

# **THE SPEED REVIEW:**

## **ROAD ENVIRONMENT, BEHAVIOUR, SPEED LIMITS, ENFORCEMENT AND CRASHES**

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**Abstract:**

A study was undertaken to review the role of vehicle speed in road crashes, speed limits, enforcement and behaviour, and the environment. A review of the international literature was initially carried out to highlight overseas findings and issues identified for further research and development. Visits were also made to a select number of overseas research and government agencies in Scandinavia, Europe and the United States to gain first hand knowledge of problems and research being undertaken in these countries. A meeting was then organised of 45 Australian experts with research, government authority, and motoring backgrounds, as well as a keynote speaker from Sweden, to identify current problems and issues in Australia. From this extensive review, 22 items requiring further research and 12 action items were identified and prioritised in terms of their importance and value for reducing speed related crashes. Prominent topics requiring future research were the development and exploitation of perceptual counter-measures, the credibility of speed zone limits, road design and travel speed, speed and crash involvement and behavioural correlates, the effectiveness of Local Area Traffic Management (LATM) devices, enforcement tolerance and travel speed, safety consequences of changes to speed limits, and more travel speed and crash speed data. Priority items for future action programs included greater use of low cost perceptual road treatments, a trial program of top speed limiters for cars, need for a change in community attitude towards speeding, an Australia-wide expert system for determining speed limits, speed zone policy and practice publicity, more repeater signing in speed zones, and widespread use of effective speed reduction technologies.

**Key Words:** Speed, Accident, Enforcement, Speed Limit, Environment, Pedestrian, Research Needs, Driver, Behaviour, Countermeasures, Design Speed, Perception.

**Notes:**

- (1) This report is jointly produced by FORS and RSB and is disseminated in the interest of information exchange.
- (2) The views expressed are those of the author(s) and not necessarily those of the Commonwealth Government or RTA (NSW).
- (3) The Federal Office of Road Safety publishes four series of reports:
  - (a) reports generated as a result of research done within FORS are published in the OR series;
  - (b) reports of research conducted by other organisations on behalf of FORS are published in the CR series
  - (c) reports based on analysis of FORS statistical data bases are published in the SR series;
  - (d) minor reports of research conducted by other organisations on behalf of FORS are published in the MR series.
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  - (a) reports generated as a result of research done within RSB are published in RN series.
  - (b) reports conducted by other organisations on behalf of RSB are published in the RSB's CR series.

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# Executive Summary

Speeding has long been recognised as a major factor in many road crashes. Excessive speed was noted as a *definite* cause in 8 percent of crashes and up to twice that as a *probable* cause in studies overseas. In Australia, excessive speeding has been noted as a contributing factor in up to 30 percent of fatal crashes. On these statistics, speed related road trauma is likely to cost the Australian community up to A\$1 billion annually.

Much is already known about the consequences of excessive speed in a crash. The faster the impact speed, the greater the likelihood of severe injury or death in a collision as predicted by physics. This relationship is further evident by reports on the consequences of changes in speed limits where the overwhelming weight of evidence shows that if actual travel speeds are reduced, there will be a resultant decrease in the number of injuries and severe trauma on the road.

Less is known, however, about how excessive speed leads to crashes. Early reports suggested that large variances above or below the mean traffic speed were associated with increased risk of crash involvement. However, much of this evidence is old and somewhat biased and therefore not particularly conclusive. This is primarily because accurate and comprehensive information on travel speed at the time of collision has not been readily available.

Furthermore, knowledge of the effects of speed limits, speed enforcement, and the environment on influencing travel speed and therefore crashes is fragmented and lacks clear direction for use in speed management intervention.

With this in mind, the Road Safety Bureau of the Roads and Traffic Authority (NSW) along with the Federal Office of Road Safety recently commissioned the Monash University Accident Research Centre to undertake a detailed review of the role of speed in a number of important areas to highlight directions for future research and action aimed at reducing speed related trauma.

## THE REVIEW OF SPEED

The project specification called for a review of *four* specific speed related topics, namely the relationship between speed and crashes, the role of speed limits on travel speed, the effects of speed enforcement on travel speed and driver behaviour, and the influence of the environment on speeding. A number of separate tasks were undertaken during the course of this review.

### Literature Review

First, a thorough review of the international literature was undertaken to highlight what had been previously reported in the four key speed areas of crashes, speed limits, enforcement and behaviour, and the environment. Over 250 references were located and critically reviewed to outline previous findings and shortcomings from this body of research knowledge. From this extensive review, a number of conclusions and options for future research and development were able to be outlined.

### Overseas Visits

Visits were made to a number of key research and government agencies in Scandinavia, Europe, and the United States to discuss current speeding issues and interventions, either operating or planned for the future in these regions. Attention was also given to past efforts in this area and what lessons were to be learned from these experiences.

Senior officers of MUARC undertook these visits during recent overseas trips and provided extensive reports on the outcomes of their visits to the study team. These are found, along with other specialist papers, in the Appendices at the back of this report.

### **Speed Workshop**

A one-day workshop was then arranged in conjunction with the Road Safety Researcher's Conference in Canberra to consider the findings from the review and the overseas visits and especially how they translate to current Australian speed management issues. Forty-five Australian experts in road safety with a specific interest in speed were invited to attend this meeting.

In addition, Dr. Göran Nilsson of the Swedish Road and Traffic Research Institute was brought to Australia as a keynote speaker for the workshop. Dr. Nilsson has had an extensive background in speed research and management in Sweden and the rest of Europe and was able to provide an excellent overview of current problems and initiatives in a number of these countries.

As well as invited presentations, the workshop included four "*brain-storming*" sessions, each one addressing one of the four key speed related topics outlined by the project objectives. The findings from each of the workshops have been documented in this report.

### **Prioritising Future Research and Action**

From the wealth of information gathered during the course of this project, 22 research and 12 action items were identified requiring further attention for speed management intervention in this country.

These items were listed along with indications of how they could be undertaken, what would be the expected outcome, how easy or difficult they would be to carry out, and the likely cost of the research or the action. Lists were then distributed to each workshop participant who was asked to rank these items in terms of their importance and value. These rankings were then summed across all respondents to provide a consensus view on speed priorities.

## **AREAS IDENTIFIED THAT REQUIRE FURTHER RESEARCH**

A number of important research topics were identified and prioritised for future efforts aimed at improving knowledge and/or reducing the number and severity of speed related crashes in Australia. The *eight* most pressing topics included:

- the identification (and exploitation) of perceptual countermeasures against speeding,
- speed zoning and the credibility of these speed limits among motorists,
- the relationship between road design and travel speed,
- understanding the relationship between crash involvement and travel speed and the behavioural explanations for speeding,
- the effectiveness of Local Area Traffic Management devices in reducing travel speed and crashes,
- the consequences of enforcement tolerances above the speed limit on travel speed behaviour,
- confirmation of overseas findings regarding the safety consequences of changes in the posted speed limit, and
- the collection of more accurate and extensive speed and crash data.

## AREAS IDENTIFIED THAT REQUIRE FURTHER ACTION

As well as the research items, a number of action programs were identified that could be undertaken immediately to reduce speed related trauma in this country. The most prominent of these were:

- greater use of low cost road treatments to modify driver's perceptions of the road and environment to reduce travel speed,
- introduction of top speed limiters on a suitable sample of passenger cars to demonstrate their likely effectiveness,
- the development of public education programs to promote a widespread change in community attitudes to speeding, similar to that experienced with drink-driving,
- the development of an Australia-wide system for determining appropriate speed limits based on existing expert systems,
- education and publicity among motorists of current speed zone policies and practices throughout Australia,
- greater attention to repeater signing of speed limits within zones to ensure motorists are aware of these speed limits, and
- the more wide-spread use of available and effective speed enforcement technologies in all States and Territories.



# 1. INTRODUCTION

Excessive speeding has long been recognised as a major factor in road crashes. The Federal Office of Road Safety (CR 119) for instance noted excessive speed to be at least a contributing factor in up to 30 percent of fatal crashes in Australia during 1991/92. While the relationship between impact speed and injury severity has been well documented, relatively less is known about the role of speed in crash involvement.

At the 1991 Experimental Safety Vehicles conference in Paris, government representatives from most major European and North American countries listed speed involvement in crashes as one of the *three* major challenges facing the road safety community in making further reducing the road toll. This has been noted by representatives of road traffic authorities from all states at recent researcher's conferences in Australia as well.

The Monash University Accident Research Centre was commissioned by the Roads and Traffic Authority (N.S.W.) and the Federal Office of Road Safety to review the relationship between travel speed and road safety. The overall aim of the project was to describe the current state of knowledge in a number of speed related areas with a view to outlining directions for further research and action in speed management.

## 1.1 PROJECT OBJECTIVES

There were a number of specific objectives stipulated for this project, namely:

1. to review the influence of speed on the incidence and severity of road crashes and identify any shortcomings in our current state of knowledge;
2. to examine current practices world-wide in setting speed limits for urban and rural roads and highways and their influence on travel speed;
3. to investigate the effect of speed enforcement and driver behaviour and travel speed and identity aspects requiring further research and development; and
4. to look at the role of the environment in influencing a driver's decision about what speed to travel at and behavioural consequences.

The project outcome ultimately was to help foster a safer road environment where roads and road settings could be designed on the basis of a reasonable ability to predict what features will influence drivers' speed choices and what speed they will ultimately select to travel at.

## 1.2 PROJECT DESIGN AND REPORT STRUCTURE

This study comprised a number of complimentary research tasks which are reflected in the structure of this report.

### 1.2.1 Literature Review

The first research task was a review of the international road design and safety literature to update current knowledge on the four relevant subject areas identified above and to identify current issues of concern world-wide. This review set out to describe research into the relationships between speeding and crashes, speed limits, enforcement and behaviour, and behaviour and the environment and is reported in Chapters 2 to 5 of this report. The review included more than 250 references from over 15 countries throughout the world. A number of

speed related issues requiring further research and development were identified from the literature review.

### **1.2.2 Speed Workshop**

The next phase of the research program brought together 45 key local and overseas people with experience in speed research and policy making to participate in a one day speed workshop. The meeting was intended to review these research and action items and to expand them where necessary based on their experience and knowledge in this area. The workshop comprised a limited number of invited presentations on overseas and local developments as well as “*brain-storming*” sessions on each of the four topics. The results of the workshop findings and resolutions are found in Chapter 6 while papers of the invited presentations are included in an Appendix to this report.

### **1.2.3 Speed Priorities**

The final phase of the program was to prioritise the list of research and action items to reflect an Australia-wide view of what needs to be done to reduce the number of speed related crashes and conflicts in this country. The final lists comprised 22 research and 12 action items and these were circulated to the 45 workshop participants for them to nominate how important and valuable each item was. The final listing of these priorities is shown in Chapter 7, while the more important and pressing of these issues are briefly discussed along with how they might be undertaken to improve knowledge or intervene to reduce speed related road trauma.

The authors are especially grateful for the time and effort so freely given by each of the 45 participants in participating in the workshop and helping to establish a consensus view on what needs to be done to tackle a major problem area currently in road safety. It is hoped that the findings from this report will be useful for many Australian and overseas agencies in helping to set future speed management research and action agendas.

## 2. SPEED AND CRASHES

The literature reporting on the relationship between travel speed and crashes dates back to the 1950's and 1960's. Early studies attempted to establish functional relations between travel speed and either the likelihood of being involved in an accident (*crash involvement*) or the likelihood of sustaining an injury given a crash (*crash consequence*). Indeed, these are important distinctions (also referred to as *primary* and *secondary* safety) when considering the relationship between travel speed and crashes as they are markedly different and have quite separate implications for speed countermeasures.

Crash involvement is about what causes crashes and what should be done to prevent accidents from occurring, while crash consequence is about protecting the individual involved in a crash. For vehicles, primary safety intervention is aimed at driver and vehicle behaviour (improved braking, driver alertness, and so on) while secondary safety is about reducing the likelihood of injury from being thrown out of the vehicle (eg; wearing seatbelts) or from preventing contact with the various components inside vehicle (eg; the steering wheel, instrument panel, etc).

Much is known about the consequences of speed in crashes and what can be done to minimise injury. While there has been considerable effort aimed at explaining the relationship between speed and crashes, it has tended to be patchy and limited, given some of the problems that are inherent in this type of research. More recently, researchers have tended to focus on more specific aspects of speed in crashes rather than the relationship itself. Changes in speed limits or speed limit enforcement are examples of this type of more specific research. Indeed, it can be argued that simply establishing overall relationships between travel speed and crash involvement ignores important driver and vehicle characteristics that are essential for programs aimed at reducing road trauma.

Put another way, establishing a relationship between travel speed and crash involvement is simply relating one descriptive feature of the accident (speed) to the number of accidents. In so doing, it overlooks relevant fundamental processes involved in accidents and the role speed plays in these processes.

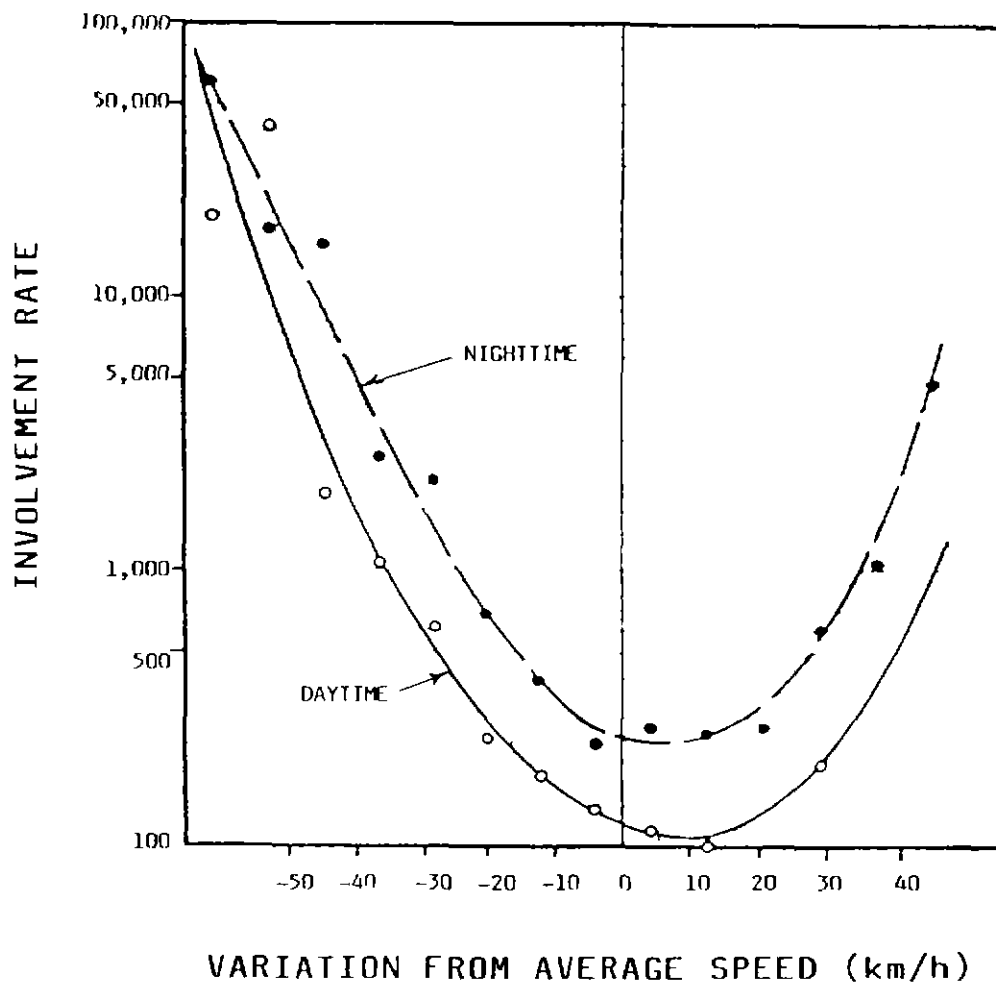
### 2.1 SPEED AND CRASH INVOLVEMENT

#### 2.1.1 Early Research

Early research conducted by Solomon (1964) reported a relationship between crash involvement and speed. Traffic-stream speed distributions on a number of sections of two- and four-lane divided highways were constructed from traffic observations. Accident records were consulted in order to identify drivers that had been involved in an accident on any of the sections of highway for which speed distributions were known. Comparing the distribution of estimated speeds of crash involved vehicles with the free speed distributions showed that accident involved drivers were over-represented in both high and low speed categories of the speed distribution. Solomon also undertook surveys which provided travel distance information by observed speed of travel on these roads. These were then used to establish crash involvement rates per distance travelled for the different crash speed ranges.

A salient finding was the danger associated with large deviations in individual vehicle speeds from the average speed of the traffic stream. Solomon argued that it was speed **variance**, not the mean travel speed, that was important in crash involvement. The resultant relationship

between crash involvement and travel speed relative to the mean speed of travel takes the form of a “U-shaped curve” with minimum value slightly above the average speed of the traffic stream (see Figure 2.1). Thus variations from this mean speed were associated with increased crash risk both above and below the mean travel speed. Solomon further claimed that the results of his study indicated that “...low speed drivers are more likely to be involved in accidents than relatively high speed drivers” (p. 9).



**Figure 2.1 Solomon's U-Shaped Curve of crash involvement by variation from the mean traffic speed.**

At around the same time, Taylor (1965) was investigating the importance of the shape of the speed distribution on the occurrence of accidents on rural highways. Speed distributions were measured on a number of segments of highway, and classified as normal or abnormal in terms of kurtosis (the peakedness of the distribution) and skewness (the extent to which the distribution is symmetrical about the mean). Accident statistics were then consulted to determine the number of accidents on each of the study segments. Using skewness as a measure of normality, a significantly greater number of accidents occurred on segments of highway that had skewed (abnormal) speed distributions than occurred on those that had normal distributions. However, there were no differences in the number of accidents occurring on segments of highway classified normal or abnormal in terms of kurtosis.

The impact of the speed limit on these speed distributions and accident rates was also examined by Taylor (1965). He tested the assumption that imposing a speed limit would be more likely to reduce the accident rate if an abnormal speed distribution became normal after the imposition of the speed limit than if the speed distributions were already normal. This assumption presupposes that imposing a speed limit will, in fact, have a normalising effect on speed distributions. Notwithstanding this, he found support for the hypothesis when skewness was used as the criteria for normality but not for kurtosis. It was concluded that the skewness, not kurtosis, of a speed distribution was a good indicator of potential accident reduction. The speed of crash involved vehicles was not addressed by Taylor, rather the implicit assumption was made that the speed distribution on a particular road, not the speed of individual vehicles, was the critical factor for crash involvement. The authors are unaware whether this approach has been used subsequently in setting speed limits on rural highways.

Munden (1967) also reported a U-shaped relationship between crash rate and relative speed in the UK, similar to that reported by Solomon for the US. He reported that vehicles travelling more than one standard deviation below or above the mean speed had an inflated crash rate. Munden's research differed from Solomons in a number of ways. First, he assessed relative speed compared to neighbouring vehicles in the same traffic stream. Second, he included accidents on any road in the region of investigation to calculate involvement rates, rather than only accidents on the study roads. Finally, he compared the crash rates of drivers who were observed driving relatively fast with those driving relatively slowly, avoiding the need to make assumptions about the connections between crash rates at different speeds with observed speed distributions. Nevertheless, the fact that these different studies reported similar findings suggests they are still somewhat complimentary.

Hauer (1971) not only supported the crash involvement curves derived by previous research such as Solomon (1964) but also provided an explanation for the curve by demonstrating that the rate of overtaking in traffic was dependent upon variance from the average traffic speed. Hauer related the crash involvement rate to the rate of overtaking and concluded that on highways with both lower and upper speed limits, the lower limit can be two or three times more effective than the upper limit in reducing overtaking and crash involvement rates. On the efficacy of minimum speed limits Hauer claimed that "*... the indiscriminate public crusade against speeding should be replaced by a balanced approach emphasizing the dangers of both fast and slow driving.*" (p. 7). Recent findings from the FORS fatal file, however, indicate that crashes involving overtaking manoeuvres are only a small proportion of all crashes (3.2% of all fatalities and 3.8% of mid-block fatalities in 1988).

Cumming and Croft (1971) reviewed much of the literature on speed control and concluded that there is an intimate relationship between the rate of crashes and the speed deviation of vehicles from the mean speed. Vehicles exhibiting large deviations from the mean speed of the traffic stream, especially below the mean, were over-involved in accidents. In addition, they claimed a correlation between crash severity and speed where severity increased with speed. If the objective of speed control was to reduce the number of crashes, they argued, then speed variation should be reduced. If, however, the aim was to reduce crash severity, then absolute speed should be reduced.

Unfortunately, much of this early work suffered from the fact that the travel speed of crashed vehicles was based either on police reports, driver self-reports, or third party estimates. The Research Triangle Institute (RTI 1970) addressed this criticism by using speed estimates based on on-site analysis of crashes. Furthermore, a system of magnetic loop detectors with appropri-

ate software support was installed on one of the highways under investigation which furnished accurate speed measurements. These researchers state that the detected speeds were integrated into the pre-crash speed estimation process “*whenever possible and appropriate*”. However, no indication is given about the level of concordance between the expert estimated speeds and the detected speeds and of course it was not possible to link observed speed with individual crash involved vehicles. Some 200 accidents were subsequently investigated in this study, all of which took place on highways and country roads with speed limits of 40 mph or greater. They reported a similar yet less pronounced U-shaped relationship between crash involvement and vehicle speed.

West and Dunn (1971) from the Research Triangle Institute research team reported the findings on the highway that the magnetic loop system was installed on. Both these studies ignored crashes involving turning vehicles (44% of all observed crashes) from other crash types in reporting on the relationship between speed and crash involvement as they maintained that “*...vehicles that come to a stopped or near stopped condition and do not yield a measure of the likelihood of accident involvement for slowly moving vehicles*” (RTI 1970, p. 15). The exclusion of these crashes from the analysis again weakened the U-shaped nature of the relationship reported by Solomon (1964). With few turning vehicles, the curve is extremely flat and there is little difference in involvement rate for speeds up to 25 km/h from the average speed. Deviations from the mean speed greater than approximately 15 mph (25 km/h) increased the likelihood of being involved in a crash by a factor of about ten. This relationship reported by West and Dunn is illustrated in Table 2.1

**TABLE 2.1      RELATIONSHIP BETWEEN SPEED AND CRASH INVOLVEMENT**  
**(from West and Dunn, 1971)**

Speed Deviation from mean travel speed (mph)	Involvement rate per million vehicle miles	
	Including Turning Crashes	Excluding Turning Crashes
Less than 15.5 below	42.3	6.3
15.5 to 5.5 below	2.3	0.7
-5.5 to +5.5	1.6	0.8
5.5 to 15.5 above	1.5	1.0
More than 15.5 above	8.5	6.9

### 2.1.1 More Recent Findings

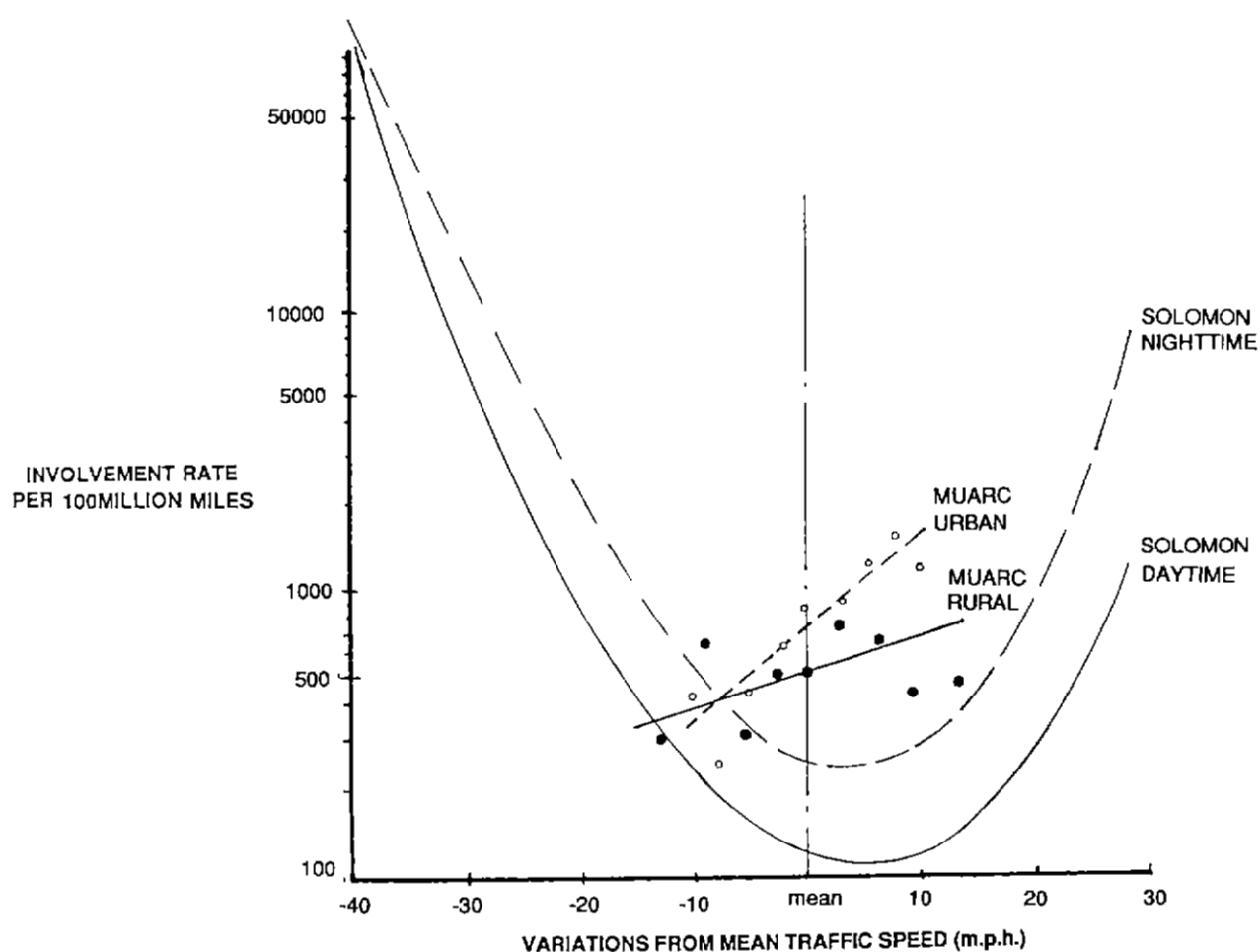
There was a long period of time between the early 1970's and mid-1980's where little research into the relationship between speed and crash involvement seems to have been undertaken. However, Garber and Gadiraju (1988) more recently reported on their research that investigated engineering factors that influence speed variance (posted speed limit, design speed and other traffic variables) to determine the extent to which speed variance affects accident rates. Using a similar methodology to that employed by Taylor in 1965, these researchers examined whether the accidents recorded at each of the sites could be attributed to the observed speed characteristics (ie; mean speed, speed variance and hourly volumes) for that site, thus negating the need to determine the pre-crash speed of crash involved vehicles.

They reported that accident rates increased with increasing variance on all road classes, although not necessarily with increasing mean speed. The difference between design and posted speed had a significant effect on speed variance, where variance was minimal when the posted speed limit was less than 10 mph that of the design speed. Mean speeds, they claimed, increased with increasing design speeds, regardless of the posted speed limit. Garber and Gadiraju (1988) include a caveat regarding the possibility that inter-correlations between the above factors such as design speed and average speed, and average speed and speed variance might explain the some of the observed relationships.

Lave (1985) again reported on the importance of variance in crash involvement. He conducted analyses of travel speed and crash involved vehicles using police reports and suggested that in some situations, raising the speed limit would result in a reduced accident rate (where a reduction in speed variance would result). Lave concluded that *"...speed limits designed to reduce the fatality rate should concentrate on reducing variance. This means taking action against slow drivers as well as fast ones"* (p. 14).

Finally, Fildes, Rumbold and Leening (1991) re-examined Solomon's U-shaped Curve of crash involvement using self-reported accident data collected at road-side surveys from drivers whose travel speed had been taken but without the drivers' knowledge. They compared their findings from both urban and rural arterial surveys with that reported by Solomon and found a similar trend of increasing crash involvement for variance above the mean speed in both locations (see Figure 2.2). However, no such a relationship was found for slow travellers as has been previously reported. Indeed, they failed to observe any vehicles travelling at the very slow speeds reported by Solomon on rural highways.

These authors argued that while their crash data were small in number and self-reports are inherently unreliable, nevertheless, these findings cast some doubt over the claim that travelling slow is somehow crash inducing. They claimed that further research into the relationship between speed and crash involvement of current roads and vehicles is warranted, using objective measures of travel speed at the time of the crash.



**Figure 2.2** *Involvement rate by variation from the mean traffic speed*  
(from Fildes et al 1991)

### 2.1.2 Causal Studies

Another method of investigating the speed and crash relationship referred to as clinical studies in which trained experts subjectively determine the contribution of various accident causes, speed being one of these. Research by Treat, Tumbus, McDonald, Shinar, Hume, Mayer, Stansifer, and Castellan (1977) was a comprehensive clinical study of traffic accident causation where assessments of causation were based on information collected by researchers who attended the scene of the accident soon after it occurred. The assessments were based, not only on the information gathered at the scene, but also on independent investigations of a subset of this information undertaken by trained professionals. A factor was defined as “causal” if it was considered that the accident would not have occurred in its absence. Excessive speed was defined rather subjectively though as any speed above that chosen by a “high but reasonable standard defensive driver”. They noted that excessive speed was a definite causal factor in seven to eight percent of accidents investigated and at least probable in 13 to 16 percent. Ruschman et al (1981) noted that these findings were quite conservative from a review of a number of these studies where “excessive speed” played a causal role in up to 37 percent of fatal crashes.

A more recent clinical study of crash causation was conducted by Bowie and Walz (1991) who made clinical evaluations of the causal factors involved in 1.4 million crashes. Speed was



reported to be involved in close to 12 percent of the crashes evaluated. Further it was the most prevalent driver error-related cause contributing to crash occurrence. Notably, 70 percent of speed related fatal crashes were single vehicle accidents. It was estimated by these researchers that the societal cost of speed related crashes to the USA in 1989 was in excess of 10 billion dollars. If these findings are also applicable in this country, then speed related crashes in Australia are likely to cost up to AUS\$1 billion yearly.

### **2.1.3 Comment**

Much of the previous research into the relationship between travel speed and crash involvement is severely flawed for one reason or another. The work reported during the 1960's and early 1970's relied upon retrospective speed assessments, at best from in-depth scene analysis but often from police accounts or self-reports. In most of these studies, it is impossible to assess the effect of inaccuracies or gross errors on the findings. Thus, the reader is left wondering whether the U-shaped function is simply a reflection of inaccuracies in reporting travel speed of crash involved vehicles. Furthermore, most of the studies focused on particular settings (eg; rural highways) and assumed that these findings apply equally to all roads and all environments. Studies that used objective speed measurement but retrospective crash data of those vehicles and drivers also suffer from the assumption that somehow speed behaviour today is applicable to yesterday's crashes. Moreover, when these crashes are also self-reports, then the question of the individual's ability to remember past events and his or her motivation to report all crashes is also of some concern.

Most of these studies have also failed to address the question of travel speed and speed related crashes adequately. In most studies, all crashes are implicated in these findings while a few reports have at least removed turning crashes. However, none of the studies have attempted to define what is a speed related crash or show that a relationship exists between travel speed and crash involvement for these relevant crashes only. Again, the reader is left wondering how the travel speed of vehicles in general is related to crash causation. How, for example, is travel speed relevant for a vehicle that is struck in the rear because it had to brake suddenly and was hit by a following vehicle that was travelling too close and too quickly. Issues of culpability would seem to be central to this relationship, especially if slow moving vehicles are supposedly "causing" crashes. Finally, one is left pondering the question of how meaningful it is to look for these simplistic relationships between travel speed and crash involvement without considering the characteristics of the drivers who choose to travel at these speeds. Studies such as that by Fildes et al (1991) showed that excessively fast drivers in rural settings were likely to be young, on business, travelling long distances, behind schedule, and driving recent model vehicles. Slow travellers were more likely to be older, travelling for domestic or recreation purposes, towing, and driving older vehicles. Thus, assuming that it is simply variance from the mean speed that is crash inducing overlooks other important characteristics behind this relationship. If the focus is to reduce speed related crashes, these characteristics cannot be overlooked.

There is clearly an urgent need for a re-examination of the relationship between travel speed and crash involvement, involving objective travel speed data of crashed vehicles. This would seem to require on-board speed monitoring equipment, similar to (although not as sophisticated as) an aircraft *black-box*. If indeed drivers who travel at speeds excessively above and below the speed of the rest of the traffic are causing speed related crashes, then measures should be introduced to prevent these crashes. However, these measures will need to take account of who

these drivers are, the type of vehicles they drive, the trip circumstances, the type of crashes they cause, and the environment in which they travel if they are to be successful in the long-term.

#### **2.1.4 Summary**

Considerable research has been undertaken into the relationship between speed and crash involvement. Early studies suggested that variance above and below the mean speed of the traffic was the critical factor in causing speed related crashes. While recent studies have confirmed the relationship for vehicles travelling above the mean speed, it is not clear whether slow travel speeds are also crash inducing. Furthermore, many of these studies are flawed for one reason or another because of the lack of objective travel speed data for crash involved vehicles. Evidence from clinical studies seems to suggest that excessive speed is probably involved in between 12 and 16 percent of crashes and is the most prevalent source of driver error. On this evidence, speed related crashes may be costing up to \$1 billion in Australia. Again, though, it is difficult to put much reliance on these findings because of the imprecise nature of these judgements. There is clearly an urgent need for more definitive research into the relationship between travel speed and crash involvement.

### **2.2 SPEED AND INJURY SEVERITY**

The relationship between travel speed and injury severity is considerably more convincing than for crash involvement. Indeed, the dissipation of energy resulting from any collision can be expressed by the physical relationship between vehicle mass and speed. Wadsworth (1966) among others explained how kinetic energy is generated by the moving vehicle by the square of the speed rather than speed itself, defined by the following physical relationship:

$$\text{Kinetic Energy} = \frac{1}{2} \times \text{mass} \times (\text{velocity})^2$$

Thus, a 20 percent increase in speed will, for example, result in a 44 percent increase in kinetic energy to be dissipated. This means that the likelihood of injury in a crash increases exponentially with the speed of collision. While this relationship also probably increases the associated level of injuries for vehicle occupants, the exact nature of the exchange of energy between vehicle and occupants can also influence the severity of injuries sustained.

#### **2.2.1 Empirical Studies**

The relationship between travel speed and the amount of injury sustained in a road crash was examined by Solomon (1964), Munden (1967), and Bohlin (1967). They reported a curvilinear relationship between injury and speed for vehicle occupants where the probability of a serious injury or death was substantially greater at high impact speeds, as predicted from physics. Solomon (1964) concluded that this increase was extremely rapid at travel speeds in excess of 60 mph (96 km/h). It was also shown that the probability of a fatality markedly increased above 70 mph (112 km/h). Bohlin (1967), too, reported that the curvilinear relationship can be changed (shifted) by the wearing of seat belts.

The probability of serious injury has also been shown to depend on the type of road user (Fisher and Hall 1972), vehicle involved (Campbell 1970; Mackay 1987), its mass or weight (Cerrelli 1984; Evans 1991), the type of collision (Aldman 1983), the safety features included in the vehicle (Monash University Accident Research Centre 1992; Cameron et al 1992a) and especially whether it had an airbag fitted (Evans 1991; Zador & Ciccone 1991), and for bike riders, whether they were wearing a helmet or not (Whitaker 1980; Cameron et al 1992b). Again,

some of these empirical studies are subject to the same criticisms raised in the earlier discussion of speed and crash involvement. However, there is reason to be more sure about the finding that the faster you travel, the greater the likelihood of injury. This is so because of the physics of the situation and the fact that some of these studies have related injury sustained to crash velocity, an objective measure of speed involvement (albeit not always directly related to travel speed because of skidding and braking).

### **2.2.2 The Conflict Between Cause and Consequence**

It was noted earlier that the distinction between crash causation and consequence is critical for understanding the relationship between speed and crashes and for developing useful counter-measures. From the evidence reviewed so far, it is clear that under some situations, these two characteristics can actually work against each other in attempting to alleviate road trauma. If, for example, excessively slow travellers *cause* crashes as is suggested by the U-shaped curve hypothesis, then it could be argued that increasing their travel speeds is necessary for reducing the number of crashes on the road. However, the consequence for these people will inevitably be an increase in outcome severity for those involved in crashes. Thus, there will be a trade-off in road safety between reductions in the number of crashes but an increase in the number of casualties and fatalities among these road users. For those travelling faster than the mean speed, reducing their speed will actually produce a double benefit in reduced number of crashes and fewer injuries.

### **2.2.3 Summary**

In terms of injury then, excessive speed for car occupants, motorcyclists or pedestrians is any speed that places harmful forces on the individual involved through contact with the road, its furniture, or the vehicle during a collision. Recent evidence suggests that the risk of serious injury or death can occur for different road users at relatively slow vehicle speeds (IRCOBI 1975; Whitaker 1980; Mackay 1988). It should be stressed, though, that in this situation, excessive speed may not have caused the accident so much as aided in the level of injury sustained from the collision. It is important to consider both the effects of cause and consequence in any program aimed at reducing speed related trauma.

## **2.3 SPEED LIMITS & ACCIDENTS**

The role of speed limits and road crashes has also attracted considerable attention over the years for what it implies about the effects of speeding. A number of studies have evaluated the effects of changes in speed limits on crash involvement and injury rates.

### **2.3.1 Reductions in the Speed Limit**

In a comprehensive international review of research conducted to investigate the relationship between rural speed limits and accident rates, Fieldwick (1981) reviewed studies from South Africa, Belgium, Finland, France, Great Britain, Germany, USA and New Zealand. The reductions in speed limits ranged from imposing a speed limit where there had not previously been one, to the simple reduction of an existing speed limit by as little as 5 mph (8 km/h). In every study reported there was a reduction in the incidence of road accidents associated with the reduced speed limit, the extent of the accident reductions ranged from 8 to 40 percent.

Salusjarvi (1982) was unique in reporting a simple relationship between the effects of a speed limit and its level relative to the 85th percentile of free speeds. He presented three different

effects of speed limits on accident rate (minor accidents and injury/death accidents), mean speeds, and the standard deviation depending on the level of the speed limit relative to the 85th percentile speed. Salusjarvi integrated the results of approximately 16 years of speed limit experiments undertaken in Finland. Speed limits set above the 85th percentile caused increases in crash rate (minor accidents only, injury/death accidents were unaffected) and mean speed, at the same time causing decreases in standard deviation of speeds. Speed limits set at the 85th percentile speed also caused reductions in standard deviation of speeds, however, no changes resulted in mean speed or accident rate (though injury/death accidents were decreased). Limits set below the 85th percentile caused decreases in crash rate (both minor accidents and injury/death accidents), mean speed and standard deviation of speeds. These researchers then plotted the relationship between the number of accidents and the change in mean speed. Significantly the relationships between both the injury/death accidents and all accidents passed through the origin, which means that no decrease in accident rate can be achieved in the absence of decreased mean speeds. It was reported that approximately 80 percent of the variation in Finnish road accidents was explained by the variation of travel speeds.

