDINIA RESERVOIR Wellington Road 126 E7 Before Aura Vale Rd.	7.4m	3.7m	4m	walled (cutting)	200m	100	91.34	99	9.91
7	2-lane	horiz. RH-curve (flat)	CARDINIA RESERVOIR Wellington Road After Aura Vale Rd. 126 B9	7.4m	3.7m	5m	spacious	500m	100	91.55	100	8.95
8	2-lane	vertical curve (crest)	NARRE WARREN EAST Wellington Road 84 D10 After Hallam-Belgrave Rd.	7.4m	3.7m	4m	walled (treed)	75m	100	79.94	91	8.86
9	2-lane	horiz. RH-curve (flat)	LYSTERFIELD Wellington Road After Ryans Rd. 83 J8	7.4m	3.7m	3m	walled (treed-cutting)	120m	100	91.32	100	8.66
10	2-lane	vertical curve (sag)	LYSTERFIELD Wellington Road Before Glen Rd. 73 H10/11	7.4m	3.7m	4m	walled (treed)	500m	100	86.03	97	11.97
11	2-lane	vertical curve (sag)	FERNTREE GULLY Napolean Road 73 H10/11 After Kelletts Rd.	7.4m	3.7m	4m	spacious	500m	100	79.51	88	7.50
12	2-lane	vertical curve (crest)	FERNTREE GULLY Napolean Road 73 K8/9 Before Blackwood Pk. Rd.	7.4m	3.7m	4m	spacious	50m	100	86.32	95	10.22

*Map references from MELWAY-GREATER MELBOURNE, EDITION N^{o}. 17, 1987.

APPENDIX A - 4

LARGE RADIUS, DIVIDED ROADS - HORIZONTAL SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
1	spacious	LH R=1040	Sth. Gippsland Hwy., (Phillip Is. bound) Tooradin 144 E4*	7.4	3.7	10	ing tri	550	100	94.3	105	1[illegible]22
2	spacious	LH R=1720	Western Hwy., (Ballan bound) Ballan 253 D12	7.6	3.8	25	orchard	700	110	102 1	110	8.84
3	spacious	RH R= 1160	Sth. Gippsland Hwy., (After Rawlins Rd.) Cranbourne 138 F3	7.4	3.7	5	open farming (median strip)	550	100	98.2	108	10.86
4	spacious	RH R=1720	Western Highway, (Melbourne bound) Ballan 253 D12	7.6	3.8	25	orchard	700	110	101.[illegible]	1[illegible]0	9.36
5	walled	LH R=1160	Princes Highway, East of Deep Crk., (Melbourne bound) Pakenham 256 R6	7.6	3.7	5	cutting	350	110	95.0	105	10.59
6	walled	LH R=1200	Hume Highway (M40) Wallan 254 L11	7.5	3.75		cutting	400	110	100.2	112	11.23
7	walled	RH R=1040	Hume Highway (M80) Broadford 254 M8	7.5	3.75	5	treed	350	110	101.6	109	8.60
8	walled	RH R=1040	Hume Highway (M107) Avenel 254 N5	7.5	3.75	3.5	shrubs/trees	350	110	99.5	109	8.81

R= curve radius LH= left hand RH= right hand *Map references from MELWAY - GREATER MELBOURNE, EDITION N^{O}. 17, 1987.

SMALL RADIUS, DIVIDED ROADS- HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	S ULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
9	spacious	LH R=575	Sth. Gippsland Hwy., *Before M^cDonalds Rd.* (Phillip Is. bound) Koo Wee Rup 256 R7	7.4	3.7	10	open farming *(median strip)*	400	100	98.4	110	11.43
10	spacious	LH R= 750	Western Hwy. (M50) (Ballarat bound) Baccus Marsh 216A D1	7.6	3.8	20	crops/farming	450	110	97.5	106	8.94
11	spacious	RH R=720	Sth. Gippsland Hwy., *(Dandenong bound)* Koo Wee Rup 256 R7	7.4	3.7	10	open farming (median strip)	450	100	97.2	106	9.51
12	spacious	RH R= 760	Princes Hwy. (Melb. bound) W. of Morwell 252 A11	7.4	3.7	10	grazing	450	110	98.6	106	8.21
13	walled	LH R=650	Princes Hwy. East of Gumscrub Crk. Officer 215 B5	7.4	3.7	5	treed	400	100	97.1	105	9.39
14	walled	LH R= 580	Princes Hwy. (Melb. bound) before Moe-Newbgh. 252 A11	7.4	3.7	4	cutting	400	110	97.4	105	9.00
15	walled	RH R= 480	Princes Hwy. (Melb. bound) East of Kennedy Crk. Pakenham 256 R6	7.4	3.7	3	treed	450	100	90.6	99	8.37
16	walled	RH R=500	Sth. Gippsland Hwy., btw. Abbotts-Knowles Rds. (Dand. bound) Lyndhurst 96 AB	7.4	3.7	5	treed	350	100	99.0	111	12.35