Johnson, Klien, Levy and Maxwell (1981) investigated the life saving benefits of the 55 mph National Maximum Speed Limit (NMSL) imposed in the USA from 1974 to 1979. Time series modelling of fatality statistics were undertaken in an attempt to similarly quantify the effects of the NMSL. The road safety literature reviewed varied in the extent to which the observed fatality reduction was attributable to reduced speeds, from the entire reduction to about half of the reduction. Johnson et al. reported that the NMSL could be realistically attributed with being responsible for slightly more than half of the observed reduction in fatalities. This finding was in keeping with those of The National Safety Council (1979, cited in Johnson et al., 1981) who reported the fatality reducing effects of the NMSL were in the order of 44 percent of the difference between the observed and expected (based on extrapolation from previous years) fatality rate for a given year (ie; 1977).

Christensen (1981) presented an overview of Danish observations of the effects of general speed limits collected both in 1973, when general speed limits were introduced, and also in 1979, when general speed limits were revised. The introduction of speed limits brought about moderate reductions in mean speeds (4 and 9 km/h on roads signed at 90 and 110 km/h respectively) whereas the reduction in speed variance was considerable (5 and 4 km/h on roads signed at 90 and 110 km/h respectively). Notwithstanding difficulties in determining a control group for comparison, the number of injury accidents fell considerably with the introduction of the general speed limits (estimated reductions in the order of 20 percent). In 1979 general speed limits were reduced from 110 and 90 km/h to 100 and 80 km/h respectively. In response to the reductions the general speed limits, mean speeds fell a modest 2km/h as did speed variance (representing a 15 percent reduction), however levels of non compliance rose from approximately 15 percent to approximately 33 percent. The reductions in injury accidents again fell considerably following the revision of the general speed limits (estimated reductions ranging from 13 to 21 percent).

Since the Christmas of 1960, when speed limits on roads outside built up areas in Sweden were first introduced, research has been conducted into the effects of speed limits on motorists' behaviour and road safety (Nilsson, 1981). A large proportion of the research conducted has studied the effects of lowered speed limits, the results of which "*...indicate that the accident rates are strongly dependent upon the speeds*" (Nilsson, 1981, p. 7). Accident severity was also found to increase with increasing speed. Nilsson (1981) quantified the accident rate reducing

effects of reduced median speeds (presumably resulting from reduced speed limits) as follows: *“The percentage drop in accident rates outside built up areas is  $n$  times the percentage drop in mean speeds where  $n=4$  for fatal accidents,  $n=3$  for personal injury accidents and  $n=2$  for all accidents”*. This relationship was based on the results of Swedish research, but is in keeping with (and often times, more conservative than) the findings from other countries (OECD, 1981).

More recently, Nilsson (1990) described the effects of reducing the maximum speed limit on Swedish roads for two months during the summer of 1989. The reduction in the maximum speed limit from 110 to 90 km/h was enacted in response to increases in personal injury accidents (in which persons are injured or killed) during 1988 and the spring of 1989. In conjunction with the reduced speed limits, various information and surveillance activities were carried out, which alone may have caused reductions in travel speed and accident rates. Estimates of the effect of the speed limit reductions were made for the 110 and 90 km/h roads by comparing the traffic safety trends (speed behaviour, the number of accidents and the number of persons injured or killed) on roads on which the speed limits were reduced (110 and 90 km/h) and roads on which the speed limits remained unchanged (70 km/h). Nilsson warns that the use of 70 km/h roads as a control group was not without difficulties, as the speeds on these roads also fell, making estimates of change somewhat conservative. Compared to the summer of 1988, 1989 median speeds for roads on which the speed limit was reduced from 110 to 90 km/h fell between 11 and 14.4 km/h depending on the type of road. It was estimated that reductions in personal injury accidents of 27 percent and the number of persons killed or injured of 21 percent were attributable to the reduced speed limit from 110 to 90 km/h on 5500 kilometres of road. Though not significant, the effects of the lower speed limits also led to reductions in travel speeds on roads where there were no reductions in speed limit (ie. all of the 70 and some of the 90 km/h roads).

Swedish welfare economics assessments of the dollar value of the reduced accident rates put the savings in the order of SEK 350 million. Again, it must be emphasised that a number of information and surveillance activities were carried out in conjunction with the reduced speed limit so the safety effects found can not be attributed solely to the reduced speed limits. Rather, the changes in road safety must be attributed to the changes in driving behaviour, both known and unknown, that come about as a result of the combined effects (poorly understood) of speed limit changes, publicity and surveillance.

While the results of individual studies described above and that previously reported by others (OECD, 1972; Johnston, White & Cumming 1973; Nilsson 1977; Johnson 1980; Hearne 1981; Lassarre & Tan 1981) may have various methodological deficiencies, it would appear lowering speed limits has result in reducing the number and severity of crashes. Certainly, researchers that have undertaken extensive reviews of studies investigating the relationship between speed limit changes and crashes have all concluded that reductions in speed limits have associated benefits in terms of reduced crash rates (Fieldwick, 1981; OECD, 1981; Sanderson & Cameron, 1982; Cowley, 1987). However, the reasons for these benefits were not made clear in most of these reports, whether the reduction in crashes and injury severity can be attributed to reductions in mean speed, reductions in speed variance, reductions in traffic volumes or perhaps some increased general awareness effect can not be determined.

### **2.3.2 Increases in Speed Limits**

More recently, there have been reports (mainly from the US) on the consequences of **increasing** speed limits in terms of subsequent injuries. The Insurance Institute for Highway Safety in the

USA reported that the overall effect of increasing the speed limit from 55 mph (88 km/h) to 65 mph (104 km/h) on rural interstate highways in 38 States was an increase in vehicle fatalities of 22 percent, compared to other rural highways (IIHS 1988). Unfortunately, they did not report how many deaths were actually involved and what happened to the collision rates on these roads after the speed limit changed. While they did report an increase in overall mean speed on some of these higher posted roads (O'Neill, 1987; 1988), it appears that speed variance may have also reduced and hence, the number of crashes might be expected to have actually decreased. In other words, fewer collisions but a greater likelihood of being killed at the higher speeds.

Wagenaar, Streff and Schulz (1989) subsequently examined the effects of raising the maximum speed limit on Michigan's rural limited-access highways from 55 to 65 mph (88 km/h to 104 km/h) in December 1987/January 1988. They used multiple time-series analyses to compare the number of crashes, injuries and deaths on roads where the speed limit changed with roads where the speed limit remained unchanged. The reported effects of the increased speed limit were described as follows: 48 percent increase in fatalities, 32 percent increase in serious injuries, 30 percent increase in moderate injuries, 27 percent increase in property damage only accidents and no difference in minor injuries. There was a spill-over effect reported in which fatalities on freeways with no increase in speed limit were found to have increased. In conclusion these researchers stated that while the majority of the public support the increased speed limit (65 mph) the benefits of reduced travel times have high associated costs.

Streff and Schulz (1991) conducted a similar study to that formerly undertaken by Wagenaar, Streff and Schulz (1989) focussing on a much larger database available on Michigan's speed limit changes. They showed similar findings with regard to fatalities (28 percent increase), serious injuries (39 percent increase), and moderate injuries (24 percent increase). However, these researchers reported no change in the number of "traffic units" involved in crashes. This finding was interpreted as support for the notion that raising the speed limit causes increases in injury severity not the incidence of accidents. Wright and Sarasua (1991) studied the effects of increasing the speed limit on federal interstate highways in Georgia in 1988. In a "before" and "after" comparison design, odds ratios were used to compare the numbers of fatal accidents, fatalities, and injuries in the six months prior to the speed limit increase to the six months following. This research "confirmed the expectation" that increased speed limits would lead to increased fatalities of around 10 percent.

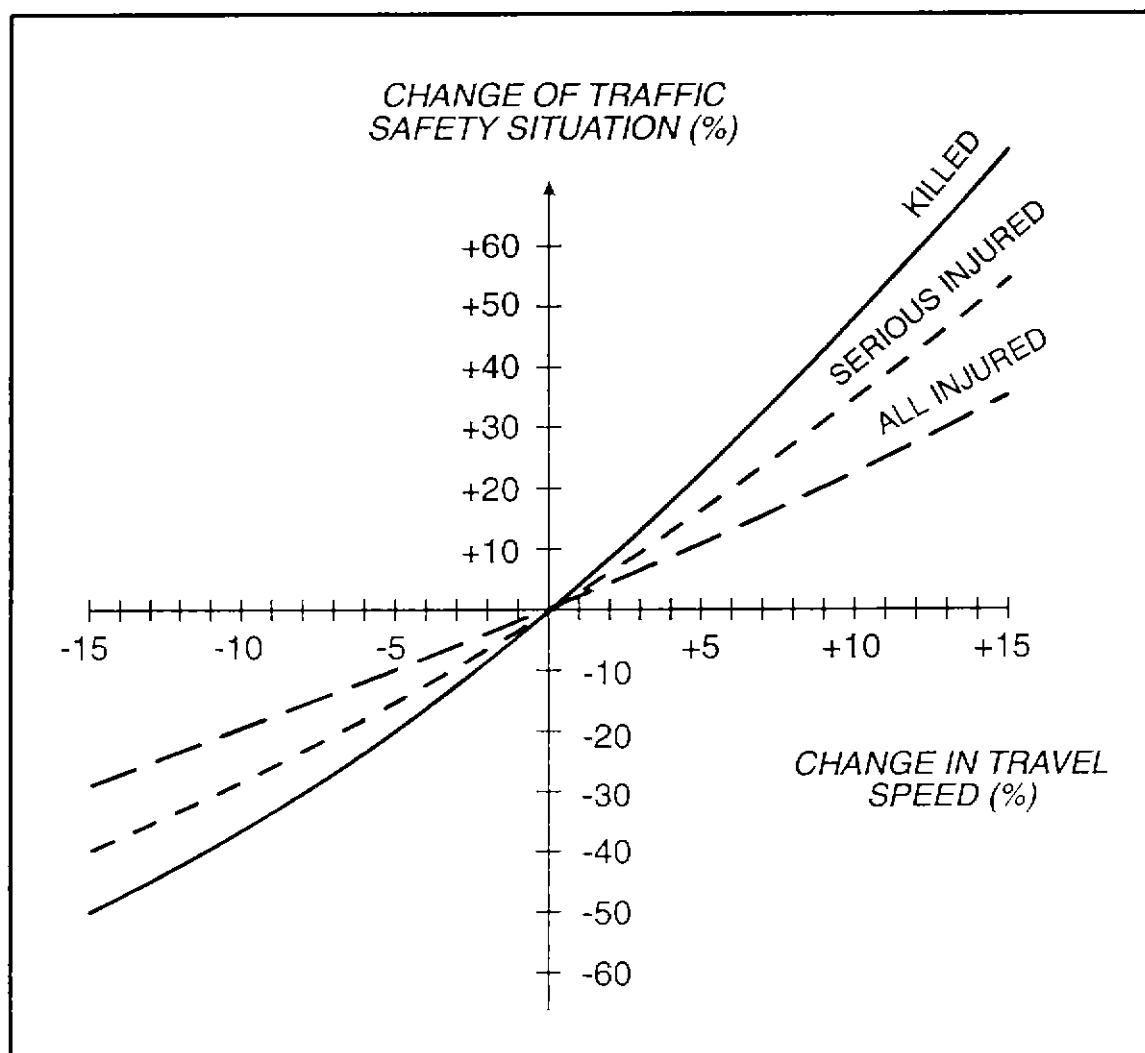
Garber and Graham (1990) examined the effects of the increasing the speed limit from 55 to 65 mph on USA rural highway fatality counts. State by state analyses were conducted for each of the 40 states that had adopted the increased speed limit prior to mid 1988. The effects of the speed limit varied widely from state to state, however, the median effect of the speed limit was increases in fatalities of 15 percent on rural interstates, and 5 percent on rural non-interstates. Baum, Wells and Lund (1990) also claimed that higher limits on these highways caused between a 26% to 29% increase in fatalities on these roads.

Using a similar analysis to that carried out by Garber and Graham but including allowance for "system-wide effects", Lave and Elias (1992) reported that fatality rates actually fell by between 3.4% and 5.1%. They attributed this reduction to drivers switching to safer roads (attracted by the higher speed limits), a shift in enforcement to higher pay-off activities, and a decline in speed variance. However, they failed to provide any evidence to support these claims. An alternative might also be that the reductions in fatalities they observed "state-wide" might also

be the result of other system-wide changes such as economic activity variations, the introduction of other intervention programs, etc., rather than the effects of speed limit changes per se.

### 2.3.3 Speed Limit Change and Safety

From at least 50 different investigations of speed limit changes in Sweden in rural and urban areas, Nilsson (1992) arrived at a series of empirical functions that he argued explains the relationship between changing the speed limit and the safety in that country. Figure 2.3 shows this function. The likely increase in fatal accidents he argued can be expressed as the change in velocity to the power 4 for fatal accidents, the power 3 for severe injury accidents, and the power 2 for all injury accidents. In addition, he outlined similar functions for estimating the likely increase in the number of fatalities, severely injured, and all injuries in these crashes. Thus, his model is a potentially powerful tool for estimating the likely benefits or disbenefits of increasing or decreasing travel speed.



**Figure 2.3** Effect of changes in the speed limit on the severity of outcome of crashes (from Nilsson).

Similarly, Salusjarvi (1982) also produced curves which predicted the likely safety consequences of a change in the speed limit in Finland. How well these functions describe safety benefits or disbenefits in other countries subject to differing *cultural* standards on the road is unclear. Moreover, these functions would need to be used carefully as they refer to changes in travel speed, *not* changes in the speed limit. Nevertheless, this approach has considerable merit for demonstrating the likely effects of inducing changes in speed behaviour in this country. The relevance of the formula presented, though, would need to be established for Australian conditions.

### **2.3.4 Summary**

Collectively, these reports tend to show that lowering speed limits can result in fewer serious injuries and deaths in the short-term, while increased speed limits, reported mainly in the USA, seem to have resulted in higher levels of injury severity and more fatalities. This finding is in line with that expected from the evidence reviewed earlier about the relationship between crash speed and injury severity. However, very few of these studies examined the consequences of speed limit changes on free speed distributions and crash involvement rates, and those that did were somewhat equivocal. Moreover, the long-term effects of changes in speed limits in terms of the reduced injuries, number of crashes, and the difficulty of maintaining compliance with lower speed limits on highways is essentially still unanswered. The work in Sweden and Finland in specifying mathematically the relationship between changes in travel speed and safety is promising but requires reliability testing in this country before it could be adopted for use in Australia.

## **2.4 OTHER SPEED AND CRASH STUDIES**

A number of other specific studies on various aspects of speeding and crashes was uncovered during this review and is included here for completeness.

### **2.4.1 Stopping distance**

Vehicle speed can influence accident rates and severity through the effects of speed on stopping distance. Increases in speed cause disproportionately greater increases in stopping distance. The stopping distance of vehicle is affected by a number of factors including driver reaction time, vehicle speed, alignment of the roadway, and the friction between the brake/tyre/road interface. Jernigan, Lyn and Garber (1988) compared the stopping distances associated with different speeds using the following equation to calculate the distance covered between application of the brakes and stopping:

$$\text{Distance} = \text{velocity}^2 / (30 \times \text{coefficient of friction})$$

It can be seen that this distance covered between application of the brakes and stopping will vary exponentially with vehicle speed. The distance covered between detecting a hazard (a need to stop) and application of the brakes also increases with vehicle speed in a linear fashion where greater distances are traversed in the constant reaction time for greater vehicle speeds. The combined effects of these increases are such that disproportionate increases in stopping distance result from increased travel speed. Using this relationship Jernigan et al. (1988) demonstrated that an 18 percent increase in speed between 55 and 65 mph resulted in a 38 percent increase in stopping distance.



Under conditions of slow speed, large sight distances (of hazards) and normal levels of friction, sight distance (the distance to the hazard at the time of sighting) far exceeds the minimum stopping distance. In such circumstances the difference between these two distances represents a safety margin or allowable reaction time. Logically, all things being equal, increases in speed serve to erode this allowable reaction time. The term "*over-driving*" (eg. over-driving headlight visibility) has been used to describe the practice of driving at speeds that render the minimum stopping distance greater than the sight distance for the prevailing conditions. Here, the appearance of a road hazard spells almost certain disaster, or at least certain collision.

#### **2.4.2 Multiplicity of Effects**

The problem of bringing about safer road travel is not a simple one to address. There are safety benefits from reduced travel speed through reduced injury severity if not through reduced frequency of crashes. However, many other factors apart from travel speed can also influence safety, such as the type of vehicles involved, their mass, degree of safety features, and the type of collision. Driver variables, too, including BAC level, the level of fatigue, the presence of other drugs, similarly also contribute to road trauma. One or two studies have identified a number of important interactions between travel speed and other factors likely to influence speeding behaviour.

Fildes et al (1991) reported that a number of driver, vehicle and trip characteristics were linked with travel speed. They reported that drivers travelling excessively fast were most likely to be aged less than 34 years, on business, behind schedule, driving a car less than five years old, and not towing a trailer. Not unexpectedly, those travelling at excessively fast speeds were also more likely to report previous accident involvement, and also more likely to report medical and hospital treatment for their injuries resulting from these crashes.

An analysis of the Federal Office of Road Safety 1988 Fatality File (FORS 1992) containing detailed information on all fatal crashes in Australia in 1988 revealed that time of day and alcohol involvement was associated with the incidence of speed related crashes. An assessment was made of each crash to determine whether or not it involved a vehicle that was probably exceeding the speed limit. Approximately 60 percent of the fatal crashes between 3.00am and 4.00am involved a vehicle that was probably exceeding the speed limit, while only 25 percent of the fatal crashes between 6.00am and 4.00pm were similarly assessed. Moreover, the hourly variations in speeding were closely related to alcohol involvement in fatal crashes. The incidence of speeding was much higher in crashes that involved at least one driver with a BAC above .05, and alcohol involvement was maximal at night and minimal during the day in a similar fashion to that observed for speed involvement. It was concluded that most of the variation in speed involvement by time of day could be predicted from the time of day by alcohol and speeding by alcohol involvement data.

Current practices for controlling travel speeds, such as speed limits supported by enforcement and mass media publicity, generally treat drivers as a homogeneous group of potential speeders. This evidence suggests that there may be particular sub-groups of the driving population that are more likely to speed than others and that other factors (eg; drugs, alcohol, fatigue) may predispose drivers to speed. This area warrants further investigation

### 2.4.3 Automatic Enforcement

The major safety benefits of speed enforcement are thought to be achieved through reduced travel speeds. Then, through reduced travel speeds, safety benefits such as reduced crash frequency (not unequivocally supported) and severity are gained. In a sense the safety benefits are once removed from the enforcement, a secondary effect. An alternate, or perhaps additional, hypothesis to the one described above is that speed enforcement has some direct effect on safety quite separate from that passed on through reduced travel speeds. It seems reasonable to postulate that enforcement may bring about increased levels of driver vigilance (in the hope that early sighting of police will reduce the likelihood of detection and punishment), and that these increased levels of vigilance will have inherent safety benefits.

Whether the safety enhancing effects of enforcement act through mechanisms that are direct or secondary, they are not often directly assessed. Rather, the effects of speed enforcement are usually measured in terms of reduced travel speed. However, two recent evaluations of speed camera campaigns have measured the effects of enforcement on accident frequency and severity directly. As reported earlier, Blackburn and Glance (1984, as cited in Freedman, Williams & Lund, 1990) evaluated the effect of introducing automatic enforcement to enhance compliance with a new reduced speed limit (100 km/h) on a German autobahn. The annual number of crashes decreased from 300 to just nine after the introduction of a speed cameras, likewise the injuries fell from 80 to five, and deaths from seven to none. While the effects of enforcement are confounded by the unknown affects of the new speed limit alone, significant effects of speed enforcement were measured directly in terms of increased safety.

More recently Cameron, Cavallo and Gilbert (1992) undertook an evaluation of the effects of the Victorian speed camera program between July 1990 and December 1991 on casualty crash frequency and severity. These researchers used time series analysis to control for long term trends, seasonal cycles and other patterns in the measures employed. The speed camera program was attributed with a state-wide reduction in the frequency of casualty crashes in the order of 20 percent. Similarly, state-wide reductions in casualty crash severity between 28 and 40 percent were attributed to the speed camera program. It is not clear from this report though whether the crash reduction benefits were associated with speed reductions (injury savings) or simply increased vigilance (fewer crashes). There would be merit in a more detailed analysis of the effects of automatic enforcement on crash reduction, especially whether any crash reductions were due to speed reductions or increased vigilance effects.

### 2.4.4 Summary

The review of other speed and crash research revealed several interesting findings. First, increases in speed lead to reduced braking efficiency and poor driver reactions and appear to cause disproportionately greater increases in stopping distance. An 18 percent increase in speed from 55 to 65 mph (88 to 104 km/h) reportedly resulted in a 38 percent increase in stopping distance. Interactive effects between speeding and other factors need to be considered in programs aimed at reducing travel speed. There was a suggestion that drink-driving is correlated with excessive speeding, especially at certain times during the day. Additional analysis is warranted to establish these interactions. Furthermore, it would also be worthwhile conducting a more detailed analysis of the effects of automatic enforcement on crash reduction, especially whether any crash reductions were due to speed reductions or increased vigilance effects.

## 2.5 CONCLUSIONS FROM THIS REVIEW

A number of important conclusions can be reached as a result of the review of the relationship between speed and crashes.

1. It is critical to distinguish between crash involvement and crash consequence in examining the role of speed and safety. They are fundamentally different concepts requiring separate consideration in any program aimed at improving safety.
2. Early research suggested that the cause of speed in road crashes was variance from the speed of the rest of the traffic, rather than the absolute speed level itself. The U-shaped hypothesis claimed that both slow and fast travel speeds relative to the mean speed were crash inducing. A recent study failed to show any evidence that slow travel was associated with increased crashes. A skewed speed distribution was more likely to have higher crash rates than a more normal speed distribution.
3. Many of these studies were severely flawed methodologically by their retrospective nature. The assumptions that needed to be made in deriving relationships between travel speed and crash involvement were highly questionable. Moreover, it was suggested that there is little merit in establishing overall relationships between speed and crash causality without examining the characteristics of slow and fast travellers.
4. Evidence from clinical studies seems to suggest that excessive speed is probably involved in between 12 and 16 percent of crashes and is the most prevalent source of driver error. On this evidence, speed related crashes may be costing \$1 billion in Australia. It is difficult to put much reliance on these findings though because of the imprecise nature of these judgements.
5. The evidence of the consequence of speed in crashes is more clear-cut. The faster the collision, the greater the likelihood of injury, severe injuries or death. This is supported by physics that shows that impact force is a function of mass times velocity squared. The exponential relationship between crash speed and injury risk can vary depending on the type of road user, safety devices, age of the victim, etc.
6. A conflict exists when considering improved road safety benefits for slow travellers. While increasing their speed *may* lead to fewer crashes, it will inevitably result in an increase in outcome severity for these people.
7. Reports of the effects of changing speed limits have shown that lowering speed limits can result in fewer serious injuries and deaths while increased speed limits seem to have resulted in higher levels of injury severity and fatalities.
8. Very few of these studies, though, have examined the consequences of speed limit changes on free speed distributions and all crash involvement rates, and those that did were somewhat equivocal. The long-term effects of speed limit changes on safety has not been adequately addressed.
9. The work in Sweden and Finland in mathematically specifying the relationship between changes in travel speed and safety is promising. Reliability testing of these findings in this country is required before it could be adopted for use in Australia.

10. Increases in speed cause disproportionately greater increases in stopping distance, resulting from lower braking efficiency and poor driver reactions. It was reported that an 18 percent increase in speed from 55 to 65 mph (88 to 104 km/h) results in a 38 percent increase in stopping distance.
11. Future programs aimed at reducing travel speed on the road should consider the interactive effects of travel speed with other known road safety risk factors such as drink-driving, fatigue, and possibly other drug use.

## 2.6 OPTIONS FOR FUTURE RESEARCH AND DEVELOPMENT

The following options for further research and development seem paramount from this review.

1. There is clearly a pressing need for further research into the speed and crash involvement relationship, using more of a prospective design strategy. While there would be merit in demonstrating the existence or otherwise of a variance hypothesis still, the focus should also be on determining the circumstances under which drivers choose to travel excessively fast or slow relative to the rest of the traffic. This will help identify countermeasures that are required to reduce the number of speed related crashes in Australia. This work should examine crash involvement rates for different road environments, crash types, driver and vehicle characteristics, trip purposes, culpability, and to the degree possible, degree of impairment (BAC, fatigue, etc). Associated issues or R and D for this study should include:
  - . how to obtain objective measures of speed in crashed vehicles. This would seem to require the development of a "*black-box*" recorder that could be installed on a sufficient number of representative vehicles to provide meaningful results.
  - . what is a speed related crash. If the study is to provide meaningful data about crash causation, then the results need to emphasise "*causes*" and not "*effects*". There is little agreement about what constitutes a speed related crash and this needs further consideration.
  - . more detail crash analysis including occurrence-consequence process, time-sequence modes, energy damage modelling, fault tree analysis, etc.
2. It would also be useful to establish (to the extent possible) speed and injury findings similar to those reported in Sweden and Finland. This would help further our understanding of the consequences of increasing or decreasing speed limits in certain situations and allow the use of additional inputs to speed limit setting such as cost-benefit and crash equalisation considerations.
3. There would be merit in further research aimed at clarifying the real benefits of enforcement effects from speed cameras. In particular, are the benefits in crash reductions ascribed to automatic enforcement due to speed reductions or simply higher vigilance.

### **3. SPEED LIMITS**

As a result of the international oil crisis in 1973, there was an urgent world-wide realisation that energy supplies were not endless. Consequently, many countries introduced new or lower open road speed limits principally as an energy conservation measure. An additional, and to some extent unanticipated, result of the reduced maximum speed limits was a significant reduction in road trauma. This observation then led to the adoption of speed limits as a recognised countermeasure to road trauma, and therefore a quintessential component of road safety programs.

#### **3.1 PRINCIPLES UNDERLYING SPEED LIMITS**

##### **3.1.1 Mobility and Safety**

It should be mentioned that as in many aspects of travel, the setting of speed limits represents a trade-off between mobility and safety. The underlying intention of speed limits is to optimise both these aspects to the degree possible, bearing in mind that ultimately, mobility and safety requirements will be in conflict. Thus, there has been considerable resistance in the past to calls for a general increase in speed limits, given the likely cost this will inevitably have in increased road trauma.

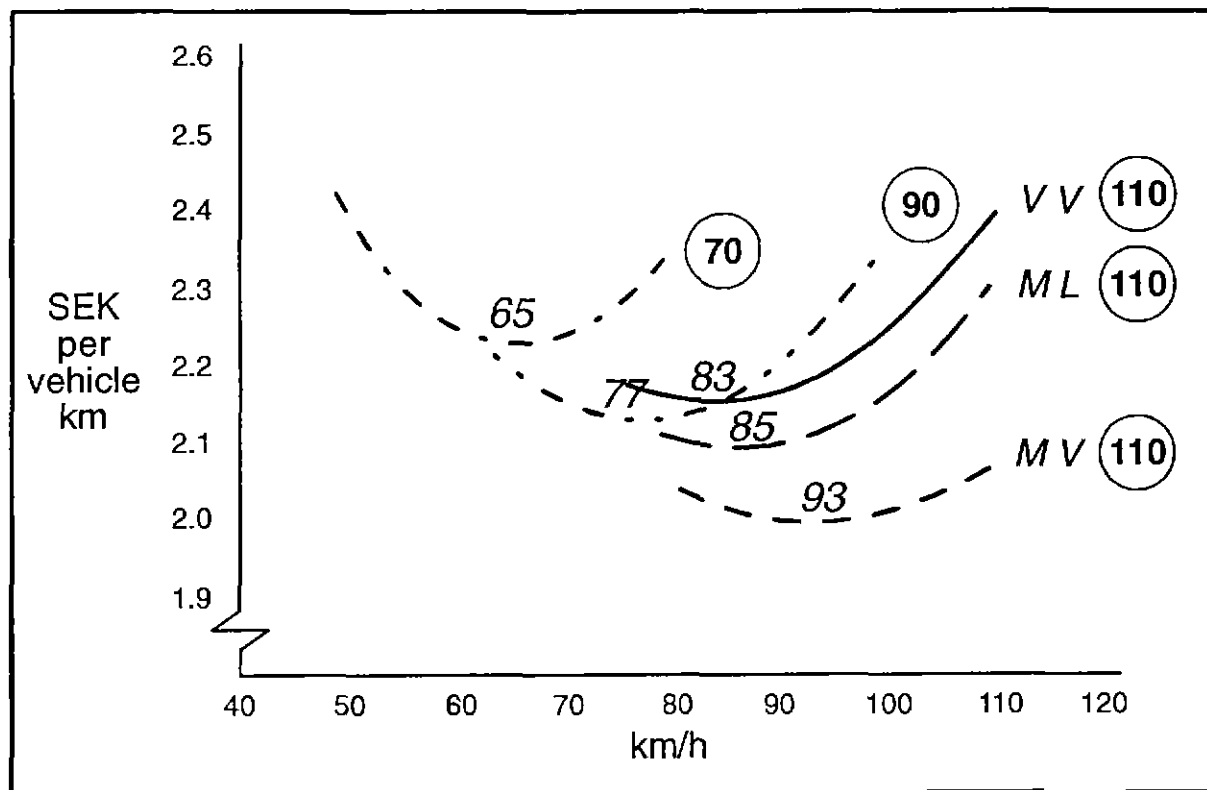
Speed limits need to be set at levels that motorists generally accept as a reliable guide to the appropriate speed for a given section of road. An appropriate speed would be one that the driver believes is an acceptable trade-off between meeting the often antagonistic needs for mobility and safety. The need for greater mobility can often be best met by higher speeds, whereas the need for improved safety may dictate slower speeds (stationary being absolutely safe). Balancing these two needs is a difficult task indeed. A driver's mobility needs are constantly changing; in rational terms, mobility is a function of the vehicle and roadway, trip purpose, trip function, duration, economic consequences, utility, and so on. Any one of these can change from moment to moment thereby altering a driver's immediate mobility needs. A driver's perception of safety (risk of a crash or injury) is also not immediately apparent from an increase in travel speed, given that crashes are relatively rare events. Not surprising then, authorities are often accused of erring on the side of safety. That is, they are often criticised for setting limits that do not always reflect a credible balance between the many factors affecting speed choice under optimal driving conditions. Taken to the extreme, the lack of credibility between posted speed limits and motorists' perceptions of an appropriate travel speed can be counter-productive.

Nilsson (1992) attempted to determine optimum speeds taking account of these multiple factors and his resultant curves are shown in Figure 3.1. These curves incorporate allowances for safety, mobility, fuel consumption, and environmental effects. It should be pointed out that in deriving these curves, Nilsson was forced to make several assumptions about particular states or values of these variables which if changed could lead to a shift or change in these functions. Nevertheless, the curves demonstrate how speed limits can take account of different community aspects of safety, mobility, and the environment.

##### **3.1.2 The Need for Credible Speed Limits**

Speed limits must match the expectations of drivers to some degree. General acceptance of speed limits is required to ensure adequate levels of voluntary compliance in the absence of

enforcement. It was recognition of this fact that is behind recent calls for setting speed limits that more correctly address the multiplicity of factors involved in arriving at an appropriate travel speed (SDC 1991). The credibility of speed limits rests on drivers' perception of their appropriateness in terms of specific road sections, and relativities with other limits on equivalent road sections. Naturally, if drivers learn through experience that it appears perfectly "safe" to exceed the speed limit (that is, not likely to result in immediate crashes or fines), they will pay them little attention.



**Figure 3.1** Optimum speed limits taking account of safety, mobility, fuel consumption and other environmental effects

It has been claimed that excessive speeding in part can be attributed to improper speed limits where some drivers believe that their behaviour in exceeding the speed limit is not risky and therefore not deemed illegal (Ruschman, Joscelyn, & Treat, 1981). The criminalising of such common behaviour also can have the undesirable effect of distributing scarce police resources towards what can amount to rather trivial mis-behaviours. More appropriate speed limits would enable enforcement to target more life threatening behaviour, for example, unsafe overtaking (Mr G. Quayle in statement made to the SDC, 1991; Ruschman, Joscelyn, & Treat, 1981).

### 3.1.3 Design Speed Considerations

A consequence for the credibility of speed limits involves discrepancies between posted speed limits and the “*design speed*” for that road, particularly on major arterials and freeways. In rural areas, for example, engineers designing freeways commonly assume a travel speed of 130km/h which supposedly allows a minimum 2.5 second reaction time for drivers to respond to an object on the road. While the reaction time concept has previously been criticised as too simplistic (McLean and Hoffman 1972; Fildes 1986), designers nevertheless have argued that adopting this practice is good for safety as it allows a margin for error (NAASRA 1980). Not surprisingly then, some motorists tend to travel close to these speeds on these roads and other motorists report difficulty in trying to keep their speeds down to a lower speed limit (Fildes et al 1991). Effective speed management on these roads, therefore, may require high levels of speed enforcement and one is left questioning the validity of this approach.

Speed limits on freeways have been a contentious issue in Victoria recently. While the Speed Management Strategy for Victoria (RTA 1987) and the Social Development Committees Inquiry into speed limits (SDC 1991) both recommended 110km/h maximum speed limits on these roads, the Victorian Government decided on a 100km/h limit to reduce trauma. The effectiveness of this program is the subject of a report soon to be released by Vic Roads. While it is difficult to argue for blanket increases in travel speeds generally from a pure road safety perspective, the merits for increasing speeds to approximate design conditions and the crash consequences of this has not been adequately addressed in the literature. Conversely, the need for 130km/h design speeds in the light of slower legal limits might need to be re-examined if speed limit increases are generally undesirable. This is an area clearly requiring further research.

### 3.1.4 Summary

Maximum speed limits need to be cognizant of motorists’ perceptions of what constitutes an acceptable travel speed. There will be inevitable conflict between the many factors that will affect optimal speed. With constant improvements in the quality of roads and vehicles, enforcement will ultimately be required to maintain traffic speeds to an acceptable level. There is a need to consider the relationship between design speed and travel speed and its consequences for enforcement and crashes.

## 3.2 TRADITIONAL APPROACHES USED IN SETTING SPEED LIMITS

Speed limits traditionally consist of general rules that apply in discrete areas, such as urban or rural settings. Where these limits vary due to roadway, traffic or adjacent land use, the practice has come to be known as “*speed zoning*” (NAASRA, 1980). Limits themselves can either be specified as *absolute*, being the maximum speed at which a vehicle is permitted to travel, or *prima facie*, being the speed above which a driver would have to prove that the speed was compatible with prevailing conditions. Absolute (maximum) speed limits appear to exert a greater influence on the distribution of speeds than *prima facie* limits. Cleveland (1970) and Cumming and Croft (1971) reported reductions in the number of excessively speeding vehicles when appropriate absolute limits were chosen, although the average speed was not affected very much. This has not been proven yet for *prima facie* limits (Herbert & Croft 1979).

### 3.2.1 The 85th Percentile Method

Historically, speed limits have been set at or near the 85th percentile speed of the traffic, that is, the speed at or below which 85% of motorists choose to travel. This choice stems from the research undertaken by Witheford (1970) who stated that:

*"the 85th percentile speed is that most desirably approximated by a speed limit. Because of the general straight and steep slope of the typical speed distribution below the 85th percentile, a speed limit set only a little lower will cause a large number of drivers to be violators".*

The Research Triangle Institute (1970) study of the relationship between speed and accidents endorsed the 85th percentile speed as the criterion for the setting of maximum speed limits. These researchers recommended that the upper speed limit be set at the 85th percentile speed, with supporting enforcement against those exceeding the 95th percentile speed. Similarly, at the other end of the speed distribution, it was recommended that minimum speed limits be set at the 15th percentile speed, with enforcement action to be taken against those travelling slower than the 5th percentile speed.

Joscelyn, Jones and Elston (1970) undertook a survey of practices used in the United States to establish maximum speed limits, together with a major review of the various techniques for establishing speed limits. From a screening analysis, it was suggested that three methods were worthy of further consideration for full scale implementation. These included the theory of speed distribution skewness (Taylor, 1965), cost orientation (Oppenlander, 1966), and the 85th percentile method. Their analysis showed a strong relationship between deviation of the speed of the crashed vehicle from the mean speed of the traffic stream (Joscelyn et al 1970). This report also showed that the cumulative crash rate was relatively independent of speed until the 85th percentile value after which it rose exponentially. The authors recommended that maximum speed limits should be based on the 85th percentile of the observed travel speeds (whether they meant set at the 85% speed or enforced at the 85% speed is not clear from this report). Salusjarvi (1982) also argued for the 85% method for setting speed limits to minimise crashes.

In a statement to the SDC (1991), Mr. Jim Jarvis argued that the 85th percentile speed is not always the best method of setting speed limits. While drivers usually drive at reasonable and sensible speeds this is not always the case. A method of zoning that does not rely on the perceived appropriate speed of the driver is necessary because the driver does not always have all of the information necessary to make a truly informed decision. The concerns expressed above by Jarvis are reinforced by the findings of Sanderson and Corrigan (1984) who assessed the appropriateness of speed limits on Victorian arterial roads. They reported that speed limits of 60 and 75km/h were inappropriate as determined by mean and 85th percentile speeds. Moreover, they reported that speed behaviour did not differ if the road was with or without service roads. The reported indifference of drivers' speed behaviour towards the high levels of access control afforded by service roads supports the notion that the 85th percentile speed is not always appropriate.

Finally, accurately determining the unconstrained free flow 85% speed is not without difficulty. In most situations, drivers are aware to some degree of the speed limit that applies on the road they travel (motorists are aware that all roads in Australia have a speed limit ranging generally from 60km/h in urban areas to 100 or 110km/h on rural highways). Thus, the 85% speed reflects these constraints and hence, they are not true indications of what 85% of the population would choose if no constraints apply. In short, the 85% is not an unconstrained measure of



motorists' perceptions but rather an expression what the majority of motorists are prepared to travel at on that road, influenced by the prevailing speed limit, enforcement activity, amount of traffic, time of day, etc.