APPENDIX A - 6

LARGE RADUIS, 2-LANE ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
17	spacious	LH R=870	Midland Hwy. (South bound) Sth. of Morwell 252 A11	7.6	3.8	20	grazing	200	100	98.0	106	11.76
18	spacious	LH R= 750	Northern Hwy. (M156) Near Belt Road Runnymede 253 H1	7.4	3.7	5	grazing	650	100	90.9	99	8.92
19	spacious	RH R= 1100	Midland Hwy. (South bound) South of Morwell 252 A11	7.6	3.8	20	grazing	200	100	97.0	105	8.56
20	spacious	RH R= 870	Midland Hwy. (North bound) South of Morwell 252 A11	7.6	3.8	20	grazing	200	100	96.6	109	11.86
21	walled	LH R= 720	Wellington Road After Aura Vale Rd. Menzies Crk. 126 F7	7.4	3.7	3.5	cutting	200	100	93.6	103	9.12
22	walled	LH R= 650	Bass Hwy. Before Ullathorne Rd. Inverloch 256 S12	7.0	3.5	5.5	treed	200	100	82.5	92	8.83
23	walled	RH R= 720	Wellington Road Before Aura Vale Rd. Menzies Crk. 126 F7	7.4	3.7	3.5	cutting	200	100	91.3	99	9.91
24	walled	RH R=650	Bass Highway Before Ullathorne Rd. Inverloch 256 S12	7.0	3.5	5.5	treed	200	100	88.5	98	9.00

APPENDIX A - 7

SMALL RADIUS, 2-LANE ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
25	spacious	LH R=400	Maroondah Hwy. Near Growlers Gully Rd Merton 254 T6	7.4	7	6	grazing	350	100	97.6	106	9.89
26	spacious	LH R=480	Melba Hwy. Near Devlins Bridge. Glenmore Prop. 254 Q10	7.4	3.7	8	grazing	400	100	94.5	104	9.02
27	spacious	RH R=400	Maroondah Hwy. Near Growlers Gully Rd. Merton 254 T6	7.4	3.7	6	grazing	350	100	96.6	103	9.53
28	spacious	RH R=450	Maroondah Hwy. Near Kubeils Road Woodfield 254 T6	7.4	3.7	5	grazing	400	100	92 1	102	9.85
29	walled	LH R= 360	Melba Hwy. After Kinglake Road Mt. Slide 254 Q11	7.4	3.7	2.5	heavily t eed	200	100		-	
30	walled	LH R=450	Goulbourn Valley Hwy. Near Native Dog Crk. Yea 254 R8	7.4	3.7	3.5	cutting	250	100	102.0	112	9.39
31	walled	RH R=360	Melba Hwy. After Kinglake Road Mt. Slide 254 Q11	7.4	3.7	2.5	heavily treed	200	100	-	-	-
32	walled	RH R=450	Goulbourn Valley Hwy. Near Native Dog Crk. Yea 254 R8	7.4	3.7	3.5	cutting	250	100	94.2	106	9.43