### **3.2.2 Other Approaches from Overseas**

*Pace speed* has been advocated as an alternative and more appropriate reference for speed limits than the 85th percentile value (Carter, 1949, as cited in Ruschman, Joscelyn, & Treat, 1981). The pace speed is defined as the 10mph (16km/h) band in which the majority of the vehicle speeds occur. It was recommended that the limit be set at the upper bounds of the pace speed. However, Ruschman et al argued that under normal circumstances, this speed closely resembles the 85th percentile speed.

A more recent alternative to the 85th percentile speed approach involves cost-benefit analysis. Cowley (1981) suggested that speed limits could be set at speeds which minimise overall transportation cost. The European Conference of Ministers of Transport (1977) discussed cost-benefit analysis with respect to general limits, reviewing previous studies and the advantages and disadvantages of the method. It was concluded that the cost-benefit approach would have to be developed further before it could be effectively evaluated.

Nilsson in Sweden proposed a variant of the cost-benefit approach, based on setting maximum speed limits that equate crash involvement (Cameron 1992). Salusjarvi (1981) too proposed a variant of this approach. These researchers argued that speed limits should be chosen for all roads to balance to some predetermined "acceptable" level of road trauma (some predetermined rate of crashes and injuries). Nilsson proposed that this road trauma balance is achieved by examining the distribution of speed and crash involvement level for a particular road and then, using a series of speed and injury curves for differing outcome severities, determine what the necessary speed reduction should be to achieve this acceptable level of trauma, thus arriving at the speed limit for that section of road. While this method has some intuitive appeal, it is yet to be demonstrated whether this balance can be achieved in the long term and it raises the thorny question of what is an acceptable level of trauma.

### **3.2.3 Summary**

In spite of criticisms levelled at the 85th percentile method of speed limit setting, it has historically been an important criterion employed for the determination of speed limits, both overseas and in Australia. Its strength has been its acceptance of motorists' expressions of what they perceive an acceptable speed limit is (speed limits that do not meet with driver's expectation are bound to lead to poor levels of compliance in the absence of heavy enforcement). Whether it continues to be the most appropriate means of setting speed limits in the current environment however is subject to debate. The issue of whether motorists always drive at the most appropriate speed is of concern. In addition, competing forces such as the need for consistency and the desire to reduce crashes and injuries often work against the 85th percentile approach.

## **3.3 SPEED LIMITS IN AUSTRALIA**

Speed limits in Australia appear to have had their origins in the mid 1930's with the introduction of a 30mph (48km/h) speed limit in built up areas through the National Road Safety Code. In most states this urban limit was raised to 35mph (56km/h) in the early 1960's in recognition of improvements in roads and vehicles. It was not until the late 1960's and even into the 1970's

that all states (except the Northern Territory) introduced maximum speed limits (Thomson 1982). The improvements in roads and vehicles also contributed to the introduction of higher maximum speed limits in rural areas. Until this time, the speed behaviour of motorists was, to a large degree, determined by the speed potential of the car and the road, rather than the speed limit. However the speed potential of the car fleet has continued to increase to the point where it now far exceeds speed limits.

The lack of documentation into setting speed limits in Australia suggests that overseas experience has been used extensively in the past and that Australia has been led, rather than a leader, in this area. More recently however, a number of states have taken a keen research interest in legitimizing Australian speed limit setting practices through locally based reviews of the principles and implementation of speed zoning practices. These reviews, for example, have resulted in documents such as "*A Speed Management Strategy for Victoria*" by the Victorian Road Traffic Authority (1987), the Social Development Committee of Victoria's "*Inquiry into Speed Limits in Victoria*" (1991), and the Traffic Authority of New South Wales' (1988) "*Speed Zoning: A Review of Principles and Practice in New South Wales*".

All states in Australia currently impose both general speed limits and to some extent, speed zoning, on road traffic. General speed limits are defined as limits that are applied throughout areas of like traffic environment. Throughout Australia, a general speed limit of 60km/h applies in urban areas (where street lighting exists) and 100km/h in rural areas. The need for speed zoning or the practice of imposing more variation in speed limits to adjust for varying road and roadside setting changes is currently receiving widespread attention. These designated speed zones take precedence over the general speed limit that would normally apply to these roads.

The Standards Association of Australia publish guide lines for the setting of speed limits, Australian Standard 1742.4, Manual of Uniform Traffic Control Devices- Part 4- Speed Controls. However, while some states choose to use these guide-lines for setting speed limits (ACT, Northern Territory, Queensland and South Australia) others have developed their own guide-lines that incorporate the general principles outlined in AS 1742.4 and the particular needs of the state (New South Wales, Victoria, Tasmania and Western Australia). It would be worthwhile reviewing what is current practice in all states and territories in Australia in setting speed limits.

### **3.3.1 New South Wales**

The determination of speed limits in New South Wales is based on the information found in section 4.15, *Speed Limits of the Signs and Markings* manual. Speed limits employed range from 10km/h to 110km/h, in 10km/h increments, including all eleven limits within this range. The maximum speed for a given section is determined from:

- ☐ road development
- ☐ road characteristics
- ☐ alignment
- ☐ formation
- ☐ road hazards
- ☐ accident experience
- ☐ traffic characteristics
- ☐ traffic pattern
- ☐ pedestrians
- ☐ 85th percentile speed

Regarding the importance of the above listed factors, the manual states that “*They are all important and the field practitioner needs to exercise judgement in integrating their individual contributions*” (p. 5). However, Section 5, Procedure for Speed Zoning, of the manual explains that in the first instance the speed limit appropriate for the road-side development should be determined. Then, only in the event that consideration of the road characteristics, accident experience or traffic characteristics warrants doing so, should the speed limit indicated on the basis of road-side development be modified.

### 3.3.2 Victoria

The criteria used by Vic Roads for setting speed limits in Victoria are documented in “*A Speed Management Strategy for Victoria*” (1987). Currently the following speed limits are employed:

- 10 and 20km/h - used in high pedestrian areas, some car parks and foreshores
- 40 and 50km/h - used on a trial basis in local traffic areas,
- 60km/h - general urban limit,
- 75km/h - high standard arterials and buffer zones between 60 and 100km/h,
- 80km/h - in rural settlements requiring reduction zones from the rural limit,
- 90km/h - as a buffer between 75 and 100km/h zones, and
- 100km/h - general rural arterial limit including high standard urban freeways.

The factors formally considered by Vic Roads speed limit sub-committee (now decentralised and undertaken by regional authorities) included road environment, abutting development, road users and their movements, existing speeds, accident history, adjacent speed zones, the speed zone index (a numerical index based on the weighted combination of the factors listed, according to their importance).

For reasons of increased objectivity and consistency, the process of determining the appropriate speed limit based on the influence of all the relevant factors is undertaken by the expert system VLIMITS (see later discussion of VLIMITS speed limit adviser). A new set of draft guide-lines on speed limits is currently under review in this state. These guide-lines advocate the implementation of a wider range of speed zones than that currently employed in this state. The draft guide-lines advocate the use of the following limits:

- 10km/h - shared zones, to restrict vehicles to walking pace,
- 40km/h - time based school zones, and local traffic areas,
- 50km/h - general urban limit,
- 60, 70, 80 and 100km/h - urban traffic route zones as determined using VLIMITS,
- 80km/h - also used a buffer between 60 and 100km/h zones,
- 90km/h - restricted use in outer urban fringe areas as determined by VLIMITS, and
- 100km/h - general rural limit.

As stated, the draft guide-lines advocate the wider use of speed zoning, utilising a range of speed limits where appropriate rather than a small set of limits for zoning under normal circumstances (60 and 100km/h) and others for buffer zones and strictly defined situations (40, 50, 75, 80, and 90km/h). The other major change is the reduction of the general urban limit from 60 to 50km/h. These draft guide-lines have been circulated for discussion and comment and should be introduced sometime during 1993.

### 3.3.3 Tasmania

The Tasmanian Department of Roads and Transport have recently published a document titled “*Tasmanian Speed Zoning Practice*” which outlines the criteria used to establish speed zones. The following speed limits are used:

- 40km/h - high pedestrian areas eg. school zones, recreational and resort areas,
- 60km/h - built up areas with >24 dwellings/km,
- 70km/h - >24 dwellings/km but with >12 or >24 dwellings/km on one side, and the 85th percentile speed near 70km/h,
- 80km/h - >24 dwellings/km >12 and high standard road or dwellings set back; used as buffer zone; 85th percentile speed near 80km/h,
- 90km/h - limited access suburban arterials,
- 100km/h - open road limit, and
- 110km/h - highways built to National Highway Standard.

It can be seen that speed limits are determined on the basis of road-side development and 85th percentile speed, however, no indication is given as to how conflicts in these specifications are resolved.

### 3.3.4 Western Australia

In Western Australia, the speed zoning requirements of the Procedure Manual are used in conjunction with the Australian Standard AS 1742.4 to determine speed limits. The limits employed range from 60 to 110km/h in 10km/h increments. The speed limit for a particular section of road is determined after considering the road and traffic characteristics, accident records and an assessment of what is a reasonable and acceptable limit to the majority of drivers (usually the 85th percentile speed). Again, no indication is given about how to resolve conflicting criteria.

### 3.3.5 Australian Capital Territories

The ACT Roads and Traffic authorities use the Australian Standard AS 1742.4 only to determine speed limits. Section 7.2, “*Criteria for the Establishment of Speed Zones*” describes the 85th percentile speed as a *major factor*, road-side development as a *most important aspect*, and the road and traffic characteristics as *having to be considered*. The inferred hierarchy of importance is quite salient, given the chosen descriptors. The speed limits used in the ACT, typically include:

- 20km/h - shared zones eg. car parks
- 40km/h - school zones, operating 8 am. to 4 pm Monday to Friday
- 60km/h - general urban limit
- 70km/h - arterials with abutting development
- 80km/h - arterials
- 100km/h - maximum speed limit

### 3.3.6 South Australia

The Australian Standard AS 1742.4 is used by the South Australian Department of Road Transport to determine speed limits. The speed limits employed include;

- 60km/h - general urban limit
- 70km/h - based on 85th percentile speed
- 80km/h - based on 85th percentile speed
- 100km/h - general rural limit
- 110km/h - the South Eastern Freeway and most urban arterials

### 3.3.7 Queensland

The Queensland Main Roads Department's Manual of Uniform Traffic Control Devices, Part 4 - Speed Controls, contains the criteria for speed zoning in that state. In regard to speed zoning and speed limits this manual is a reproduction of AS 1742.4. The speed limits employed include 60, 70, 80, 90, 100, and 110km/h, based on the 85th percentile speed, road-side development, and the road and traffic characteristics.

### 3.3.8 Northern Territory

The Northern Territory Department of Transport and Works use the Australian Standard AS 1742.4 to determine the speed limit appropriate for a given section of road. The speed limits employed include 60, 70, 80, 100, and 110km/h. However, no general speed limit is imposed on motorists outside built-up areas in the Northern Territory. This seems to have been based on both the difficulty of enforcing speed limits in the vast expanses of this state, as well as the questionable safety benefits derived from doing so, given the relatively sparse amount of travel that occurs in these regions.

### 3.3.9 Summary

Generally speaking, all states consider factors such as the 85th percentile speed, roadside development, road characteristics, or traffic characteristics (including accidents) when setting speed limits. The importance granted to different factors varies from state to state. In N.S.W. for example, greater preference is given to road-side development, while in South Australia, 85th percentile speeds (within reason) are used to determine some limits (70 and 80km/h). The speed limit setting process tends to lack objective means of resolving conflicts between the demands of the different associated factors. The New South Wales *Signs and Markings Manual* is among the most specific in giving an indication of the priority attributed to each the different factors influencing the choice of speed limits, however, the resolution of such a dilemma is not explicitly stated. One of the aims of producing guide-lines is to bring increases in objectivity and consistency to the speed limit setting process. These aims are undermined by the use of terms such as "... *if warranted modify the speed indicated by the roadside development* ..." (p. 7). The impression remains that the determination of speed limits is a process reliant on subjective judgement and the balancing of many opposing influences (not to mention political and community influences).

The speed limits used by the different states of Australia are summarised in Table 3.1. The speed limits are seen to vary not only in the range of speed limits used but also in the number of increments within the range that are used. Victoria and the ACT have a maximum speed limit of 100km/h, whereas the rest of the states have a maximum speed limit of 110km/h with the exception of the Northern Territory where there is no upper speed limit. Minimum speed limits imposed vary from 10km/h used in New South Wales and Victoria, to 60km/h in the Northern Territory, South Australian and Queensland. In New South Wales, South Australian, Western Australian and Queensland every 10km/h increment between the minimum and maximum

speed limits is utilised, however the other states fail to make use of some of these speed limits preferring more coarse increments. Victoria is alone in its use of 75km/h speed limit, seemingly a remnant from the metric conversion of speed limits.

**TABLE 3.1 SUMMARY OF SPEED LIMITS USED ACROSS AUSTRALIAN STATES AND TERRITORIES**

Speed Limit	NSW	Victoria	TAS	WA	ACT	NT	SA	QLD
10	*	*						
20	*				*			
30	*		*					
40	*	***	*		***			
50	*	***						
60	*	*	*	*	*	*	*	*
70	*		*	*	*	*	*	*
75		*						
80	*	***	*	*	*	*	*	*
90	*	***		*			*	*
100	*	*	*	*	*	*	*	*
110	*		*	*		*	*	*
derestricted						*		

\* - Speed utilised in this state

\*\*\* - limited use in specific circumstances eg. buffer zones, school zones, trial basis, etc

### 3.4 RECENT AUSTRALIAN DEVELOPMENTS

#### 3.4.1 The Speed Zone Index

Traffic characteristics are an important consideration in the determination of an appropriate speed limit and the 85th percentile speed is seen as an expression of these. There are often occasions where free speed studies cannot be undertaken to assess the 85th percentile values. In these situations, Traffic Commission Victoria (1976) outlined a method of estimating the likely 85th percentile speed, based on an evaluation of various factors that supposedly influence the subjective assessment of speed. These factors include such things as roadway characteristics, alignment, shoulder construction and width and roadside development. The speed zone index is subsequently determined after assessing the existence and likely effects of these factors at a particular road site.

The speed zone index, therefore, acknowledged the role of perceptual factors in speed determination on the road. This view was also shared by the National Association of Australian State Road Authorities (1980) and Lay (1984). Unfortunately, however, the method adopted for

arriving at the 85th percentile speed using the speed zone index relied upon “*several years of experience*” in interpreting the likely perceptual effects. Also the speed zone index, calculated through a system of “*weighting*” prescribed criteria identified in the 1970’s, was used infrequently due to its decreasing relevance to continually developing speed zoning guide-lines (RTA, 1987).

In 1986 a Vic Roads’ task force was established to examine and prepare an overall strategy for all aspects of speed management. The task force highlighted the inadequacies of the existing speed zone index and recommended that the procedure of assessing the road and road-side characteristics be improved in terms of its objectivity. The response from Vic Roads was to immediately set about improving the speed zone index (RTA, 1987). Researchers at the Australian Road Research Board (ARRB), however, determined that by its very nature the speed zone index was destined to remain of questionable reliability, flexibility and validity (Jarvis & Hoban, 1988). These researchers concluded that the need for objectivity was best served through the use of an expert system generating question, answer, and explanation sequences. Subsequent to gaining Vic Roads approval, ARRB undertook the development of such a system called “*VLIMITS*”.

### 3.4.2 VLIMITS

VLIMITS is a PC based expert “*adviser*” system devised in Victoria by ARRB for setting speed limits. Expert systems are best described as computer systems that mimic the decision processes of an expert to solve complex problems in a given domain of knowledge. The determination of speed zones met all of the criteria for the appropriate use of an expert system, whereas the past use of linear mathematical models had failed. The attributes of expert systems were detailed by Jarvis and Hoban (1988). Expert systems have the capability to consider many more factors than their human counterparts which is important considering the number of factors that can influence the determination of speed zones. However, the decisions made by the system are only as objective and consistent as those made by the experts whose knowledge is used to design the system. Expert systems, also, do not cope well with unexpected factors which are often considered by human experts thus ensuring the continued use of human experts in these situations. A true expert system is further advantaged by the system’s ability to upgrade itself from statistical learning.

In constructing the system, a panel of design experts was formed to determine appropriate factors and numerous consultations were held with the Victorian Speed Limits Sub-Committee convened by Vic Roads. The factors identified by this process included:

- lane and median width,
- width of service road (outer medians where applicable),
- provision for parking,
- abutting development,
- movement of pedestrians and cyclists,
- intersections,
- road alignment,
- traffic volume,
- zone lengths,
- presence of schools,
- future development,
- accident history, and
- 85 percentile speed.

Although the VLIMITS speed zone adviser has been widely distributed to Victorian authorities, its use is not currently a mandatory requirement. Use of the adviser does remove most of the guess work previously involved in speed limit determination, however the system is truly an adviser in that it requires interpretations and decisions to be made by the operator.

The Social Development Committee's inquiry into speed limits in Victoria (SDC 1991) endorsed the use of the VLIMITS speed zone adviser "*...as the best available method of setting speed limits and overcoming inappropriate speed zoning*" (p. 17). It recommended that the 85th percentile speed should be given more emphasis in the determination of speed limits to ensure their credibility with road users. At the time of the SDC inquiry, the 85th percentile speed was not considered by the VLIMITS adviser. However, the current version does include an 85th percentile speed assessment in helping decide on the appropriate speed limit, but still allows the operator discretion in its use. The VLIMITS program is currently under review and modifications are contemplated for use in other states. An NLIMITS version is planned for use in N.S.W. shortly, while one or two other Australian states have expressed interest in having a similar version developed for their use. To date, there is no formal requirement for an Australia-wide version, given each states control of its own speed limit setting. Indeed, it could be argued that greater consistency and credence would be achieved if speed limits were consistent across all Australian states.

### **3.4.3 Summary**

The concept of a Speed Zone Index was embraced because it allowed for varying road and roadside variables to influence the posted speed limit. However, it failed ultimately to be an objective system for setting speed limits. The more recent development of a computerised expert system (VLIMITS) formalised the speed zone index concept into a useable objective system for determining appropriate speeds in particular environments, based on road and environmental characteristics. With differing standards of the relative importance of these features across states and territories, though, a truly national VLIMITS system to optimise the credibility of speed limits among Australian motorists, especially in populated areas, warrants further consideration.

## **3.5 VARIABLE SPEED LIMITS**

A possible solution to the problems inherent in setting rigid speed limits that apply under all conditions is variable speed limits. The logic being that as the relationship between speed and safety varies with driving conditions, so too should the speed at which a desired balance between safety and mobility can be found. It seems logical that the credibility and reliability of speed limits would be optimal if drivers were to learn that, under any and all conditions, travelling at the speed limit will maintain their safety and mobility balance.

### **3.5.1 Bad Weather Restrictions**

SDC (1991) reported evidence that speed limits should vary according to adverse weather conditions. While a number of submissions advocated the reduction of speed limits under conditions of poor weather, poor road condition and poor visibility, several difficulties were also acknowledged in achieving this. For example, what criteria are used for making reductions and by how far should speed limits be reduced. The SDC conceded that although the need to modify driving speeds under conditions of adverse weather was unquestionable, current tech-



nology will require further development before variable speed limits on this basis can be introduced. A VLIMITS variant may be able to play a role here.

Variable travel speeds are currently employed in one or two locations in Victoria, for example, the West Gate Bridge in Port Melbourne, where speed limit signs are equipped with flashing lights signifying that speed limit modifications apply. During inclement weather, bridge staff activate the flashing lights, thereby signalling motorists to observe reduced limits. Its success at reducing travel speeds (and crashes), however, is untested to date. It should also be noted that this system of variable speed limits is made possible only because the bridge is constantly manned which is hardly an option on general road networks. Intuitively, though, variable speed limits should gain greater credibility among motorists as drivers perceive some rationality and logic behind their use in that they are responsive to changes in the level of danger associated with changing climatic conditions. However, this is yet to be established.

### **3.5.2 School and Residential Zones**

A different application of variable speed limits is the implementation of school speed zones which are reduced limits that apply in the general vicinity of schools during those hours of the day that children are at school. Like all variable speed limits, school zones seek credibility and respect from drivers on the basis that they apply only during “times” of increased danger (ie; when the children are at school).

Pak-Poy and Kneebone (1988) carried out evaluations of the 130 school zones in the ACT. The school zones in the ACT imposed a speed limit of 40km/h between the hours of 8am and 4pm through the use of sign posts that displayed a standard speed limit sign, a “SCHOOL ZONE” sign, and a sign outlining the hours of operation of the zone. Surveys of vehicle speeds before and after installation and during and after school holidays revealed that while mean speeds were significantly reduced from approximately 60km/h to 46km/h, general compliance with the 40km/h speed limits was not attained. Notwithstanding the failure to gain high levels of compliance, the average reductions of 14km/h in mean speeds and 9km/h in 85th percentile speeds were considered an improvement in the safety of school children in the vicinity of schools.

### **3.5.3 Dynamic Speed Signs**

Variable speed limits that respond to accurate information regarding road and driving conditions would seem to have some potential. A system of speed limits that varies from *lower limits* (lower than current speed limits invoked during poor driving conditions) to *normal limits* consistent with optimal driving conditions could potentially reduce not only mean travel times, but also the incidence of accidents under unfavourable driving conditions. However, such a system would be dependent (at least in part) on the ability of the system to provide responsive information to motorists about limits that apply at a particular moment.

There are sparse instances of dynamic speed signing reported or observed overseas. For example, Emmerson and Linfield (1986) reported on trials of variable message traffic signs in the UK which could be used for imposing speed restrictions. They noted that these signs need to be carefully designed to convey the right information to drivers with particular emphasis on controlling for “Sun Phantom Effects”. Nevertheless, they concluded that dynamic signs are feasible for displaying varying messages to motorists. It should be pointed out, though, that human factor aspects of these applications need careful examination. Dynamic speed signing

systems have been used overseas to aid traffic flow by advising motorists about appropriate speeds to synchronise green lights at traffic signals. A trial of such a system was implemented in Victoria recently (Rogerson 1991) on a 60km/h arterial in a busy Metropolitan Melbourne suburb. The trial was ultimately unsuccessful for a host of reasons. One major problem was that it would not allow divergences about the posted limit of 60km/h and therefore called for abnormally slow speeds at times (eg; 20km/h) which were disobeyed by the majority of motorists.

Special curfew speed limits can also be invoked at certain times of the day. Slower speed limits apply, for instance, on particular roadways at night (eg; the South Eastern Arterial roadway in Melbourne) to reduce noise for local residents. Changeable signs display the limit that applies at each time period thereby eliminating the chance of confusion. Similarly, special limits can be evoked on freeways when blockages occur providing adequate dynamic signing is available. Area-wide computerised systems for linking traffic signals have been installed in most large Australian cities. Although these systems do not currently allow for feedback information, they could conceivably include dynamic displays of appropriate travel speed. These systems, of course, introduce a whole new set of criteria for speed limit setting which will not be discussed further here.

### **3.5.4 Driving Restrictions**

A further application of the principle of variable speed limits is to apply differing speed levels to subsets of the driving population based on driver, vehicle, or road characteristics. Lower maximum speed limits applying to cars engaged in towing, school buses and heavy vehicles (trucks) exemplify this principle. Differential speed limits and punishment severity to inexperienced drivers such as probationary licence holders are further examples of applying different speed limits to subsets of drivers based on the danger they represent to themselves and other road users. The effectiveness of these discriminatory speed limits and the wisdom of actively promoting the wider distribution of speed variance has been questioned (Cameron, 1981; Jernigan et al., 1988; Manders, 1983). To date, discriminatory speed limits such as these have not undergone rigorous evaluation.

### **3.5.5 Minimum Speed Limits**

The relationship between accident rate and deviation from the mean travel speed of the traffic stream, first reported by Solomon in 1964, suggests that increasing deviation from the mean (both above and below the mean) results in increased accident rates. This finding has been used to suggest the need for speed limits, not only to slow those travelling faster than the mean speed, but also to increase the speeds of those travelling below the mean. Long before the work of Solomon that linked accident rates to relative travel speeds, others had advocated the implementation of minimum speed limits of one half of the maximum speed limit to promote the flow of traffic and avoid congestion. Later, when high standard, limited and controlled access roads became more prevalent minimum speed limits much closer to the maximum were advocated (McClintock, 1925, as cited in Ruschman, Joscelyn, & Treat, 1981). Ruschman et al (1981) also reported, that in the USA, minimum speed limits apply to most express-ways (high standard, limited and controlled access roads), in addition to which basic speed laws contain "... *a broad prohibition of unreasonably slow speeds on any highway.*" (p. 13).

It must be stressed, however, that the introduction of a minimum speed limit may not be a benefit to all travellers. While minimum limits have the potential to reduce speed variance (and

possibly reduce the number of crashes), it will result in increased crash severity for those crashes that would have previously occurred at slower speeds. In short, one motorist's gain may well be another's loss. The net benefit (or cost) of imposing minimum speed limits has not been established and further work is clearly required to demonstrate the effectiveness (and cost-effectiveness) of minimum speed limits.

### **3.5.6 Summary**

Variable speed limits are often suggested to overcome the inherent problems associated with fixed limits. Poor driving conditions at night and during inclement weather could be accounted for by reducing the posted speed limit at these times. Their success would be dependent upon motorists obeying these amended recommendations. However, there is still a need for further developments in the technology required to monitor and display variable speed limits. Lower speed zones for schools and special residential areas seems sensible but requires support of speed management devices or substantial enforcement effort to be effective. Driving restrictions for vehicles and drivers that present special speed related problems are again a possibility but will also require strong supporting measures (engineering, education, and enforcement) for their success. The concept of minimum speed limits to force slow motorists to travel faster requires further research at this time.

## **3.6 CONCLUSIONS FROM THIS REVIEW**

A number of important conclusions can be drawn from this review regarding the setting of speed limits both overseas and in Australia.

1. Speed limits on urban and rural roads should attempt to strike a balance between the conflicting needs of motorists for mobility and safety. They must be credible among motorists if they are to be adhered to.
2. Traditional approaches to setting speed limits have emphasised the 85th percentile speed value of the traffic. While this seems to be an intuitively sound means of setting speed limits, this approach assumes that motorists know what an appropriate speed is on all roadways. Further, the 85th percentile method has been criticised for its failure to take account of other important factors such as crash rates, residents concerns and other local needs.
3. Alternative approaches have been proposed overseas such as maximising transportation costs (cost-benefit analysis) or equating crash rates. However, further development is necessary before these methods are likely to be viable alternatives.
4. In Australia, the Speed Zone Index was seen as a desirable approach to speed limit setting because of its ability to take account of a range of important speed characteristics. However, it proved to be unsatisfactory because of its subjective nature.
5. The recently developed VLIMITS expert system is an objective approach that models speed limits around a range of road, and environment factors known to be relevant. However, it is still only an adviser system and used on a state-by-state basis.
6. Speed limit setting practices in Australia generally stress the 85th percentile speed, road-side development, road and traffic characteristics, and crash rates. However, a range of differing speed limits exist across Australian states. There is clearly a need for greater consistency across all Australian states to ensure credibility among motorists.

7. Variable speed limits have been proposed to account for poor visibility and driving conditions, special speed restriction needs (school zones, etc.), and driver abilities. Evidence suggests that these special speed restrictions are only effective if they are accompanied with engineering support (LATM's or vehicle interlocks) or high levels of enforcement. Dynamic signing is also an important issue to ensure motorists are adequately informed of these limits.
8. The benefits of minimum speed limits in terms of crash reduction or mobility improvements still needs to be established.

### **3.7 OPTIONS FOR FUTURE RESEARCH AND DEVELOPMENT**

Several options for future research and development in setting speed limits in Australia were identified from this review.

1. Consistency in road behaviour rule making would seem to be desirable across all Australian states to ensure greater acceptance by motorists. In setting speed limits, there would be considerable merit in a single national system. The development of an AUSLIMITS system incorporating current VLIMIT technology therefore, would seem to be a high priority for future speed limit setting in this country.
2. There is a need to continue to examine alternative methods and priorities in setting speed limits. The cost-benefit approach or the method of minimising crash rates on all roads may have some appeal for the future. However, the degree to which these methods complement or contradict existing "environmental" approaches needs to be established. Furthermore, the difficulties of enforcement when these speed limits are at variance with motorists' perceptions also needs to be addressed.
3. Before efficiencies associated with speed limits and transportation can be adequately considered, there is a real need for a definitive analysis of the costs and benefits of mobility and the economic consequences of changes in travel times.
4. Further consideration of the consequences of discrepancies between design speed and the posted speed limit is clearly warranted. This might include the conditions under which discrepancies are allowed, what is an acceptable difference between these two aspects, and what are the likely consequences for enforcement and speed limit credibility.
5. The advantages of variable speed limits taking account of poor visibility, bad driving conditions, or special needs such as school zones warrants further consideration. This should include means of informing motorists of these special speed limits as well as any special needs for education, engineering or enforcement support.
6. There is an on-going monitoring requirement of the relationship between the posted speed limit, motorists' perceptions of them, and subsequent travel speed and crash rates to improve knowledge and highlight conflicts that need to be addressed.

## 4. ENFORCEMENT AND BEHAVIOUR

The need to set limits on travel speeds (and the resulting enhancement of safety) has a sound research base. Speed limits however, are not always respected by road users. There exists a body of research that demonstrates the impact of speed limits on speed choice. A most salient finding is that exceeding the posted speed limit is quite common in this country and other countries as well (for example see Fildes, et. al.). The effects of non-compliance with speed limits have been well reported internationally. Estimated levels of exceeding the posted speed limit range from 20% to 80%, depending on such parameters as the country, rural or urban setting, type of road, level of enforcement, the weather, and so on (eg; Rothengatter, 1990). While these levels of non-compliance are alarming and may seem unbelievable, Fildes, Rumbold, & Leening (1991) reported only a 9% compliance with a particular 60km/h urban speed limit in Victoria, suggesting that such estimates are, if not conservative, at least realistic for Australia too.

If posted speed limits are to be considered realistic, clearly there is an urgent need to minimise such discrepancies between posted speed limits and the chosen speed of drivers. While this may involve readjusting inappropriate speed limits and educating drivers about the desirability of travelling at the posted speed, it certainly demonstrates the need for effective enforcement strategies, too.

### 4.1 GENERAL PRINCIPLES OF TRADITIONAL POLICE ENFORCEMENT

The most rudimentary manipulations of enforcement levels (for example see Summala, Naatanen, and Roine, 1980) have demonstrated that travel speeds are determined to some degree by traditional police enforcement activities. Mean speed or variance are measures often employed to investigate the effects of enforcement, where reducing travel speeds is the goal. While there is some debate about the mechanisms or models underlying enforcement and its effect on road user behaviour, the general principles behind most speed control programs to date tend to be similar.

Most are based on the rational behaviour assumption that the choice of travel speed follows a process of weighing the *utilities* (advantages) of disobeying the speed limit against the *disutilities* (disadvantages) of such a violation. The utilities of speeding are considered varied and include such things as time saved (directly translatable to economic cost), the thrill of taking risks, the urgency of the trip, to even the pure exhilaration of speed. The disutilities of speeding include the consequences of breaking the law (and getting caught), increased likelihood of being involved in a crash, increased fuel consumption and vehicle wear and tear, and air pollution. The risk of being involved in a crash (actual and perceived) is considered by many to be negligible (Ruschman, Joscelyn, & Treat, 1981; Summala, 1988; Rooijers, 1990). The role played by most speed control strategies is to bolster the disutilities of speeding, with the aim of tipping the balance in favour of the decision to not speed.

Traditional speed control has emphasised the role of police enforcement in which the disutilities of speeding are bolstered by adding to them the risk of being detected and punished. Typically, police enforcement is thought to have two main functions; *deterrence* and *detection* of speeding drivers. There are several mechanisms through which police enforcement can deter drivers from speeding. The first, (often called specific deterrence) is based on the assumption that drivers who are caught and punished for speeding will be discouraged from committing further speeding offences. The second deterrence mechanism (often called general deterrence) is based

on the assumption that those exposed to the enforcement, apprehended or not, will be discouraged from speeding for fear of detection and punishment.

Both specific and general deterrence are commonly thought to operate through on-site effects, memory effects, and general risk of detection effects. On-site (visibility) effects refer to reductions in speed for a finite time and distance after encountering enforcement. Memory effects are any reduction in speed that occurs at the site where enforcement activities have previously been encountered (see later discussion of time and distance halo effects). General risk of detection effects describe any reduction in speed due to an increased perceived risk of detection attributable to the diffusion of knowledge about the apprehension of speeders and prevalence of speed enforcement (Sanderson & Cameron, 1982; Hauer, Ahlin, & Bowser, 1982; Rothengatter, 1990).

#### **4.1.1 Specific Deterrence**

Specific deterrence is usually aimed at changing a particular individual's behaviour by suitable means. So far as speeding is concerned, detection of inappropriate behaviour clearly plays a major role; the greater the likelihood of being detected, presumably, the less likely a particular driver is to speed. Specific deterrence measures commonly involve traffic surveillance, apprehension of offenders, and the actual imposing of some form of punishment on that individual. The precise mechanism by which specific deterrence works however is likely to vary depending upon the individuals own motivations, desires, beliefs, etc.

Traditional speed enforcement has emphasised police presence and the consequences of being caught and punished. There is much evidence to show that this approach can influence a specific individual's speed behaviour, but how widespread it is and the role of other factors (eg; publicity, early notification, knowledge of others detected, etc.) is not well documented. Because the number of apprehended offenders typically represents such a small proportion of all offenders the impact of specific deterrence is likely to be quite limited. Moreover, it is not clear what the precise links or boundaries are between specific and general deterrence. In addition, the focus of traditional enforcement on retribution has been questioned by some psychologists concerned about the effects of constant negative reinforcement on behaviour. Improved knowledge is essential in this area if we are interested in designing more effective enforcement programs for future use in speed management in Australia.

#### **4.1.2 General Deterrence**

General speed deterrence (the widespread reluctance among the population at large to speeding) also depends to large degree on the detection and apprehension of speeding drivers. However, unlike specific deterrence, general deterrence has the potential to influence the behaviour of all potential offenders through various means such as information dissemination, knowledge of others who have been caught and punished, and the general fear of detection and punishment among the community. It follows then that general deterrence is likely to be promoted by increasing the perceived intensity of enforcement, whether real or otherwise. More specifically, general deterrence enforcement strategies must convey to the driving population (potential violators) that exceeding the speed limit has an associated high risk of detection and punishment.

### 4.1.3 Perceived and Actual Risk

It is important to note that it is the *perceived risk* (not necessarily the actual risk) of detection and punishment that operates here. In describing the general deterrent effect of drink-driving, Ross (cited in Sanderson & Cameron 1982) proposed that the impact of deterrence on behaviour is mediated by *three* aspects of detection and punishment: (1), its perceived certainty, (2), its severity, and (3), its celerity or swiftness to punish. These components of general deterrence are recognisable as mediating characteristics of classic behaviour modification: contingency, intensity, and immediacy of rewards or punishments.

After reviewing a number of Scandinavian studies Ostvik and Elvik (1990) concluded that the relationship between actual and perceived risk of detection and punishment is such that increases in actual risk are under-estimated by drivers. They reported that increases in enforcement level of less than *three* times the previous level appeared to have little or no effect on changing the subjective risk of apprehension, or more importantly speeding behaviour. When the actual risk of detection and punishment was increased by a factor of *three*, they argued that subjective or perceived risk by increased by a factor of between 1.4 and 1.9. They maintained that there is scope for manipulating both the perceived and actual risk of detection and punishment in campaigns aimed at speed reduction. The effects have the potential to influence those individuals who are actually apprehended (through specific deterrence), along with the possibility that the apprehended offender may discourage a few others from offending (general deterrence). The greatest instrument for manipulating subjective risk is publicity.

### 4.1.4 Summary

In summary, travel speeds can be reduced by police enforcement where deterrence and detection play a major role. Rational behaviour theory suggests that the degree of effectiveness is a function of a motorist's utilities (and disutilities) to speed relative to other travel alternatives. Specific deterrence (to an individual) is more likely to be affected by local police enforcement activity, whereas general (widespread) deterrence principally involves constant visibility, publicity, word of mouth knowledge, etc. Perceived risk of detection is critical for general deterrence effectiveness but in the long term must equate with actual risk for on-going benefits. Further research is warranted in understanding further the relationship between specific and general deterrence for improved enforcement strategies and other future developments.

## 4.2 HALO EFFECTS IN GENERAL AND SPECIFIC DETERRENCE

As previously stated, speed enforcement activities can influence speed choice in several ways. First, drivers will slow down in the vicinity of the enforcement site while enforcement is taking place. The distance from the site that the effects of the enforcement activity is detected has been referred to as the *distance halo effect* of enforcement. This is usually measured in kilometres upstream and down stream from the enforcement activity site. Second, some drivers will slow down in the vicinity of the enforcement site on subsequent occasions of passing the enforcement site in anticipation of again encountering enforcement. The time from encountering the enforcement activities that the effects of these activities can be detected at the site is similarly referred to as the *time halo effect* of enforcement. The time halo effect is commonly measured in days from the time of the enforcement activity.

It follows that the goal of any speed enforcement strategy is not just to reduce mean speeds, but also to maximise the time and or distance halo effects of the enforcement. It is through

knowledge of the distance and time halo effects of enforcement that optimal enforcement strategies can be developed in terms of the distance between enforcement activities and the frequency with which a particular site would need to be enforced to achieve the desired result. There have been a number of reports in the literature which attempted to outline and measure mechanisms at work in both general and specific deterrence.

#### **4.2.1 Distance Halo Effects**

Hauer, Ahlin, and Bowser (1982) conducted a series of experiments in which the influence of police presence involving both a distance and time halo effects was investigated. Vehicle speeds were measured before, during, and after enforcement took place at several distances from the enforcement sites (distance halo effects). In addition, these researchers also recorded number plates of passing vehicles so that the effects of enforcement on individual vehicles day after day could be determined (time halo effects). At the enforcement sites, mean speeds were reduced by 23% to 28% (and always to within 2km/h of the speed limit). They reported that, when enforcement activity was in operation, travel speeds were close to the posted speed regardless of the pre-enforcement speed or the speed limit being enforced. Hauer et al. (1982) also reported reductions in variance in response to enforcement, caused by faster drivers slowing more than slower drivers. They claimed that the speed reducing effects of enforcement decayed exponentially (reduced by half every 900 metres) with the downstream distance from the enforcement site. An up-stream distance halo was attributed to drivers warning each other about the presence of enforcement.

Armour (1984b) studied the effect of police presence in the form of a marked police car (not apprehending offenders) on urban streets. Speed surveys were carried out to determine the proportion of drivers exceeding the limit before, during, and after the enforcement period. It was reported that the presence of the police vehicle brought about a reduction in the proportion of drivers exceeding the speed limit by approximately 70% at the test site but that the effect did not last long past the site. However, she did report that these speed reductions persisted for up to two days after the removal of the enforcement.