APPENDIX A - 8

LARGE RADIUS, GRAVEL ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
33	spacious	LH R=300	EDE Track (2-way) Monegeeta 253 J10	8.5	4.25	10+	farming	300	75	-	-	-
34	spacious	LH R=260	Colbinabbin - Lake Cooper Road, Colbinabbin 253 J1	7.1	3.55	10	grazing	300	75	-	-	-
35	spacious	RH R=300	EDE Track (2-way) Monegeeta 253 J10	8.5	4.25	10+	farming	300	75	-	-	-
36	spacious	RH R=260	Colbinabbin - Lake Cooper Road, Colbinabbin 253 J1	7.1	3.55	10	grazing	300	75	-	-	-
37	walled	LH R=540	Whroo-Nagambie Rd. Reedy Lake 254 M3	7.5	3.75	2	light forest	250	75	-	-	-
38	walled	LH R=250	Cumberland-Woods Pt. Road. (W59) Cumberland 254 V12	7.1	3.55	2	forest	150	75	-	-	-
39	walled	RH R=540	Whroo-Nagambie Rd. Reedy Lake 254 M3	7.5	3.75	2	light forest	250	75	-	-	-
40	walled	RH R=250	Cumberland-Woods Pt. Road. (W59) Cumberland 254 V12	7.1	3.55	2	forest	150	75	-	-	-

SMALL RADIUS, GRAVEL ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SP ED L			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
41	spacious	LH R=160	Colbinabbin-Lake Cooper Road Colbinabbin 253 J1	7.1	3.55	7	grazing	200	75	-	-	-
42	spacious	LH R=140	EDE Track (Riddells Rd) Monegeeta 253 J10	7.0	3.5	10+	grazing	200	75	-	-	-
43	spacious	RH R=160	Colbinabbin-Lake Cooper Road Colbinabbin 253 J1	7.1	3.55	7	grazing	200	75	-	-	-
44	spacious	RH R=140	EDE Track (Riddells Rd) Monegeeta 253 J10	7.0	3.5	10+	grazing	200	75	-	-	-
45	walled	LH R=180	Reef Hills Road Benalla 254 V1	7.4	3.7	3	forest	200	75	-	-	-
46	walled	LH R=190	Watts Rd. Off River-View Drive Shepparton 251 J6	7.5	3.75	2	forest	200	75	-	-	-
47	walled	RH R= 180	Reef Hills Road Benalla 254 V1	7.4	3.7	3	fore t	200	75		-	-
48	walled	RH R=190	Watts Rd. Off River-View Drive Shepparton 251 J6	7.5	3.75	2	fore t	200	75		-	-

APPENDIX A - 10

LABORATORY VALIDATION STUDY

CLOSE FOLLOWING TEST SITES.

SITE NUMBER	SITE DESCRIPTION	AREA	ROAD CATEGORY	SPEED LIMIT (kph)	FREE SPEED (kph) (means / 85%)	FREE SPEED (std dev)	SEAL WIDTH (m)	LANE WIDTH (m)	ROADSIDE ENVIRONMENT	SHOULDER WIDTH	SIGHT DISTANCE
1	Dandenong 90 H3	semi - rural	4-lane Divided Arterial.	75	74.8/ 84	9.5	7.4	3.7	spacious - grazing land	5.0m	500m
2	Mulgrave Freeway, Dandenong 91 A6	semi - rural	4-lane Urban Freeway.	110	97 / 105	8.0	7.4	3.7	walled - treed	3.0m	1000m
3	Thompson Road, Cranbourne 129 K10	Rural	2-lane Undivided Collector.	100	84.2/ 93	9.6	7.4	3.7	spacious - market gardens	2.5m	1000m
4	Narre Warren-Cranbourne Road, Cranbourne 130 B12	Rural	2-lane Gravel Collector.	75	62.9/ 74	10.3	7.2	3.6	spacious - open paddocks	5.0m	1000m
5	Narre Warren-Cranbourne Road, Cranbourne 134 B1	semi - rural	2-lane Gravel Collector.	75	62.3/ 72	10.4	7.2	3.6	walled - treed	2.5m	500m
6	Narre Warren-Cranbourne Road, Cranbourne 134 B1	semi - rural	2-lane Gravel Collector.	75	65.5/ 74	12.0	7.2	3.6	walled - treed	2.5m	500m
7	Narre Warren-Cranbourne Road, Cranbourne 130 B12	Rural	2-lane Gravel Collector.	75	66.5/ 79	12.2	7.2	3.6	spacious - open paddocks	5.0m	500m
8	Narre Warren-Cranbourne Road, Cranbourne 130 C7	Rural	2-lane Undivided Collector.	100	90.6/ 101	10.3	7.4	3.7	walled - treed	5.0m	750m
9	Narre Warren-Cranbourne Road, Narre Warren 130 C4	Rural	2-lane Undivided Collector.	100	90.1/ 100	10.9	7.4	3.7	spacious - open paddocks	5.0m	1000m
10	Narre Warren-Cranbourne Road, Narre Warren 110 D9	Rural	2-lane Undivided Collector.	100	89.1/ 98	9.7	7.4	3.7	walled - treed	2.5m	1000m
11	Mulgrave Freeway, Dandenong 91 A6	semi - rural	4-lane Urban Freeway.	110	98.4/ 108	9.3	7.4	3.7	walled - treed	3.0m	1000m
12	Heatherton Road, Dandenong 90 H3	semi - rural	4-lane Divided Arterial.	75	77.5/ 87	8.4	7.4	3.7	spacious - grazing land	5.0m	750m