Barnes (1984) determined that the response of motorists to a visible traffic officer (marked police car) was to start reducing their speed more than two kilometres before reaching the enforcement site although the distance at which the activity could be seen was less than one kilometre. In the vicinity of the enforcement site, speeds were appropriate for the speed limit, however motorists accelerated quickly after the site and returned to their pre-enforcement site travel speed within four to six kilometres. Barnes attributed the ineffectiveness of existing enforcement strategies to visibility and predictability of enforcement (aided through headlight flashing and radar detectors), and the technical limitations of the detection equipment (specifically its inability to perform reliably under conditions of high traffic volumes). More recent speed enforcement technology such as speed cameras were not assessed by Barnes.

Leggett (1988) also investigated the effects of a novel enforcement strategy involving the random (but regular) deployment of stationary marked police cars on vehicle speeds, offence rates, and accident rates on a major highway in Tasmania. A small decrease in mean speeds (3.6 km/h) was attributed to the enforcement program. Although no direct measure of distance halos was made, he estimated the distance halo effect to be of the order of 21 kilometres. In addition, he noted that the rate of speed limit offending decreased, as did the number of serious casualty accidents (58% reduction compared to the pre-enforcement rate). These impressive findings (and others by authors such as Edwards and Bracket (cited by Leggett 1988) have led to a



number of calls for more effective (and higher levels) of police enforcement in other Australian states.

#### **4.2.2 Time Halo Effects**

As noted earlier, Hauer et al (1982) examined the tracking behaviour of individual vehicles (assumed to be a surrogate for individual drivers) over several days. They concluded that repeated exposure to enforcement had no impact on the distance halo effect but did produce a dose dependent time halo effect. While the residual speed reducing effects of one day of enforcement activities was observed to endure for up to three days, five days of enforcement resulted in a time halo of at least six days. It should be noted that the effect of increased enforcement on the time halo was robust enough to be observed at the level of the speed distribution (without regard to repeated exposure of individual vehicles).

Nilsson and Sjorgen (1982) also investigated the memory effect (time halo) associated with a number of different types of enforcement; marked and unmarked police cars, radar and helicopters. The statistical analysis compared the speeds of repeater traffic (vehicles that passed the enforcement site more than once) and non-repeater traffic. A memory effect, defined as a significant difference between the speed of the two groups of traffic, was found for all methods of enforcement except the unmarked police car. Following six days of enforcement the duration of the time halo for both the radar and the marked police car was of the order of ten days, whereas for helicopter surveillance it was of the order of 17 days. Unfortunately, the longer term halo effects of enforcement (1, 6, or 12 months after the event) have not been reported upon in the literature. The relationship between the duration of the time halo and the nature of the enforcement activity (both in duration and frequency) is one that warrants further investigation.

#### **4.2.3 Summary**

The research reviewed here suggests that the optimal performance of police surveillance in terms of time and distance halos is of the order of two weeks and 20km/h respectively, although only under particular operational conditions. As the resources for police enforcement of speed have tended to be limited, detection rates from conventional police enforcement of speed have been rather low. Consequently, the threat of punishment does not seem to weigh heavily on the minds of potential violators and compliance rates have been low. Optimal strategies for speed enforcement are needed to achieve enduring effects in terms of both time and distance halos. With the emergence of new speed enforcement technologies such as speed cameras, the deterrent mechanisms that result from these devices need further examination.

### **4.3 DETERRENCE AND PUNISHMENT ISSUES**

Essential to optimising speed enforcement strategies is a thorough understanding of the parameters which impact on their effectiveness. The three classic mediators of deterrence (behaviour modification) are the certainty, severity and celerity (immediacy) of punishment. A review of research conducted in each of these areas is presented below. By far, the majority of the speed enforcement research uncovered during this review has focussed on the effects of the certainty and the severity of punishment.

### 4.3.1 Certainty of Punishment

It has been suggested that police surveillance can only bring about a change in behaviour through the threat of punishment, rather than a change in attitudes, motivations or the perception of safety on the road (Rothengatter, 1990; Shinar & McKnight, 1984, as cited in Riedel, Rothengatter, & de Bruin, 1988). There is a substantial body of psychological evidence that questions the degree of influence that punishment can have in changing behaviour in the long term.

Recent experience with other road safety campaigns such as Random Breath Testing to reduce drink-driving is sometimes heralded as proof that certainty of punishment can lead to long term behaviour or attitude changes. High level random activities such as RBT can increase the (perceived) likelihood of an individual being detected and the associated high penalty of being found with an illegal BAC level is a concern to most motorists. In addition, while not conclusively demonstrated, it would appear that this on-going campaign over many years has led to a change in motorists (and the community at large) attitudes about the acceptability of this behaviour. However, it would be ambitious to expect the threat of punishment alone to be entirely responsible for this as there have been many other associated activities aimed at bringing about this attitude change (publicity, education, etc.).

An interesting “*real world experiment*” is currently underway in some Australian States involving high activity (random) speed camera enforcement that sets out to use the experience gained from the Random Breath Testing campaign to bring about a community change in attitude towards speeding. This campaign, too, challenges existing theories of behaviour and attitude change mechanisms by relying on intensive enforcement activities (and associated perceived risk of detection and punishment) to bring about a new (unacceptable) attitude to excessive speeding. It is not clear, though, whether it will be possible to discriminate the effects of *enforcement from education and publicity in this campaign too*. Thus, it may not have much relevance for the debate on the influence of certainty of punishment.

### 4.3.2 Severity of Punishment

All basic behaviour modification and conditioning theories dictate that the intensity of a reward or punishment will mediate its impact on behaviour. While any number rewards or punishments could potentially be used to modify speeding behaviour, usually punishment in the form of fines is employed. Logic dictates that the impact of a fine on behaviour will depend on how large a change in total wealth the fine brings about. The most obvious way to operationalize a system of fines that would impact equally on each individual would be to index the size of fines incurred for speeding to some measure of an individuals nett wealth (probably income) however such a system is unheard of. Two Swedish studies have investigated the impact of increased penalty severity on speed limit violations.

In 1982 the fines for speeding in Sweden were doubled. In a before-after study 43 000 non-visible speed measurements were taken and some 3 293 drivers interviewed regarding, among other things, their knowledge of the amount of speeding fines. Although one third of drivers knew of the old and knew fine amounts no changes in speeding behaviour were detected as a result of the new fine amounts (Aberg, Engdahl, & Nilsson, 1989). In 1987 the fines for speeding in Sweden were again raised, and an investigation was conducted to assess the impact on the increased fines on speeding behaviour. Once again no changes in speeding behaviour could be attributed to the increase in fines (Andersson, 1989). It is important to stress that these

findings do not suggest that penalties could be arbitrarily raised or lowered without observing any change in speed limit compliance, rather that the size of the manipulations instituted in Sweden failed to reach some threshold level of perceivable change in penalty intensity (amount of fine). It has been suggested that such findings do not imply that the severity of penalties is of no consequence but that their severity is less crucial to their deterrent impact than their existence (Bjornskau & Elvik, 1990).

It seems logical to expect that lowering the fines associated with violation of speed limits would detract from the perceived disutility of speeding, resulting in more drivers "deciding to speed". In the absence of any documented studies in which the penalties for speed limit were decreased support for this proposition can be derived from the observations of Summala, Naatanen, and Roine (1980). These researchers observed the Finnish driving population during a two week police strike in which effectively no traffic enforcement took place. A survey of speed behaviour found that the number of serious speeding offences increased by 50-100%. Contrary to these findings are those of Maakinen and Joki (cited in Maakinen, 1988) who reported that warning letters and fines were equally as effective at bringing about a reduction in travel speeds of offenders. Speed reductions were maintained three months after receiving fines/warnings, however, 12 month after receiving fines/warnings travel speeds of both groups had returned to population levels.

Similarly, it seems logical to propose that continual increases in the fines incurred for violation of the speed limit would eventually increase the perceived disutility of speeding (note that this level was apparently not reached in the Swedish studies) such that increasingly less drivers would 'decide' to speed. Consider the extreme scenario in which a speeding driver's car would be confiscated, not to be returned. It is difficult to imagine that many drivers would speed under these circumstances. Support for this proposition can be derived from the findings of Fosser (1989, as cited in Bjornskau & Elvik, 1990) who reported significant increases in seat belt wearing rates when, four years after its introduction, violation of the compulsory wearing law resulted in a fine. The increase in penalty intensity (from no penalty to 200 kroner) was sufficient to affect driver's behaviour, that is it was above the threshold of perceivable change in penalty intensity. However, a subsequent increase in the size of the fine from 200 to 300 kroner had no impact on wearing rates, apparently failing to reach the threshold of perceivable change in penalty intensity.

Findings from Fildes et al (1991) suggested that the average motorist in Victoria thought that current speeding fines were appropriate. They suggested that there could be a case for increasing these amounts to act as a further deterrent but only in conjunction with greater enforcement effort.

#### **4.3.3 Celerity (Immediacy) of Punishment**

The issue of celerity or immediacy of feedback has not long been an issue for traffic enforcement programs aimed at behaviour change. However, with the advent and inevitable proliferation of automatic enforcement strategies such as red light and speed cameras it is an issue which needs to be addressed. Behaviour modification theory suggests that for maximum benefit, punishment must be immediately contingent upon behaviour.

Rothengatter (1990), though, seems to stand alone in the literature in calling for swift punishment after committing a traffic offence. The importance of immediacy of rewards and punishments in behaviour modification has long been established. It is suggested by Rothengatter that

on site information be communicated to the driver that they have just committed a speeding offence and the penalty that they have incurred. He argued that care should be taken to ensure that the feedback was operating as feedback to offenders and not as a warning to potential offenders that they were about to enter a surveillance area. However, with the recent success of red light camera operations and the finding that the warning sign itself is an effective moderator of red light running, there is clearly some interaction between punishment after committing an offence and warning of the dangers of doing so.

In reviewing the effectiveness of deterrence against drink-driving, Ross (cited in Sanderson & Cameron, 1982) found no scientific evidence one way or the other regarding the effectiveness of swiftness of justice. He concluded that it would appear reasonable to expect long delays between apprehension and punishment would be undesirable for effectiveness deterrence. That is, the sooner, the better !

#### **4.3.4 Summary**

Classical behaviour theory specifies the importance of the certainty, severity, and celerity of punishment in changing undesirable behaviours. The certainty of punishment in speed behaviour has been well researched. While there is some evidence to support its role in moderating travel speed, the relationship is not firmly established. The severity of the punishment too appears to have some influence on travel speed from reports in the literature. However, it seems unlikely to have a predominant role in long term behaviour change and needs to be used in conjunction with greater enforcement effort to ensure lasting effects. Evidence of the importance of punishment celerity was inconclusive among the road safety literature reviewed.

### **4.4 OTHER RELEVANT ENFORCEMENT ISSUES**

#### **4.4.1 Visibility of Enforcement**

It has been claimed that the best way to maximise the perceived risk of detection and hence maximise the effects of both specific and general deterrence would be to use highly visible enforcement strategies. This was the crux of the campaign behind the impressive effects reported by Leggett (1988) in Tasmania. However, it has been suggested that highly visible enforcement strategies are often compromised by drivers simply adapting their behaviour to suit the speed limit upon sighting the enforcement activity (Armour, 1984a). Hence, these effects are more likely to be local than widespread. However, this would be somewhat dependent upon the level and visibility of the enforcement activity.

It is not surprising that the use of concealed (not visible to offenders up to the point of detection) enforcement has been advocated (Cameron & Sanderson, 1982; Armour, 1984b; Barnes, 1984; Ostvik & Elvik, 1990). Concealed enforcement prevents drivers from adapting their behaviour to suit the speed limit upon sighting the enforcement activity. In addition concealed enforcement not only serves to increase the uncertainty as to where and when enforcement might be encountered, but also reduces the possibility that offenders will feel confident that vigilance will prevent their being detected and punished.

Galizio, Jackson and Steele (1979) conducted a study in which the impact on travel speeds of four different enforcement symbols; a speed limit sign, a radar ahead sign, an unmarked police car, and a marked police car. They reported that while the presence of a marked police car had a significant speed reducing effect, the presence of an unmarked police car resulted in no change in travel speeds. Cameron and Sanderson (1982) stated the circumstances under which

they felt that both visible and non-visible enforcement strategies were appropriate. In particular, they argued that “*fixed offences*” (eg; drink-driving or unlicensed driving) were most suited to visible enforcement as the offender cannot change behaviour quickly to avoid punishment. On the other hand, “*transient offences*” such as speeding where the offender can alter behaviour are more suited to non-visible enforcement.

Barnes (1984) examined the effectiveness of radar enforcement in police cars using visible and non-visible enforcement methods in New Zealand. While he concluded that the radar gun was relatively ineffective at both apprehending speeding drivers and reducing travel speed except in the immediate vicinity of the enforcement activity, visible enforcement resulted in substantially fewer excessive speeding charges than non-visible enforcement. This low effectiveness was attributed to drivers head-light flashing to warn each other of the enforcement activity, and to a lesser extent radar detectors. Armour (1984b) claimed that no evidence was found to indicate that the effectiveness of a police presence was compromised when the police did not apprehend and punish offenders. However, this was from only 100 hours of impotent enforcement undertaken in conjunction with normal police operations where offenders are normally punished. It is unlikely that drivers would increasingly disregard the police presence if this practice continued.

While the above studies could be taken as damning evidence for the ineffectiveness of concealed enforcement (unmarked police cars), it must be noted that in these studies no detection or punishment activities were undertaken. The result being that no specific deterrence would be operating, nor was any publicity undertaken, rendering general deterrence almost ineffective. Under these circumstances general deterrence would be minimal as some drivers do perceive an unmarked car as a threat of enforcement. However, non-visible enforcement continues to be used widely perhaps out of frustration with the ineffectiveness of visible enforcement in apprehending speeding offenders. Curiously though, the simple and logical combination of non-visible enforcement mass media campaigns, to stimulate general deterrence through increased perceived risk of detection and punishment, has not undergone any systematic evaluation.

#### **4.4.2 Enforcement Mobility**

Council (1970) investigated the effect of a stationary or moving police car on mean speed, speed variance, and the proportion of vehicles exceeding the speed limit, measured two kilometres both up and downstream from the police car. Neither the stationary nor the mobile police car had any effect on speed variance. The stationary car caused a reduction in both mean speed and the proportion of vehicles exceeding the speed limit. The mobile police car had no significant effects on vehicle speeds. Shinar and Steibel (1986) conducted a similar study to that of Council (1970) in which the effect of mobility of a marked police car on vehicle speeds was investigated. Again, the stationary police car had the greatest effect on speed behaviour at the site of enforcement, the effects of the mobile car were however greater four kilometres downstream of the “*mobile site of enforcement*”.

The effect of mobility on enforcement is poorly understood as is the interaction between mobility and other factors such as visibility and publicity. The research evidence suggests that stationary enforcement has a greater speed reducing effect at the site of enforcement, however the general deterrent effect of a mobile car may exceed that of a stationary car as its mobility may be seen as preparedness to apprehend. Further, it has been suggested that the locations suitable for stationary cars the limited and hence become predictable, and also that drivers may

assume that having seen one stationary car another will not be encountered for some time (Armour, 1984a). There are a number of unresolved issues regarding the mobility of enforcement activities.

#### 4.4.3 Publicity

The use of publicity and feedback to drivers has also received considerable attention in the research literature. In particular, the relationship between publicity and enforcement has been reported on recently. In reviewing what makes an effective road safety campaign, Elliott (1989) notes that previous mass communication (advertising) campaigns have not always met with success. Reasons for non-success he argues include inadequate conceptions about marketing and the unique characteristics of safety to other behaviours. He maintains that publicity can be effective in eliciting a road safety behaviour change providing they are supportive of other community efforts (legislative, enforcement, etc) and are sensitive to the special demands of safety. Publicity can help create a desirable supportive climate of opinion in which other measures can operate.

In a subsequent study, Elliott (1993) conducted a meta-analysis to examine both successful and unsuccessful advertising campaigns. He reported that the average mass media campaign will achieve approximate improvements in road safety of 6%. Campaigns with persuasive orientations were significantly more effective than those with educative orientation although the latter were more widely employed. Other successful campaign characteristics included those which had a theoretical model, those based on qualitative and quantitative research, simple identifiable characters and language, emotional rather than rational, and those with legislative support.

The type of message and the medium used can influence the effectiveness of publicity. Rooijers (1988) found that the greatest reductions in the proportion of motorists exceeding the speed limit came from a behaviourally orientated message, rather than one stressing attitude change. He noted that attitude change does not always have to precede a behavioural change, a point also made by Elliott (1989). In evaluating a publicity campaign in the Netherlands, Rooijers (1990) and Liedekerken and van der Colk (1990) further concluded that television was the most effective medium for eliciting change, compared with others such as roadside billboards. However, Manders (1983) failed to show any vehicle speed reductions from a publicity campaign in Victoria using television, radio, and billboards, although this may have been the result of the relatively short duration of the campaign.

The need for campaigns involving both publicity and enforcement has been stressed by other speed researchers. Riedel, Rothengatter and de Bruin (1988) reported on the effectiveness of a publicity campaign with and without police enforcement in reducing speeding behaviour on open roads. While publicity alone did produce some speed reductions, publicity and enforcement had a much larger and more lasting effect. Similar results were also reported by Rooijers and de Bruin (1990) in another joint evaluation study although they found that publicity alone had a larger effect than enforcement alone. However, this may have been confounded by order or carry-over effects; enforcement preceded publicity in the single treatment conditions.

Roszbach (1990) described a *three* phase speed enforcement strategy developed at SWOV in the Netherlands. In phase one publicity stressing punishment is employed to bring about short term reductions in the numbers of drivers violating speed limits. Phase two takes advantage of the reduced number of violators, in that a high probability of detection should be possible. It is suggested that phase two should continue until new speed behaviours are established with some

degree of stability. Included in phase two is differential punishment administered to multiple offenders, and for degrees of exceeding the speed limit. Phase three sees the lifting of increased enforcement in combination with monitoring any reverting to old unwanted behaviours. Unfortunately, though, this campaign is still seeking acceptance and there is no evaluation of its effectiveness to date.

#### 4.4.4 Feedback

Another method of speed control shown to have had some success is the public posting of appropriate and inappropriate speeding behaviour. Roadside signs showing the proportion of drivers exceeding and not exceeding the speed limit (above some predetermined tolerance limit) have been employed in the past. A series of experiments were conducted by Van-Houten and Nau (1983) on the public posting of speeding behaviour. The roadside sign conveyed to drivers the level of compliance with the speed limit on the previous day, along with the highest level of compliance ever recorded. The sign was found to be more effective than conventional enforcement and remained effective six months after its installation.

The study by Rooijers and de Bruin (1990) mentioned earlier also examined the effects of warning signs and feedback to motorists regarding the percentage of drivers not exceeding the limit and excessive speeding in the preceding week. While they reported that warning signs were less effective than publicity, they did show significant speed reductions to control sites. Maroney and Dewar (1987) investigated the effects of using a traffic sign to communicate to drivers over a six week period the proportion not exceeding the 50km/h speed limit by more than 15km/h on the previous day. Implementation of the sign resulted in reductions in mean speeds and the proportion of drivers travelling at excessive speeds. Over the six weeks that the sign was in place the level of compliance with the speed limit (plus 15km/h) increased from 79% to 94%. They reported that the larger the percentage of drivers not speeding the more effective was the sign at slowing drivers travel speeds, and that the speed reducing effects of the sign were still evident four weeks after its removal.

In Australia, Philips and Maisey (1989) examined the benefits of public posting of speeding behaviour on an urban arterial in Perth that had a history of speeding and an associated high accident rate. The proportion of drivers exceeding the speed limit by more than 20km/h decreased significantly with the advent of the feedback posting. Moreover, they reported the effects were still evident six months after the implementation of the sign, a result obtained with only minimal obtrusive police enforcement. The authors concluded that the public posting of speeding behaviour was an effective (and cost effective) method of reducing excessive speeding. Rogerson (1990) however found that while a trial installation of an electronic roadside sign in Victoria did result in fewer vehicles exceeding the speed limit during its operating period, the effects quickly dissipated and therefore she argued it was *not* likely to be cost effective.

It may be that these feedback mechanisms of general behaviour are not sufficient to bring about change in an individual's behaviour. Most motorists do not perceive themselves to be "*average motorists*" and therefore population information may have little effect on their subsequent behaviour. Perhaps feedback of speed violations should be aimed specifically at individual indiscretions. Conceivably, this could be done either privately (feedback displays inside the vehicle) or publicly by dynamic roadside displays showing local instances of excessive speeding immediately they occur. This may act to embarrass those individuals into slowing down. There were not reports of such trials found in the literature.

#### 4.4.5 New Enforcement Technology

New speed enforcement technology is either in use today or currently under consideration in most Australian states. Victoria and New South Wales have piloted the use of these devices and both states are presently engaged in regular speed camera enforcement operations. It is still too early to judge the effectiveness of these programs. The N.S.W. campaign was reported successful in terms of its effect on travel speed and motorists' attitudes towards these devices (Roads and Traffic Authority 1992). The Victorian program (which is several times more intense than in N.S.W.) is currently under evaluation for its effect on travel speeds and crash reductions. A report on this program is due later this year. It should be pointed out, though, that both programs have involved not only camera surveillance but intensive publicity and it will be difficult to assess these two effects separately.

There are a number of ways in which automatic policing systems could contribute to speed limit enforcement. The first and most obvious is that automatic enforcement has the potential (although never the reality) to increase the probability of being detected and punished for speed limit violation to equal one, absolute certainty. Automatic enforcement can also increase the subsequent likelihood of being punished for such a violation, by in many cases producing proof of the offence having been committed. Additionally the objectivity and fairness of detection can only be served by systems in which the police officer does not play a judgemental role (Rothengatter, 1990).

Lamm and Klockner (cited in Ostvik & Elvik, 1990) reported a 20km/h reduction in mean travel speed on a German motorway following the implementation of an automatic surveillance system. This followed a 30km/h reduction after implementing a 100km/h speed limit, therefore they claimed the 20km/h reduction was due to the combined effects of the speed limit and the automatic enforcement program. Ostvik and Elvik (1990) reported that mean speeds on an 80km/h road decreased up to 10km/h as long as two years after the start of an automatic enforcement program with cameras active for an average of only twelve hours per week. It is reported by these researchers that reduced speeds due to the automatic enforcement persist for periods up to two months without enforcement (cameras inactive).

Blackburn and Glance (1984, as cited in Freedman, Williams & Lund, 1990) reported that the effect of installing automatic enforcement on a German autobahn to enhance compliance with a 100km/h speed limit. The annual number of crashes decreased from 300 to just nine following the implementation of the automatic enforcement strategy, likewise the injuries fell from 80 to five, and deaths from seven to none. However the automatic enforcement was again implemented to enhance compliance with a new reduced speed limit, therefore the effects of the automatic enforcement can not be accurately determined.

Freedman, Williams and Lund (1990) conducted a public opinion pole of residents to gauge public opinion and acceptance of photo radar enforcement. While considerable support for this form of automatic enforcement was found, more so in those communities in which it was being used, a minority of residents disapproved of its use. Importantly the two most often volunteered reasons for disapproval were the possibility of the wrong person receiving a fine (despite the fact that the only possibility of error lies with the owner onus system) and the "sneakiness" of the program (despite the fact that warning signs and clearly marked police cars were used). Hence disapproval was based mainly on mis-information and general resentment of being policed. A positive finding reported by these researchers was that approximately 50 percent of respondents who were aware of the automatic enforcement strategy said that they were driving



more slowly as a result. This self reported account of speeding behaviour has yet to be confirmed through observation of speeding behaviour.

There have been calls for other enforcement measures too. Fildes et al (1991) noted that the emphasis of enforcement should be aimed at excessive speeders and called for greater education and enforcement against these motorists. In addition, they argued that there could be greater use made of engineering solutions to speeding such as urban speed monitors (in-road devices to provide either feedback or penalties to offenders), or top speed limiters for all vehicles to prevent excessive speeding above the maximum speed limit. As these latter devices would effectively eliminate rural speeding, it could reduce the need for enforcement effort in these areas and hence be cost effective.

#### **4.4.6 Tolerance Levels on Speed Limits**

Almost all speed enforcement agencies employ a level of speed tolerances, a margin above the maximum speed limit within which drivers are not apprehended or punished. Internationally, these tolerances vary from unofficial and unwritten policies to official specified guide-lines. In Victoria, for instance, a margin of 10 percent plus 3 km/h of the posted speed limit has been applied by the police in enforcing travel speed by the use of speed cameras in this state.

The reasons for these tolerance limits are numerous. First, the measurement of speed for prosecution is controversial among the courts. The police compensate for likely challenges to offences by allowing a tolerance for speedometer error and inaccuracies in the speed measurement equipment and procedure. As well as maximising the likelihood that their evidence for speeding offences will stand up in court, this practice also promotes good will among motorists by concentrating on high-risk speeders (Ruschman et al 1981). The practice of setting speed limits at or around the 85th percentile speed limit means that the number of violators will commonly exceed the number that can be policed realistically. Thus, it seems sensible to focus mainly on excessive speed violations (which are more likely to be dangerous) and overlook the more minor indiscretions. The consequence of this practice, however, is to artificially inflate the speed limit as the public become aware of these speed tolerances. While these tolerances for the most part are not intended for public knowledge, nevertheless motorists become aware of them through various sources which leads to higher travel speeds in general and undermines confidence in (and compliance with) the posted speed limits. Nilsson (1990) suggested that drivers simply add the tolerance level to the posted maximum speed limit to arrive at their desired travel speed, and further, that this accepted limit is often regarded as a guide to minimum speed.

During 1987 in Sweden, Andersson (1989) evaluated the effects of a 3 to 5 km/h reduction in speed enforcement tolerance on vehicle speeds in urban two test areas, compared with speeds in unchanged control areas. While the study design is not perfect and the details provided are scant, nevertheless Andersson reported a drop in mean speed by approximately 1 km/h (around 2 percent) with some apparent reduction in standard deviation as well. They also reported that 20 to 30 percent of motorists interviewed in these areas were aware of the reduction in tolerance. They attributed the observed reductions in speed to the increased risk of detection associated with the lower speed limit tolerance levels. These findings support Nilsson (1990) suggestion that drivers add the enforcement tolerance level to the posted limit when determining the maximum allowable speed. This apparent abuse of the speed limit has been claimed to erode the efficacy of speed enforcement. However, there is no simple solution to the problem. While the use of zero tolerance levels would presumably add more face validity to speed limits

and hopefully lead to lower travel speeds, such a practice would be strongly challenged technically in the courts by motorists and their legal representatives seeking to dismiss their charges. Thus, a zero tolerance would more than likely lead to a reduction in public confidence in speed limits, rather than to increase it. The only realistic solution seems to be adopting *minimal* tolerance levels in conjunction with rationalised speed limits based on what is an appropriate and acceptable travel speed.

#### **4.4.7 Summary**

Highly visible police enforcement activities seem to be effective at reducing travel speeds especially when there are multiple region activities. Non-visible police enforcement has greater impact on *fixed offences* such as *drink-driving* and may result in greater general deterrence effect through greater uncertainty. Stationary police operations seem more effective at reducing speed than mobile ones, although the mechanisms for this are poorly understood. The role of driver attitude in speed behaviour is not clear. However, publicity should not be used as the sole medium for eliciting speed reductions, but rather as a supporting environment for other activities. A multi-facet program would seem to be desirable to bring about long term speed behaviour change. There was some suggestion that roadside signs displaying speed violation information was effective in reducing travel speed overseas, although local experience so far has been equivocal. There may be merit in altering the form of this information from population to individual indiscretions to embarrass speeding motorists into slowing down. New technology brings with it the possibility of greater specific and general deterrence from increased probability of detection (both perceived and actual) and punishment. There is also some evidence of crash reductions from these devices overseas. There is an urgent need for a full evaluation of the effectiveness of new technologies in this area.

#### **4.5 TARGET GROUPS OF SPEEDERS**

To maximise the effectiveness of police enforcement effort, it is imperative that enforcement programs are focussed on individuals and actions that present a particular risk on the road. The undesirability of excessive speeding has been noted by a number of researchers and review panels in this country and elsewhere (eg; Solomon 1964; Vic Roads 1987; Nilsson 1989; Fildes et al 1991). It is important, therefore, to identify the various individual, vehicle, road and trip characteristics involved in this behaviour. Solomon (1964) *first identified the characteristics of drivers and vehicles found to be speeding on rural highways in the US in the 1960's*. He noted slightly higher mean speeds for young drivers, out of state vehicles, armed forces vehicles, buses, and recent model high powered passenger cars, especially sports models. He did stress that these differences were only moderate but this was partially a function of the relatively insensitive method he used for assessing these differences. More recently, Nilsson (1989) compared interview responses with speed data on 90 km/h main roads in Sweden and reported a relationship between vehicle speed and trip purpose, length of journey, vehicle performance, age of the vehicle owner, width of the road, and use of a trailer. *Unfortunately, it is not perfectly clear from their report the method they employed in this study and hence the link between the observations and the driver interviews.*

Fildes et al (1991) actually observed speeds in both urban and rural locations in Victoria, then stopped vehicles in various speed categories and interviewed the driver (without disclosing that their speeds had been observed). He reported statistical relationships between excessive speeders and not towing, driver age, number of occupants, purpose of the trip, travel schedule, year of manufacture of the vehicle, weekly travel distance, and reported accident history.

Moreover, using factor analysis and multi-regression techniques, they were able to prioritize the relative importance of these variables (and groups of them) in both environments. This type of detail on the characteristics of speeding drivers is vital for enforcement and advertising targeting to reduce speeds. In addition, it provides a greater appreciation of the excessive speeding problem and additional countermeasures required to reduce speeding and speed related crashes on the road.

#### **4.6 CONCLUSIONS FROM THIS REVIEW**

There are a number of conclusions that can be made from this review of the research literature into speed enforcement and behaviour.

1. Detection and deterrence play a major role in police enforcement of speeding. The perceived risk is as important (if not more important) as the actual risk of detection in effective police enforcement.
2. Conventional police enforcement appears to have its greater influence on specific (individual) deterrence. General (community wide) deterrence seems to be more affected by publicity and feedback, although high specific deterrence is likely to flow through to general deterrence by word of mouth knowledge.
3. Distance and time halo effects vary depending upon the level of police activity and location factors. Large effects have been reported for repeated enforcement activities although the long term consequences have not been fully established.
4. The role of punishment in speed reduction is not clear. The certainty of punishment seems to be a mechanism in specific deterrence. The severity of the punishment also appears to have some effect on travel speed although not as the sole mechanism of enforcement. The importance of celerity (immediacy) of punishment is not clear from the travel speed research literature.
5. Highly visible police enforcement activities seem to be more effective for speed enforcement than non-visible activities. Curiously, though, the effectiveness of non-visible enforcement in general deterrence has not undergone systematic evaluation. Stationary police operations appear to have more influence on travel speed than mobile operations.
6. Publicity has a role to play in speed enforcement although it should not be relied upon solely to bring about reductions in travel speed. Police activities in conjunction with widespread publicity and education seems to be a desirable program for speed enforcement.
7. Providing feedback to motorists of speed violations has had some influence on travel speeds overseas, although it has met with mixed success previously in Australia. There may be merit in examining alternative (specific) feedback mechanisms of speed violations for individual motorists.
8. New enforcement technology such as speed cameras has potential to have a marked influence on travel speed behaviour on the road from markedly increasing the perceived (and actual) risk of detection. There is some evidence from overseas that speed cameras can also reduce crashes, although this is not conclusive. There is a need for an evaluation of the effectiveness of these devices and the means by which they influence speed behaviour.

9. The characteristics of speeding motorists have been shown to include driver, vehicle, trip, and road variables. Identification of these factors is important for targeting enforcement and advertising campaigns aimed at reducing travel speed. there is a need for further work in this area to confirm some of these findings in particular locations or regions.

#### **4.7 OPTIONS FOR FUTURE RESEARCH AND DEVELOPMENT**

A number of issues requiring further research and development were identified during this review and have been listed below.

1. There is a general lack of theoretical understanding of many of the mechanisms operating in enforcement and speed control. In particular, the precise relationship between specific and general deterrence in enforcement is not well understood nor, too, is the role of perceived and actual risk of detection.
2. Understanding the relative importance of behaviour and attitude in speed control is paramount for effective speed management. This has not been adequately addressed in psychological studies in this area so far, although the difficulties inherent in this type of research generally are acknowledged.
3. The role of punishment in conditioning studies focuses on the importance of certainty, severity, and celerity of the punishment. It is not clear from the literature, though, whether these mechanisms are equally important in speed control on the road. The role of rewards versus punishment is a contentious issues in behaviour modification and one that seems to have received little attention in this area.
4. The long term effects of enforcement also seem to have received little attention in the literature. Studies of halo effects, for instance, have tended to focus on short term enforcement activities and short term evaluations. There is clearly a need for a more systematic and longer term speed enforcement program with a thorough evaluation of its full effects if long term changes in speed behaviour and attitudes are expected.
5. Information on speed violations seemed to have had some effect in moderating travel speed overseas, although previous programs in this country have met with mixed success. There was a suggestion that this feedback needs to be aimed at specific offenders, rather than just providing population information. Mechanisms for achieving this and the role of embarrassing deviant drivers would be a useful area of future research in speed management.
6. Understanding the characteristics of speeding drivers (especially those travelling at excessive speeds) is critical for optimising enforcement programs in the future. While there is some evidence already available on this, future research in this area would be profitable in furthering our understanding of excessive speeding.
7. Speed camera technology is a recent enforcement development in Australia and is attractive because of its relatively low cost of operation. It has the potential to have a marked influence on travel speed because of its widespread use and therefore its consequences for perceived and actual risk of detection. However, the full ramifications of this technology are yet to be established and comprehensive evaluation studies are warranted.

8. There are a number of additional enforcement devices that have been suggested to reduce travel speeds. These include local street speed controllers and highway top speed limiters for all vehicles. To the authors' knowledge, none of these measures has been systematically evaluated and further research and development in this area would seem to be important.
9. Further research into the relationship between changes in perceived risk and subsequent behaviour and the extent to which this relation is stable would be worthwhile.
10. While punishment is unlikely to change behaviour without enforcement, it seems there would be merit in examining punishment options and their role in speed reduction. In particular, how effective loss of demerit points is compared with monetary punishments.

## 5. SPEED BEHAVIOUR AND THE ENVIRONMENT

Driving involves a number of complex tasks including both route and path planning as well as vehicle control (and especially the need to respond appropriately in the face of an emergency). Implicit in performing these tasks safely is the driver's ability to make relatively accurate estimates of his or her own speed and that of other vehicles (Triggs, 1986). Assessing vehicle speed is often achieved through the use of a speedometer, however, on occasion, time does not permit this luxury. Notwithstanding the need to make instantaneous and accurate estimates of absolute speed, often judgements of relative speed are more important to the driving task, and these can not be gained from normal vehicle instrumentation. Hence, speed perception is an ability central to safe and successful driving.

In recent history there has been increasing interest in the effects of changing the appearance of the road environment to manipulate (either increase, or make more accurate) the perceived speed of a drivers own vehicle. When investigating such environmental manipulations an important distinction must be made between manipulations that affect drivers' *perception* of speed and those that affect drivers' *choice* of speed (Triggs, 1986).

Manipulations that affect drivers' choice of speed, often do so through alerting them to the presence of a potential hazard on the road ahead. Changes in speed in response to such advice (eg; an advisory speed sign) commonly occurs only after a decision is taken by the driver to heed the warning offered. The conscious decision regarding the degree of compliance with a given warning involves a great many considerations (eg. personal, attitudinal, economic, etc.).

Conversely, environmental manipulations can also affect a drivers' perception of speed without requiring deliberate decisions to comply, such as manipulations that influences the pre-conscious perception of speed. It should be noted that the distinction between the two is not always clear, for example, the way in which reflectorized guide posts affect a driver's perception of speed in a curve may involve both perception and choice of speed.

### 5.1 THE CONCEPT OF PERCEPTION

Perception has different connotations for different people and professions. On one hand, it is often used to refer to the relatively automatic sensory processes of an individual interacting with his or her environment. In this sense, it is the first stage of the psychological process that occurs between a human being stimulated and subsequently responding and can be referred to as the *sensory perceptual* phase of driving.

Alternatively, perception has also been used to describe the deliberate and conscious thought processes involved in human response, involving an individual's beliefs, motivations and desires. An example would be in the expression "*He perceived that politics was an important factor in the decision*". In this sense, perception involves higher order decision making processes where the social consequences of an action can influence the ultimate response. For convenience sake, this is referred to as the *cognitive perceptual* stage.

The speed at which a driver chooses to travel can clearly involve both of these perceptual constructs. While sensory perception will determine from the outset what information is available to a human operator in a particular stimulus situation, the internal states or social forces can nevertheless influence the form of the ultimate response to that information. Given that sensory perception is the basis for a human response in his or her environment, manipulat-

ing the visual cues involved in sensory perception on the road has the potential to bring about long-term improvements in road behaviour.

## **5.2 THE INFLUENCE OF VISUAL CUES ON SPEED PERCEPTION**

A number of studies have investigated the sensory aspects of speed perception and how visual cues can influence speed perception. These are summarised below.

### **5.2.1 Visual Pattern**

Denton (1971, 1973) reported that speed judgements in a driving simulator and on the road were highly dependent on the nature of the visual pattern presented to the driver's eye. Transverse line treatments were introduced at selected roundabouts in the United Kingdom to induce drivers to slow down during their approach to these intersections. Evaluation studies (Denton, 1973; Rutley 1975; Helliard-Symons, 1981) reported subsequent reductions in speed, speed variation and lateral position, although the speed effects of this treatment tended to dissipate somewhat with time (Denton, 1973; Rutley, 1975).

Cairney and Croft (1985) and Cairney (1986) reported two studies which investigated the effects of various environment and road factors on drivers' speed judgements. Unfortunately, these studies used static photographs of roads and subjects made verbal speed limit responses; the results, therefore, are difficult to interpret solely in terms of sensory perceptions of speed. More recently, Fildes, Fletcher and Corrigan (1987) and Fildes, Leeming and Corrigan (1989) reported on drivers' judgements of safety and speed on urban and rural roads (straight and curved) during daylight and night-time conditions. This research demonstrated the influence of various road and roadside factors in a driver's perception of speed and listed a range of perceptual countermeasures to speeding. Unfortunately though, many of these measures have not been evaluated and their effectiveness is yet to be established.

### **5.2.2 Retinal Encoding**

It is important to understand how speed information is encoded on the eye. The concept of "*retinal streaming*" was proposed by Gibson (1950, 1958, 1968) and Calvert (1954) as an explanation of the cues used in perceiving speed. In essence, retinal streaming explains how the visual pattern presented to a moving observer varies from a stationary image at the point of fixation of the eye (the fovea on the retina) to a blur of increasing magnitude the further the distance from the fixation point. Thus, it provides a means of interpreting velocity information directly from visual stimulation in the periphery of the eye.

The notion of "*retinal streaming*" in depth perception has been criticised (Johnston, White & Cummings, 1973; Regan & Beverley, 1978; 1982). However, most authors agree that some form of relative coding on the retinal surface of the eye is an extremely important cue for the perception of speed (Gibson & Crook, 1938; Gordon, 1966; Moore, 1968; Lee & Lishman, 1977; Harrington, Wilkins & Koh, 1980). Gordon (1966a) and Moore (1968) described the consequences of a moving image on the road in terms of "*velocity gradients*" on the retina of the eye. They argued that the perception of velocity on the road can be determined solely from the integration of movement information on the retinal surface. These theoretical accounts of speed perception are in general accord with Gibson's (1950) motion parallax concept in depth perception.

### 5.2.3 The Effect of Roadway Characteristics

The accuracy with which drivers perceive their environment has been shown to vary under different road and road-side conditions. Shinar (1977) argued for an illusive curve phenomenon in driving where the curvature of an approaching bend in the road can be under-estimated under certain curvature conditions. Indeed, Ten Brummelaar (1983) described the critical features of a road curve viewed in perspective for veridical perception. Many of these features were subsequently shown to influence a driver's perception of curvature (Fildes 1986). In particular, the subjects tested in this latter research program showed an inappropriate preference for the curve's angle when judging curvature.

Fildes et al (1987; 1989) set out to test the effects of various road and roadside characteristics on a driver's perception of speed. They found that the road surface (width, number of lanes, etc) had the strongest influence on judgements of safety and travel speed, while the roadside environment was also effective but to a lesser degree. Night illumination had a marked effect on speed perception and driver inexperience was relevant in assessing a safe travel speed in curves. From this research, they argued that manipulating the driving environment was likely to be successful in reducing travel speed in situations where drivers were not feeling overly safe (ie; narrow walled environments).

### 5.2.4 Summary

While there are conflicting views about the precise mechanisms of speed perception in vision, there is broad agreement that relative velocity and size movements on the retina are important cues. The literature reviewed showed that manipulating the visual pattern of observers (and in particular, the road and immediate surroundings) can have a strong influence on their perception of speed. Thus, manipulating the visual scene presented to a driver has the potential to act as a countermeasure to speeding, although more work is required to establish the range and effectiveness of these measures.

## 5.3 COGNITIVE ASPECTS IN SPEED PERCEPTION

A number of other associated driver characteristics (cognitive abilities) in speed perception were also reported in the literature and these are summarised below.

### 5.3.1 Guiding and Object Recognition

An illusion of "*perceptual mis-calibration*" that can lead to drivers having a falsely inflated belief in their ability to see and react to road hazards was described by Leibowitz & Owens (as cited in Bower, 1990). The essence of the illusion lies in the fact that the components of the human visual system involved in spatial guidance (eg. steering a car) and those involved in object recognition (eg. reading road signs) have vastly different capabilities under poor conditions. They argued, for example, that guidance can be performed with success in poor lighting whereas object recognition is seriously degraded. Obviously safe driving requires both components to operate. Under conditions of poor lighting (eg. twilight, darkness, rain, fog, etc.) drivers can be fooled by their ability to guide their car into believing that they can also recognise road hazards with the same level of proficiency. This belief, they claimed, could lull drivers into travelling at speeds inappropriate for the prevailing conditions.



### **5.3.2 Absolute Judgements of Speed**

A few studies have investigated a driver's ability to estimate his or her own travel speed. Hakkinen (1963) found that speed judgements were under-estimated by subjects responding to films and by passengers in actual traffic situations in the medium and high speed ranges. Salvatore (1968, 1969) and Reason (1974) reported that subjects consistently under-estimated speed across a 20 to 60 mph (32 to 96 km/h) velocity range in both vehicles and simulators. Both Hakkinen and Salvatore showed that errors of estimation increased substantially when sensory inputs (visual, auditory, kinaesthetic, tactile and vestibular) were withheld.

Evans (1970a, 1970b) found that slow speeds were, in fact, well under-estimated whereas high speeds were only slightly under-estimated in vehicle tests on the road. Moreover, he found that the perspective view presented to subjects in laboratory tests of speed estimation was critical for replicating road speed judgements. Any test of speed perception, therefore, needs to take account of the absolute level of speed involved and the presentation method of moving road environments.

### **5.3.3 Speed Adaptation**

Triggs (1986) described speed adaptation as the effect where prolonged exposure to vehicle speed causes subjects to under-estimate their speed judgements. It is the feeling of practically stopping when slowing down to pass through a country village, even though travel speed is still substantial. Bower (1990) describes speed adaptation as a subjective feeling of a change in speed being greatly enhanced by its contrast to the speed to which the person has adapted. The situations under which the speed adaptation operates, however, are at variance between these two researchers, suggesting the need for further research in this area.

It should be pointed out that speed adaptation differs from driver fatigue in that adaptation does not necessarily occur with driver tiredness (Triggs 1986). Nevertheless, it does tend to occur only after long periods of fairly constant high speed travel (Reason, 1974) and thus is often compounded with driver fatigue effects. Speed adaptation can lead to drivers adopting high speeds in situations where lower speeds are appropriate and therefore placing themselves and others in great danger.

### **5.3.4 Summary**

The skill of travelling at the correct travel speed is clearly dependent upon both sensory and higher-order cognitive factors. Just as unambiguous sensory inputs are important for accurate perceptions of speed, so to the mental state of the driver can have a marked influence on their perception of what is an appropriate travel speed. The evidence reviewed here showed that human estimates of velocity are more accurate at higher than lower speeds and very much dependent upon the amount of visual stimulation provided. Moreover, a driver's perception of speed will be moderated by the amount of driving and subsequent "*adaptation*" to movement. The ability to perform one skill satisfactorily can also have a pronounced illusory effect on other perceptual abilities.

## **5.4 ENVIRONMENT, ROAD, & DRIVER FACTORS IN SPEED PERCEPTION**

A number of environment, road, and driver factors are likely to exert some influence on the perception and choice of travel speed. Jennings and Demetsky (1983), for instance, listed 16 road and environment variables they claimed would influence driving behaviour on the road,

shown in Table 5.1. A review of the literature revealed that many of these factors can indeed influence speed perception and behaviour.

**TABLE 5.1 POSSIBLE ROAD AND ENVIRONMENT VARIABLES**  
(from Jennings & Demetsky, 1983)

ROAD or ENVIRONMENT FACTORS	
time of day	roadway grade
radius of curvature	length of curve
lane and road width	existing pavement markings
shoulder width (if any)	nature of adjacent lane
intersecting roads or driveways	traffic volumes
average speeds of traffic	delineator spacing (if any)
delineator type and number (if any)	condition of delineators
weather conditions	sight distance

#### 5.4.1 Urban and Rural Environments

There are several reasons why speed perception is likely to differ between these two environments. First, speed limits are generally different for urban and rural roads. Road design incorporates proposed speed limits and other major urban-rural environment differences. Hence, urban and rural roads differ considerably in terms of their engineering and community expectations (Lay, 1984). Westerman (1990) provided a model of road and environment typology that takes account of function and roadside setting.

Hungerford & Rockwell (1980) and Jennings and Demetsky (1983) noted that travel on rural roads was noticeably different from that on urban streets in that speeds were generally higher, traffic volumes were much lower and the severity of crashes increased. Researchers such as Sanderson and Corrigan (1984, 1986) and Norrish (1991, 1992) have demonstrated that many drivers disproportionately violate urban speed limits to a greater extent than rural limits.

#### 5.4.2 Roadside Development

Roadside development can be broadly defined as any aspect of the environment close enough to the roadway to influence driving. NAASRA (1980) claimed that the roadside environment will influence traffic speed and this has particular importance for traffic engineering and planning (Brindle, 1980). The "*Woonerf*" environment in the Netherlands for instance, uses benches, different paving, winding vehicle paths and other physical and perceptual effects to reduce vehicle speed in a car and pedestrian environment. (Refer also Boeminghaus, Bever-Jaenichen & Ernest (1984)). Westerman (1990) argued that road design must include the relationship between traffic on the road and the activities alongside it.

Wilson (cited in Joscelyn et al 1970) found that roadside culture and establishments resulted in lower spot-speeds on four-lane highways. Smith and Appleyard (1986) also reported that house

set-back distance was positively correlated with urban car speeds. They hypothesized that an urban “walled” effect was operating on the driver and considered building type to be an important consideration in urban speed behaviour. Rankin and Hill (1974) did not find land use alongside their test roads to affect travelling speed, although it was noted worthy of more detailed investigation. Part of the failure of land use to be a significant variable in this study may have been due to the very broad based categories used and the failure to control for factors such as traffic volume. This lack of variable control was, in fact, noted in explaining their differing results on the significance of road shoulder, width, and condition in speed determination.

Early research cited in Joscelyn et al (1970) and Leong (1968) found shoulder width and condition to be correlated to free speed. In re-analysing Leong’s data, Troutbeck (1976) however, was unable to find any effect for these factors and claimed Leong’s result was spurious. A correlation between crash rates and shoulder paving was found by Turner, Fambro and Rogness (1981) when they applied a more rigorous categorisation of variables than that used in the earlier studies. The rationale used by Turner et al was that road shoulders occur in such a variety of types that careful classification is necessary. However, care must be taken when using shoulder crash studies to assess speed as different types of shoulders, paved, gravel and so on may have different crash potential in themselves.

Rural roads with no prominent side features have been associated with lower speed judgements than similar tree-lined roads (Shinar, McDowell & Rockwell, 1974). Triggs (1986) suggested that this effect may be due to either increased peripheral stimulation or motion parallax effects. As stated earlier, Fildes, et. al. (1987) reported that speed perception effects were dependent on the environment. In rural environments, roads without roadside trees were perceived as safer, and travel speeds under-estimated much more, than those heavily treed. This was especially so for faster travel speeds.

For semi-rural environments, though, roadside trees generally had less influence on speed perception. Moreover, their effect was dependent on the type of road and, seemingly, on the degree of urban development as well. Urban roadside environments were noticeably different to rural and semi-rural settings, comprising either residential or commercial or industrial developments. Residential settings were perceived to be slightly safer than industrial and commercial settings, although these differences were only very small. The effect of commercial and industrial complexes was to decrease the estimates of safety for 4-lane and 2-lane roads but increase safety estimates on divided roads. This result was explained by the increased spaciousness of service roads and off-street parking, often found at commercial and industrial complexes located on major divided arterials.

Fildes et al. (1989) found an important interaction in the safety estimates of curved sections of road. The interaction was such that small radius, walled, gravel curves were judged to be particularly unsafe. Vaniotou (1990) conducted experimental work based on the general hypothesis “*that bends with the same geometry but with different immediate surroundings are perceived differently by road users*” (p. 39). It was reported that bends with both flat and hilly “wider surroundings” could give rise to the perception of danger or security depending on the nature of the “immediate surroundings”. The immediate surroundings, the shape and characteristics (spatial dominance, position, shape, continuity and field of view) of the elements usually on the outside of the bend were found to play an important role in the way the bend was perceived.

The immediate surroundings included such things as safety rails, fences and walls; vegetation (from tall trees to low lying ground cover); poles; overhead cables; reflective posts. Different combinations of surroundings, both immediate and wider, combined to give different perceptions of danger or security on bends with essentially similar bend geometry. It was suggested by Vaniotou that knowledge of the effects of road surroundings on the perception of danger or security could be utilised to control drivers' perception of safety on a section of road hence controlling chosen travel speed.

#### **5.4.3 Road Alignment**

In a review of the relationship between road geometry and single vehicle crashes, Sanderson and Fildes (1984) reported that the most consistently associated road feature was horizontal curvature. In most instances, decreasing the radius of curvature led to an increase in run-off-the-road crashes. The frequency of curves did not appear to influence crash rates, although there was a suggestion that an unexpected sharp curve may be crash inducing (Raff 1953). Sanderson and Fildes analysed single vehicle crashes in Victoria between 1978 and 1982 and found that 47 percent occurred on bends and 53 percent on straights. They concluded that while single vehicle crashes on curves were over-represented in the statistics, crashes on straight roads were still a significant problem in this Australian State. Similar results have also been reported for other Australian States (Cowl & Fairlie, 1970; Peter Casey & Associates, 1979).

#### **5.4.4 Road Category and Lane Width**

The crash data on the role of the number of lanes and lane widths reveals some interesting trends. Raff (1953) reported that wide pavements and shoulders were associated with lower crash rates on two-lane curves in the USA, although he failed to find any strong association on tangents. More recently, Evans (1985) argued that fatality rates in the USA differ by a factor of four or more depending on the type of road involved. Peter Casey and Associates (1979), however, found no conclusive evidence concerning relative safety and number of lanes on straight sections in Australia. However, there was some suggestion of an increase in fatal crashes on straight narrow roads of sub-standard rural widths, and motorways tended to have less fatalities than other highways.

Solomon (1964) found that two-lane roads had a head-on crash rate five times that of four-lane sections, and four-lanes less than 15 feet (5.4 m) wide were twice as likely to have a head-on crash than four-lanes greater than 15 feet (5.4 m) wide. He reported no consistent relationship between median width and head-on collisions, although the presence or absence of a median had a strong crash effect. It is very difficult to ascribe perceptual effects from these data, however, because of the likely relationship between lane encroachment and crash involvement.

In New South Wales, Johansen (1992) compared crash rates (per 100 million vehicle kilometres) between various homogeneous groups of road sections, namely 2-lane non-divided roads, 2-lane non-divided roads with overtaking lanes, 4-lane non-divided roads, 4-lane non-divided roads with overtaking lanes, and 4-lane divided roads. Accident rates tended to reduce as the number of lanes increased. Surprisingly, there were increases in crash rates between 4-lane divided and undivided roads (35-37 cf. 34 or up to 8 percent greater). On all undivided roads, the accident rates were between 21 and 54 percent higher on roads with a sealed shoulder less than 1 metre than on roads with a much larger sealed shoulder. On 4-lane divided roads, the opposite was true. The unexpected findings for divided roads may simply reflect other

characteristics of the roads selected or differences in traffic levels and environments between the different sections studied on these major highways.

The performance data here is particularly relevant. A positive relationship was reported between vehicle speed and street width in several studies (Oppenlander, 1966; Leong, 1966; Smith & Appleyard, 1981). Moreover, Vey and Ferrari (1968) found greater speed, less headway and less speed and headway variance for 11'3" (3.4 m) lanes over 9'9" (3.0 m) lanes across two comparable road bridges in Philadelphia. Smith and Appleyard (1981) report a direct relationship between drivers' speed and "apparent width" which encompasses the influence of the immediate surrounding environment on the actual road surface (a perceptual interpretation of a geometric feature). Von Morner (1984, as cited in Bowers, 1986) also demonstrated that in the relationship between carriageway width and speed it is the perceived width that counts. He suggested that the perceived width was determined by the width over which the driver has unobstructed vision.

Fildes et al (1987) reported that the type of road influenced speed perception. Roads with a higher design standard and greater width generally resulted in higher estimates of safety and greater under- estimates of travel speed. They warn, however, that this finding varied as a function of the region and whether the road was divided or not. Fildes et al. (1989) also reported that speeds on divided roads were judged to be more safe than on 2-lane roads, but travel speeds were under-estimated more on these high quality roads. Gravel road speeds were generally assessed to be quite safe, although again, travel speeds were grossly under-estimated. Free speeds on the road tended to increase as the type of road improved.

McLean and Hoffman (1972) found that drivers adopted different steering strategies for narrow lanes at high speeds than for more moderate lane widths and speeds. Joscelyn et al (1970) suggested that drivers in multi-lane roads adjusted their speed in accordance with vehicle speeds in the slower parallel lane, although they only reported data from other studies to support this claim. A correlation was also suggested between vehicle speed and street or block length (Leong, 1968; Loder & Bayly, 1980; Smith & Appleyard, 1981; Armour, 1984b). However, this is probably related more to sight distance than street length per se. The smoothness of the road surface was found to be directly related to vehicle speed (Oppenlander, 1966; McLean, 1982) but not crashes (Raff, 1953). McLean (1982) also reported mean free speeds about 15-20 km/h lower on unpaved two-lane roads than on equivalent paved surfaces. While not thoroughly evaluated, Van den Dool and McKeown (1991) claimed that LATM treatments which reduce 4-lane undivided roads into 2-lane with a right-turn laneway lead to improved traffic conditions.

#### **5.4.5 Horizontal Curvature**

By far, the most consistent road feature associated with the rate of single vehicle road accidents is horizontal curvature. In many instances, an increase in run-off-the-road accidents has been attributed to a decrease in the radius of curvature (Cowl & Fairlie 1970; McLean 1977, 1978; Peter Casey & Associates 1979) and especially below 500 meters (McBean 1982). Similarly, relationships have also been found between crash rate and the degree of curvature, measured as the ratio between curve angle and arc length (Raff 1953; Kadriyah, Viswanathan, Jain & Gupta (1981); Wright & Zador (1981); Hall & Zador (1981)). These findings suggest that variations in curve radius alone may not be the only factor influencing these single vehicle accidents. The frequency of curves did not seem to influence the crash rate directly, although there was some suggestion that an unexpected sharp curve may have been accident inducing

(Raff, 1953) and that the geometry preceding the curve may also influence subsequent curve negotiation (McLean, 1978).

The performance literature also suggests considerable differences in driving perception and performance between straight and curved sections of roadway. Gordon (1966b), Blaauw and Riemersma (1975) and Shinar, McDowell and Rockwell (1977) all reported significant differences in driver eye movements between straight roads and curves. They noted that visual fixations for straights were much more static and generally involved longer distance fixations. Presumably, these visual differences are related to differences in perception and performance, although this was generally not established in these reports. Triggs, Harris and Fildes (1979), Fildes (1979) and Triggs, Meehan and Harris (1982) reported differences in delineation requirements for roads of differing vertical and horizontal curvatures. They argued that these differences reflect differing visual requirements between crests and sags in the road. Fildes (1986), in fact demonstrated differences in the perspective road geometry as a vehicle approached a road curve and claimed that the visual demands in the approach zone of a road curve (straight section) are noticeably different to those in the curve itself. Milosevic and Milic (1990) assessed drivers' perception of their driving speed on curves. Drivers under-estimated their vehicle speeds, however, drivers who had seen warning and speed limit signs made more accurate speed estimations.

Research into curve perception suggests that the visual cues used by drivers in negotiating right-hand (RH) and left-hand (LH) road curves are quite different (Gordon 1966a; Blaauw & Riemersma, 1975; Cohen & Studach, 1977; Shinar, McDowell & Rockwell, 1977; Stewart, 1977; Zwahlen, 1982). Triggs, et al (1979), Triggs, et al (1982) and Fildes and Triggs (1984) reported a performance superiority for RH curves in curve perception experiments. This was subsequently explained in terms of enhanced curvature information available for RH curves when viewed from the left side of the road (Fildes, 1986).

While these studies collectively demonstrate differences in visual demands under certain circumstances, it is not clear though how these effects express themselves in curve negotiation on the road. It would be expected that visual differences are related to performance differences in driving but this has not been generally established. This would be a useful program of research for further investigation.

#### **5.4.6 Vertical Curvature**

Behavioural studies which have attempted to evaluate vertical curvature effects have been generally inconclusive. Some report a relationship with road contour, although no relationship has been found between on-road behaviour and either road camber or super-elevation. The results for gradient, however, have been mixed, seemingly dependent on the measurement technique employed. The perceptual evidence on vertical curvature relates more to the effects of reduced sight distance on performance, rather than vertical curvature per se. Gibson and Crooke (1938), Ives and Kissam (1964), the American Association of State Highway Officials (1965), NAASRA (1980) and McGee (1979) all argued that sight distance was the critical variable in defining a driver's performance on the road. Furthermore, Michaels and Van der Heijden, (1978) and Kadiyali, et al (1981) proposed models in which sight distance was the prime factor for determining the free speed of vehicles in curves on two-lane rural highways. These results, though, were not particularly convincing, given the small sample of roads and the severe restrictions imposed on the numbers of geometric variables that were investigated.

Other researchers, however, found no statistical relationship between sight distance and driving performance in curves (Babkov, 1970; Waldram, 1976; McLean, 1977a; Stockton, Brackett & Mounce 1981; Farber 1982). This lack of effect led McGee (1979) to propose that sight distance based on physical constraints alone provides an unsatisfactory basis for road design. He argued that the effect of reducing sight distance on driving performance needs to take into account a driver's ability criterion or a "*decision sight distance*". Thus, restricted preview on the road may only have an effect on driving performance below some minimum distance required for a driver to make travel decisions. In this respect then, it might be expected that severe restriction in sight distance of road crests would unduly influence a driver's speed perception on the road.

In terms of crashes, Agent and Deen (1975) reported a disproportionate number of crashes on graded sections of roads than on flat roads, although the incidence of crashes at curve crests was surprisingly low. Cooper (1980) found a similar relationship and suggested that "*increased vehicular speeds on downgrades may be the culprit*". Wright and Zador (1981) and Hall and Zador (1981) also reported an increased risk of single-vehicle fatal roll-over crashes on downhill slopes than along level or uphill sections. Kostyniuk and Cleveland (1986) further argued that there were significantly fewer crashes at sites where vertical curvatures were of larger radii than design standards.

#### **5.4.7 Road Marking and Delineation**

While road markings and delineation are normally used to define lane width, they have also been used to improve the visibility of the road ahead. Gordon (1966a; 1966b), Riemersma (1979) and Godthelp, Milgram and Blaauw (1984) argued that the edge-lines are useful for controlling direction, vehicle speed and travel path. Thus, the type of line marking may well influence perception of the road ahead. Witt and Hoyos (1976) reported that a varying pitch broken edge-line in the approach to a road curve resulted in drivers adopting a more suitable speed profile while negotiating a curve in a vehicle simulator. Rockwell, Malecki and Shinar (1974) also reported that novel pavement markings can influence perceived speed and roadway width on curves, although they noted these influences may be site specific and might not necessarily hold with time (Hungerford & Rockwell, 1980).

As noted earlier, Denton (1973), Agent (1980) and Helliard-Symons (1981) found that the perception of speed could be modified by transverse stripes across the road approaching an intersection. However, only reductions in speed variation were still evident at sites 18 months after installation. While road markings have been used to influence speed judgements for curved road sections and at intersections, they have not been totally successful. Lum (1984) found no effect of narrow longitudinal pavement markings (with raised pavement markers) on either the mean speed or speed distributions on straight sections of road at residential sites. Others, too, have failed to show any difference in speed on straight roads for wide edge-lines (Cottrell, 1985) or special treatments in mountainous areas (Garber & Saito, 1985). It would appear that the major benefit for edge-lining on straight sections of two-way rural roads is for maintaining a safe position within the lane itself (Triggs & Wisdom, 1979; Triggs, 1986; Cottrell, 1985). Evidently, edge-lines on straight sections do not really add very much to the perspective view of the road presented to the driver.

Guide-posts with reflectors were shown to have a marked influence on curve detection (Triggs, et al, 1979; Fildes, 1979; Triggs, et al, 1980; Nemeth, Rockwell & Smith, 1985), night-time run-off-the-road crashes (Neissner, 1983) and curve negotiation strategy (Hungerford & Rockwell,

1980). Under some circumstances, posts and post height can influence straight road guidance at night (Godthelp & Riemersma, 1982; Blaauw, 1985). However, no studies were found that specifically evaluated the effects of guide-posts on vehicle performance during the day, presumably because these delineation treatments are mainly reserved for improving night-time curve negotiation performance.

#### **5.4.8 Sight Distance and Gradient**

Road design assumes that sight distance is a critical factor in setting speed limits (Joscelyn et al 1970, NAASRA 1980). Leong (1968) reported a positive correlation between spot speed and sight distance while Olson, Cleveland, Fancher, Kostyniuk and Schneider (1984) also noted a similar relation between sight distance and crashes. However, this latter study did not control for other speed factors like traffic density (Galín, 1981) and, therefore, the results must be treated cautiously. In his review of the spot speed literature, Oppenlander (1966) placed sight distance amongst the significant but less important variables, compared to traffic density. McLean (1982) claimed that sight distance restrictions induced a small reduction in the speed adopted by the faster travelling drivers, but had little, if any, effect on the speeds of other drivers. However, he argued that it is difficult to separate sight distance effects from other effects of the changing road geometry.

In an early crash data study in the USA, Raff (1953) found no correlation between grade and crashes. This study, however, looked at a range of geometric variables and could not have accurately controlled for gradient effects alone in road crashes. Road gradient was cited as a factor in influencing observed spot speed by Oppenlander (1966), but Troutbeck (1976) was not able to clearly differentiate it from sight distance effects. In short, it is difficult to separate the effects of gradient alone from sight distance in the speed literature.

#### **5.4.9 Other Traffic and Density**

The Australian Road Design Handbook (NAASRA, 1980) states that the volume of traffic will influence a driver's chosen speed. Traffic volume and density, both in the direction of travel and in the opposite direction, have been associated with varying vehicle spot-speeds (Oppenlander, 1963, Rankin & Hill, 1974; Armour, 1983). In general, increasing traffic leads to reduced travel speed, although flow density can be a compounding factor here. Crash rates generally increased with increasing traffic volume on straight roads (Raff, 1953; Peter Casey & Associates, 1979). However, these studies did report a threshold effect at high volumes, presumably because traffic flows became severely restricted. Worsey (1985) also found a similar crash rate increase, although he did not observe any threshold ceiling. This may have been due to minimum traffic volume levels observed in the study.

Traffic volume, however, does seem to exert a marked effect on the speed behaviour of drivers on the road and is likely to have some influence on a driver's perception of the road ahead. The National Association of Australian State Road Authorities (NAASRA, 1980) suggested the nature of the traffic mix can influence speed. However, there was no relationship observed for heavy vehicle volumes on free speed (Duncan, 1974), or for the percentage of commercial vehicles on crash rates (Raff, 1953).

#### **5.4.10 Night and Day**

Night and day driving conditions represent extremes in the availability of visual information for drivers. The illumination levels at night are some 200 times less under headlamps than daylight



conditions and background information is almost completely absent (Fildes 1979). Interestingly though, driving speeds tend to be higher at night (Organization for Economic Co-operation and Development 1980; Norrish 1991). This may help to explain the high propensity of fatal and serious injury crashes that occur during darkness (OECD, 1980; Joscelyn et al 1970) and those involving young drivers (Drummond, 1985).

A number of factors have been associated with different driving performance at night. The Organisation for Economic Co-operation and Development (1980) reported abnormally large speed differences at night in bad weather. Triggs and Berenyi (1982) found that subjects made more accurate judgements of rural road travelling speed at night. They attributed this to the increased angular speed of elements visible to the driver which, under headlights, are much closer than normal and form streaming patterns produced by reflectorized road delineators. Sanderson (1985) reported no difference in crashes on freeways in Melbourne that were both lit and unlit, supporting the notion of perceptual narrowing at night.

Fildes, et al (1989) investigated the perception of speed on rural straight roads during the day and at night. They reported that speed perceptions were generally more safe for daylight scenes (and subjects made fewer errors in estimating travel speed) than nighttime scenes of the same roads. However, there were no differences observed in free speed at these same sites during either the day or night which they attribute to the high quality of the roads and the fact that their subjects' responses at no time were ever judged to be markedly unsafe. The level of perceived safety for daytime "*spacious*" sites was similarly reduced by both a "*walled*" roadside environment and darkness. However, trees on the side of the road had no influence at night, consistent with the lack of visual information available to drivers at this time. Night testing had little influence on the subjects' responses, indicating that biological rhythms, previously shown to affect human performance on various tasks, play very little part in speed perception.

Elliott (1981) surveyed various groups of Australian drivers to formulate hypotheses regarding their speeding behaviour. He found that drivers were actually encouraged to travel at higher speeds at night because the road somehow seemed safer. However, verbal reports are inherently unreliable in perception studies as many of these influences occur without the driver's knowledge.

#### **5.4.11 Parked Vehicles and Pedestrians**

The evidence available on the effects of parked vehicles and pedestrians on speed behaviour and crashes was not particularly convincing. Loder and Bayly (1980), for instance, suggested that parked cars and the presence of pedestrians are a major threat to safety. However, they only presented a small amount of evidence showing an increase in the crash rate and no suggestion of how these factors influence vehicle speed. Westerman (1990) referred to the relationship between vehicle speed and pedestrian density and noted higher levels of pedestrian crossings on roads when vehicle speeds are 20km/h or less. He suggested that a greater degree of conflict between pedestrians on the road and vehicular traffic is acceptable if traffic speeds remain low.

Smith and Appleyard (1981) showed that vehicle speed was positively correlated with "*apparent width*" which they argued was strongly influenced by the presence of parked vehicles. However, Joscelyn et al (1970) claimed that objects on road shoulders had little effect on free speed unless the total lane width was less than 20 feet (6.2m). Surprisingly, Thompson, Fraser and Howarth (1985) reported that driving behaviour was only marginally influenced by the presence of pedestrians. Roadside children had no effect on vehicle speed, although small

reductions were observed for large groups of pedestrians in the U.K. Samdahl (1986) evaluated the effectiveness of a neighbourhood road safety campaign in New South Wales. He reported instances of minor speed reductions in particular local streets following the intensive campaign to reduce pedestrian casualties. However, he acknowledged that these speed changes may have been due to other factors, such as weather or parking which were outside the control of the survey. More alarmingly though, he reported instances where drivers drove closer to the children after the programme than before, further confirming that the presence of pedestrians can have little influence on driver behaviour.

More work is clearly required to determine the likely effects of parked vehicles and pedestrians on a driver's speed on the road, and especially whether the two interact in the perception of speed.

#### **5.4.12 Weather**

Morris, Mounce, Button and Walton (1977) reported that rain had a substantial effect on the visual performance of drivers in a rain simulator during both daylight and night time conditions. The degradation in performance was a function of the rain rate, drop size and vehicle speed but not affected by wiper speed above 50 cpm. Unfortunately, it is difficult to interpret this study in terms of the likely on-road effects of weather on speed behaviour. Levin (1977) found that subjects assessed poor weather conditions as less safe for driving on a subjective scaling test. This result has instinctive validity and is supported by the higher proportion of fatal crashes recorded during wet weather on highways in New South Wales over the period 1968 to 1977 (Peter Casey & Associates 1979). However, these effects may not be wholly speed related.

Oppenlander (1966) reviewed a number of studies which found inclement weather was associated with lowered spot-speeds. However, Olson et al (1984) found no significant differences between speeds at selected sites on wet and dry days. These differences may be due to the different roads and conditions examined by these researchers. It is difficult to measure weather quantitatively on the road and the results could reflect reduced visibility as well as altered handling characteristics of the vehicle when braking and cornering on slippery roads. Inclement weather may also interact with other road conditions (such as night vision) leading to an increase in road crashes for night driving in wet conditions (OECD, 1980).

#### **5.4.13 Trip Purpose and Distance**

The length of the trip and the number of passengers can also vary between rural and urban journeys. Joscelyn et al (1970) and Hirsch (1986) reported that trip distance and purpose significantly affected speed, although the number of passengers gave conflicting results. This may have resulted from the different samples of drivers and environments used in these studies. The longer journeys associated with rural travel are more likely to induce speed adaptation and driver fatigue.

Mast, Jones and Heimstra (1966) showed that driver tracking error and speed control were significantly different in the last hour of a six hour continual tracking task. Safford & Rockwell (1966) reported that speed control diminished with time over a 24 hour driving task, but interestingly, a rest period of only a few minutes was sufficient to offset these effects in the short-term. These data probably reflect pure driver fatigue influences. Fildes, et al (1987) reported that roadside environment effects were very much dependent on the environment under test; rural, semi rural or urban. Moreover, Fildes, et al (1991) further showed an

interaction between these effects where trip variables were more relevant for travel speed in rural settings.

#### **5.4.14 Driving Experience**

Evans and Wasielewski (1983) reported a direct relationship between the amount of acceptable headway and driver age, while Cowley (1983) linked speeding with young males. Free speed surveys by Seal and Ellis (1979) and Wasielewski (1984) in the USA show that younger drivers tend to travel at faster speeds. However, this was not observed for first year drivers in South Australia (Johns, 1981) or Victoria (Manders 1983) where inexperienced drivers are constrained to lower maximum speed limits. Thus these results are not directly comparable with the overseas findings.

Driving experience has been found to influence the perception of road hazards (McKeown, 1985). Inexperienced drivers also responded differently (slower) to dangerous situations (Quimby & Watts, 1981) adopting less safe visual strategies (Mourant & Rockwell, 1972). Riemersma (1982) explained differences in straight line tracking observed between novice and experienced drivers as different strategies adopted by these drivers in responding to lateral speed cues. Driver experience had only minimal effect on estimates of safety and travel speed in laboratory experiments (Fildes et al 1987; 1989). However, first year drivers responded less conservatively in their estimates of what constituted a safe travel speed on curves than experienced drivers, suggesting that speed perception may be slightly different between novice and experienced drivers in these environments. Similarly, Milosevic and Milic (1990) assessed drivers' perception of their driving speed on curves and reported that experienced and middle aged drivers made less accurate (under-estimates) speed estimates than younger, inexperienced drivers (accurate estimates). Hence it can be seen that the effect of experience on speed perception remains poorly understood.

#### **5.4.15 Summary**

The review of the literature on the effects of the road, environment, and driver factors on perception, speed behaviour, and crashes has demonstrated that the factors most likely to have a marked effect on speed performance, include:

- urban and rural environments and mixed settings,
- road alignment including straight and curved sections,
- road category such as freeways, arterials, collectors or local streets (sealed and unsealed roads are also likely to produce different perceptual effects),
- lane width, especially roads that have exceptionally narrow or wide travel lanes,
- roadside development comprising both "*walled*" and "*spacious*" settings,
- driver experience, especially among novice drivers,
- traffic density below levels that severely restrict free travel speed,
- sight distance in relation to road geometry and traffic headway,
- parked vehicles and pedestrians (large groups), and
- day and night vision.

Other factors, such as guide-post delineators, the weather and the amount of daylight may also have some influence but these effects are not clearly demonstrated. Manipulating guide-post layout on the side of the road could offer a relatively inexpensive and quick solution to

particular hazards for the perception of speed, if they could be shown to be an effective countermeasure against speeding.

## **5.5 ENVIRONMENTAL SPEED CONTROL**

Traditional approaches to speed control have emphasised 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. There have been calls for alternative forms of speed control (Klein & 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 & Walker, 1982; Parker & Tsuchiyama, 1985; Wright & Boyle, 1987; Armstrong, Black, Lukovich, Sheffield & Westerman 1992).

### **5.5.1 The History of Environmentally Adapting Speed Behaviour**

Environmental control of vehicular traffic speed was first attempted in Holland in the 1960's. Prior to this innovative attempt to reduce conflicts between light traffic (pedestrians and cyclists) and cars, other solutions had been tried. The first response to the pressure of increased traffic volumes was to add more lanes and new roads to the existing road network. Continually increasing traffic volumes soon exceeded that which could be accommodated on arterial networks causing traffic to flow over onto less congested local roads.

Blocking the local roads proved to be a largely unsatisfactory solution in terms of efficient emergency service access and excessive detouring in general. The realisation in the 1960's, that separating the light and heavy road users was the best method to reduce conflict was well accepted and implemented internationally. However, the potential for expansion of the road network in established and historical cities was making separation difficult. In response to problems of little space for expansion and separation of traffic, problems with through traffic and "*alien*" (non-residents) parking in local streets, these streets were remodelled for "*traffic integration*". Treatments included the placement of benches, tables and sand boxes, leaving space for cars to pass at walking pace. Vehicle speeds were reduced through the placement of humps, staggerings and narrowings. This solution known as the "*Woonerf design*", the earliest of local area traffic management schemes, has been openly accepted throughout the Western world since the mid-1970's (Kjemtrup & Herrstedt, 1992). Australia, in particular, has been keen to adopt these countermeasures to speeding, doing so more extensively than most countries since the late 1970's (Brindle, 1992). More recently, the use of environmental adaptation has been advocated for main streets in rural towns (Armstrong et al 1992).

However, as Westerman (1990) pointed out, the effects of these measures need to be viewed in terms of the total transportation system. While these speed management devices have the potential to stem the flow of traffic in "*precincts*" (local environments), there will be no overall gain to the system unless the main "*corridors*" (arterial and collector roads) are capable of carrying the excess traffic.

### **5.5.2 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). LATM devices transfer

the costs associated with speeding in residential streets from unprotected road users (death and injury of pedestrians and cyclists) to the vehicle drivers and their passengers (physical discomfort and danger). The Victorian Parliamentary Social Development Committee inquiry into child pedestrian and bicyclist safety stated that this transfer of costs often arouses opposition from the community, forcing traffic authorities to defend rather than promote the implementation of such devices. LATM devices or "*friction factors*" (Westerman 1990) usually employ some form of physical restriction on the road or in the travel path forcing motorists to slow down or adopt a more desirable track. Unlike simple traffic control signs, LATM devices are continuously reinforcing. There is a penalty (in terms of occupant discomfort) every time a driver passes such a device at an excessive speed.

In a comprehensive review of traffic and speed control measures, Armstrong et al (1992) listed some 46 devices that have been used in various locations throughout Australia. They differentiate between "*control measures*" (those introduced retrospectively to control the traffic flow) and "*design and construction measures*" which tend to be built into the system. Control measures include channelisations, speed and other zoning constrictions, controlled parking, loading and heavy traffic movements, one-way streets, controlled advertising and shopping hours, and streetscapes, while design and construction measures include such items as street closures, gateway treatments, staggered roadways, roundabouts, staggered junctions, raised pavements, medians, shared spaces, lane narrowings, separated traffic movements, etc. It is worth reviewing scientific evidence of the effectiveness of some of these measures in controlling speed from the literature to the extent possible for this review.

**RAISED PAVEMENTS OR SPEED HUMPS:** Humps, bumps, and raised sections of the roadway have been widely used in this country as speed controlling devices and are usually effective in bringing about reduced travel speeds in these locations. Reductions in 85th percentile speeds below 30km/h at the device site are common and total travel speed reductions dependent upon inter-device spacing (Vis, Dijkstra & Slop, 1990; Lynam, 1987; Stephens, 1986; Engel, 1990; Engel & Thomsen, 1992). The underlying principle of speed humps is that increased vehicle speeds lead to increased occupant discomfort. Stephens (1986) makes clear the distinction between humps and bumps, the former having dimensions in the order of a 4metre radius and 10cm height, whereas the latter have a radius between 0.1 and 1.0metre and height variations from 5cm to 15cm. Humps are designed to be used on residential streets with speed limits up to 40km/h, whereas bumps are designed to be used in parking lots and the like, where walking pace speeds are more appropriate.