*Map references from MELWAY - GREATER MELBOURNE, Edition No. 17, 1987.

APPENDIX B - 1

INSTRUCTIONS FOR THE ROAD SPEED EXPERIMENT

The purpose of the driving test today is to measure how safe you consider driving to be in a variety of road and traffic situations. You will be asked to make a series of judgements about whether you feel the speed you are travelling at in a particular road situation is too fast or too slow. There is no need to be unduly concerned about your safety as you wil not be put through any dangerous exercises. We are only interested in your perceptions of speeds over a range of different travel speeds and road environments.

The pad on your knees is for recording your responses. You will note that each page has a line on it marked at each end as either too fast or too slow. For each site, you make your speed assessment by simply scribing across the response line at a position indicating your judgement. You may not wish to use either of the two extreme positions. However, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feeling of safety, for each of the sites you will be tested on.

A second response is also required at each site. Immediately following the slash-line response, would you please estimate to the nearest 5 kilometres per hour what speed you think you are travelling at and record it in the box in the right-hand corner of the response page. Remember, however, that the slash-line response should always be your first response and that the speed estimate response is secondary.

The course we will be travelling on has 12 sites for assessment. In addition, we will give you some practice before we start the main experiment. There will be plenty of warning when a site is approaching. When instructed, look down at the response pad and only look up when asked to do so. You will be given 5 seconds to view the road and then instructed to look down again and make your response. Please do not respond until after the full 5 seconds of viewing time.

When viewing the road during a test trial, try to concentrate on looking straight ahead and not be distracted by objects in any of the side windows. Also, try not to use any car cues about travel speed but rely entirely on the road and the environment immediately ahead of you.

Are there any questions?

APPENDIX B - 2

INSTRUCTIONS FOR THE LABORATORY SPEED EXPERIMENT

The purpose of this experiment today is to measure how safe you consider driving is in a variety of road and traffic situations. You will be shown a series of road scenes as viewed from the driving position of a moving car. Your task is to judge whether the speed you are travelling at is too fast or too slow compared to what you consider is a safe operating speed. There is no need to be concerned about speed limits when making your judgements. We are not interested in knowing what speed limit is appropriate but rather what you believe is a safe operating speed for a range of different travel speeds and road environments.

The pad in front of you is for recording your responses. You will note that each page has a line on it marked at each end as either too fast or too slow. For each site, you make your speed assessment by simply scribing across the response line at a position indicating your judgement. You may not want to use either of the two extreme positions, however, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feelings of safety for each of the road scenes you will be tested on.

A second response is also required for each scene. Immediately following the slash-line response, would you please estimate to the nearest 5kph what speed you think you are travelling at and then record that in the box in the right hand corner of the response page. Remember, however, that the slash-line response should always be your first response and that the speed estimate response is secondary.

You will be shown a range of road scenes for assessment. **Each road scene will** be displayed on the screen in front of you for 5 seconds followed by 10 seconds of blank screen. **During each road presentation, you should concentrate on** looking only at the screen. When the road scene disappears, then look down at your response book and quickly make your assessments. **We will give you warning** when another scene is about to appear. In addition, you will also be given practice at making these judgements before we start the main experiment.

And finally, when viewing the road during a test trial, try to concentrate at looking straight ahead as you would if you were driving. **Try not to be distracted** by anything happening around you during a test trial.

Are there any questions?