Stephens (1986) reviewed a number of empirical studies of the effectiveness of speed humps in Australia, USA and the UK. The speed reductions observed at the various sites varied with the pre-installation speed such that the largest reductions (40-45km/h) occurred at those sites where the pre-installation speed was greatest (65-70km/h). Conversely the smallest reductions of the order of 10km/h occurred at those sites where the pre-installation speed was lowest (30-40 km/h). The between hump speed reductions followed the same relationship to pre-installation speed, varying from approximately 5 to 25km/h. Engel and Thomsen (1992) investigated the effects of combinations of environmental countermeasures to speeding, however, they attributed speed humps with the speed reducing effects of one km/h reduction in speed for every one centimetre of height of the hump. Engel (1990) reported that speed humps brought about the greatest change in speed when compared with a number of other LATM devices including humps, lateral dislocations (single and double deflection slow points) and carriageway narrowings.

An alternative form of speed humps that has been successfully employed to control speeds is speed tables, consisting of a ramp up onto a level section with another ramp down the other side (for example see Davies, 1988). The length of the table may be as small as three metres but an essential to their functioning is that the length of the table exceed the wheel base of the vehicle, such that both the front and rear wheels of the vehicle are briefly on the table. Bowers (1986) describes a variation of a speed table that has a raised central section that allows heavy vehicles to straddle it, and two wheeled transport to pass either side, while cars must pass over the device forcing them to slow their speed. There is no reason that this configuration could not be applied to the installation of speed humps and bumps, however, the practice of “*gutter running*” would probably be facilitated by this configuration and would need to be addressed. Gutter running is a term used to describe the practice undertaken by many drivers to minimise the effects of vertical alignment devices by aligning on side of their vehicle with a gap in the device (typically, such devices terminate before the gutter to enable drainage).

**SHORT NARROWING: CHICANES AND SLOW POINTS:** An important consideration in the installation of short road narrowings is the structure of the device needed to effectively narrow the carriageway. Von Morner (cited in Bowers, 1986) demonstrated that in the relationship between carriageway width and speed it is the perceived width that counts. He suggested that the perceived width was determined by the width over which the driver has unobstructed vision. It follows therefore, that road narrowings that have very little height above the road surface impinge little on the perceived width of the roadway. Bowers (1986) stated that short narrowings that have no strong vertical elements such as vegetation or lamp standards rely on vehicles passing in opposite directions at or near the narrowing for their effectiveness, and that this is often an uncommon occurrence. The effectiveness of road narrowings then can be enhanced by the addition of vertical elements such as trees and lamp standards, the combination of which is often labelled a “*gateway treatment*”.

Engel and Thomsen (1992) reported that the effects of a double lateral dislocation was a speed reduction in the order of 4km/h, similarly for a single dislocation a speed reduction of 2 km/h was reported. Taylor and Rutherford (1986) evaluated the effectiveness of ‘diagonal slow points’ or chicanes as they are sometimes called. Speed profiles of vehicles passing through the slow points were used to estimate a ‘zone of influence’. They reported that diagonal slow points were effective at slowing traffic (from greater than 50km/h to less than 30km/h at the site of instalment). The zone of influence however, was reported to be “*certainly less than 100m*”, generally in the vicinity of 80meters (ie; approximately 40meters either side) of the instalment site.

Bowers (1986) suggested that the optimal configuration for the installation of slow points should create 45deg changes in direction of the carriageway approximately every 50metres with an offset of the full width of the carriageway. The full width offset blocks the motorists view of road receding into the distance, dividing the road into small sections. The effectiveness of such offsets are undermined by excessively wide carriageways and/or low traffic volumes allowing vehicles to flatten out the offsets by using the full width of the carriageway. The installation of offsets lends itself ideally to lengths of parking bay on alternating sides of the road (Bowers, 1986).

**ROUNABOUTS:** Roundabouts are an effective means of breaking up long lengths of road that otherwise might encourage speeding without causing undue delays. Klyne (1988) investigated the effects of 10 roundabouts and S-bend slow points on traffic speeds. He was able to describe the simple relationship between traffic speeds and the path radius of vehicles travelling

straight through the intersection. Under conditions of "good sight distance", the 95th percentile speed was equal to six times the square-root of the vehicle's path radius in metres (with small adjustments for sight distances less than good). Using this relationship it is a simple matter of transposition to calculate the speed expected at a particular roundabout installation, or the required size of a roundabout to obtain a particular 95th percentile speed.

Herrstedt (1992) reported that roundabouts can be effective speed management tools, however, their effectiveness in reducing vehicle speed is mediated by the extent to which drivers are forced into a roundabout manoeuvre. A large roundabout used to mark the entrance to a small town was successful at slowing motorists, while a mini-roundabout did not reduce speeds to an appropriate level. Lynam (1987), Schnull and Lange (1990) and Davies (1988), also found that roundabouts were successful at keeping vehicle speeds down and breaking up the perceived "straightness" of the road.

**GATEWAY TREATMENTS:** Based on findings discussed previously that drivers react differently in rural and urban (travelling more slowly in urban environments) there are safety benefits, particularly in urban settings, to be gained from clearly informing drivers of the transition from one to the other. A popular method of doing so is through the use of gateway treatments, usually a combination of a short narrowing and strong vertical elements, though often simply the careful arrangement of vertical elements on the road side to bring about the perception of passing through a constricted "gateway" opening. Herrstedt (1992) is one of many to employ gateways, formed by changes in the road surface flanked by a gauntlet of trees closing in on the road, to mark the entrance to rural towns to encourage drivers to slow their speeds. Unfortunately, the effects of gateway treatments alone can not be determined from the available research literature as they were always implemented as one of many environmental adaptations.

**SYSTEM-WIDE EFFECTS:** Some studies have attempted to assess the overall benefits of LATM treatments. Fisher and Van den Dool (1989) evaluated 67 LATM sites from an operation and financial viewpoint and reported them to be generally successful in reducing traffic speed and volumes as well as crashes and, by inference, noise levels. They concluded that LATM treatments were a sound investment with a BCR normally greater than two and with crash and amenity reductions of around 50 percent. Chua and Fisher (1991) reported similar findings for a specific LATM case study North of Sydney, Australia (50% reduction in crashes, 35% reduction in through traffic, and a 25% reduction in speed). In evaluating resident responses, they reported general indifference to the scheme in terms of their perception of amenity, safety and noise which did not necessarily equate with reality.

Herrstedt (1992) reported speed reductions in the order of 10km/h (speed limits of 40 and 50km/h) resulting from combined effects of pre-warning signs and rumble strips, speed signs, gateways at entrances created by changes in road surface and flanking by trees, staggerings created by lateral and central islands, parking sections between the lateral islands, roundabouts, trees and hedges and lighting elements placed at gateways and traffic islands. It was claimed that the cost of implementing an environmentally adapted through road are approximately one fifth of price of a by-pass, and that all European studies that have investigated the effects of adaptation on the number of traffic accidents have reported significant reductions (Kjemtrup & Herrstedt, 1992). Reductions in the number of seriously injured as a result of environmental adaptation by 78 percent have been reported in Denmark (Engel, Krosgaard & Thomsen, 1989, as cited in Kjemtrup & Herrstedt, 1992). These researchers also reported that no accident migration had been observed.



Engel and Thomsen (1992) investigated the effects of combinations of environmental adaptations of local streets re-classified as "*living areas*" with speed limits of 15 and 30 km/h. These researchers were then able to calculate the speed reducing effects attributable to each of the measures, the most important of which were the height of a speed hump, the type of lateral dislocation, the type of street narrowing, and the distance from countermeasures (both behind and ahead of the vehicle). It was reported that the speed limit of 30km/h was able to be reached at distances more than 50metres away from the countermeasures, beyond this distance no description of vehicle speed is offered. A reduction in accidents (24 percent) and casualties (45 percent) was reported for the adapted streets, while adjoining streets also benefited from "*accident migration*" where the number of crashes and casualties were also reportedly reduced (18 and 21 percent respectively).

Bowers (1986) reviewed the effectiveness of a number of German approaches to traffic management by environmental design which included the use of carriageway narrowing, speed tables, gateway treatments, large speed tables raising entire intersections above the surface of the road, and greater emphasis on intersections through the use of elaborate cross-banding. He concluded that the schemes employed created vastly improved environments in which cars "typically" travelled between 20 and 30km/h. While the rate of crashes remained unchanged, the severity of accidents (for both occupants and vehicles) was reduced by approximately half. Engel (1990) reported that humps, lateral dislocations (single and double deflection slow points) and carriageway narrowings had safety enhancing effects in terms of both the number and rate (per kilometre) of casualties. Kjemtrup and Herrstedt (1992) reported findings from environmental adaptation studies from Holland and France, where accident reductions in the range of 30 to 60 percent were found.

These studies are extremely important in demonstrating the need for and usefulness of these programs. However, they tell us little about the success or otherwise of particular measures or combinations of measures which is also important for refining or prescribing treatments. Moreover, unless they are extremely broad, they also cannot usually describe the effects of these programs on the total system (addressing the issues of accident and traffic migration) which is critical for addressing Westerman's (1990) concerns about the total system benefits and shortcomings.

**COSTS AND BENEFITS:** Ho and Fisher (1988) estimated the Benefit-Cost-Ratios (BCR) of various area-wide LATM treatments. The degree of treatment ranged from *maximum* (embracing multiple combinations of often severe treatments) to *peripheral* which included programs with less emphasis on inconvenience to the traffic. They reported BCR's which ranged from 1.5 to 2.6 for maximum treatments to as high as 6.8 for peripheral programs. Ho and Fisher estimated the area-wide cost of LATM's to be about 10 percent of the original costs of the local roads and about 0.25% of the property values of the area. They concluded that LATM's are a cost-effective means of treating speed and amenity in a local area and with adequate planning, can have minimum impact on intrusion of vehicular traffic.

### 5.5.3 Potential Difficulties with LATM Devices

In many situations, these countermeasures have met with a degree of success. Webster & Schnerring (1986), for instance, reported a significant reduction in mean speed of 5km/h compared to a control precinct after installing a 40km/h speed zone in two residential areas in New South Wales with existing LATM devices. However, the exact nature of the success of LATM devices 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 neighbourhood after LATM was introduced (i.e. in statistical terms, a truncation rather than a downward shift in the overall speed distribution).

Moreover, in installing these devices, one needs to be careful to ensure that these speed reductions are not obtained at the expense of an increase in the number of crashes because of their very presence (eg; large bollards and trees close to the edge of the road may lead to perceptual narrowing and hence speed reductions but also more crashes from drivers needing to take avoidance actions. 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.

Vis, Dijkstra and Slop (1990) measured traffic volumes before and after the introduction of LATM type engineering measures in fifteen areas in the Netherlands. Reductions in traffic volumes using the adapted roads were in the range of 5 to 30 percent, through traffic in particular was reduced. Engel and Thomsen (1992) also reported that reduced traffic volumes contributed to the reductions in accident rates observed. Stephens (1986) too presented a review of documented traffic volume changes as a result of installing LATM devices ranging from no change to a 64 percent reduction in one study. While reduced traffic volume was the aim of installing such a devices in some cases in others it was not and the potentially undesirable impact on adjacent and parallel roads was acknowledged.

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. Herrstedt (1992) reported that the nature of the accidents occurring had changed in two out of three small towns in which a number of LATM devices were installed. In these two towns accidents now occur in which drivers collide with the speed reducing devices. It was suggested, however, that alcohol and speed play a major role in most of these crashes.

LATM devices are often perceived as obstructions on the road and the very notion of degrading the smooth paved surface is often perceived counter intuitive by traffic management authorities and drivers alike. Modern LATM devices must bare the burden of ineffective and often hazardous early designs, the impressions from which drivers do not forget quickly (Hakkert, Zaidel & Pistiner, 1990). Vehicles traversing these devices, particularly those that interrupt vertical alignment and rumble strips, can produce noise and vibration, such effects are seen as detrimental to both the road user and local residents. The defence offered in answer to most criticisms of LATM devices is that they present no hazard to drivers if traversed at an appropriate speed.

Objections to LATM devices on the basis of restricted mobility in emergency situations has also come from emergency services such as police, fire and ambulance. However, there have been no reported cases of damage, increased damage, risk, or operational difficulties associated with emergency vehicles operating in communities with LATM devices installed (Hakkert,

Zaidel & Pistiner, 1990). It has been suggested that the installation of LATM devices can have detrimental effects on drivers' attitudes which in turn result in unsafe driving behaviours. For example, creating offsets in the road way without any other form of speed reducing measures has been likened to creating a race track effect, challenging drivers to "*perform*". Gutter running is another dangerous behaviour undertaken by drivers in response to LATM devices, endangering not only road users but also pedestrians on nearby footpaths. Gutter running is a problem that must be addressed by all LATM devices that operate through interrupting the vertical alignment of the carriageway.

#### **5.5.4 Summary**

Environmental speed control is an effective alternative (supplementary) means of speed control to traditional police enforcement. With its beginnings back in the 1960's in Europe, it has been quickly adopted for use in this country. Environmental speed control has relied heavily in the past on Local Area Traffic Management (LATM) devices in residential and heavy traffic streets, including speed humps and tables, short narrowings, chicanes, slow points, roundabouts, and gateway treatments. These devices have met with success in reducing travel speed, crashes and injuries and have been shown to have impressive benefit-cost ratios with potentially minimal effect on vehicular traffic intrusion. It was noted that the precise nature of these benefits, however, is not always clear and one needs to be careful to ensure that speed reductions are not obtained at the expense of an increase in crashes from their mere presence. In any event, the use of these measures is paramount for any campaign aimed at reducing travel speed in residential areas.

### **5.6 PERCEPTUAL COUNTERMEASURES TO SPEEDING**

An alternative to the harsh physical design and construction measures discussed above is the less intrusive control measures aimed at changing perception of the environment. Fildes et al (1989) conducted a thorough review of the literature and presented a comprehensive list of possible environmental countermeasures to speeding. They argued that these measures are likely to have long-term benefits because of the unobtrusive nature by which they influence a driver's perception of speed (they operate without the driver's awareness or need for action). In addition, they are advantaged by their low cost of application and they often do not require the introduction of additional physical hazards on the road surface.

#### **5.6.1 Likely Effectiveness of these Measures**

These authors, however, argued that these measures are not always likely to be equally effective in reducing travel speed. They reported that environmental countermeasures to speeding will be very much dependent upon a driver's perception of safety in a particular location. When perceptions were overly safe (for instance, in spacious environments with high quality wide roadways), modifying the environment will to some degree change this perception but this will not be translated to slower travel speeds. In these situations, they claimed, other factors such as a desire to be law abiding or not to be caught and punished for speeding are also exerting some influence on a driver's choice of travel speed. Hence, perceptual factors are less critical in this setting.

However, when a driver's perception in a particular location is less safe (for instance, in a narrow walled environment such as a forest), then modifying the environment in this setting can be directly translated into reduced travel speed. That is, speed perception is more dependent

upon sensory inputs in these more “*threatening*” settings and less dependent upon other social or enforcement factors. Thus, the use of perceptual countermeasures needs to be selective if they are to be effective. The authors claimed they are especially suited to “*black-spot*” speed related applications although they may also be suitable for use on particular roads that are over-designed and speed inducing. In the longer term, the use of these measures need to be balanced against the need for high design speeds in road construction.

### 5.6.2 Perceptual Countermeasures

The evidence supporting these measures has been extensively outlined in Fildes et al (1989) and is summarised here. Those interested in more detail should seek the original publication.

**TRANSVERSE ROAD MARKINGS:** One of the most well known perceptual treatments against speeding is the transverse line treatment originally developed in the UK and used on the approach to roundabouts and intersections. This treatment has been shown to have desirable long-term speed reduction benefits in these locations both in the UK (Helliard-Symons, 1981) and in Australia (Jarvis, 1989). The perceptual mechanism first reported by Denton (1971) by which this treatment influences travel speed, however, has been criticised (Rutley, 1975; Jarvis, 1989). The addition of rumble bar effects at these locations does not appear to have any additional perceptual or behavioural benefit over just the lines themselves.

**LANE WIDTH REDUCTIONS:** As road width had such a strong influence on speed perception in Fildes et al (1987; 1989), it would seem to be an ideal candidate for manipulation. 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. Minimum lane widths of 3.0 m or less seem necessary to induce sufficient perceptual effect to ensure free speed reductions on the road. These treatment, however, suffer from “*floor effects*” as care must be taken to ensure there is enough lane width for the largest vehicle that travels the road to avoid introducing another hazard.

**CENTRE- AND EDGE-LINE TREATMENTS:** A slight perceptual advantage in speed perception may be gained from the presence of both centre-line and edge-line treatments on the road. Standard traditional edge-lines appear less likely to produce significant reductions in travel speed and road crashes than other (novel) kinds of road surface treatments. For instance, 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.

**CURVATURE ENHANCEMENT:** Curvature can be mis-perceived when curvature is tight and insufficient sight distance through the curve is available. There seems to be some potential for using novel guide-post arrangements or chevron markers to influence speed perception at these locations. However, the mechanism and effectiveness of these treatments in the long-term is somewhat questionable.

**INTENSIVE ROAD TREATMENTS:** In some locations, special road treatments have been used that severely restrict the number and size of travel lanes. These treatments have involved the use of wide white gravel medians with edge-line marking and have been shown to reduce travel speed in some locations. The full perceptual effects of this treatment, including their long-term consequences, however, need to be tested further.

**SPECIAL SIGNING:** While special purpose signs on the side of the road may have a marginal effect at reducing vehicle speeds in some locations, they seem very much dependent on a driver's motivation and expectation and the "*element of surprise*". Moreover, they are less likely to continue to be effective in the long-term given that drivers stop looking at familiar road signs. These are hardly desirable characteristics for any long-term benefits in the perception of speed.

### 5.6.3 The Need for More Evaluation

The goal of speed reduction is paramount in the treatments discussed above. Indeed, this is why these treatments are generally used in speed management today. However, as noted earlier with LATM devices, one needs to be at least aware of the crash consequences of many of these measures. While perceptual treatments are less likely to introduce physical barriers for motorists to collide with, they may, nevertheless, cause confusion which could have ramifications for their safety benefits.

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. To help satisfy this need and show the desirability of perceptual countermeasures at reducing speed and road crashes, a range of measures could be installed at suitable hazardous locations to test their speed reduction potential. 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. An alternative (supplementary) approach would be to adopt a risk engineering approach to the evaluation, rather than wait for the crashes to happen. To date, this promising approach has not been used extensively in this area and would be worth further investigation.

### 5.6.4 Summary

Perceptual countermeasures have been proposed as a means of reducing travel speed by altering the sensory scene available to drivers. They are likely to be advantaged by their low cost and scope for long-term improvements in speed control. However, their effectiveness will be somewhat site dependent. A range of perceptual countermeasures are available including transverse road markings, lane width restrictions, centre-line and edge-line markings, curvature enhancement treatments, intensive road treatments, and special signing. However, many of these treatments have not been tested fully and their effectiveness, especially in the long-term, is yet to be established. Further work in testing these potential speed perception countermeasures is warranted here.

## 5.7 CONCLUSIONS FROM THIS REVIEW

1. Driving involves a number of complex tasks including both route and path planning as well as vehicle control, implicit in which is the ability to make relatively accurate estimates of a driver's own speed and that of other vehicles. This necessarily involves the perceptual abilities of drivers.
2. Perception involves both sensory and cognitive information processing stages. Sensory perception (the way an individual perceives environmental cues) is the basis for human response in moving about in his or her environment.

3. While there are conflicting views about the precise mechanisms of visual cues and their role in speed perception, there is broad agreement that relative velocity and size movements on the retina are important.
4. Visual pattern can influence speed judgement. In particular, variations in the road and immediate surroundings can have a marked influence on the perception of safety and travel speed. Manipulating the visual scene presented to a driver, therefore, has the potential to act as a countermeasure to speeding.
5. Human estimates of velocity are more accurate at higher than lower speeds and very much dependent upon the amount of visual stimulation provided. Perception of speed will be moderated by the amount of driving and subsequent "*adaptation*" to movement. Differing sensory abilities can lead to perceptual conflicts under some circumstances.
6. Road and environment factors likely to have a marked effect on speed perception include urban, rural, and mixed environments, road alignment, road category, lane width, road-side development, driver experience, traffic density, sight distance, parked vehicles and pedestrians of all ages, and day and night vision.
7. Environmental speed control is an alternative (supplementary) means of speed control to traditional police enforcement in residential and heavy traffic streets. It has relied heavily in the past on Local Area Traffic Management (LATM) devices, including speed humps and tables, short narrowings, chicanes, slow points, roundabouts, and gateway treatments.
8. While these devices have met with success in reducing travel speed, crashes, and injuries, the precise nature of these benefits is not always clear. In any event, the use of these measures is paramount for any campaign aimed at reducing travel speed in residential areas.
9. Perceptual countermeasures offer a means of reducing travel speed by altering the sensory scene available to drivers. They are likely to be advantaged by their low cost and scope for long-term improvements in speed control. However, their effectiveness may be site dependent.
10. Perceptual countermeasures include transverse road markings, lane width restrictions, centre-line and edge-line markings, curvature enhancement treatments, intensive road treatments, and special signing. However, many of these treatments have not been tested fully and their effectiveness, especially in the long-term, is yet to be established. Further work is warranted here.

## **5.8 OPTIONS FOR FUTURE RESEARCH AND DEVELOPMENT**

1. Several road and environment factors were shown to influence travel speed by manipulating the perception of speed by drivers. However, there is a need for further experimentation to test the role of other variables such as trip purpose, other traffic and traffic mix, poor weather, etc. in speed perception. The apparent lack of an effect of parked vehicles and pedestrians on travel speed and speed perception of neighbouring vehicles needs urgent further examination.

2. Perceptual countermeasures have considerable potential as low cost road treatments against speeding. However, there is a need for systematically implementing and evaluating many of these treatments to assess their usefulness (and cost-effectiveness) in speed management. In addition, the area-wide benefits of many of these treatments needs to be established if they are to become standard countermeasures against speeding.
3. Much is still relatively unknown about how drivers relate to their environment while driving. In the interest of improving our understanding of these relationships and the scope for exploiting perception factors to reduce travel speed, further research in this area should be encouraged.
4. A better appreciation of the speed adaptation process and the mechanisms and parameters is urgently needed. Adaptation to travel speed, like other driver factors such as alcohol, drugs, and fatigue, can be dangerous in particular travel situations and lead to gross driver errors by its degrading effect on speed perception.
5. The interplay between perceptual treatments to reduce travel speed and high design speeds in road construction (which ultimately induce higher travel speeds) warrants further consideration.

## **6. SPEED WORKSHOP**

A one-day workshop was held on the 23rd November 1992 in Canberra in conjunction with the 1992 Road Safety Researcher's Conference to consider the whole question of speeding and the need for further research and action. There were 45 invited participants to the meeting comprising leading experts in the field from research organisations and government authorities throughout Australia. In addition, Dr. Goran Nilsson of the Swedish Road and Traffic Safety Research Institute (VTI) in Sweden also attended the meeting to advise on current research and action developments on speed management issues in Europe. The guest list for this workshop is listed below.

### **6.1 WORKSHOP STRUCTURE**

The workshop was structured to include a number of formal presentations from invited guests on a range of relevant speed related topics involving both local and overseas developments and trends. These were immediately followed by a series of workshop sessions where delegates set out to define the current state of knowledge, shortcomings, and needs for research and action in each of the four key topic areas. A summary session where the findings from each of the four workshops were presented to the whole group followed the workshop sessions. The program for this one-day workshop also follows.

#### **6.1.1 Keynote Address & Invited Presentations**

The key address to the workshop was presented by Dr. Nilsson on "*Road Safety Strategic Planning in Europe*" and the "*Swedish Road Safety Program*". These topics included an overview of road safety developments as well as a review of current speed management issues in Europe and Sweden.

The workshop also included a number of other formal presentations from invited participants on a broad range of relevant speed related topics. Three participants presented papers from recent visits to key road safety organisations in Europe and the United States emphasising speed developments at these Centres. In addition, Senior Officers from VIC ROADS in Victoria and RTA in New South Wales provided an overview of recent developments in each of these Australian States towards improved speed management practices. Details of the invited presenters and their topics are listed in the one-day workshop program, while the papers are included in an Appendix of this report. See Report CR 127a (FORS); CR 3/93a (RSB)

#### **6.1.2 Workshop Sessions**

As noted above, there were four workshop sessions on each of the nominated topic areas of speed and road crashes, speed limits, speed behaviour and the environment, and enforcement and behaviour. Two workshop sessions were held in the morning and two in the afternoon. Each session lasted for approximately one and one-half hours and each participant attended one morning and one afternoon session. At the conclusion of each workshop session, a summary of the findings from both workshops was presented to the total group of participants where additional input was allowed.

Each workshop session was assigned a Chairperson and a Reporter and participants were allocated to sessions on the basis of their expertise and knowledge. The Chairperson and Reporters were instructed on the objectives of the project and workshop and suggestions for structure, task, and conduct of the session. Critical tasks addressed included:

- Identification of current problems in the area;
- Information or data requirements needed to support these efforts;
- Programs or actions necessary to facilitate improvements; and
- Outstanding research and development requirements for future advancement.



## 6.2 LIST OF WORKSHOP PARTICIPANTS

Mr Jim Jarvis	Australian Road Research Board
Dr Peter Cairney	Australian Road Research Board
Ms Deborah Donald	Australian Road Research Board
Mr Ron Scriven	Department of Road Transport
Dr Alec Fisher	E Consultancy
Mr Barry Elliott	Elliott & Shanahan Research
Mr Chris Brooks	Federal Office of Road Safety
Mr Ken Smith	Federal Office of Road Safety
Dr Steve Ginpil	Federal Office of Road Safety
Mr Keith Seyer	Federal Office of Road Safety
Mr Dominic Zaal	Federal Office of Road Safety
Mr Peter Moses	Main Roads Western Australia
Ms Antonietta Cavallo	Monash University Accident Research Centre
Dr Peter Vulcan	Monash University Accident Research Centre
Dr Brian Fildes	Monash University Accident Research Centre
Professor Thomas Triggs	Monash University Accident Research Centre
Mr Max Cameron	Monash University Accident Research Centre
Mr Stephen Lee	Monash University Accident Research Centre
Mr Mike Tziotis	Monash University Accident Research Centre
Mr Dick van den Dool	National Roads and Motorists Association
Mr Peter Steele	National Roads and Motorists Association
Dr Jack McLean	NHMRC Road Accident Research Unit
Ms Vivienne Moore	NHMRC Road Accident Research Unit
Dr Tony Ryan	NHMRC Road Accident Research Unit
Inspector Col Craig	NSW Police Service
Mr Doug Woodbury	Queensland Department of Transport
Mr Doug Lee	Queensland Department of Transport
Dr Mark Leggett	Queensland Department of Transport
Mr Peter Croft	Roads and Traffic Authority NSW
Mr Fred Schnerring	Roads and Traffic Authority NSW
Dr Dave Saffron	Roads and Traffic Authority NSW
Mr John Bliss	Roads and Traffic Authority NSW
Mr John Norrish	Roads and Traffic Authority NSW
Mr John Sanderson	Royal Automobile Association of Victoria
Mr Ian Faulks	Staysafe; Joint Standing Committee
Mr Göran Nilsson	Swedish Road & Traffic Institute
Mrs Fae Robinson	Tasmanian Department of Roads and Transport
Mr Mike Hammond	Transport Accident Commission
Mr Theo ten Brummelaar	University of New South Wales
Professor Hans Westerman	University of New South Wales
Mr John Lambert	VIC ROADS
Mr Ted Barton	VIC ROADS
Mr John Cunningham	VIC ROADS
Mr Barry Newton	Victorian Police Department
Mr Gavin Maisey	Western Australian Police Department

## 6.3 WORKSHOP PROGRAM

### Sunday 22nd November 1992

6.00pm      Arrival and registration at University House  
7.00pm      Dinner in the Scarth Room  
9.00pm      Hypothetical - *A 30km/h Speed Zone for Mytown*

Accommodation provided at University House

### Monday 23rd November 1992

8.30am      Conference commences - Main Conference Room  
Welcome address - Thomas Triggs - convenor

8.40am      Introduction & Purpose of the Meeting - Brian Fildes

9.00am      Invited paper 1 - *Speed Research & Current Issues in Sweden*  
Göran Nillson, VTI Sweden  
Invited paper 2 - *Current Issues at National level in USA*  
Peter Vulcan, MUARC  
Invited paper 3 - *Speed Management in NSW*  
Peter Croft

10.00am      Refreshment Break

10.20am      Morning workshop session commences (2 parallel sessions)  
Workshop 1 - *Speed and Crashes* - meeting room 1  
Workshop 2 - *Speed and Speed Limits* - meeting room 2

11.50am      Summary of workshop findings

12.15pm      Lunch - Gardens at University House

1.00pm      Invited paper 4 - *Speed Research & Current Issues in Scandinavia*  
Max Cameron, MUARC  
Invited paper 5 - *Speed Research & Current Issues in Holland*  
Chris Brooks, FORS  
Invited paper 6 - *Speed Management in Victoria*  
John Cunningham/Ted Barton

2.00pm      Afternoon workshop session commences  
Workshop 3 - *Speed and the Environment* - meeting room 1  
Workshop 4 - *Speed Behaviour & Enforcement* - meeting room 2

3.20pm      Summary of workshop findings

3.45pm      Conclusions from the meeting

4.00pm      Meeting closed

**ALLOCATION OF PARTICIPANTS  
SPEED ENVIRONMENT DESIGN WORKSHOP**

**FACILITATOR:** Professor Thomas Triggs

**WORKSHOP 1. SPEED AND CRASHES** - Chair: Peter Croft

Fae Robinson	John Cunningham
Max Cameron	Barry Newton
Brian Fildes	Doug Lee
Jim Jarvis	Ian Faulkes
Ken Smith	Theo ten Brummelaar
Jack McLean	Mike Hammond
Vivienne Moore	Steve Ginpil
Peter Steele	Keith Seyer
Thomas Triggs	Dominic Zaal
Chris Brooks	Antionetta Cavallo
Alec Fisher	Mike Tziotis

**WORKSHOP 2. SPEED AND SPEED LIMITS** - Chair: Peter Vulcan

Barry Elliott	Ron Scriven
Gavin Massey	Hans Westermann
Mark Leggett	John Sanderson
Peter Cairney	Deborah Donald
Col Craig	John Bliss
Doug Woodbury	John Norrish
Dave Saffron	John Lambert
Ted Barton	Fred Schnerring
Dick van den Dool	Peter Moses
Tony Ryan	Stephen Lee
Göran Nilsson	

**WORKSHOP 3. SPEED AND THE ENVIRONMENT** - Chair: Thomas Triggs

Fred Schnerring	Doug Lee
Brian Fildes	Ted Barton
Peter Moses	Ron Scriven
Theo Ten Brummelaar	Vivienne Moore
Alex Fisher	Stephen Lee
John Cunningham	Ken Smith
Jim Jarvis	Deborah Donald
Hans Westerman	Steve Ginpil
Peter Steele	Keith Seyer
Peter Croft	Tony Ryan
Mike Tziotis	

**WORKSHOP 4. BEHAVIOUR AND ENFORCEMENT** - Chair: Chris Brooks

Mark Leggett	Doug Woodbury
Antionetta Cavallo	Max Cameron
John Bliss	Barry Newton
John Norrish	Col Craig
John Sanderson	Mike Hammond
Dave Saffron	John Lambert
Ian Faulkes	Gavin Massey
Dick van den Dool	Jack McLean
Peter Cairney	Barry Elliott
Peter Vulcan	Dominic Zaal
Fae Robinson	Göran Nilsson

## 6.4 NOTES FOR WORKSHOP CHAIRPERSONS AND REPORTERS

### NOTES FOR WORKSHOP CHAIRPERSONS

#### **WORKSHOP STRUCTURE**

There are *four* workshop sessions planned to run in parallel, *two* in the morning, and *two* in the afternoon. A summary session will follow both the morning and afternoon workshop sessions in which the main findings from each of the parallel sessions will be presented to the whole workshop group. Workshop sessions will be of one-and-a-half hours duration.

#### **YOUR ROLE**

Your role as a workshop chairperson and as someone familiar with the general topic area, is to facilitate the discussion and ensure that the main points are recorded. An appointed reporter for your group will be responsible for recording the main points from the discussion - see accompanying 'Notes for Workshop Reporters'.

Your job is to make sure that it all happens in a smooth and efficient manner. In conjunction with the session reporter you will be expected to summarise and present the main findings from our workshop in the summary session that follows each of the workshop sessions. In addition, you and the reporter from your session, will be required to provide a written summary of the session (after the workshop) for inclusion in the workshop proceedings.

#### **YOUR OBJECTIVE**

Your objective is to have the group's discussion reach some point of agreement on what are the main RESEARCH ISSUES to be confronted (needs, findings, or techniques) in the topic area. Your group should strive to clearly state these issues for presentation to the workshop delegation.

It is suggested that you, the chairperson, lead the workshop in such a way as to address the following issues:

1. What are the current problems in the area
2. What knowledge/information is needed to address these problems
3. Is there a need for specific countermeasures/programs to address these information needs.
4. Where should be *Research and Development* resources be directed - identify and discuss priorities
5. What research is currently underway or planned in this area.

It is important that each of the above objectives are addressed, therefore we suggest that chairpersons be mindful of the time spent on each (as a guide, allocating 15 minutes to each of the objectives would allow some leeway).

#### **YOUR TASK**

- Introduce yourself to the group, and outline your role.
- Introduce, and outline the role of, the group reporter.
- Introduce the topic that has been given to the group, and emphasise the objectives of the session.

- Maintain the focus of discussion towards the objectives.
- Ensure that the reporter records all of the main points.
- In conjunction with the reporter from your group, present the outcomes of the group's discussion to the summary session that follows each of the workshop sessions.

### ***SOME SUGGESTIONS***

- Don't waste time with introductions all around the group.
- Try to ensure that everyone gets a chance to contribute.
- Don't allow "speeches" to be made.
- Don't spend too much time trying to resolve conflicting viewpoints; the important thing is to identify the conflicts and the issues as they are raised.
- Remember your role is as a discussion leader/facilitator, not a "lecturer".
- Use the butchers paper or whiteboard to record progress so that all group members can see how the discussion is developing.
- In the presentation of the session summary, concentrate on the outcomes of the discussion; don't spend too much time explaining how they were reached.

## NOTES FOR WORKSHOP REPORTERS

### **WORKSHOP STRUCTURE**

There are *four* workshop sessions planned to run in parallel, *two* in the morning, and *two* in the afternoon. A summary session will follow both the morning and afternoon workshop sessions in which the main findings from each of the parallel sessions will be presented to the whole workshop group. Workshop sessions will be of one-and-a-half hours duration.

### **YOUR ROLE**

Your role as a workshop reporter is to record the main the points of the groups discussion. In conjunction with the session chairperson you will be expected to summarise and present the main findings from our workshop in the summary session that follows each of the workshop sessions. In addition, you and the chairperson from your session, will be required to provide a written summary of the session (after the workshop) for inclusion in the workshop proceedings.

### **YOUR OBJECTIVE**

Your objective is to prepare a concise summary of the position reached by the group in discussing the topic area.

The chairperson will be leading the discussion in such a way as to address the following issues:

1. What are the current problems in the area
2. What knowledge/information is needed to address these problems
3. Is there a need for specific countermeasures/programs to address these information needs.
4. Where should be *Research and Development* resources be directed - identify and discuss priorities
5. What research is currently underway or planned in this area.

It is suggested that the above objectives should form a frame work around which the session notes are taken, *ensuring that discussion of each is recorded.*

### **YOUR TASK**

- Make sure you note down the essence of the main points being made; seek clarification from other workshop participants if necessary.
- Sketch out the framework adopted for trying to tackle the question.
- Note down the main points (major issues, differences and/or agreements) made during the discussion.
- Rearrange and summarise the points for clarity.

## 6.5 WORKSHOP 1: SPEED AND CRASHES

### CHAIRMAN: MR PETER CROFT

This workshop session was concerned with the topic of speed and crashes, including both crash causation and crash consequence. The session was structured to address *four* fundamental issues of interest to this topic, namely:

1. What are the current problems in furthering efforts to reduce speed related crashes in this country,
2. What information or data are required to support or facilitate this aim, and
3. What programs are needed to bring about improvements, especially the need for new countermeasures or initiatives
4. The need for further research and development

#### 1. CURRENT PROBLEMS

##### 1.1 Definitions

The first problem area identified concerned appropriate definitions;

- what is inappropriate speed (exceeding the speed limit or travelling at unsafe speeds),
- is it always so or only under certain circumstances (eg; at high pedestrian times or during bad weather conditions).

##### 1.2 What Is Speeding

Difficult to talk about speeding per se. Better to focus on what is "appropriate" speed behaviour and speed management techniques to control inappropriate or deviant actions.

Community acceptable speed management will only happen if we improve our knowledge of the costs and benefits to motorists;

- costs and benefits must be system-wide,
- treatments must also be of benefit to the whole system,
- need to predict outcomes of our actions more accurately than we do presently,
- we need good relationships (information) about the cost of speed behaviour on the total network (the Swedish model)

### **1.3 Speeding Is Not A Single Entity**

- . Fundamental problem to defining unsafe speeding is the trade-off between travel speed and mobility;
  - motorists are prepared to accept some level of crashes simply for the benefits of being mobile,
  - speed, therefore, will always be a compromise between travel and safety,
  - we do not appreciate motorists' perceptions of what is an acceptable level of speed trauma,
  - different objectives set by different authorities.
- . Speed decisions are often made without due consideration to the full ramifications on the system. We need "*multi-criteria*" decision analysis in arriving at speed management policy.
  - safety is not always a consideration when arriving at speed management policy. Safety needs to be overtly taken into account,
  - cannot ignore transportation aspects when discussing speed,
  - Speed management resources must be allocated on the basis of road usage, mobility, and safety.

### **1.4 Consequences of Speeding Not Always Obvious**

- . We have not been successful in promoting the safety aspects of appropriate speed behaviour among motorists;
  - problem of lack of understanding motivation for speed choice,
  - problem of poor communication on the part of the authorities,
  - lack of agreement generally about what is appropriate speed behaviour among the experts,
  - everyday experiences tend to reinforce the mobility, rather than the safety, aspects of speeding.

### **1.5 Confusion Between Cause And Effect**

- . Difficulty in conceptualising the different relationships between speed and crash involvement and speed and the consequences of collision.
  - general agreement about speed and crash severity function,
  - less agreement about the speed and crash risk relation,
  - interesting that what we need to communicate the most we know least about,
  - Speed data in crashes is generally very poor.



- . Travel speed is not always a good proxy for collision speed, yet often these two are considered to be the same.

## **2. INFORMATION REQUIRED**

### **2.1 Greater Knowledge Of The Problem**

- . There was much debate within the workshop group over what we know and what we still need to know about the relationship between speed and crashes;
  - some felt that we do not understand the issue well enough yet,
  - others believe current knowledge good enough to go forward,
  - difficulty raised about what measures are appropriate if we do not fully understand the problem at the outset (will intervention only confuse rather than be of benefit).

### **2.2 The Need for Better Speed Data in Crashes**

- . There was some consensus on the need for better crash speed data to improve our knowledge and help develop crash countermeasures;
  - MUARC are presently examining the possibility of introducing on-board speed monitors in a sufficiently large sample of vehicle to obtain travel speed data of crash involved vehicles but they were experiencing problems with this project,
  - RARU in Adelaide are currently looking at the role of speed in fatal crashes in that state. Early results seem to suggest that retrospective analysis may still be useful if a thorough in-depth examination of all the evidence is involved.
  - a major break through is still required in this area. There is no sign of such a break through overseas yet, although Folksam Insurance in Sweden have developed a relatively cheap delta-V recorder that could be of some (restricted) use,
  - the need for any analysis of crashes to focus on only those that are speed related (culpability important too).

### **2.3 System-Wide Effects**

- . We need to strive for better quantification of the large picture of the effects on the system as a whole. The Swedish curves present a real opportunity for examining these system-wide effects;
  - need to establish the validity of the fourth and eighth power rule for speed limit changes in Australia,
  - have a real opportunity to test this in Victoria with recent changes up and down in speed limits in rural areas,

## **2.4 Interactive Effects**

- . We don't really understand the interaction between speed limits, enforcement and crashes. Communication is central to this issue.
- . We do not appreciate fully the role of attitude and behaviour in this area;
  - a change in attitude does not always mean a change in behaviour and visa versa,
  - need to change the system to "force" behavioural change,
- . High correlation between blood alcohol level and speeding;
  - is booze or speed the real problem,
  - doesn't really matter in a sense as both are target factors,

## **2.5 Higher Order Explanations**

- . What is needed is more detailed explanations of speed involvement in crashes. Previous models have been too superficial to be of real use in addressing this problem;
  - cannot address speeding alone without examining *who* speeds, *where* they speed, *when* they speed, and *why* they speed,
  - this questions the quality of data available, including the need for more behavioural and attitudinal data,
  - motivation for speeding needs greater emphasis (if motorists derive pleasure from speeding then changing behaviour will be more difficult).

## **2.6 Optimal Speeds**

- . Need to get away from talking about speeding and focus on *optimal* speeds;
  - we need to define an acceptable travel speed, bearing in mind the inevitable trauma, mobility, and cost consequences,
  - the use of sensitivity analysis in applying different models,
  - the use of multi-decision-analysis to determine criteria including access, safety and environment aspects,
  - the need to also consider unprotected road users and their expectation and difficulties in judging travel speed.

## **3. THE NEED FOR NEW PROGRAMS & INITIATIVES**

- . There was a loud call for more action generally aimed at excessive speeding. The apparent success of the speed camera program in Victoria should be a model for other states to follow.

### **3.1 Educational Measures**

- . Education to inform motorists of the dangers of speeding (including the sometimes illusory effects of excessive speeding).
- . Better communication between authorities and motorists about speed management issues.

### **3.2 Engineering Measures**

- . Vehicle manufacturers to adopt a more safe approach in marketing their vehicles (stop stressing how fast they can travel at).
- . Better ergonomically designed speed control instrumentation.
- . Greater use of in-vehicle speed controllers (both pre-set and top speed).
- . Encourage the use of stiff accelerators to prevent inadvertent speeding,

## **4. FURTHER RESEARCH REQUIRED**

- . Better understanding of the relation between speed and crash involvement.
- . Improved knowledge of the role of behaviour in speed related crashes.
- . The validity of the fourth power rule in Australia.
- . Quantify the relationships between speed and mobility in terms of crashes
- . Higher-order conceptual models of speed related crashes.
- . How to get more safety in action effective programs (must be evaluated).

## 6.6 WORKSHOP 2: SPEED AND SPEED LIMITS

**CHAIRMAN: PROFESSOR PETER VULCAN**

### 1. WHAT ARE THE CURRENT PROBLEMS IN THE AREA?

- **Objectives of speed limits**

- The objectives of speed limits are not always clearly understood
  - : the first requirement of any discussion of speed limits is a clear understanding of the objectives to be met.
- The consensus opinion was that the objectives of speed limits should be to balance the conflicting needs of amenity, safety, and mobility.
  - : it is recognised that balancing the objectives of speed limits has a different emphasis for different
    - road types
    - driver groups
    - vehicles
    - time of day
    - weather conditions

- **Rational and Obvious system of speed limits**

- Some argue that the biggest problem faced by the authorities charged with setting speed limits is the increasing trend that both roads and vehicles are designed to operate at speeds far exceeding that which the legal system is willing to allow. The legal system and the vehicle-road system onto which it is superimposed are not fully compatible.
- The speed limit applicable to a given section of road is not always obvious to motorists, which would be the ideal situation.
  - : drivers should be able to estimate the speed limit
  - : given the vast diversity of road users making similarly diverse value judgements regarding which speed is appropriate for a given section of road, a system of speed limits that is transparent to all users is very difficult to achieve.
  - : this problem is accentuated by the increasing trend in speed limit setting practice to use 10 km/h increments. The use of a large number of speed zone values serves its intended purpose of matching the speed limit with the road environment more consistently than was ever possible using a more limited number of speed limits. However, drivers are now less confident about the limit that applies in the absence of a speed limit sign.
  - : issue of how to communicate the operating speed limit - "WHAT speed WHERE ?"

- Speed limits are not always commensurate with the prevailing physical environment through which the driver is passing, resulting in the driver receiving conflicting messages regarding the appropriateness of a chosen speed

- : this can result in drivers being frustrated with travelling at speeds (speed limits) that are considerably slower than that which seems safe and appropriate

- often occurring as a result of the general urban speed limit in built up areas

- similarly maximum speed limits on rural highways are usually considerably below the speed for which the road has been designed

- : conversely, under some circumstances, speed limits are set at levels above which many drivers would choose for themselves, in which case drivers travelling slower than the speed limit must decide to either speed up or inhibit traffic flow (neither a safe option).

- : it was suggested that this problem could, to some degree, be alleviated by matching more closely the intended operating speed of a road with the design speed.

- **Use of the term 'design speed'**

- While the term 'design speed' is often used extensively in the discussion of speed limits, its actual meaning is poorly understood, furthermore the relationship between design speed and safety, which is often taken for granted, is also poorly understood. The design speed of a road is a description of the maximum 'safe' speed on the least safe section, for example, a turn or a crest, under ideal weather conditions while long straight sections of road may have a much higher design speed of 200-300 km/h.

- Despite not knowing exactly how design speed relates to operating speeds (speed distribution) and safety, road planning and engineering authorities continue to use the design speed when planning and building roads.

- **Don't know how drivers select their speed**

- At present we don't have a complete understanding of how motorists select their travelling speed.

- : while we have a limited understanding of some of the elements which are important, there are many gaps in our knowledge

- **Impact of speed zoning poorly understood**

- Opinion was divided on the appropriateness of adjacent speed zones being only 10 km/h different. The practice of speed zoning can lack credibility with drivers when the speed limit decreases by only 10km/h, from say 100km/h to 90km/h in the absence of any obvious changes in the road environment. It was suggested that adjacent speed zones should differ by some minimum amount (say, 20 km/h) so as to maintain the credibility of the limit system.

- **Lack of uniformity**

- Concern raised about the lack of uniformity (both inter-state and intra-state) in speed limits.

: while the lack of uniformity can be confusing for motorists, some questioned the validity of unifying a system so poorly understood.

- **Impact of enforcement tolerance poorly understood**

- It was suggested that the common enforcement policy of allowing speeding motorists a speed tolerance within which they are not apprehended should be taken into account in the setting of speed limits. Most motorists are aware that there is a sign-posted speed limit and an enforced speed limit, the latter being the sign-posted limit plus the enforcement tolerance. Enforcement authorities insist that enforcement policy is not an issue for those setting speed limits to concern themselves with. However, the reality is that enforcement policy and strategy must be addressed if the desired travel speeds are to be achieved. Opinion was divided over this issue.

## **2. WHAT KNOWLEDGE OR OTHER INFORMATION IS NEEDED TO ADDRESS THESE PROBLEMS?**

- **Objectives of speed limits**

- In order for the objectives of speed limits to be met, the effects of speed on each of the objectives needs to be better understood. Therefore, road safety researchers must include in their agenda the pursuit of knowledge that will allow the effects of speed on safety, mobility, and finally amenity to be quantified preferably in terms of cost. Such information is required for different

- : road user groups
- : types of road function
- : vehicles
- : times of day
- : weather conditions

- **Differential (or variable) speed limits**

- Given the transient nature of many of the above listed influences on the appropriateness of a speed (and hence speed limit, such as road types, driver groups, vehicles, time of day, weather conditions, etc.), it is argued that differential (or variable) speed limits that take account of the above factors before "deciding" on an appropriate speed limit will be an improvement on current practice when the technology is sufficiently developed. The refining and testing of such technology must be undertaken prior to its implementation.

- **Rational and Obvious system of speed limits**

- The most important questions to be addressed by research is - How do drivers select their travel speed?, and - Which elements of the driver-car-road environment are important in the decision process?

: we must 'fill in' the gaps that currently exist in our knowledge regarding the influence of many of these driver-car-road environment elements.

- In order to make the speed limit system more obvious and predictable to motorists we must first determine how motorists determine their travel speed.
  - : then will we be in a better position to manipulate these aspects of the road environment, supplementing it with whatever signing is necessary.
- The problem of speed limits not always matching the drivers assessment of the physical environment, can also be addressed once the we can determine how drivers determine their travel speed.
  - : with this knowledge it will be possible to manipulate the physical environment in such a way that the speed limit will more closely match with the speed that seems safe and appropriate.
  - : similarly, it was suggested that this problem could, to some degree, be alleviated by matching more closely the intended operating speed of a road with the design speed (however the characteristics of a road that determine its design speed are most likely only a subset of those used by drivers to determine travel speed) .

#### • Definition and influence of 'design speed'

- There is an pressing need to improve knowledge about the influence of 'design speed', in terms of its impact on both speed distributions and safety.
  - : until such time as the relationship between design speed and operating speed is better understood use of the former in road design and construction will be questioned by some.

#### • Impact of speed zoning

- With the increasing trend toward the use of speed zoning (using a wide range of speed limits), we need to investigate the impact it has on speed distributions, compliance with, and credibility of the speed limit system and road safety.
  - : there is a need to gain a better understanding of the impact of the speed limit changing only 10 km/h in adjacent speed zones.

#### • Impact of enforcement tolerances

- The whole circular issue of and the subsequent compensatory act of undersetting speed limits is one that deserves further investigation.
  - : presently some drive up to the enforced limit and some to the signed limit
  - : logically, speed variance will be lowest if all are driving within the same speed limit
  - : in addition to the increase in speed variance, drivers that are driving up to the enforced limit (the signed limit plus the enforcement tolerance) are travelling faster than may have been intended by those setting the limits.

### 3. ARE THERE SPECIFIC COUNTERMEASURES OR PROGRAMS REQUIRED TO ADDRESS THESE NEEDS?

#### • Limiting the speed potential of the vehicle-road system

- The partial incompatibility between the legal system and the vehicle-road system onto which it is superimposed can be addressed in a number of ways. Any or all of the three components of the system (legal, vehicle, or road) could potentially be altered to reduce the incompatibility.

: Limiting the speed potential of vehicles is a common practice in large vehicles that removes the burden of controlling speed from both the legal and road systems. The development of a speed limiting system for all vehicles that the motoring public would find least constraining on their freedom, a considerable challenge, could bring about huge safety benefits.

: On the other hand reducing the design speed of rural highways would bring about considerable savings in road construction costs.

: Concerns were raised about the notion of reducing design speeds. It was suggested that the margin between the design speed and the mean/median speed of traffic allows a margin for error for even the top part of the speed distribution.

#### • Communicating the speed limit to drivers

- The increasing trend in speed limit setting practice to use a large number of speed limits (in 10 km/h increments), could erode driver confidence in his or her ability to estimate the speed limit that applies to a given section of road.

: to combat this situation it was suggested that the density of signing will need to be markedly increased, or that some alternative system of communicating to drivers the speed limit in operation be developed. A system of marking the roadway in such a way that the speed limit was continuously indicated would be the ideal.

#### • Rational and Obvious system of speed limits

- Some effort must be made to render the speed limit applicable to a given section of road more obvious to motorists

: in order to increase the confidence with which drivers can estimate the speed limit it was suggested that the decision process by which speed limits are determined should be communicated to the driving community

- armed with knowledge of this process, drivers would have a greater appreciation of the rationale for speed limits (be they orientated towards mobility safety or the environment). This would lead to drivers having greater respect for speed limits, and being better able to estimate the speed limit in the absence of a speed limit sign

: drivers also need to be reminded that maximum speed limits are just that - **maximum** speed limits and that at times it is more prudent to travel at speeds lower than the maximum allowable speed.



- **Minimising the effects of enforcement tolerances on speed limits**

- The 'non-enforced speeding' associated with enforcement tolerances on speed limits could be minimised by reducing the size of the tolerance from its present level of 10%, or alternatively, overcome by eliminating the enforcement tolerance entirely.

- : eliminating the enforcement tolerance, such that the enforced speed limit was in fact the signed limit, would have the same effect on many drivers as reducing the signed speed limit by 10%

- : Swedish experience tells us that reduced tolerance limits result in slower travel speeds, a comprehensive program of investigation must be conducted to enable a better understanding of the effects of enforcement tolerances on travel speeds.

#### **4. WHERE SHOULD RESEARCH AND DEVELOPMENT RESOURCES BE DIRECTED?**

- **Studies that will aid and assist the process of balancing the objectives of speed limits**

- including the pursuit of knowledge that will allow the effects of speed on safety costs, mobility costs, and finally amenity costs to be quantified. - - Such information is required for different road user groups, types of road function, vehicles, times of day, weather conditions, etc

- **Studies that undertake to refine, develop and evaluate variable speed limit systems**

- such systems that take account of many of the transient influences on the appropriateness of a speed will enhance the credibility of speed limits by ensuring that speed limits are more often commensurate with the prevailing road environment.

- **Research that seeks to refine, develop and evaluate vehicle speed limiting devices**

- an obvious way to reduce excessive speeding is to limit the speeding potential of vehicles

- what is needed is a system that limits the potential speed of vehicles appropriately for the prevailing speed limit while allowing the driver some freedom to accelerate when needed (for example to pass).

- limiting the speed potential of vehicles is a common practice in large vehicles that removes the burden of controlling speed from both the legal and road systems. There is no logical reason why similar systems couldn't be applied to all vehicles, or at least to the vehicles of habitual speeders.

- **Research that examines the impact of using a wide range of speed limits**

- there is some suggestion that speed zoning contributes to the situation whereby drivers are unsure which speed limit applies to a given section of road.

- : such allegations must be investigated and the considered in any evaluation of speed zoning

- **Research should be conducted into alternative means of communicating to drivers the speed limit in operation such that the speed limit is continuously indicated**

- : suggestions include marking the roadway either with colours, numbers or some other system of symbols

- **Studies that evaluate the impact of enforcement tolerances on compliance with speed limits**

- Swedish experience suggests that drivers are aware of these tolerances and drive at the enforced speed limit rather than the signed speed limit, the extent to which this is the case in Australia is not known.

- **Research that investigates the nature of the relationship between the design speed and operating speed for a range of different road environments**

- The impact of the design speed on both speed distributions and safety is to date unclear.

## **5. IS THERE ANY RESEARCH CURRENTLY UNDERWAY OR PLANNED IN THIS AREA?**

- **Ongoing development of VLIMITS and NLIMITS expert speed limit advisor systems**

- work at the Australian Road Research Board continues on the development of computer based expert advisor systems for the determination of speed limits

- **Buffer zones and advance warning signs**

- Effects of buffer zones and advance warning signs two alternative methods of 'smoothing' and encouraging the transition from high speed zones to adjacent lower speed zones currently underway at the Australian Road Research Board.

## 6.7 WORKSHOP 3: SPEED AND THE ENVIRONMENT

### CHAIRMAN : PROFESSOR TOM TRIGGS

#### 1. WHAT ARE THE CURRENT PROBLEMS IN THE AREA?

##### • Two direct problems concerning the interaction of the environment and traffic.

- The effects of the environment on the traffic - sometimes referred to as friction factors. These include such environmental characteristics as the road frontage, width, alignment, users (heavy vehicles, bicyclists, pedestrians, etc.), traffic volumes, roadside environment (parking bays- parallel and angle, trees, etc.
- The effects of the traffic on the environment - sometimes referred to as impact factors. These include effects of traffic such as noise pollution, air pollution, access to property, etc.
- Simplifying the relationship between these factors and speed is complicated by the fact that they sometimes moderate speed and at other times are moderators of speed.
- The importance and consideration due to each of these factors varies with the emphasis of the road from arterial corridors and freeways where traffic flow considerations take precedence over the environment, to situations in which traffic and environmental considerations are weighed equally, and finally to situations in which environmental considerations are dominant of traffic considerations.

##### • Poorly conceived notion of what actually constitutes the road environment

- Only more recently beginning to appreciate that the road environment also includes the traffic or activity environment of the road and frontage and that these too must be considered.
- We must continue to clarify the role played by the various aspects of the road/traffic environment in the decision process undertaken by drivers when choosing their travel speed
- There is a general supposition that our perception of speed comes solely from processing of the visual environment, but we know that auditory and kinaesthetic information also plays a role in the perception of speed
- The road environment is continually changing according to the prevailing natural conditions (weather and daylight).
- The road environment differs fundamentally between rural and urban settings (functionally, geographically and in terms of appropriate speeds).
- This noted changeability of the road environment renders the task of establishing an appropriate speed limit a difficult one.

- **Conflicting demands**

- Given the multiple functions that many roads must serve it is difficult to please all users. Often times the best that can be done is to arrive at a compromise between the conflicting demands of residents, pedestrians and motorists (both commercial and personal/domestic).

- **Environmental adaptation**

- We now know that it is possible to influence travel speeds through manipulation of the environment. Various LATM treatments have now undergone evaluation, and their effectiveness determined (though often in a crude sense). However, there remains a great deal which is unknown.
  - : the impact on effectiveness of interaction between various vehicle and treatment types
  - : the traffic (accident) transferral effects of various treatments and the situations under which transferral will be likely
  - : which, if any, forms of environmental adaptation are appropriate (adaptable) to high speed roads
- There are large costs involved in changing the environment.
  - : It was suggested that given the cost/benefit ratios (CBR) of environmental adaptation, the cost is irrelevant, the treatments will pay for themselves in time.
  - : However, regardless of the CBR associated with environmental adaptation, the fact remains that the capital must be available to 'invest' in such works.
- Difficulties arise when retro-fitting these treatments to existing roads. Suggested that we should now be in a position to build safe roads from the outset.
- LATM treatments are not universally accepted, particularly buses and emergency vehicles continue to raise objection to the implementation of such devices. Similarly residents of treated areas and areas proposed for treatment often raise objections.

- **Un- coordinated efforts**

- Town planning authorities are not in touch with road zoning practices and authorities

## **2. WHAT KNOWLEDGE OR OTHER INFORMATION IS NEEDED TO ADDRESS THESE PROBLEMS?**

### **• Definition of Environment**

- We must continue to develop our understanding of the multiplicity of environmental factors that influence travel speed and the perception of speed including
  - : both the built and activity (traffic and frontage) profiles
  - : continually changing prevailing natural conditions (weather and daylight).
  - : rural and urban settings (functionally, geographically and in terms of appropriate speeds).

### **• Objectives of manipulating the environment**

- While we know that it is possible to influence travel speeds through manipulation of the environment, the evaluations that have been undertaken have often been crude. In order for the many information deficits that currently exist to be met the effectiveness evaluations of environmental adaptation must improve.
  - : first one or more appropriate criteria for effectiveness must be established (eg. safety, speed reduction, amenity, etc.)
  - : next these criteria must defined operationally, such that clearly defined goals can be set (eg. reduce speed by 15 km/h, or a 20% reduction in pedestrian accident rate).
  - : will then be in a position to match the expectations of residents and those implementing the adaptation
  - : Ideally must encourage in-built, thorough and comprehensive effectiveness evaluations of environment adaptation treatments
- It was explained Danish evaluation of LATM has resulted in an evolved model of the changed in speed that can be expected as a result of implementing different treatments.
  - : It was suggested that the development of this type of "prospective potential" model applicable to Australian environmental adaptation would be invaluable

### **• Road user acceptance**

- With increasing use of environmentally based speed management treatments there is an obvious need to investigate road user acceptance/perception of such treatments.
- Not only road user acceptance/perception must be measured, local residents are affected by such treatments not only in the changes brought about in traffic behaviour ( such as: probably noisier, possibly slower, and possibly less patient if feeling unjustifiably slowed-up) but also by the changed appearance of their streetscape (for better or worse).

- **Problem transfer**

- There is varying evidence in the literature that environmental speed management treatments (LATM) owe at least some of their effectiveness to the simple transfer of traffic volumes, and associated safety problems, to adjacent non-treated roads. In many situations this is clearly an unacceptable outcome, and the extent to which 'problem transfer' occurs and methods of overcoming it are largely unknown.

### **3. ARE THERE SPECIFIC COUNTERMEASURES OR PROGRAMS REQUIRED TO ADDRESS THESE NEEDS?**

- **Definition of environment**

- We must continue to clarify the role played by various aspects of the driver/road/traffic environment in the perception, and hence, choice of travel speed. Programs that undertake to measure the influencer's of speed perception can only enhance our appreciation of the defining characteristics of the environment as it pertains to speed perception.

- **Evaluation of environmental adaptation**

- There is a need to improve the often questionable evaluation studies conducted in conjunction with environmental speed management (LATM) treatments. It was suggested that this could be achieved through appropriate criteria, operationally defined such that clearly defined goals can be set, and valid and reliable evaluations made.

- : We will then be in a position to match the expectations of residents with those of the implementors of such treatments, essential to optimising satisfaction with the treatment .

- : Ideally must encourage in-built (most importantly in terms of budgeting), thorough and comprehensive effective evaluation studies of environmental adaptation treatments.

- : Only then will we be in a position to develop the type of "prospective potential" model developed by the Danish that allows them to predict the changes in speed that can be expected as a result of implementing different treatments.

- The prevalence of "problem transfer" should also be addressed by evaluation studies of environmental speed management treatments. The transferral of traffic volumes (particularly those that speed) and the associated decrements safety is not difficult to measure, however it is seldom reported in published evaluation studies.

- **Financial incentives to encourage implementation of LATM treatments**

- There are large costs involved in changing the road environment. Regardless of the often impressive cost/benefit ratios (CBR's) of environmental speed management, the costs of the treatment must be met in the short term. It was suggested that financial incentives should be offered to local governments to install such treatments, particularly those with CBR's that exceed one.

- **Resident/road user acceptance of LATM treatments**

- LATM treatments are not universally accepted, not only are residents and general road users against the implementation of such treatments, certain specific road user groups such as bus companies and emergency service providers continue to raise objection to such treatments.

- : It was suggested that these obstacles could to some extent be overcome by communicating to road users and residents alike the increases in safety and amenity afforded by such treatments, in conjunction with an accurate estimate of the usually minimal increases in travel time.

#### **4. WHERE SHOULD RESEARCH AND DEVELOPMENT RESOURCES BE DIRECTED?**

- **Behavioural research**

- There is a need to investigate new methods (and revisit old ones) of influencing road user behaviour

- : We should research techniques for affecting lower vehicle speeds (for example, measures designed to impart on the driver the sensation of "speeding" : The effects on driver behaviour/performance of publicity campaigns needs to be better understood, including the effects of the message content and the medium (the effect of road-side advertising in particular was questioned).

- **Acceptable levels of risk**

- To facilitate the process of road design and the subsequent setting of appropriate speed limits research is needed to determine acceptable levels of risk for varying road environments.

- **Contribution of speed to crashes**

- Age old need for research that accurately describes the degree to which speed contributes to different crash types.

- **Evaluation of speed reduction measures**

- Need a large body of good research which evaluates the effectiveness of speed reduction measures. Only then will we be in a position to develop an Australian model of "prospective potential" speed changes similar to that developed by the Danish which allows then to predict the changes in traffic speed that can be expected as a result of implementing different treatments.

- **Combinations of speed reduction treatments**

- Need for research that examines the effects of speed reduction treatments in combination as they are often implemented, rather than in isolation. The interaction of various treatments is little understood.

- **Safety impact of speed reduction measures**

- **We must investigate the safety effect of speed reduction treatments.** Both in terms of the safety effects resulting directly from the reductions in traffic speed, and also effects that are secondary (eg. pedestrian behaviour at treatments, reduced driver sight distance, etc.).

- **Interactive driver/road environment**

- **Should encourage research that sets about to refine and develop new interactive driver/road environment technology that will advise drivers of an appropriate/safe speed given the prevailing conditions.**



## 6.8 WORKSHOP 4: BEHAVIOUR AND ENFORCEMENT

**CHAIRMAN: MR CHRIS BROOKS**

### 1. WHAT ARE THE CURRENT PROBLEMS IN THE AREA?

- **Dependence on enforcement**

- How much should we depend on enforcement as a speed management tool
  - : there is a tendency to become over dependent on enforcement which can result in adverse community reaction to speed management practices.
- enforcement should be used in conjunction with other speed management methods such as
  - : engineering treatments;
  - : environmental adaptation
  - : public education; and
  - : technical modifications to vehicles.
- we should try not to rely too heavily on enforcement. The challenge is to find a balance between the level of enforcement and other speed management methods.

- **What method or device do you use**

- speed enforcement can be either visible or non-visible, stationary or mobile
  - : visible enforcement strategies are likely to have the most significant speed reducing effects
  - : non-visible enforcement strategies are more effective when targeting excessive speed behaviour
    - + because drivers are unaware of the location and nature of the enforcement vehicle which increases the perceived risk of getting caught. i.e every vehicle encountered might be a police car
  - : stationary units are best used to target specific speed problem areas
  - : mobile units appear to have a greater impact on speed behaviour generally over a larger area.

- there are also various speed enforcement devices that can be used. The most recent and controversial of these devices is the speed camera
  - : speed cameras appear to have little impact on average speed but do however have a dramatic impact on excessive speeders
  - : they have also resulted in a dramatic increase in the percentage of drivers with demerit points
  - : speed cameras may not provide visual deterrence. You can not often see them and only realise your error when you get the ticket several weeks later
    - + this in turn has a significant impact on the time halo effect of enforcement.
- **How to best maximise the method selected**
  - the challenge is to use particular methods and devices that work best for particular situations in order to maximise the effectiveness of enforcement
    - : the end result should be a sound and balanced enforcement strategy that the community perceives as being effective and fair.
  - it is also important to be patient with new methods
    - : you need time to establish the full impact, in terms of road safety, effectiveness, behaviour change, and so on of the enforcement method.
- **How the public perceive the method of enforcement**
  - it is important to confront the issue of how the public perceives the method of enforcement
    - : if the community doesn't view the method as a road safety measure, their behaviour may not change.
  - all too often the community perceives the method to be a revenue raiser
    - : this perception must change if we want to reduce driver's speeding behaviour
    - : driving behaviour may change if drivers understand why enforcement methods are in use.
- **How to decide between acceptable and unacceptable behaviour**
  - one of the problems with enforcement is where do you draw the line between acceptable and unacceptable behaviour
    - : should you be targeting marginally speeding drivers or excessive speeders
      - + we also need to determine what is excessive speeding

- : the decision as to who to target can have both social and economic consequences.

- **Self enforcement**

- we tend to go for the relatively cheap solution with regard to enforcement
  - i.e. get the police to do it. It might now be time to spend some money to tackle the problem of speed by using self enforcement methods such as
    - : speed governors
    - : road bar-coding
    - : devices in the vehicle that tell you that you are speeding
- with regard to enforcement we need to decide whether we go for a behavioural fix, a technical modification to the vehicle or a combination of both

## 2. **WHAT KNOWLEDGE OR OTHER INFORMATION IS NEEDED TO ADDRESS THESE PROBLEMS?**

- **Need for a theory about why people speed**

- there is a definite need to have a more complete theory about why people speed and what factors have an impact upon their speed related behaviour.
  - : instead of targeting the end result shouldn't we try to better understand the process underlying the behaviour that leads to speeding.
- we also need to have a good look at the relationship between speed and perceived risk taking behaviour.
  - : if we can better understand the processes involved then we may be able to design strategies to minimise such behaviour

- **Need to look at how levels of enforcement affect driver behaviour**

- the level of enforcement has also been shown to have an effect on speed behaviour of motorists
  - : the greater the level of enforcement the greater the actual and perceived likelihood of being caught and the greater the likely reduction in speeding (or excessive speeding)
  - : the lower the level of enforcement the higher the incidence of speeding (or excessive speeding).
- too much enforcement, however, may not be cost effective
  - : need to examine how levels of enforcement affects speed behaviour and use the information to find an optimal enforcement level
    - + both in terms of cost effectiveness and the level of deterrence provided.

- **Need to optimise the use, and determine the effectiveness, of the enforcement methods and devices**
  - we need to determine which enforcement methods and devices work best in which particular situations and on which particular drivers.
    - : this will allow us to optimise the use of available resources to combat the problem of speed.
  - there is also a need to determine the effectiveness of the various enforcement methods and devices
    - : so that we can allocate available resources to those methods and devices that will provide maximum returns.
- **Need to optimise the perceived risk of getting caught**
  - if we can increase the perception of getting caught then we can reduce speed behaviour
    - : a reduction in risk taking behaviour can be achieved by increasing the perceived risk.
  - we need to use methods which will increase the public awareness of enforcement and optimise the perceived risk of getting caught.
- **Need to combine enforcement with a program of social marketing**
  - we need to keep the enforcement going but also inform and educate the public that speeding is a problem
    - : the community must be made to realise that enforcement is being undertaken to target the crime associated with speed
  - we need to sell the message that speed has social and economic consequences that are detrimental to the well being of society.
    - : speed should marketed as a crime against society

### 3. **ARE THERE SPECIFIC COUNTERMEASURES OR PROGRAMS REQUIRED TO ADDRESS THESE NEEDS?**

- **Need to increase public awareness of the crime associated with speed**
  - peoples attitudes to speeding must be changed in order to bring about modifications in speeding behaviour

- public acceptance of speed limits will only come about when
  - : the community starts to perceive excessive speeding as socially unacceptable behaviour.
    - + this can be achieved by making the community perception of people who speed the same as that for people who drink and drive.
  - : drivers agree with the posted speed limits and understand why particular limits apply to certain road environment conditions.
    - + this may require drivers to be educated as to why speed limits are used and in what particular situations.
- **Need to educate motorists about the use of enforcement methods**
  - Speeding behaviour may change if motorists understand why enforcement methods are in use
    - : all too often drivers view enforcement in a negative way not fully realising the adverse consequences associated with speeding.
- 4. **WHERE SHOULD RESEARCH AND DEVELOPMENT RESOURCES BE DIRECTED?**
  - **Time risk studies**
    - we need to look at why drivers speed and in particular the relationship between travel time, risk and speed behaviour
      - : one of the main reasons people speed seems to be because they want to get to their destination in as short a time as possible. This can result in a time / speed trade-off, although the benefits and disbenefits are often illusory
        - + drivers don't really appreciate the "marginal" benefits that accrue from speeding.
      - : the variable that can effect the time / speed trade-off is the amount of risk a driver is prepared to take to get to his or her intended destination as quickly as possible.
    - instead of expending a large amount of effort targeting speed behaviour what we should be doing is looking at the processes behind speeding
      - : what is needed is a good theory about why people speed.

- **Studies examining the benefits and effectiveness of various enforcement methods and devices.**
  - information is also required about the benefits, disbenefits and effectiveness of the various enforcement methods and devices that can be used to target speeding behaviour
    - : this will allow us to optimise the use of those methods and devices that are most cost effective.
  - when examining benefits one should take into consideration not only the cost and deterrence value but also the public perception of the device / method being used.
- **Studies that examine which enforcement methods work best in what situations and on which particular drivers**
  - We need to undertake studies examining which enforcement methods work best in what situations and on which particular drivers
    - : this will allow us to target particular situations and drivers with particular methods
      - + therefore allowing us to optimise the use of available resources.
- **An examination of alternative methods of enforcement**
  - an examination of alternative methods of enforcement such as self enforcement, engineering treatments and environmental adaptation should be undertaken
    - : we should not rely too heavily on traditional enforcement methods

## **5. IS THERE ANY RESEARCH CURRENTLY UNDERWAY OR PLANNED IN THIS AREA?**

- **Speed Camera evaluation in Victoria**
  - MUARC are close to completing their evaluation of the speed camera program in Victoria
    - : initial results relating to the effectiveness of the program and public acceptance are quite encouraging.
  - a speed Camera evaluation is also underway in NSW.

## 7. RESEARCH AND ACTION PRIORITIES

The final phase of the research program was to bring together the various research and action items identified in the literature review and workshop sessions into a comprehensive list and to prioritise these in terms of their importance and potential value to the community.

### 7.1 RESEARCH ITEMS AND PRIORITIES

A total of 22 outstanding research issues and questions were identified that need to be followed up to improve knowledge and provide direction for the development and implementation of speed related countermeasures. These are listed in Tables 7.1 (a, b, c) along with the type of research required, likely benefits for undertaking the research, and how feasible the research would be to undertake (from easy to difficult) given current methods and technology available.

From this information, it was possible to rate the “*importance*” of each item in terms of how desirable it is for improved information and knowledge.

In addition, indicative costs were also assigned to each research item to provide some indications of what the likely costs to undertake the work and the subsequent cost effectiveness of the research. These costs were on the basis of similar previous research efforts and are not meant to be anything more than indicative at this time. However, with this added information, an assessment of the “*value*” to the community of undertaking the research was also possible.

#### 7.1.1 Rating Research Priorities

An important aim of the project was to arrive at a comprehensive priority list of research and action items required to address speed related road trauma in this country. For the priority listing to be meaningful and of maximum usefulness, it was felt that it should reflect the views of a representative cross-section of the road safety research and policy making community.

To this end, the Speed Workshop had been called to elicit the assistance of a number of leading researchers and policy makers from across Australia and overseas. Thus, it was logical to ask each of the workshop participants to help in assigning priorities to the items they had assisted in compiling.

The research tables were distributed to each workshop participant with instructions about how to rate each item from 1 to 5 depending on their judgement for that item. Zeros were also allowed if the participant felt that there was absolutely no need for any particular research item. Participants were given over 2 weeks to make their judgements and every effort was made to obtain as many participant responses as possible to ensure the resultant listing was representative.

**IMPORTANCE JUDGEMENT:** The instructions asked for the participant to first rate how important they felt each item was for improved knowledge with a view to developing speed related accident countermeasures for the future. They were asked to assign the number 5 if they felt that a particular item was *very important* and the number 1 if they believed the item to be of *low importance*.

They were encouraged to use the full five points of the scale roughly evenly across the 22 research items to minimise the likelihood of bunching around the centre of the scale (central tendency effect). Moreover, they were to complete their importance judgements for each item before going on with any further assessments.

Table 7.1(a) Priority Ratings for Research Items

RESEARCH ITEM	TYPE OF RESEARCH	LIKELY BENEFITS	HOW FEASIBLE IS THE STUDY	IMPORTANCE (how desirable is it)	INDICATIVE COST	VALUE (can we afford it)
1. Establish a Crash Involvement function similar to a Solomon or Borkenstein curve for both fast and slow travellers	on-board monitors and a prospective study design (in-depth crash analysis)	Countermeasures Fewer crashes & injuries World first finding	Possible		> \$500k	
2. Development of theories (models) of both fast and slow travel speed behaviour (Why drivers choose to travel at particular travel speeds by time and locations)	on-board monitors and a prospective study design (observational and interview study)	Countermeasures Fewer crashes & injuries	Possible		< \$200k	
3. Confirm the existence of a 4th power rule for varying speed limits in Australia (confirm Nilsson's relationship between speed change and injury consequence)	Data analysis using existing States' experiences (both urban and rural)	Rational speed limits Fewer crashes & injuries (?) Useful model technology	Possible		< \$100k	
4. Establish acceptable crash risk for drivers using the "willingness to pay" method	Survey of drivers assessments	Improved knowledge Countermeasures (?)	Possible		< \$100k	
5. Cost-benefit analysis for determining speed limit (incl. mobility, transportation, environment, safety, access & travel time)	BCR analysis, surveys, other data analysis	Rational speed limits Improved knowledge	Possible		< \$100k	
6. Implications of speed zoning on the credibility of speed limits	Survey of drivers attitudes	Rational speed limits Better speed management	Easy		< \$50k	
7. More speed and crash analysis using risk assessment techniques	Risk analysis	Improved knowledge Measures (?) crashes (?)	Possible		< \$100k	

IMPORTANCE RATING SCALE: 5 = very important

to

1 = low importance

0 = not necessary

VALUE RATING SCALE: 5 = good value for money

to

1 = poor value

0 = no value at all



**Table 7.1(b) Priority Ratings for Research Items**

RESEARCH ITEM	TYPE OF RESEARCH	LIKELY BENEFITS	HOW FEASIBLE IS THE STUDY	IMPORTANCE (how desirable is it)	INDICATIVE COST	VALUE (can we afford it)
8. Improved knowledge of the relationship between road design and travel speed (how this influences drivers choice)	Observational studies, experimentation, driver surveys.	Countermeasures Better speed management Speed enforcement	Difficult		< \$200k	
9. Examination of the preferred method of repeater signing of speed zone limits (colours, numbers, other signs, on-board etc)	Observational studies, experimentation, and/or driver surveys.	Better speed management Improved enforcement Fewer crashes & injuries (?)	Easy		< \$100k	
10. Investigating the feasibility and means of variable speed limits to suit prevailing conditions (poor weather, high traffic, high pedestrians, high black spots, etc )	Feasibility study followed by experimentation, implementation & evaluate	Better speed management Improved enforcement Fewer crashes & injuries (?)	Possible		< \$150k	
11. Examination of the range and feasibility of speed limiting devices in passenger cars.	Feasibility study initially then in-vehicle trials	Fewer injuries & crashes (?) Enforcement & Mgmt.	Easy		< \$50k	
12. The consequence of the enforcement tolerance on travel speed.	Data analysis and observational studies	Better speed management Speed limit setting	Easy		< \$50k	
13. Better understanding of the mechanisms of enforcement (specific vs general deter )	Data analysis across different States & areas	Improved knowledge Countermeasures Improved enforcement	Difficult		< \$200k	
14. The role of rewards and punishments in improved enforcement (is there a role for merit as well as demerit points ?)	Trial programs and evaluation of their effectiveness	Improved enforcement Better speed management Fewer crashes & injuries (?)	Possible		< \$100k	

IMPORTANCE RATING SCALE: 5 = very important

to

1 = low importance

0 = not necessary

VALUE RATING SCALE: 5 = good value for money

to

1 = poor value

0 = no value at all

Table 7.1(c) Priority Ratings for Research Items

RESEARCH ITEM	TYPE OF RESEARCH	LIKELY BENEFITS	HOW FEASIBLE IS THE STUDY	IMPORTANCE (how desirable is it)	INDICATIVE COST	VALUE (can we afford it)
15. Assessment of community attitudes to enforcement (police, cameras, other)	Community surveys	Improved enforcement Better speed management	Easy		< \$100k	
16. Measurement of the travel time benefits of speeding in rural & urban environments	Observational studies, Driver surveys	Education & promotion Better speed management Fewer crashes & injuries	Easy		< \$100k	
17. Cost-benefit analysis of the various types of enforcement methods.	Data analysis by State BCR analysis	Improved enforcement Better speed management	Possible		< \$100k	
18. Further research into understanding and exploiting perceptual measures against speeding (eg; low cost road treatments)	Trial programs and evaluation of their effectiveness, more experimentation	Better speed management Improved enforcement Fewer crashes & injuries	Easy		< \$100k	
19. Better understanding the role and mechanisms of speed adaptation in excessive speeding and crashes	Data analysis and experimentation studies	Speed limit setting Countermeasures Fewer crashes & injuries	Difficult		< \$200k	
20. Evaluate the effects of LATM devices on speed, crashes, & relative effectiveness (including interactive effects)	Data analysis, observational studies, on-road tests	Better speed management Fewer crashes & injuries	Possible		< \$250k	
21. Examine the system-wide effects of LATM's (speed and crash migration, congestion, etc)	Data analysis, observational studies, on-road tests	Improved knowledge Better speed management	Difficult		< \$100k	
22. Evaluate community acceptance and attitudes to LATM devices)	Community surveys	Better speed management	Easy		< \$100k	

IMPORTANCE RATING SCALE: 5 = very important

to

1 = low importance

0 = not necessary

VALUE RATING SCALE: 5 = good value for money

to

1 = poor value

0 = no value at all

**VALUE JUDGEMENT:** Once the importance judgements had been made, the participants were then asked to rate the value of each research item in terms of how affordable they felt it would be and whether it was likely to be a good expense of research funds (ie: that it was likely to be in some general sense cost effective). They were asked to assign the number 5 for items they felt were *good value for money* and the number 1 for items they believed to be *poor value*. Again, they were encouraged to use the full five points of the scale roughly evenly across the 22 research items for reasons previously discussed.