APPENDIX - B3

"CLOSE FOLLOWING" STUDY - ONROAD INSTRUCTIONS

The purpose of the driving test today is to measure how safe you consider driving to be in a variety of road and traffic situations. You will be asked to make a series of judgements about how safe you feel about the distance between you and the vehicle in front. There is no need to be unduly concerned about your safety as you will not be put through any dangerous exercises. We are only interested in your feelings of safety for a range of different travel speeds and road environments.

The pad on your knees is for recording your responses. You will note that each page has a line on it marked at each end as either very safe or very unsafe. For each site, you make your safety assessment by simply scribing across the response line at a position indicating your judgement. You may not want to use either of the two extreme positions. However, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feelings of safety for each of the road sites you will be tested on.

A second response is also required for each site. Immediately following the slash line response would you please estimate to the nearest 5 kph what speed you think you are travelling at, and then record that in the box in the right hand corner of the response page. Remember, however, that the slash line response should always be your first response and that the speed estimate response is secondary.

The course we will be travelling on has 12 sites for assessment. In addition we will give you some practice before we start the main experiment. There will be plenty of warning when a site is approaching. When instructed, look down at the response pad and only look up when asked to do so. You will be given 5 seconds to view the road and then instructed to look down again and make your response. Please do not respond until after the full 5 seconds of viewing time.

When viewing the road during a test trial try to concentrate on looking straight ahead and not be distracted by any objects in any of the side windows. Also try not to use any car cues but rely entirely on the road and the environment immediately ahead of you.

Are there any questions?

APPENDIX - B4

"CLOSE FOLLOWING" STUDY - LABORATORY INSTRUCTIONS

The purpose of this experiment today is to measure how safe you consider driving is in a variety of road and traffic situations. You will be shown a series of road scenes as viewed from the driving position of a moving car. Your task is to judge how safe you feel about the distance between you and the vehicle in front for a range of different travel speeds and road environments.

The pad in front of you is for recording your responses. You will note that each page has a line on it marked at each end as either very safe or very unsafe. For each site you make your safety assessment by simply scribing across the response line at a position indicating your judgement. You may not want to use either of the two extreme positions. However, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feelings of safety for each of the road scenes you will be tested on.

A second response is also required for each scene. Immediately following the slash line response would you please estimate to the nearest 5 kph what speed you think you are travelling at, and then record that in the box in the right hand corner of the response page. Remember, however, that the slash line response should always be your first response and that the speed estimate response is secondary.

You will be shown 12 different road scenes for assessment. Each road scene will be displayed on the screen in front of you for 5 seconds, followed by 10 seconds of blank screen. When the road scene disappears, then look down at your response book and quickly make your assessments. We will give you warning when another road scene is about to appear. In addition you will also be given practice at making these judgements before we start the main experiment.

And finally, when viewing the road during a test trial, try to concentrate on looking straight ahead as you would if you were driving. Try not to be distracted by anything happening around you during the test trial.

Are there any questions?

TABLE C-1
ANALYSIS OF VARIANCE SUMMARY TABLE
DAY & NIGHT VISION EXPERIMENT
SAFETY ESTIMATE DATA
SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	w^2
SPEED	52,400	1	52,400	104.5***	.0918
TYPE OF ROAD	13,485	2	13,485	23.8***	.0229
SEX OF THE DRIVER	15,425	1	15,425	3.7	.0199
ROADSIDE ENVIRONMENT	7,836	1	7,836	72.3***	.0137
SPEED X FILMTIME	4,574	1	4,574	46.9***	.0079
FILMTIME	3,817	1	3,817	8.8**	.0060
FILMTIME X ROADSIDE	3,221	1	3,221	31.2***	.0055
TESTTIME	7,018	1	7,018	1.7	.0055
ROAD X FTIME X SIDE	2,232	2	1,116	15.6***	.0037
SPEED X ROAD	1,891	2	946	13.1***	.0031
SPEED X ROAD X FTIME X SIDE	1,179	2	590	6.8**	.0018
SPEED X ROAD X SIDE X SEX	1,025	2	512	6.4**	.0015
SPEED X SIDE X EXP X SEX	826	1	826	9.1**	.0013
SPEED X ROAD X FTIME X SIDE X EXP	875	2	438	5.1**	.0012
SPEED X FTIME X EXP	656	1	656	6.7	.0010
ROAD X FILMTIME	795	2	397	3.6	.0010
SPEED X ROAD X EXP X TTIME	693	2	347	4.8	.0009
ROAD X ROADSIDE	758	2	379	3.4*	.0009
SPEED X ROAD X SIDE	579	2	290	3.6	.0007
FTIME X SIDE X EXP X TTIME	424	1	424	4.1	.0006
FILMTIME X TESTTIME	20	1	20	<1	.0000

*** prob <.001 ** prob <.01 * prob <.05

TABLE C-2
ANALYSIS OF VARIANCE SUMMARY TABLE
DAY & NIGHT VISION EXPERIMENT
SPEED ESTIMATE ERROR DATA
SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	w^2
SPEED	30,876	1	30,876	118.4***	.0809
ROAD	17,632	2	8,816	56.3***	.0458
FILM TIME	15,334	1	15,334	59.5***	.0398
SEX X TEST TIME	10,853	1	10,853	2.5	.0170
EXPERIENCE	7,386	1	7,386	1.7	.0078
SEX	7,100	1	7,100	1.6	.0071
ROAD X SEX	1,715	2	857	5.5**	.0037
SPEED X FILMTIME	1,431	1	1,431	20.9***	.0036
SPEED X ROAD	1,404	2	702	13.8***	.0034
ROAD X FILMTIME	1,103	2	551	7.1**	.0025
FILMTIME X SEX	1,160	1	1,160	4.5	.0023
SPEED X ROADSIDE	582	1	582	14.1***	.0014
SPEED X ROAD X SIDE X EXP	498	2	249	5.8**	.0010
SPEED X ROAD X FTIME X SIDE X EXP	516	2	258	3.7*	.0010
ROADSIDE	369	1	369	7.4**	.0008
ROADSIDE X SEX	354	1	354	7.1*	.0008
ROAD X FTIME X SIDE	394	2	197	4.6	.0008
ROAD X FTIME X SIDE X EXP X SEX	350	2	175	4.1	.0007
SPEED X ROAD X SIDE X SEX	306	2	153	3.6	.0006
ROAD X FTIME X SIDE X SEX	300	2	150	3.5	.0006
SIDE X EXP X SEX X TTIME	209	1	209	4.2*	.0000
TESTTIME X FILMTIME	1	1	1	<1	.0000

*** prob <.001 ** prob <.01 prob <.05

TABLE C-3
ANALYSIS OF VARIANCE SUMMARY TABLE
CURVATURE VALIDATION STUDY
SAFETY ESTIMATE DATA

EFFECT	SS	df	MS	F	w^2
SITE	4,266	11	388	3.7**	.0657
EXPERIMENT X SITE	3,975	11	3,975	3.4**	.0595
EXPERIMENT	87	1	87	<1	.0000