## 7.2 ACTION ITEMS AND PRIORITIES

Action items differed from research items in that their shortcomings were not in the level of knowledge or the availability of suitable countermeasures but rather in the lack of implemented programs and/or evaluation of their likely success. There were 12 action items identified during this project that could also be prioritised. These are listed in Tables 7.2 (a, b) along with the type of action proposed, the likely benefits to accrue from their implementation, and how feasible it would be to implement and evaluate them, again from easy to difficult.

As with the research items, workshop participants were asked to make judgements on the importance they placed on each item and the value they believed it represented in reducing speed related trauma in this country. The method and instructions were similar to those described above for the research items. Costs were generally restricted to the measure being implemented in a pilot program to demonstrate its desirability and benefits. Possibilities for self-funding of these measures or programs (ie; through generating their own revenue from fines, etc) were alluded to but not included in these costs.

Once again, the participants were asked to use all 5 points on the rating scales roughly evenly across the 12 judgements for both the importance and the value judgements. There was no encouragement given to rate the relative importance of research over action items but this was somewhat implied by distribution differences seen between the research and action items for each participant.

## 7.3 PRIORITY RESULTS

At the time of compiling this report, responses had been received from 82% of the participants. Each individual's results were entered onto a spreadsheet comprising columns for each item by research or action and by type of judgement (importance or value). Each participant was also coded in terms of four possible categories of organisation and/or interest groups they represented, namely:

- Researchers;
- State Government authorities;
- Federal Government authorities; and
- Motorists' representatives.

This was done so that the responses could be further summarised across these different interests to reflect possible differences in priority order by type of activity. The summary of the findings for the Research Items (importance and value) is shown in Tables 7.3 and 7.4 while the equivalent Action findings are summarised in Tables 7.5 and 7.6.

Table 7.2(a) Priority Ratings for Action Items

ACTION ITEM	TYPE OF ACTION	LIKELY BENEFITS	HOW FEASIBLE IS THE ACTION	IMPORTANCE (how desirable is it)	INDICATIVE COST	VALUE (can we afford it)
1. Greater attention to punishing deviant speeders (persistent violators) through severe fines and penalties.	legislation court practices publicity	fewer excessive speeders fewer repeat offenders fewer crashes/injuries	Easy			
2. Introducing behaviour modification programs for deviant speeders.	psychological programs	discourage speeders Fewer crashes & injuries fewer violators	Possible			
3. Develop and trial alternative (supplement) forms of speed enforcement techniques (on-board monitors, violation recorders, etc)	Vehicle design IVHS road sensors	speed management Fewer crashes & injuries (?) less policing	Difficult			
4. Develop a change in community attitude to speeding (the BAC experience) through publicity, education, and enforcement	publicity education enforcement	better attitude to speeding higher compliance fewer crashes/injuries	Possible			
5. Greater use of low-cost road treatments to change drivers' perception and modify speed behaviour at those sites	road markings minor road construction signing	black-spot improvements some area-wide effects	Easy			
6. More wide-spread use of effective speed enforcement technology (eg: Victoria's recent speed camera program)	publicity camera enforcement legislation	general speed reductions changed attitude to speeding fewer crashes/injuries	Easy			
7. Introduction of top speed limiting devices on a suitable sample of passenger cars (persistent violators, volunteers, fleet)	Vehicle design enforcement education	excessive speed reductions higher compliance fewer crashes/injuries	Possible			

IMPORTANCE RATING SCALE: 5 = very important

to

1 = low importance

0 = not necessary

VALUE RATING SCALE: 5 = good value for money

to

1 = poor value

0 = no value at all

**Table 7.2(b) Priority Ratings for Action Items**

ACTION ITEM	TYPE OF ACTION	LIKELY BENEFITS	HOW FEASIBLE IS THE ACTION	IMPORTANCE (how desirable is it)	INDICATIVE COST	VALUE (can we afford it)
8. Campaign to persuade auto manufacturers to stop stressing how fast their particular models can travel	education enforcement	less emphasis on speeding changed public attitude	Possible			
9. Better ergonomically designed speed displays for ease of reading how fast	vehicle design education legislation	higher compliance fewer unintentional speeders	Possible			
10. Greater attention to repeater signing of speed limit in current (new) speed zones	signing road marking	higher compliance fewer unintentional speeders	Easy			
11. Improved education (publicity) to inform motorists of speed zoning practices and current (proposed) speed limits	publicity education	higher compliance fewer unintentional speeders	Easy			
12. Development of an AUSLIMITS system for setting speed limits across all States and Territories in Australia	ARRB expert system	rational speed limits (Australia-wide) better speed management	Easy			

IMPORTANCE RATING SCALE: 5 = very important

to

1 = low importance

0 = not necessary

VALUE RATING SCALE: 5 = good value for money

to

1 = poor value

0 = no value at all

### 7.3.1 Research Priorities

**IMPORTANCE RANKINGS:** Table 7.3 shows the overall ranking of priority in terms of how important each of the 22 research items was perceived to be. For the overall judgements, the top 6 items were:

1. The relationship between road design and travel speed (mean=3.83)
2. Understanding and exploiting perceptual countermeasures (mean=3.80)
3. Speed zoning and the credibility of speed limits (mean=3.71)
4. Development of behavioural models for fast and slow travellers (mean=3.60)
5. Establishment of an accurate crash involvement function (mean=3.54)
6. Effectiveness of LATM's on speed and crash rates (mean=3.49)

Researchers judged the crash involvement function and design speed as equal top priority; State authorities, design speed; Federal authorities, perceptual countermeasures; and motorist representatives, effectiveness of repeater signing.

**VALUE JUDGEMENTS:** Table 7.4 describes the overall priority ranking in terms of the value each participant assigned to each of the 22 research items. Across the total responses, the top 6 items were:

1. Understanding and exploiting perceptual countermeasures (mean=3.86)
2. Speed zoning and the credibility of speed limits (mean=3.83)
3. Consequence of enforcement tolerance on travel speed and limits (mean=3.66)
4. Preferred means of repeater signing (mean=3.43)
5. The relationship between road design and travel speed (mean=3.31)
6. Confirm the existence of a 4th power rule in Australia (mean=3.29)

Again, there were differences in value priority across the four interest groups. Researchers nominated the 4th power rule to be highest priority; State and Federal authorities, credibility of speed zones; while motorist representative priorities were spread across four items.

### 7.3.2 Action Priorities

**IMPORTANCE RANKINGS:** The overall priority ranking is shown in Table 7.5 where the more frequent items were:

1. Pilot testing of low-cost road treatments to modify speed perception (mean=3.97)
2. Develop a change in community attitude to speeding (mean=3.91)
3. Wider use of effective speed enforcement technology (mean=3.74)
4. Introduction of a trial of top speed limiters on sample of vehicles (mean=3.43)
5. An AUSLIMITS system for use across all States and Territories (mean=3.40)
6. Education (publicity) to inform motorists of speed zones and practices (mean=3.26)

Table 7.3 Summary of Importance Priorities for Research Items

	Involvement curve	Behaviour models	4th power rule	Willing-to-pay	Speed limit BCR	Zone creditability	Risk analysis	Design & speed	Repeater signing	Variable limits	Speed limiters	Enforce-tolerance	Enforce_mechanism	Reward & punish	Enforce_attitudes	Travel time benefits	Enforcement BCR's	Perceptual measures	Speed adaptation	LATM effectiveness	LATM system-wide	LATM acceptance
<b>SUM</b>	124	126	111	67	116	130	94	134	115	113	108	115	115	79	85	83	112	133	94	122	107	85
<b>AVERAGE</b>	3.54	3.60	3.17	1.91	3.31	3.71	2.69	3.83	3.29	3.23	3.09	3.29	3.29	2.26	2.43	2.37	3.20	3.80	2.69	3.49	3.06	2.43
<b>FREQUENCY OF 0</b>	0	0	1	3	0	1	1	0	0	0	2	0	0	2	1	0	0	1	1	0	0	1
<b>FREQUENCY OF 1</b>	4	1	5	8	7	1	3	1	4	5	6	4	3	10	8	9	0	0	6	2	4	8
<b>FREQUENCY OF 2</b>	6	5	4	16	3	5	12	1	8	4	4	5	8	10	8	10	11	3	8	5	8	10
<b>FREQUENCY OF 3</b>	5	10	10	5	6	4	12	9	8	9	6	11	8	4	13	11	9	8	10	7	8	9
<b>FREQUENCY OF 4</b>	7	10	7	3	10	13	4	16	4	12	9	7	8	8	3	4	12	12	8	16	12	5
<b>FREQUENCY OF 5</b>	13	9	8	0	9	11	3	8	11	5	8	8	8	1	2	1	3	11	2	5	3	2
<b>IMPORTANCE JUDGEMENT - RESEARCHERS</b>																						
<b>SUM</b>	58	50	55	26	49	52	36	58	49	54	50	53	45	34	35	43	44	54	38	53	45	33
<b>AVERAGE</b>	3.87	3.33	3.67	1.73	3.27	3.47	2.40	3.87	3.27	3.60	3.33	3.53	3.00	2.27	2.33	2.87	2.93	3.60	2.53	3.53	3.00	2.20
<b>IMPORTANCE JUDGEMENT - STATE AUTHORITIES</b>																						
<b>SUM</b>	48	53	36	29	43	56	39	56	46	43	40	43	48	33	35	28	47	52	38	47	44	32
<b>AVERAGE</b>	3.43	3.79	2.57	2.07	3.07	4.00	2.79	4.00	3.29	3.07	2.86	3.07	3.43	2.36	2.50	2.00	3.36	3.71	2.71	3.36	3.14	2.29
<b>IMPORTANCE JUDGEMENT - FEDERAL AUTHORITIES</b>																						
<b>SUM</b>	9	13	12	4	11	13	9	10	6	7	8	9	12	2	8	5	9	14	9	13	12	12
<b>AVERAGE</b>	3.00	4.33	4.00	1.33	3.67	4.33	3.00	3.33	2.00	2.33	2.67	3.00	4.00	0.67	2.67	1.67	3.00	4.67	3.00	4.33	4.00	4.00
<b>IMPORTANCE JUDGEMENT - MOTORISTS' REPRESENTATIVES</b>																						
<b>SUM</b>	9	10	8	8	13	9	10	10	14	9	10	10	10	10	7	7	12	13	9	9	6	8
<b>AVERAGE</b>	3.00	3.33	2.67	2.67	4.33	3.00	3.33	3.33	4.67	3.00	3.33	3.33	3.33	3.33	2.33	2.33	4.00	4.33	3.00	3.00	2.00	2.67

Table 7.4 Summary of Value Priorities for Research Items

	Involvement curve	Behaviour models	4th power rule	Willing-to-pay	Speed limit BCR	Zone credibility	Risk analysis	Design & speed	Repeater signing	Variable limits	Speed limiters	Enforce-tolerance	Enforce_mechanism	Reward & punish	Enforce_attitudes	Travel time benefits	Enforcement BCR's	Perceptual measures	Speed adaptation	LATM effectiveness	LATM system-wide	LATM acceptance
<b>SUM</b>	88	102	115	62	108	134	87	116	120	112	112	128	97	77	83	82	112	135	72	105	102	87
<b>AVERAGE</b>	2.51	2.91	3.29	1.77	3.09	3.83	2.49	3.31	3.43	3.20	3.20	3.66	2.77	2.20	2.37	2.34	3.20	3.86	2.08	3.00	2.91	2.49
<b>FREQUENCY OF 0</b>	0	0	1	3	0	1	1	0	1	0	3	0	0	2	2	0	0	1	2	0	1	2
<b>FREQUENCY OF 1</b>	13	4	6	12	10	2	8	3	3	6	3	1	8	13	8	9	1	1	9	7	5	8
<b>FREQUENCY OF 2</b>	7	11	4	13	2	2	8	3	5	5	7	4	6	6	11	11	9	2	13	5	7	8
<b>FREQUENCY OF 3</b>	4	8	6	5	6	6	10	16	8	9	2	10	10	7	6	9	11	5	8	8	10	9
<b>FREQUENCY OF 4</b>	6	8	7	1	9	10	7	6	7	8	11	11	8	4	5	6	10	15	2	11	7	4
<b>FREQUENCY OF 5</b>	5	4	11	1	8	14	1	7	11	9	9	9	3	3	3	0	4	11	1	4	5	4
<b>VALUE JUDGEMENT - RESEARCHERS</b>																						
<b>SUM</b>	40	41	60	24	47	54	33	51	54	53	50	51	39	34	32	40	48	55	32	54	42	37
<b>AVERAGE</b>	2.67	2.73	4.00	1.60	3.13	3.60	2.20	3.40	3.60	3.53	3.33	3.40	2.60	2.27	2.13	2.67	3.20	3.67	2.13	3.60	2.80	2.47
<b>VALUE JUDGEMENT - STATE AUTHORITIES</b>																						
<b>SUM</b>	38	41	36	27	39	56	36	48	45	40	42	54	40	31	37	29	45	53	26	33	41	34
<b>AVERAGE</b>	2.71	2.93	2.57	1.93	2.79	4.00	2.57	3.43	3.21	2.86	3.00	3.86	2.86	2.21	2.64	2.07	3.21	3.79	1.86	2.36	2.93	2.43
<b>VALUE JUDGEMENT - FEDERAL AUTHORITIES</b>																						
<b>SUM</b>	5	12	11	3	9	15	7	7	8	8	9	10	10	2	7	5	8	14	6	11	12	12
<b>AVERAGE</b>	1.67	4.00	3.67	1.00	3.00	5.00	2.33	2.33	2.67	2.67	3.00	3.33	3.33	0.67	2.33	1.67	2.67	4.67	2.00	3.67	4.00	4.00
<b>VALUE JUDGEMENT - MOTORISTS' REPRESENTATIVES</b>																						
<b>SUM</b>	5	8	8	8	13	9	11	10	13	11	11	13	8	10	7	8	11	13	8	7	7	4
<b>AVERAGE</b>	1.67	2.67	2.67	2.67	4.33	3.00	3.67	3.33	4.33	3.67	3.67	4.33	2.67	3.33	2.33	2.67	3.67	4.33	2.67	2.33	2.33	1.33



**Table 7.5 Summary of Importance Priorities for Action Items**

	Punishment	Behave Mod	Auto enforcement	Changed attitude	Percept. markings	Wider enforcement	Top speed limiters	No speed ads	Better displays	Repeat signing	Zoning education	Auslimits
<b>SUM</b>	<b>76</b>	<b>80</b>	<b>105</b>	<b>137</b>	<b>139</b>	<b>131</b>	<b>120</b>	<b>86</b>	<b>71</b>	<b>112</b>	<b>114</b>	<b>119</b>
<b>AVERAGE</b>	<b>2.17</b>	<b>2.29</b>	<b>3.00</b>	<b>3.91</b>	<b>3.97</b>	<b>3.74</b>	<b>3.43</b>	<b>2.46</b>	<b>2.03</b>	<b>3.20</b>	<b>3.26</b>	<b>3.40</b>
<i>FREQUENCY OF 0</i>	1	2	2	0	0	0	0	2	2	0	0	0
<i>FREQUENCY OF 1</i>	15	6	1	2	1	2	4	10	17	4	2	3
<i>FREQUENCY OF 2</i>	6	15	6	1	4	4	7	8	2	5	8	5
<i>FREQUENCY OF 3</i>	7	6	16	8	6	8	5	5	8	8	8	8
<i>FREQUENCY OF 4</i>	2	4	6	11	8	8	8	5	4	16	13	13
<i>FREQUENCY OF 5</i>	4	2	4	13	16	13	11	5	2	2	4	6
<b>IMPORTANCE JUDGEMENT - RESEARCHERS</b>												
<b>SUM</b>	<b>35</b>	<b>35</b>	<b>49</b>	<b>59</b>	<b>62</b>	<b>64</b>	<b>58</b>	<b>33</b>	<b>32</b>	<b>47</b>	<b>43</b>	<b>54</b>
<b>AVERAGE</b>	<b>2.33</b>	<b>2.33</b>	<b>3.27</b>	<b>3.93</b>	<b>4.13</b>	<b>4.27</b>	<b>3.87</b>	<b>2.20</b>	<b>2.13</b>	<b>3.13</b>	<b>2.87</b>	<b>3.60</b>
<b>IMPORTANCE JUDGEMENT - STATE AUTHORITIES</b>												
<b>SUM</b>	<b>29</b>	<b>36</b>	<b>44</b>	<b>51</b>	<b>53</b>	<b>46</b>	<b>41</b>	<b>37</b>	<b>27</b>	<b>43</b>	<b>48</b>	<b>43</b>
<b>AVERAGE</b>	<b>2.07</b>	<b>2.57</b>	<b>3.14</b>	<b>3.64</b>	<b>3.79</b>	<b>3.29</b>	<b>2.93</b>	<b>2.64</b>	<b>1.93</b>	<b>3.07</b>	<b>3.43</b>	<b>3.07</b>
<b>IMPORTANCE JUDGEMENT - FEDERAL AUTHORITIES</b>												
<b>SUM</b>	<b>5</b>	<b>3</b>	<b>6</b>	<b>14</b>	<b>13</b>	<b>10</b>	<b>9</b>	<b>6</b>	<b>7</b>	<b>9</b>	<b>11</b>	<b>10</b>
<b>AVERAGE</b>	<b>1.67</b>	<b>1.00</b>	<b>2.00</b>	<b>4.67</b>	<b>4.33</b>	<b>3.33</b>	<b>3.00</b>	<b>2.00</b>	<b>2.33</b>	<b>3.00</b>	<b>3.67</b>	<b>3.33</b>
<b>IMPORTANCE JUDGEMENT - MOTORISTS' REPRESENTATIVES</b>												
<b>SUM</b>	<b>7</b>	<b>6</b>	<b>6</b>	<b>13</b>	<b>11</b>	<b>11</b>	<b>12</b>	<b>10</b>	<b>5</b>	<b>13</b>	<b>12</b>	<b>12</b>
<b>AVERAGE</b>	<b>2.33</b>	<b>2</b>	<b>2</b>	<b>4.33</b>	<b>3.67</b>	<b>3.67</b>	<b>4</b>	<b>3.33</b>	<b>1.67</b>	<b>4.33</b>	<b>4</b>	<b>4</b>

**Table 7.6 Summary of Value Priorities for Action Items**

	Punishment	Behave Mod	Auto enforcement	Changed attitude	Percept. markings	Wider enforcement	Top speed limiters	No speed ads	Better displays	Repeat signing	Zoning education	Auslimits
<b>SUM</b>	<b>86</b>	<b>73</b>	<b>74</b>	<b>117</b>	<b>145</b>	<b>118</b>	<b>122</b>	<b>81</b>	<b>86</b>	<b>106</b>	<b>87</b>	<b>124</b>
<b>AVERAGE</b>	<b>2.46</b>	<b>2.09</b>	<b>2.11</b>	<b>3.34</b>	<b>4.14</b>	<b>3.37</b>	<b>3.49</b>	<b>2.31</b>	<b>2.46</b>	<b>3.03</b>	<b>2.49</b>	<b>3.54</b>
<i>FREQUENCY OF 0</i>	2	2	2	0	0	0	0	2	2	0	2	1
<i>FREQUENCY OF 1</i>	12	12	10	2	0	2	2	13	13	5	3	3
<i>FREQUENCY OF 2</i>	3	10	11	6	3	8	6	5	3	9	12	2
<i>FREQUENCY OF 3</i>	7	6	7	12	7	7	10	6	7	6	14	11
<i>FREQUENCY OF 4</i>	8	2	4	8	7	11	7	5	4	10	2	6
<i>FREQUENCY OF 5</i>	3	3	1	7	18	7	10	4	6	5	2	12
<b>VALUE JUDGEMENT - RESEARCHERS</b>												
<b>SUM</b>	<b>38</b>	<b>27</b>	<b>35</b>	<b>50</b>	<b>61</b>	<b>56</b>	<b>51</b>	<b>27</b>	<b>37</b>	<b>47</b>	<b>36</b>	<b>54</b>
<b>AVERAGE</b>	<b>2.53</b>	<b>1.80</b>	<b>2.33</b>	<b>3.33</b>	<b>4.07</b>	<b>3.73</b>	<b>3.40</b>	<b>1.80</b>	<b>2.47</b>	<b>3.13</b>	<b>2.40</b>	<b>3.60</b>
<b>VALUE JUDGEMENT - STATE AUTHORITIES</b>												
<b>SUM</b>	<b>35</b>	<b>37</b>	<b>31</b>	<b>43</b>	<b>59</b>	<b>44</b>	<b>51</b>	<b>40</b>	<b>34</b>	<b>38</b>	<b>31</b>	<b>48</b>
<b>AVERAGE</b>	<b>2.50</b>	<b>2.64</b>	<b>2.21</b>	<b>3.07</b>	<b>4.21</b>	<b>3.14</b>	<b>3.64</b>	<b>2.86</b>	<b>2.43</b>	<b>2.71</b>	<b>2.21</b>	<b>3.43</b>
<b>VALUE JUDGEMENT - FEDERAL AUTHORITIES</b>												
<b>SUM</b>	<b>5</b>	<b>3</b>	<b>3</b>	<b>11</b>	<b>13</b>	<b>8</b>	<b>8</b>	<b>5</b>	<b>8</b>	<b>8</b>	<b>9</b>	<b>10</b>
<b>AVERAGE</b>	<b>1.67</b>	<b>1.00</b>	<b>1.00</b>	<b>3.67</b>	<b>4.33</b>	<b>2.67</b>	<b>2.67</b>	<b>1.67</b>	<b>2.67</b>	<b>2.67</b>	<b>3.00</b>	<b>3.33</b>
<b>VALUE JUDGEMENT - MOTORISTS' REPRESENTATIVES</b>												
<b>SUM</b>	<b>8</b>	<b>6</b>	<b>5</b>	<b>13</b>	<b>12</b>	<b>10</b>	<b>12</b>	<b>9</b>	<b>7</b>	<b>13</b>	<b>11</b>	<b>12</b>
<b>AVERAGE</b>	<b>2.67</b>	<b>2</b>	<b>1.67</b>	<b>4.33</b>	<b>4</b>	<b>3.33</b>	<b>4</b>	<b>3</b>	<b>2.33</b>	<b>4.33</b>	<b>3.67</b>	<b>4</b>

Top priority for each interest group for the importance judgement of action items was wider use of enforcement technology for researchers; perceptual marking trial for State authorities; changed community attitude for Federal authorities; and evenly divided between changed attitude and repeater signing among the motorist representatives.

**VALUE JUDGEMENTS:** Table 7.6 describes the priority ranking in terms of the value each participant assigned to the 12 action items. The most common items were:

1. Pilot testing of low-cost road treatments to modify speed perception (mean=4.14)
2. An AUSLIMITS system for use across all States and Territories (mean=3.54)
3. Introduction of a trial of top speed limiters on sample of vehicles (mean=3.49)
4. Wider use of effective speed enforcement technology (mean=3.37)
5. Develop a change in community attitude to speeding (mean=3.34)
6. Greater attention to repeater signing in speed zones (mean=3.03)

There was a high degree of consensus among the various interest groups for the value judgement on action items. Researchers and State and Federal authorities all assigned greatest value priority to a trial of low-cost road treatments; while motorist representative priorities were again split between changed community attitude and repeater signing.

## **7.4 FUTURE SPEED RESEARCH NEEDS**

A number of important speed related research needs have been identified from this program. Those which have been singled out as high priority items in terms of their importance and value to the community are discussed further below.

### **7.4.1 Perceptual Countermeasures**

There was a high degree of consensus among the respondents for further research aimed at identifying low cost road treatments that are likely to influence travel speed through visual perception cues. The literature review documented previous attempts to exploit a driver's perception of the road and the surrounding environment in speed management and the scope (and possible limitations) for further improvements using this subtle intervention.

A number of promising treatments of this kind have already been identified which have potential to modify drivers' perception resulting in lower travel speeds (see Fildes et al 1989 for a list of these treatments). However, very few of them have been systematically implemented and evaluated for their effectiveness in robust on-road trials. The authors believe that at this stage, priority should be given to demonstration projects to evaluate their speed reduction potential, rather than research to identify possible new treatments.

### **7.4.2 Credibility of Speed Zoning**

Current speed zoning practices are aimed at achieving a more consistent relationship between posted speed limits and the characteristics of particular sections of road. It is intended that the use of a broad range of speed limits to suit particular roads and environments will lead to greater acceptance of these limits by the motoring public by seeming to be a more reasonable and rational system. While the basis for determining speed limits and the wider range of limits

actually employed under speed zoning seems most appropriate, the ultimate test will be in whether motorists believe them to be reasonable.

A survey of drivers' perceptions and attitudes to these zone limits as well as on-road speed studies would measure two aspects of effective speed zoning practices. First, whether current (proposed) speed limits have improved the credibility of existing speed limits. Second, while speed zones are expected to lead to more efficient speed management and enforcement practices, this study would help demonstrate the strength of the relationship between credible limits and subsequent speed behaviour and performance.

### **7.4.3 Road Design and Travel Speed**

A somewhat related issue is the influence that the design speed of a road has on speed behaviour and speed limits. Current practice for highway design in rural areas stipulates a design speed well in excess of current posted speed limits for these roads. Typically, a modern rural highway will adopt a 130km/h design speed criteria, yet be posted at either 100 or 110km/h. It is assumed that the 20 or 30km/h buffer between the design and travel speed adds an extra element of safety to these roads by providing additional time to respond to a hazardous situation than that considered to be minimum requirements. (Design speed is a somewhat arbitrary concept and does not correspond to any clearly defined level of safety.)

In actual fact, the discrepancy between design and legal speed may only serve to frustrate motorists and destroy the credibility of these limits. If the design speed concept is accurate, then motorists may perceive these roads to be capable of speeds well in excess of the limits. This could lead to dissatisfaction and low compliance (higher travel speeds than desired) possibly resulting in higher enforcement requirements and more severe injuries from higher speed crashes.

On the other hand, lower design speeds would mean shorter times for responding to hazards which could lead to higher crash rates, even if travel speeds were somewhat lower.

It may be possible to tease out the effect that design speed has on travel speeds and crash and injury rates from studies of existing roads. Relative speed distributions and exposure controlled crash rates could be compared for roads of different design speeds. In particular, roads that have been recently duplicated (where one lane is at a lower design speed than the other) would seem to be ideal candidates for such a study. Differences could be assessed in terms of their costs and benefits as well as speed management implications.

### **7.4.4 Crash Involvement and Behavioural Characteristics**

These items were judged to be of high priority for importance but of lower priority in terms of their value. This is presumably because of the rather high costs associated with this research and the uncertainty associated with obtaining valid speed measurements. Indeed, the literature review showed that previous attempts to specify the relationship between travel speed and crash involvement has been fraught with problems and uncertainty arising from the use of retrospective measures of the speed of crash involved vehicles.

By far the best, most accurate method of determining the travel speed of crash involved vehicles would be from an on-board monitor of travel speed for a period preceding the crash. While devices are available that will provide these data, they have tended to be expensive because of low production runs and a degree of over-sophistication. It should be possible to design a

specific device to provide these data relatively cheaply so that sufficient of them could be fitted to a large enough sample of vehicles to provide meaningful results. Locating such a sample and gaining the necessary acceptance and overcoming the likely high financial cost associated with the study would be a challenge.

In the first instance, a feasibility study would seem warranted to come up with a suitable device, to demonstrate the effectiveness of the device in providing these data, and to investigate ways of fitting sufficient devices to a random sample of cars to warrant a full study. This could involve discussions with suitable sponsors (insurance companies, car manufacturers, fleet owners, etc) to assess their willingness to be involved in the study.

While the problems in mounting such a study may seem immense, the benefits of having these data will also be significant. It will be possible for the first time to determine accurate relationships between travel speed and crash involvement across a range of different road and environment types. This will lead to a more rational approach to setting speed limits and enforcement tolerances, similar to that experienced once Borkenstein had specified the relationship between BAC level and crash involvement. Accurate functions will open the way for considering alternative methods for setting speed limits such as the cost-benefit or crash minimising approaches discussed earlier. Such a study would really be a world-first and place Australia in the forefront of speed management and control internationally.

Behavioural correlates would follow from detailed investigations of crash involved and non-crash involved drivers. This would also serve to target particular groups at risk of being involved in speed related crashes and illustrate potential interactions with other important covariables (alcohol, drugs, age/experience, roads, environments, travel factors, etc). This work would be valuable in understanding the reasons for dangerous speeding and countermeasures to overcome this.

#### **7.4.5 LATM Effectiveness**

There have been very few studies which have attempted to assess the effectiveness of current Local Area Traffic Management (LATM) devices in terms of their speed and crash reduction effects. Current traffic management practice includes the use of a range of devices yet little evidence is available on their effectiveness and suitability for improving road safety. This includes the devices by themselves or in combination with other types of measures.

It should be possible to make these assessments from existing databases. Similar treated and untreated roads could be compared across the road network to show overall effects. Various treatments (and combinations of treatments) could then be identified and tested for relative effectiveness. Evaluation of existing black-spot programs which have been undertaken recently could be useful for providing these data. The benefits would be in being able to prescribe the most effective and suitable treatments to reduce travel speeds and accidents in local streets and black-spot locations.

#### **7.4.6 Enforcement Tolerance**

The effect of an enforcement tolerance on the posted speed limit has been shown in Sweden to lead to an increase in mean travel speed (Nilsson 1992). It is argued that once motorists get to know what the tolerance is, they readjust their speed behaviour around the tolerance level. As such, the tolerance level becomes the surrogate speed limit for that roadway. Enforcement

tolerance effects, therefore, have implications for proposed speed zoning and its credibility among motorists.

The degree to which overseas experience translates to Australia is an important issue. It has implications for methods of setting speed limits in this country and for enforcement effort. Travel speeds (and associated crash rates) could be compared following the introduction of revised speed zones, along with assessments of motorists' knowledge of enforcement tolerances. Enforcement effort and tolerance could be systematically varied in particular regions to test the effects on subsequent travel speeds and crashes.

#### **7.4.7 Fourth Power Rule in Australia**

Nilsson's keynote workshop paper (see Appendix) describes the relationship between changes in the posted speed limit and the safety consequences. He proposed a *fourth power rule* between changes fatal and severe accidents and the mean (median) travel speed, based on overseas data (as well as third and second power rules for lesser severe crashes and injuries). In the event that the fourth power rule should apply in this country too, the implications are crucial for current speed management practices. Its existence particularly among severe crashes should be able to be tested from recent changes in the speed limits in a number of Australian states.

#### **7.4.8 Database Requirements**

Many of the research items and priorities identified highlight the need for more accurate and extensive speed data. This varies from accurate speed data for crash involved vehicles to the ability to quickly and accurately assess the on-road consequences of changes in speed management policies and practices. Sweden has commenced an extensive system of recording free speed measurements across the country for monitoring the effects of these changes as well as changes in general. A limited system exists in some States in Australia for the collection of regular speed data. While a more extensive system similar to that in Sweden would be relatively expensive to install and maintain, it would provide meaningful data on which rational speed management policy could be based.

### **7.5 FUTURE SPEED ACTION REQUIREMENTS**

A number of priority action requirements were also identified in this research program to reduce speed related trauma and improve the efficiency of the road system that can also be considered for future implementation and evaluation.

#### **7.5.1 Perceptual Measures**

This item was clearly the highest priority action item identified both in terms of importance and value. Many of the respondents from both research and administration areas clearly supported the need for more wide-spread use of low cost road treatments to address the speeding problem. Interestingly, this item also featured prominently as an area requiring further research, too.

It was argued earlier that a number of promising treatments of this kind have already been identified (see Fildes et al 1989 for a list of these treatments) which have potential to modify drivers' perception resulting in lower travel speeds. However, very few of them have been systematically implemented and evaluated for their effectiveness in robust on-road trials. It would be relatively easy for a selection of the more promising of these treatments (and any other contenders) to be applied at a number of suitable road sites (using a case-control format or

equivalent) to assess their speed reduction, crash savings, and any other possible benefits or disbenefits over say a one or two year trial period. The local vs wide-spread effectiveness as well as the long-term effects would need to be examined during this trial to demonstrate whether they are effective for both general and/or site specific use.

### **7.5.2 Top Speed Limiters**

The undesirable high discrepancy between the top speed of many vehicles in this country (often over 200km/h) and the uppermost speed limit on most Australian roads of 110km/h has ramifications for good speed management and lower risk of injury (and possibly lower crash involvement too) in this country. It is difficult to substantiate such large discrepancies without challenging the need for upper speed limits.

A top speed limiter on all passenger cars in Australia (allowing a delay period of say 5 to 10 seconds for overtaking) would seem warranted to reduce injury (and hopefully crash) risk and minimise enforcement effort on rural highways. To demonstrate their effectiveness and potential savings and problems associated with these devices, a pilot program could be initiated on a suitable sample of vehicles (persistent speed violators, volunteers, fleet vehicles, etc) and monitored over a sufficient period of time. Suitable tamper-free devices are already available that will not interfere with acceleration rates but limit top speed.

### **7.5.3 Changed Community Attitude to Speeding**

The need for a change in community attitude to speeding was rated highly desirable among the expert groups assembled for this project. There was a sense expressed that many motorists do not perceive it to be dangerous to speed (amongst some motorists, speeding was seen as acceptable behaviour in much the same way that drink-driving was in the late 60's and early 70's). Thus, it was felt that a similar program to that undertaken many years earlier to bring about a change the community attitude to drink-driving was warranted here.

There was consensus that the change in community attitude to drink-driving has been dependent upon a continuing (reinforcing) series of measures, encompassing publicity, education, enforcement, and engineering initiatives. Many of these have been evaluated and shown to have positive cost-effective benefits. The speed camera programs in Victoria and New South Wales are an attempt to bring about a similar change in attitude to speeding. These programs need the support of other measures as well (eg; further education as information becomes available, perceptual and other engineering road treatments, behavioural programs where appropriate, exposure reduction measures). Opportunities for programs to be self-funding would ensure continuing commitment to these measures. The BAC experience suggests that a change in community attitude will not happen quickly and will require a sustained program of on-going activity over several years.

### **7.5.4 Australia-Wide Speed Limits**

Varying speed limits for similar roads and environments across different States and Territories was seen as an undesirable feature for ensuring credible speed limits among motorists. It is difficult to substantiate differences of 10 to 20 percent in speed limits for similar environments, especially with a high level of interstate motoring in Australia. The more widespread use of VLIMITS technology for determining appropriate speed limits on roadways was seen to be desirable in that it is a relative "*objective*" means of setting limits. Thus, there was a strong call for an AUSLIMITS system for general use throughout Australia. Extreme differences in

environments and traffic levels would seem to be manageable within the current design parameters of the expert system.

#### **7.5.5 Speed Zone Knowledge and Practices**

There was some support for more publicity and education among motorists of current speed zone policies and practices throughout Australia. A view noted in the literature and confirmed by a number of respondents was that the majority of motorists are much more likely to comply with speed limits when they understand the reasons and rationale for them. Moreover, it is unfair to expect all motorists to appreciate the speed zone requirements after implementation without a fairly extensive widespread advertising and enforcement program. Enforcement by itself will be viewed simply as a money making exercise without adequate publicity to explain why these limits apply and the benefits to all road users.

#### **7.5.6 Repeater Signing**

In addition to explaining speed zoning thoroughly, there was also a need expressed for speed zones to be sign posted continually to ensure that motorists are aware of the limits that apply in any particular zone. The literature review noted several different repeater systems that had been proposed or have been used throughout the world. The critical aspects seem to be the type and period between displays and conspicuity issues with special reference to the needs of the handicapped and the elderly. While this item was listed as one requiring immediate action, there may be some preliminary human factors research required on particular aspects of the display.

#### **7.5.7 Wide-spread Use of Enforcement Technology**

The more wide-spread use of existing speed enforcement technologies that have been shown to be effective was rated highly in terms of importance and value. This was so particularly by researchers and state authority personnel. Recent benefits in crash reductions reported by Cameron et al (1992) for the speed camera program in Victoria and travel speed and attitude effects by the Roads and Traffic Authority (1992) from the NSW program suggest that there would be considerable merit in the use of speed camera programs in other Australian States and Territories. While the exact format for success in these programs is yet to be firmly established, it appears that intensive random programs are likely to have greater benefits in accident and injury savings than site specific installations.

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