*** prob <.001   ** prob <.01   * prob <.05

TABLE C-4
ANALYSIS OF VARIANCE SUMMARY TABLE
CURVATURE VALIDATION STUDY
SPEED ESTIMATE ERROR DATA

EFFECT	SS	df	MS	F	w^2
EXPERIMENT X SITE	1,530	11	139	1.2	.0040
SITE	1,454	11	132	1.1	.0030
EXPERIMENT	5	1	5	<1	.0000

*** prob <.001 ** prob <.01 * prob <.05

TABLE C-5
ANALYSIS OF VARIANCE SUMMARY TABLE
HORIZONTAL CURVATURE EXPERIMENT
SAFETY ESTIMATE DATA
SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	2
SPEED	352,251	1	352,251	310.5^{***}	.2380
TYPE OF ROAD	178,670	2	89,335	104.1^{***}	.1199
RADIUS	66,781	1	66,781	232.0^{***}	.0451
SEX OF THE DRIVER	48,637	1	48,637	10.2^{**}	.0297
SPEED X EXPERIENCE	15,394	1	15,394	13.6^{***}	.0097
ROAD X ROADSIDE	10,354	2	5,177	41.1^{***}	.0068
RADIUS X ROADSIDE	5,658	1	5,658	42.5^{***}	.0037
ROAD X RADIUS X ROADSIDE X DIRECTION	4,630	2	2,315	33.6^{***}	.0030
ROAD X EXPERIENCE	4,938	2	2,468	2.9	.0020
SPEED X SEX X EXPERIENCE	3,661	1	3,661	3.2	.0017
RADIUS X ROADSIDE X DIRECTION	2,484	1	2,484	34.3^{***}	.0016
ROAD X RADIUS	2,076	2	1,038	9.2^{***}	.0013
SPEED X ROAD X RADIUS	2,030	2	1,015	9.7^{***}	.0012
ROAD X RADIUS X DIRECTION	1,990	2	995	8.3^{***}	.0012
ROAD X RADIUS X ROADSIDE X EXPERIENCE	1,590	2	795	7.8^{***}	.0010
RADIUS X EXPERIENCE	1,495	1	1,495	5.2^{*}	.0008
RADIUS X DIRECTION	1,259	1	1,259	13.4^{***}	.0008
SPEED X ROAD X ROADSIDE	1,356	2	678	9.9^{***}	.0008
ROAD X ROADSIDE X SEX	606	2	303	5.1^{**}	.0007
SPEED X ROAD	1,255	2	628	5.1^{**}	.0007
SPEED X RADIUS X ROADSIDE X DIRECTION	882	1	882	4.8^{**}	.0005
SPEED X DIRECTION X EXPERIENCE	752	1	752	5.8^{*}	.0004
ROADSIDE X DIRECTION X SEX X EXP	684	1	684	9.1^{**}	.0004
ROAD X RADIUS X SIDE X SEX X EXP	771	2	385	3.8^{*}	.0004
ROAD X ROADSIDE X DIRECTION	721	2	360	4.7^{*}	.0004
DIRECTION	763	1	763	4.3^{*}	.0003
SPEED X RADIUS X ROADSIDE	586	1	586	7.0^{**}	.0003
ROAD X RADIUS X ROADSIDE X SEX	695	2	347	3.4^{*}	.0003
SPEED X RADIUS	344	1	344	4.6^{*}	.0002
ROAD X DIRECTION	651	2	326	3.1^{*}	.0002
SPEED X ROADSIDE X EXPERIENCE	241	1	241	4.0^{*}	.0001

*** prob < .001   ** prob < .01   * prob < .05

TABLE C-6
ANALYSIS OF VARIANCE SUMMARY TABLE
HORIZONTAL CURVATURE EXPERIMENT
SPEED ESTIMATE ERROR DATA
SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	w^2
ROAD	185,753	2	92,876	228.9***	.1598
SPEED	123,272	1	123,272	533.1***	.1063
EXPERIENCE	67,261	1	67,261	9.76**	.0522
SEX X EXPERIENCE	56,199	1	56,199	8.2**	.0426
ROAD X SEX	7,976	2	3,988	9.8***	.0062
ROAD X RADIUS X ROADSIDE	6,760	2	3,380	73.9***	.0057
RADIUS	5,461	1	5,461	43.8***	.0046
ROAD X RADIUS	2,456	2	1,228	21.4***	.0020
DRIVER SEX	9,742	1	9,742	1.4	.0025
ROAD X RADIUS X DIRECTION	1,307	2	653	15.1***	.0011
SPEED X ROAD	1,061	2	530	11.7***	.0008
ROADSIDE X DIRECTION	921	1	921	38.1***	.0008
ROAD X DIR X SEX X EXP	658	2	329	6.8**	.0005
ROADSIDE	560	1	560	7.2**	.0004
RADIUS X ROADSIDE X DIRECTION	547	1	547	15.6***	.0004
ROAD X RADIUS X ROADSIDE X DIRECTION	517	2	258	6.9**	.0004
DIRECTION X EXPERIENCE	420	1	420	5.9	.0003
ROADSIDE X DIRECTION X EXPERIENCE	326	1	326	13.5***	.0003
SPEED X ROAD X ROADSIDE	471	2	235	6.3**	.0003
SPEED X ROADSIDE X DIRECTION	427	1	427	12.8***	.0003
SPEED X ROAD X RADIUS X ROADSIDE	366	2	183	5.6**	.0003
ROAD X ROADSIDE	329	2	164	3.2*	.0002
ROAD X DIRECTION	347	2	173	3.6*	.0002
ROAD X RADIUS X ROADSIDE X EXPERIENCE	392	2	196	4.3*	.0002
ROAD X ROADSIDE X DIRECTION	318	2	159	4.5*	.0002
SPEED X ROAD X RADIUS X SIDE X DIR	247	2	123	3.1	.0002
SPEED X ROADSIDE	222	1	222	8.4**	.0001

*** prob <.001 ** prob <.01 * prob <.05

TABLE C-7
ANALYSIS OF VARIANCE SUMMARY TABLE
CLOSE FOLLOWING VALIDATION STUDY
SAFETY ESTIMATE DATA

EFFECT	SS	df	MS	F	w^2
SITE	322,113	11	29 283	54.2***	6235
EXPERIMENT	20 133	1	20,133	4 9*	0315
EXPERIMENT X SITE	20,677	11	1,879	3.5***	0290

*** prob < 001 prob < 01 * prob < 05

TABLE C-8
ANALYSIS OF VARIANCE SUMMARY TABLE
CLOSE FOLLOWING VALIDATION STUDY
SPEED ESTIMATE ERROR DATA

EFFECT	SS	df	MS	F	w^2
SITE	65,785	11	5,980	74.0***	.5581
EXPERIMENT	7,411	1	7,411	8.7**	.0564
EXPERIMENT X SITE	3,942	11	358	4.4***	.0262

*** prob <.001 ** prob <.01 * prob <.05

APPENDIX D: FREE SPEEDS AND TRAFFIC VO''UMES BEFORE A AFTER PERCEI AL ROAD TREATMENT ALONG KERFERD ROAD, SOUTH MELBOURNE.

SITE DESCRIPTION	AREA	ROAD CATEGORY	STAGE OF PERCEPTUAL ROAD T'MENT	DATE	SPEED LIMIT kph	FREE SPEED MEAN, STD. DEV, 85%. (kph)	TRAFFIC VOLUME	SEAL WIDTH	LANE WIDTH	SHOULDER WIDTH	SIGHT DISTANCE	E
Kerferd Rd. Mel. 2J-B8 South bound (between Herbert and Hamilton Streets)	residentia	4-lane divided, secondary arterial road.	before treatment	22-9-87 p.m.	60	62.44 8.88 71	Kerferd Rd. between Danks & Page Sts. Nov. '84, 24 hrs. 5,858 vehicles	14m	5.0m (4m parkin	4m	>500m	walled-houses and treed median strip
" "	" "	" "	after 1st stage (gravel-strip, no line mark-ing).	1-3-88 p.m.	60	59.34 9.24 68	Kerferd Rd. between Danks & Page Sts. 25-5-88 24 hrs. 5,579 vehicles	14m	3.7m (4m parkin (2.5m bike path)	4m	>500m	" "
Kerferd Rd. Mel. 2J-B8 North bound (between Herbert and Hamilton Streets)	" "	" "	before treatmer	22-9-87 p.m.	60	62.78 7.34 70	Kerferd Rd. between Danks & Page Sts. Nov. '84, 24 hrs. 5,622 vehicles	14m	5.0m	4m	>500m	" "
" "	" "	" "	after 1s stage (gravel-strip, n line mar	1-3-88 p.m.	60	64.19 6.72 71	Kerferd Rd. between Danks & Page Sts. 25-5-88 24 hrs. 5,630 vehicles	14m	3.7m (4m parkin (2.5m bike path)	4m	>500m	" "
" "	" "	" "	after 2n stage (complet line mar & gravel	22-3-88 p.m.	60	63.49 8.43 72	------	14m	3.7m	4m	>500m	" "
Mason Street Altona Mel. 55 D3 eastbound	" "	" "	control site	16-2-84 p.m.	60	65.0 8.2 73	------	7.4m	3.2m / 4.2m	4m	>500m	" "
"	" "	" "	" "	9-6-88 p.m.	60	65.36 8.15 73	------	7.4m	3.2m / 4.2m	4m	>500m	" "
Mason Street Altona Mel. 55 D3 westbound	" "	" "	" "	16-2-84 p.m.	60	66.3 6.8 72	------	7.4m	3.2m / 4.2m	4m	>500m	" "
" "	" "	" "	" "	9-6-88 p.m.	60	65.17 8.43 72	------	7.4m	3.2m / 4.2m	4m	>500m	" "